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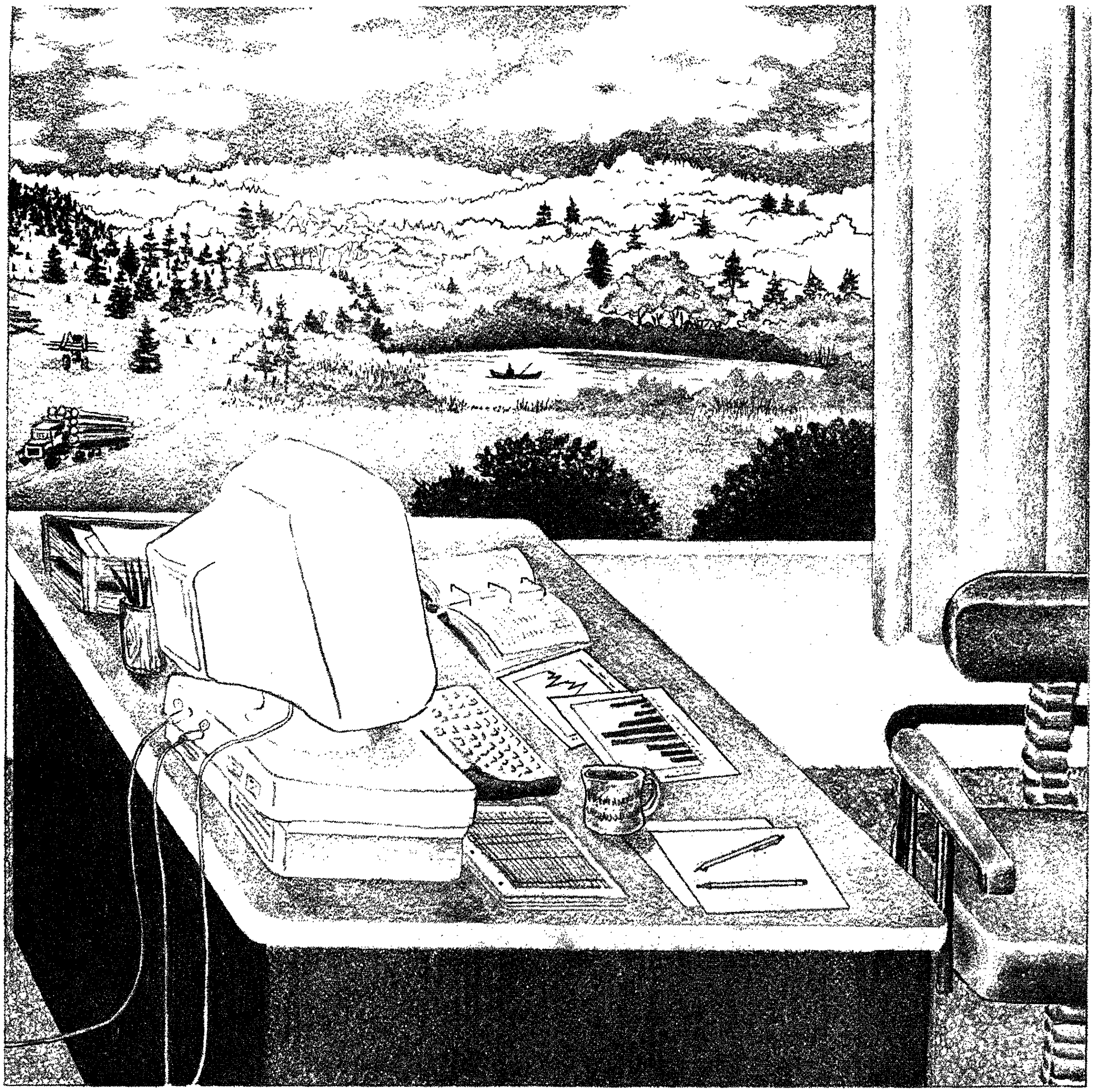

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PROCEEDINGS OF THE MEETING ON

PLANNING AND IMPLEMENTING FOREST OPERATIONS TO ACHIEVE SUSTAINABLE FORESTS

Council On Forest Engineering (COFE)
19th Annual Meeting

International Union of Forest Research Organizations (IUFRO)
Subject Group S3.04-00 Operational planning and control; work study

July 29-August 1, 1996
Marquette, Michigan USA

Hosted by

USDA Forest Service
Houghton, Michigan, USA

and

University of Minnesota
St. Paul, Minnesota, USA

Editors

Charles R. Blinn and Michael A. Thompson

FOREWORD

The Council On Forest Engineering (COFE) is a professional organization based in North America that is interested in matters related to forest engineering. Through an annual meeting with technical sessions, field sessions, and publication of a proceedings, and through regional activities, COFE encourages the exchange of information and technologies relating to forest operations (harvesting, site preparation, road building, wood procurement, etc.). The International Union of Forest Research Organizations (IUFRO) Subject Group S3.04-00 is an international network of researchers interested in the development of methods and systems used to plan and control forest operations. Subject Group meetings are held somewhere in the world on an as-needed basis.

The theme for this years joint COFE/IUFRO meeting is "Planning and Implementing Forest Operations to Achieve Sustainable Forests." The meeting is composed of five half-day technical sessions focusing in the implementation of sustainable forest practices, forest operations and the environment, improving the efficiency of forest operations, and planning and controlling forest operations. The full-day field tour highlights sustainable forest practices under upper midwest forest conditions. Other highlights include a keynote speaker from a prominent forest products company in the midwest, a COFE International Achievement Awards Ceremony, and COFE and IUFRO business meetings. Participants are from all around the world.

We would like to thank the sponsors of this meeting: USDA Forest Service, North Central Station; University of Minnesota; SISU-Valmet, Inc.; Mead Paper Company; Stone Container Corporation; Champion International Corporation; USDA Forest Service, Hiawatha National Forest; Michigan Department of Natural Resources; Minnesota Department of Natural Resources; Timberline Equipment, A Division of Lake Shore, Inc.; Quadco Equipment, Inc.; Timbco Equipment, Inc.; and Harvest Systems, Inc. Without their assistance, this meeting would not have been possible. We would also like to thank all the many individuals that helped set up the meeting, but will not name them due to space limitations (you know who you are). Special thanks go to Mary Ann Hellman of the University of Minnesota and Mary Peterson from the North Central Forest Experiment Station for their assistance in the production of this proceedings.

Charles R. Blinn
University of Minnesota
1996 COFE Co-Chair

Michael A. Thompson
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by

John Heissenbuttel
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Oral presentation only, abstract not available.

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

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by
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Oral presentation only, abstract not available.

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

CERTIFICATION AS A TOOL FOR MONITORING SUSTAINABLE FORESTRY PRACTICES[1]

by

Richard Z. Donovan
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ABSTRACT: Methods have been developed for monitoring forest management practices (pre-, during-, and post-harvest) in temperate, tropical and boreal forests. On-site assessments are implemented using techniques that provide site-specific monitoring in terms of silvicultural, ecological and community, or socio-economic impacts. A wide range of field conditions have been confronted, ranging from large, ecologically diverse single ownerships (e.g., over 1 million acres) to multiple small ownerships ranging in size from 40 to 500 acres. Costs of such monitoring can range from as high as US$1 per acre, to as low as US$ .01 per acre, depending on the forest size, biophysical diversity, land ownership patterns, and variations in harvesting and other silvicultural treatments. This presentation describes the techniques being used for this type of monitoring, costs and benefits of such monitoring, and perspectives on future changes in the state-of-the-art of such monitoring.

Key Words: certification, monitoring, reduced impact logging, ecological assessment, harvesting practices

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[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

THE INVISIBLE MONUMENT, ARMOR IN DEACTIVATION[1]

by

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ABSTRACT: Deactivation is a new science but we can now learn from the procedures of the last few comparative years. The problem that has been shown from past work is that excessive erosion has taken place in work that we have done. Erosion and subsequent sediment production is what we are trying to prevent in the deactivation process. The biggest area of concern has been where we have placed a cross ditch or waterbar and their failure due to lack of proper Armor. (Minor erosion is classified as a failure as much as the failure to direct water in its intended path. The minor erosion tends to become part of a larger problem with time.)

By the use of proper materials and proper compaction, we can prevent failures and subsequent environmentally unacceptable siltation. The benefits of this extra work will be realized by time and nature. However, the more we imitate nature's ways in our work, the more successful we will be in creating a work which in time will become invisible.

Key Words: forest, road, deactivation, water, slope stability, armor

INTRODUCTION

Test of time

Deactivation is a process carried out to ensure natural water passage, ensure slope stability, and to provide enhanced growing sites not just for the immediate future but into the next millennium. The deactivation process should not be looked upon as tearing apart or destroying a road, but as the building of a monument to the future. The deactivation process should be just as enduring as the pyramids, only a little less visible. In the future our harvesting methods will change to methods not even thought of today. We look back on the Aboriginal forest harvesting of cedar planks for lodges, wood for fish drying racks, and the use of wood for survival through to the changes of the present, and consider our "modern day" forest harvesting is just over one hundred years old. The infrastructure that we presently use for harvesting will be bypassed by technology of the day just as today's harvesting methods have totally eclipsed the methods of early this century. Long gone are the oxen and the steam train. In today's harvesting and transport, the truck and helicopter are king. The upcoming 21'st century? What will harvesting and transport systems be like in the future? Are our procedures and actions of today going to stand the test of time?

THE IMPORTANCE OF ARMOR

The forces of erosion need to be combated not with swords of steel, but with a suit of ..... "Rocks"..... The adequate compaction and Armoring of cross ditches, water bars and ditchblocks will be our monument to face the ravages of time. Preparation by taking time and care in the gathering process of suitable material before the job begins will facilitate environmentally sound construction.

In the planning process it is necessary to take the time to assess:

- will Armor be needed at this site,
- is there enough naturally occurring Armor material at the site to do the job,
- is the material of adequate size,
- can the operator separate it out,
- can the material be compacted,
- does the operator have adequate training in the deactivation processes, and
- will extra training be part of the plan?

If there is not adequate Armor material, it will need to be trucked in for the job. In the planning stage you will need to identify a source for this Armor material and record that information in the plan. Trucking can then be allowed for in the costing.

Forest Practices Code

The Forest Practices Code of British Columbia lays down a series of responsibilities and penalties for the planning, construction, modification, maintenance, and deactivation of a forest road.

Planning

Roads must be deactivated according to a Deactivation Plan previously approved by the District Manager of

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that Forest District when they are no longer in regular use and are not being regularly maintained. At this time, the roadway prism and cleared width must be stabilized and the drainage restored.

Integrated resource management objectives and ongoing and future vehicle access requirements as identified in the Access Management Plan must be incorporated into deactivation planning. The extent of deactivation as identified in the Access Management Plan must take into consideration the period of time that regular use of the road is to be suspended and the risk to other resources.

The Forest Development Plan, the Access Management Plan, The Forest Practices Code Regulations, Standards, and Road/Cutting/Special use-Permits govern the processes of deactivation. The British Columbia Forest Service Guidebooks outline suggested practices and procedures.

Deactivation

The vaunted tools of learning such as a dictionary, or an encyclopedia define deactivate as "to make inactive". WE NEED TO GO BEYOND THIS DEFINITION! Just taking an area and its associated roads from an active (in use) state to one of disuse is not enough to reverse the impact that that particular road or area has had on our environment. That particular piece of the environment belongs not only to you and I, the present people of the province, but belongs also to our children's children!

By the way........ Logging impacts are not ALL negative! What can you think of as some practical post harvest benefits of a road as well as providing site access?

I reflect that the bulk of British Columbia's roads at one time or another were the result of access to the timber or for the transport of the finished product.

Deactivation classes

As laid out in Bill 40 of the Forest Practices Code, there are three classes of deactivation: permanent, semi-permanent, and temporary (seasonal); each with its own responsibilities.

- Seasonal - Roads, culverts, and bridges to be backed up with a water control device as necessary.
- Semi-Permanent - All culverts/bridges are to be removed or backed up with a water control device. Natural drainage is to be restored. Unstable side-cast material is pulled back.
- Natural drainage is restored. Over-steepened side-cast material is pulled back and placed against the cut-bank on the outsloped and scarified road surface. Cut-banks are stabilized.

Long-term liabilities

The completion of the deactivation process does not absolve the overall responsibility for the area. Under the Code provisions, a person responsible must maintain the stability of that area. This act of maintaining stability could possibly, in the future, require further remedial action such as seeding, planting, water and slope control and remedial action.

Deactivation objectives

Natural drainage/water management

The minimizing of siltation is a priority for the deactivation process. Water management is accomplished by ensuring natural passage for a waterway. Remedial measures are to be taken to restore any interrupted drainage. Subsurface water, once disturbed is very difficult to re-establish below ground. Once it has been brought to the surface, it presents a unique problem. You now have concentrated water where previously there was none. Reintroduction to subsurface flow is not easily accomplished. Percolation is slow and may not work at all in some ground. However, using french drains that reconnect to the underground drainage system can be tried.

The Code interestingly says that we must not divert a water course. In the case of subsurface water it is generally accepted that a cross ditch be installed. But cautiously! You are now placing a concentrated amount of water onto an outside slope that has never historically felt a concentration of water on its surface.

- We must now ask, is it safe to place this concentrated water at this point?
- Will the concentrated water erode a channel and transport sediment?
- Will it over-saturate the ground and in turn cause slope instability?

- Will it fail to dissipate into the ground and continue to travel on the surface? Water has shown to travel downslope 2-300 meters and finally find a piece of ground to oversaturate with a resulting midslope failure.

Having decided (in this case) that it is unsafe to place this now concentrated flow over the bank we have in the past transported it in the ditchline (which is prone to failure) where it is introduced to the nearest watercourse and now could, in an extreme case have a detrimental effect by overloading the stream.

A solution successfully used by Dr. Bob Willington, has been to place a large french drain in the old ditch. Excavated up to 1 meter diameter this drain is filled with well-draining material such as shot rock or cobbles, which has been wrapped, sausage-like in filter cloth and then covered with the sidecast material, which probably had to be pulled back also. This engineered french drain transports the water to the stream, but it now has the added advantage of allowing a large portion of the water to return sub-surface as its movement is restricted by the cobbles, rather than free-flowing unrestricted down an open ditch, and a portion is reintroduced subsurface. The french drain also keeps the pullback material placed on it well-drained, which is an important benefit in fine textured soils.

Restoring drainage on steep ground is comparatively easy as the watercourse is usually obvious due to the accelerated erosion processes such as establishing gullies etc. However, on flat ground the direction and course of small waterflows can be very difficult to find and re-establish.

Slope stability

Slope stability is the second of the requirements under the Forest Practices Code and is one of our most serious liabilities in its capacity to do irreparable damage.

Cut Slopes. Unstable cut slopes and unstable fill slopes are the two most visually obvious candidates. The easily visible scar of the cut slope can be unstable if it is not at its natural angle of repose (too steep) or has stumps or boulders on it that could in time dislodge and lead to further slope movement. A rock face is not necessarily inherently stable. This rock face could possibly be unstable from fracturing during the blasting process, or incompetent rock overlying a cap. It could be the source for large pieces to break off from the freeze thaw effect and have an overall negative safety and environmental impact.

Fill. Unsafe fill material is not limited to side cast material from the road construction on a hillside but can also apply to fill material used to build up a road, such as a low spot or a gully. These have the potential to create a dam which could subsequently fail with great environmental impact.

Enhanced site productivity

Enhanced site productivity is the last of the ideals on the list. An ideal, because not all sites can be further enhanced. The aeration of compacted soil from ground based yarding, and the specific placing of organics on reclaimed roads can return land base to the status of a productive site, but it needs to be reconciled that grass and trees do not readily grow on bare rock or raveling slopes.

Signs

Before deactivating a road it is necessary under the Code to post information as to the hazards that may be expected. As well as the warning "Road Deactivated" it is necessary to note any other hazards such as "Bridges Removed" etc.

Re-establishing natural drainage

On roads of older construction (Pre-code) it may be necessary to re-establish natural drainage patterns. A stream may have been diverted from the path of its natural course:

- during the period of road construction,
- during the maintenance phase, or
- in the ensuing time when maintenance was abandoned and
    - drainage structures failed,
    - banks sloughed into ditches,
    - culverts plugged up.

However, caution must be taken! That diverted watercourse must be examined closely as it may not be safe to place the diverted water back into it's old channel. There may be a number of reasons.

- It may be decided that the new channel has been established for long enough to now be classified as the "natural" course.
- Rechanneling the water may create an environmental disturbance and/or generate excessive sediment.
- Have a negative effect on the environment as a whole.

- The old stream bed may not be able to handle the historical flow due to the loss of water providing nutrients to streamside foliage or other effects.

A decision like this, once recognized, under the Forest Practices Code, calls for the expert attention of a water specialist. As a note, under the code you personally may be held liable for not calling in expert advice when needed.

Slope stabilization

Slope stabilization is a priority to ensure the survival of the harvest species and to prevent excess sediment flow from the processes of erosion on a failed slope. The question needs to be asked, at what degree of slope (angle of repose) will the area in question be stable? Stable over not just the next few immediate years, but over the next few thousand years.

Cut slope stabilization

Trimming back the cut slope to its natural angle of repose is the ideal. Every material has a natural slope at which it is stable. Sandy material has a very low slope angle while another compacted material may stand at a very steep angle. Often you not only have to deal with the material but with water problems as well, such as saturation and piping of water, which can entail ingenious solutions.

However, natural slope stability can sometimes be impossible in some materials as you cannot trim back all the way to the top of the mountain. It is then that we again need to call on the soils and stability experts. Some possible solutions can include:

- buttressing the toe of the slope with the previously side cast material or with trucked in rock, and
- engineering a retaining structure at the toe of the slope.

Fill slope stability

Fill material placed on a slope can be at risk from:

- instability and movement of the material itself,
- the fill material placing an undue weight on the slope and leading to slope failure,
- saturation of a slip layer under the fill,
- decay of organic material, stumps or logs, or
- the fill material can become over-saturated and magnify all the conditions previously mentioned.

Fill material placed in a low spot or a gully is at risk as it can become a water retention barrier (dam) that not only interrupts and diverts natural water flow, but could fail, releasing pent up water in a sudden concentration with negative environmental impacts.

Brush/debris concerns and treatments

During pullback

Small brush should not be buried but should be scattered on top of the material pulled back, and larger pieces should be placed perpendicular (up and down) to the slope. These larger pieces should be securely placed (1/4 buried) into the slope, as not to move in time. Be sure to leave space to plant trees!

Other treatments

Excess brush from harvesting operations (with the goal of enhanced site productivity) may be dealt with in a number of ways:

- scattering,
- piling preparatory to burning,
- trenching and burying the compacted brush by covering with 300+ mm (1 foot+) of soil, or
- by chipping or grinding and creating a mulch which can then be spread thinly over the forest floor. The addition of other traditional "wastes" can create an enhanced mulch. (See up-coming Logging and Sawmilling Journal conference. (604- 990-9970)

Enhanced site productivity

Enhancing work areas to increase viable planting sites needs to consider both land and road surfaces.

Land surfaces

The treatment of land compacted by ground-based logging can be accomplished with tools such as a "Winged subsoiler" pulled through the ground to aerate the soil.

Road surfaces

Road surfaces can be treated with a single or double ripper on a large cat to:

- decompact the road surface,
- allow water to penetrate, or
- create a mini-climate by mounding the soil.

On pulled-back roads, ideally, material should be placed in the order that it came out, large coarse material on the bottom, mineral soils next, and then organics on top. If there are not enough organics to have a full 300mm (1 foot) layer, then quantities of good organic material should be placed (clumped) in mounds 3 Meters (10 feet) apart to provide the best enhanced planting sites.

Mounding as a general technique to enhance a planting site not only provides shelter from icy winds in the juvenile years, but the south facing slope now is warmed by the sun and, in effect, creating a mini-climate. Seedlings can also now be planted at different levels on the mound to suit the varying climatic needs of the different species.

Pullback of over-steepened sidecast material

The degree of pullback is commensurate with rendering the hillside stable. Generally, excess material is removed from as far downslope as the excavator can reach. The operator should aim to remove the excess material down to the original duff layer. Provided the area is stable and it is safe to do so, the pulled-back material is placed against the cut-bank and on the outsloped and scarified road surface. (Note: Natural drainage must be restored and maintained)

When rehabilitating older roads from earlier construction methods when side cast material was acceptable, it may be necessary to prescribe that the hoe "ramp down" to gain extra reach. But, considering that the area that you are working on is probably unstable ground due to water saturation, buried organics, vegetative slip layers and/or uncompacted sidecast, this could be unsafe to recommend. An answer that I have used is to prescribe the use of a cable dragline that can safely reach down the slope for long distances and can also place the pulled material against a high cut bank to help buttress that slope. A large machine of 50 metric tonnes (100,000+ lbs) is again too heavy for safety, as the machine is placing an undue weight on a previously identified unstable slope. I have usually recommend a smaller machine in the 25 metric tonne (60,000 lbs) class, that has a 2 cubic meter (2 yards) bucket capacity for bulking out material, yet is light enough on the slope to address the safety factor.

Drainage concerns for pulled-back sidecast material

Natural streams, bank seepages, seasonal streams, and dry watercourses, must have their drainage channels redefined so as not to restrict their flow with the placed pullback material.

Cross ditches vs. waterbars

In the past there has tended to be some confusion as to the definition and use of a crossditch and a waterbar in the deactivation plan;

The cross ditch is to drain the ditch line across the road. Whereas the waterbar stops and redirects the accumulated rain water on the roads surface.

Cross ditches

The cross ditch is, as a breakdown of its name implies; cross, as to cross the road and ditch, as to drain the ditch line. It should be as deep as the ditch that it is draining. The term "cross ditch" is also generically used when re-establishing a natural stream crossing. For permanent deactivation it is recommended the original shape of the watercourse be re-established by removing all fill material from the gully to allow unrestricted water flow in extreme event situations. This fill material, if left, could be transported during the storm event.

The cross ditch should also be constructed so as not to "pond" or retain water at its inlet which could saturate or place an undue weight on the slope. It should follow the natural, pre-existing groundline as closely as possible.

Skew - "to place at an angle" When draining a ditchline with a cross ditch, and the road is at an uphill or downhill grade or percentage, the cross ditch should be "skewed" a certain amount from the 90° angle to the road direction.

As a guide, the skew angle should be a minimum of 35° and increase 1° of skew for every increase in grade percentage. As an example, a road with an 8 percent grade would have a recommended cross ditch skew of; 35° (skew) + 8% (grade) = 43° (crossditch skew).

A deactivation operator will not have instruments with which to ascertain the basis figures to calculate culvert skew. From experience, the operator often will be able to estimate quite accurately percentages and angles. However, are you prepared to stand by the chance of a failure of an incorrect installation? And a subsequent liability in the event of that failure? I suggest, in order to eliminate the risk factor, that it should not be left up to the operator. That extra few minutes taken to identify the outfall and hang a ribbon will be well worth the knowledge that you have taken the "chance" out of the equation. As an added bonus you will have also prevented the chance of water being placed on an unsuitable slope as discussed below under "Fill and mid-slope failures"

Whether you are re-establishing a watercourse or draining a ditchline, there is a relationship between capacity and flow and it is affected by the design of the cross ditch. The hydrodynamic principle of mildly sloped, rounded bottom, gently sloping sides will give the best carrying capacity and erosion control. As the quantity of water increases, it can spread out and maintain its slow rate of flow. A steep narrow channel increases the velocity of the water and consequently it will erode the bottom and sides very quickly with the now increased force of the water. Actually the more "driveable" a cross ditch is (even if it will never see a vehicle) the better the hydrodynamic principles.

A cross ditch to drain the ditchline must be placed at the uphill end of the pullback section to keep the pullback material from becoming saturated with water from the ditchline above. Areas between pullback sections can trap water in the ditchline and attention will be needed to ensure proper drainage and need to be drained with a cross ditch.

It needs to be remembered that a ditchline with pullback material placed on top of it will still retain water and saturate the pullback material and possibly lead to instability. The need here is to ensure the ditchline is well-drained with either an open cross ditch or a covered french drain. In this case, the covered french drain would be a simple cross ditch filled with drainable material (such as coarse-grained material, cobbles or shot rock) and then covered with the pullback material. (Filter cloth may need to be placed to prevent the french drain silting in)

Historically, cross ditch failures have been the result oflack of compaction, or the absence of adequate Armor.

The inlet, base, sides, and outflow all must be adequately compacted and armored to resist erosion. The armor material must be of adequate size for the expected waterflow. If there is insufficient material at hand then it will be necessary to have armor material trucked in.

To prevent water continuing on its past way down the ditchline, we need to install a ditchblock. (For ditchblock considerations see section on ditchblocks)

If a cross ditch is expected to carry traffic, then it must be built to withstand the destructive effects of that traffic. Any of the features of the cross ditch, sides/bottom/berm, must be constructed so that they are not be damaged or deformed by the passage of vehicle traffic. Don't forget ATV's and motorcycles! The rutting caused by motorcycles can be extremely damaging due to the nature of their use.

When placing a cross ditch, the location of its outfall or discharge is paramount. Diverting a watercourse into another drainage is not acceptable. Not only do you deprive water from its natural ecosystem but you overload the impacted drainage. Damage then occurs from the extra flow volumes and extra energy now generated. A boulder of say 300mm (1 foot) that was historically stable in that stream bed can now be easily transported, altering the natural ecosystem of that waterway.

Use a cross ditch above a stream crossing location to divert accumulated ditchline water onto vegetation to filter out sediment. (Careful about the discharge though, onto a steep gully sidewall or fine-textured material will probably lead to failure!)

Caution must be taken when discharging concentrated water onto a rounded outside slope. We must always ask, is it safe to place concentrated water at this location? (See Fill and mid-slope failures section below.)

Ditchblock

To prevent water continuing down the ditchline, we need to install a ditchblock. In road construction and maintenance we needed to construct a ditchblock that was lower than the road surface to allow passage of excess water down the ditchline (or down the road) in the event the crossing structure (culvert) is overwhelmed.

To deactivate the ditchblock, direct <u>all</u> the water (even during peak events) into the constructed cross ditch. To ensure this, the ditchblock needs to be:

- higher than the road,
- constructed of suitable non-erodible material,
- well-compacted, and
- well-armored with correct size material.

Waterbars

In the deactivation plan it may be planned to leave a road surface undisturbed, such as:

- in semi-permanent deactivation,

- where stability is not a question, and
- when the road surface is not being reclaimed as a planting area.

When a road is at a grade or slope, rain water builds up and travels down the road surface. This concentration of flow (usually in the wheel tracks) as it builds up can now have the capacity to transport sediment which in this case is the road surfacing material. The immediate eye attention is drawn to the rough eroded road surface. It is unacceptable to allow deposition of eroded sediments and road fines into an adjacent watercourse.

The waterbar is used to control water on the road surface. It commonly directs built-up surface flow either into the ditchline or out onto the outside slope. Use the same caution as you would when considering to install a crossditch and discharge concentrated water onto an outside fill slope. (See Fill and mid-slope failures section below.)

As for a cross ditch, the waterbar must be skewed (placed at an angle) across the road. They should be constructed wide and shallow. They should be adequately armored on the bottom, sides, berm, and outflow area. They should no bet constructed with oversteep sides and an uncompacted bottom, berm and discharge apron that will erode with time and contribute to the siltation process that we are trying to prevent.

Fill and mid-slope failures

When we discharge concentrated water onto fill or a rounded outside slope, we must always ask, is it safe to place concentrated water at this location? We are now placing a concentrated amount of water onto an outside slope that has never historically felt a concentration of water.

- Will the concentrated water erode a channel and transport sediment?

- Will it over-saturate the ground and in turn cause slope instability?

- Will it fail to dissipate into the ground and continue to travel on the surface? (Water has been known to travel downslope 2 to 300 meters and finally find a piece of ground to oversaturate with a resulting midslope failure).

Silvaculture treatments

In the planning process, before a road is permanently deactivated, it must be considered if the cut-block ground requires mechanical treatment with equipment before planting? Potential treatments include brush piling, ground scarification, or tilling.

Back spar trail rehabilitation

Older pre-code backspar trails can have many of the same concerns as a road.

- Alteration of drainage.

- Unstable side cast material.

- Sidecast material perched on steep gully sidewalls.

- In-filled watercourses and gullies (dammed up).

- Compacted ground

Excavator size

Deactivating present and older unstable roads calls for some thought and care when selecting machine size.

- A large 50 metric tonne (100,000+ lbs) machine will give you reach and large bucket capacity but is hampered by restricted swing and its sheer mass (weight) The reason the road edge has been called to be pulled back is that the road edge is failing. For safety the operator is forced to place his machine as far to the inside of the cut bank as possible - now his swing is restricted by the bank in a large machine!

- A mid-size 30 metric tonne (60,000+lbs) machine is the popular size for deactivation. Large enough to have reach and bucket capacity, yet light enough to address the safety factor.

- A 20 metric tonne (40,000 lbs) machine is also extensively used in deactivation. Its advantage is its extremely quick cycle time, smaller size, and comparatively light weight.

- Smaller 12 metric tonne (24,000+ lbs) machines have a place in deactivation where the value desired is a nimble machine with

- where stability is not a question, and
- when the road surface is not being reclaimed as a planting area.

When a road is at a grade or slope, rain water builds up and travels down the road surface. This concentration of flow (usually in the wheel tracks) as it builds up can now have the capacity to transport sediment which in this case is the road surfacing material. The immediate eye attention is drawn to the rough eroded road surface. It is unacceptable to allow deposition of eroded sediments and road fines into an adjacent watercourse.

The waterbar is used to control water on the road surface. It commonly directs built-up surface flow either into the ditchline or out onto the outside slope. Use the same caution as you would when considering to install a crossditch and discharge concentrated water onto an outside fill slope. (See Fill and mid-slope failures section below.)

As for a cross ditch, the waterbar must be skewed (placed at an angle) across the road. They should be constructed wide and shallow. They should be adequately armored on the bottom, sides, berm, and outflow area. They should no bet constructed with oversteep sides and an uncompacted bottom, berm and discharge apron that will erode with time and contribute to the siltation process that we are trying to prevent.

Fill and mid-slope failures

When we discharge concentrated water onto fill or a rounded outside slope, we must always ask, is it safe to place concentrated water at this location? We are now placing a concentrated amount of water onto an outside slope that has never historically felt a concentration of water.

- Will the concentrated water erode a channel and transport sediment?

- Will it over-saturate the ground and in turn cause slope instability?

- Will it fail to dissipate into the ground and continue to travel on the surface? (Water has been known to travel downslope 2 to 300 meters and finally find a piece of ground to oversaturate with a resulting midslope failure).

Silvaculture treatments

In the planning process, before a road is permanently deactivated, it must be considered if the cut-block ground requires mechanical treatment with equipment before planting? Potential treatments include brush piling, ground scarification, or tilling.

Back spar trail rehabilitation

Older pre-code backspar trails can have many of the same concerns as a road.

- Alteration of drainage.

- Unstable side cast material.

- Sidecast material perched on steep gully sidewalls.

- In-filled watercourses and gullies (dammed up).

- Compacted ground

Excavator size

Deactivating present and older unstable roads calls for some thought and care when selecting machine size.

- A large 50 metric tonne (100,000+ lbs) machine will give you reach and large bucket capacity but is hampered by restricted swing and its sheer mass (weight) The reason the road edge has been called to be pulled back is that the road edge is failing. For safety the operator is forced to place his machine as far to the inside of the cut bank as possible - now his swing is restricted by the bank in a large machine!

- A mid-size 30 metric tonne (60,000+lbs) machine is the popular size for deactivation. Large enough to have reach and bucket capacity, yet light enough to address the safety factor.

- A 20 metric tonne (40,000 lbs) machine is also extensively used in deactivation. Its advantage is its extremely quick cycle time, smaller size, and comparatively light weight.

- Smaller 12 metric tonne (24,000+ lbs) machines have a place in deactivation where the value desired is a nimble machine with fast cycle times. They are excellent for constructing waterbars, small- to medium-sized cross ditches, light pullback work, and rehabilitating backspar trails.

Revegetation

Under the Code, grass seed mixture must be applied to all exposed soil that will support vegetation in the first growing season after construction. These areas include; borrow pits, waste areas, road cuts, fill slopes, pulled-back fill material, and all other disturbed ground.

Dry seeding

By hand, machine, or helicopter, dry seeding is most effective immediately after the ground is disturbed as the seed is allowed to fall into openings in the soil, before the surface becomes compacted by the effects of weather.

Hydro seeding

By truck-mounted tank and gun unit, or by helicopter, hydro seeding speeds up and increases the probability of successful germination by providing the new growth with protection, retained moisture, and nourishment. Hydro seeding as a prescription for failing slopes where water and slope stability have not been addressed is not a suitable glue together fix-all cure. (See the slope stabilization section below.)

Slope stabilization

Steep or unstable slopes may be stabilized with expert advice from a water and soils stability expert by some of the following methods.

- Water control.
- Wattling, with willow bundles stepped up the slope, rice paddy fashion.
- Structures -- Engineered retaining walls.
- Erosion mats --Mats of chopped straw or fibre, containing seed and fertilizer, anchored and pinned to the slope. They are effective on groomed slopes where the mat has an assured positive contact.
- Soil guard - A unique thick mat sprayed on with a hydro seeding gun or by helicopter bucket. It is made up of a patent compound of mulch, binder, tackifier, seed mix and fertilizer. It protects the soil from surface erosion for up to two years and gives the seed mixture time to establish. It is very effective on ungroomed slopes of varying steepness. Being sprayed on in liquid form assures positive contact and total protection to the soil surface, ensuring the complete control of siltation. It is recommended where the flow of sedimentation would be a detriment to the environment.

Identifying potential heli-sites for future access

When permanently deactivating a road, it is prudent to facilitate future access by identifying and recording natural helicopter sites on the plan, ideally with satellite navigational coordinates.

Riparian management areas

Riparian management areas are areas immediately adjacent to streams, lakes, and wetlands. There is a need to ensure that riparian vegetation at stream crossings is not damaged and continues to provide streamside habitat. Equipment must not be refueled within a riparian management zone. It is important to be aware that effects of activities in the upper reaches or headwaters of a system can impact the values of downstream areas.

Work in and around fish streams

Work may not commence until a written plan has been approved by the respective agencies, and may only be allowed in certain "work windows". If fish are present, an approved written fish salvage plan must be in place.

Environmental objectives and procedures for water crossings

A water crossing must be carefully deactivated and well-protected. It will minimize adverse impacts on fish and the aquatic environment by:

- maintaining natural stream conditions,
- providing fish passage,
- preventing pollution,
- avoiding sedimentation, and
- preserving riparian vegetation.

Saturated ground

Saturated ground has the potential for movement. From a safety standpoint, recognizing saturated ground from such sources as adjacent bodies of water (lakes, swamps, ponded ditchwaters), or extended periods of rain is important. Vibration from equipment can trigger ground movements.

FOOTNOTES

Notes on measurements in this document: All measurements are identified as Metric with English units in parentheses except where noted. E.g. 300mm (1 foot). All conversions are approximate.

This paper should not preclude legislative requirements nor replace procedures for agency review or approval, but rather it should facilitate the approval and work process and ultimately help ensure environmental protection.

SUSTAINABLE FORESTRY: EUROPEAN PERSPECTIVE[1]

by

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ABSTRACT: European forestry heritage is very rich and each country in Europe is very proud of what the foresters, biologists, silviculturists and production managers have succeeded for the benefit of society. Equilibrium between income from the market of products and the costs for renewal of the forest has been reached. New aims are given to the forest by society. Recreation, air purification, protection of water resource, smoothing of the landscape, and more ecological contribution to the environment are new requirements or they are presented as new objectives while foresters always did their work in accordance with the biological requirements of the trees they had to produce for society. However, if the forester must follow the rules of mother nature, he must also adapt the management to "modern" and continuously renewed economic and social considerations. In Europe some new perspectives are established. Let us have a look at those so-called "new views" that prepare the future.

Key Words: European forestry, silviculture, sustainability, biodiversity

INTRODUCTION

The past of European silviculture is very rich in experience. Mistakes and favorable results with the introduction of foreign species to improve wood production are observed in the course of time. However, considering the necessary period to recognize the facts over time when we know the growth rate of trees in temperate climatic zones, it is quite normal that the selections are slow.

In other respects, severe censure has been introduced about some silvicultural practices while they were practically induced by society itself due to typical demands or constraints from the users of wood. Fuel wood, timber for building or for shipyards, pit-props, round woods for paper mills, chunks for energy, chips for board industry are typical demands that influence tree selection and plantation policies.

Nowadays, new social and ecological requirements induce other criticisms while economy does not always support positively the necessary actions. Forest conservation, sustainability and diversity in the biological ecosystems lead to systematic innovations.

More schooling, more equipments or skilled man-power are requested and have heavy economic consequences that society is not yet ready to assume. The past is very rich in experience and the transfer of data into computers may help the forester of the future.

Views about the fundamentals of silviculture will certainly not change but the applications must be managed in another way. Managed biodiversity means more know how about plants and trees, about soils and their dynamics, about the relations between equipment and the environment, and between man and nature.

Not only the assessments about the dramatic evolution of the tropical forests must motivate a renewal or a drastic change, but the general statements about air - soil - water and life implications must guide our society for the next century. Foresters will look forward with a highly specialized competency because they are accustomed to look perspicacious to the far future.

EUROPEAN FOREST

Actual forest areas in the European countries following EU statistics and documents mentioned in the literature are:

	%	ha/inhabit
North Europe		
Denmark	12	0.09
Finland	58	4.19
Norway	26	1.59
Sweden	57	2.84
Western and Central Europe		
Austria	45	0.50
Belgium	21	0.07
France	25	0.28
Germany	30	0.12
Ireland	7	0.09
Italy	29	0.12
Luxemburg	32	0.24
Netherlands	8	0.02
Switzerland	24	0.13
United Kingdom	9,4	0.04

[1]Presented at the joint meeting of the Council on Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

Actual forest areas Continued

	%	ha/inhabit
South Europe		
Portugal	30	0.30
Spain	23	0.33
Greece	19	?

The ***main tree species*** are:

	conifers	broadleaves
North Europe		
Denmark	55 (s)	27 (b)
Sweden	83 (s,p)	17 (I)
Western and Central Europe		
Austria	81 (f,p,s)	19 (b)
Belgium	42 (s)	56 (b)
France	36 (s)	64 (o)
Germany	71 (p)	29 (o)
Ireland	95 (k)	5 (var.)
Italy	14 (f,s)	53 (o,b)
United Kingdom	71(k,p)	29 (o,b)
South Europe		
Greece	38 (p)	62 (b)
Spain	47 (p)	53 (I)

b = beech; f= fir; I = birch; k = sitka; o = oak;
p = pine(s); s = spruce; var. = various species

The ***ownership*** is distributed as follows:

country	private %	state %	public %	corp. %
North Europe				
Denmark	52	27	7	14
Sweden	49	27	-	24
Western and Central Europe				
Austria	85	15	-	-
Belgium	53	11	36	-
France	74	10	-	16
Germany (W)	46	30	7	17
Ireland	25	75	-	-
Italy	66	7	25	2
United Kingdom	47	53	-	-
South Europe				
Greece	23	65	12	-
Spain	66	4	30	-

% = percent of forest area; - = unknown

The above data show clearly that most of the forests in Europe are in private ownership except in Greece and Ireland. The ***area owned by the privates*** are known for some countries only. The number of owners by category of ownership area are shown in Table 1.

Table 1. Number of owners by category of ownership area.

	Belgium	Denmark	France	Germany (West)	Sweden
<50 ha	104,039	24,511	3,653,000	319,663	178,120
50-99 ha	599	200	140,000	4,171	34,461
100-249 ha	--	135	9,000	--	16,446
250-499 ha	396	59	--	800	5,382
500-999 ha	32	43	--	239	1,664
>1000 ha	--	21	--	164	--

SILVICULTURAL PRACTICES

The European forests show quite different aspects than those in the US, especially those of the West coast. However, some similarities still exist with areas in central Russia at the limits of the European continent, i.e. the Oural mountains and in the East Caucasus.

A very long forestry tradition is recognized in most of the countries and various "schools" or tending rules make the differences.

I would suggest to look at forestry from North to South and recognize the Scandinavian, German, British and French or Latin; basically French, Swiss, Belgian and Italian forestry. They are related with the past history of Europe when large and specific Kingdoms were headed by Tsars, Emperors or Empresses, Princes and Dukes. If most of the regulations were edited to limit deforestation or to organize games, in fact there were also tree management rules.

In Finland, the basis for the planning of forestry was the systematic forest inventories, which started in the 1920's and went on continuously since then. The forest industries on a rather large scale started in the 1860's - 1870's.

In Norway the first forest officers were engaged by the Government in 1857 and they were in charge of State and Private forests. A Forest Protection Law was passed in 1932. It organizes the management of the forests through Parish and County Forest Boards and introduces a regeneration tax.

Several royal ordinances were issued in the 17th and 18th centuries for the protection of the forests in Denmark. A German forester J. G. von Langen was to organize the Danish forest from 1762 forward.

The German Forest Service operates since 1795 when regulations "establish an administrative body and gain knowledge about the complex symbiotic relationship that exist in woods" (University Ingolstadt, botanist von Paula Shrank and University of Munich, Professor K. Gayer). In Niedersachsen, regulations were officially published in the beginning of the 18th century but competition remains for long time between agriculture and forestry. Forestry starts there in Niedersachsen in the nineteenth century.

An Imperial Forest Law establishing strict regulations on the clearing of forest lands was decreed in 1852 in Austria.

In the United Kingdom since 1608 inventories of the oak trees were organized and J. Evelyn was teaching about tree cultivation.

In France, monitoring and conservation of the royal forest patrimony was organized in 1291 by Philippe led Bel (Corps of Masters of Water and Forest). They promote the general interest and the protection role of forested lands. The ordinances of Colbert in the 17th century monitor the continuity of the production of logs for masts and pieces of wood for shipyards. In 1701 Vauban wrote his treatise on forest cultivation. The French forest code was edited in 1827. The specialized forest center of Nancy for ENGREF (National School for Agricultural Water and Forest Engineering) engineers and the Domain des Barres in Nogent sur Vernisson initiates many foresters to forest management, and they apply silviculture science in many European countries.

In Central Europe and the Balkan Peninsula, after the Roman Empire many other peoples like Goths and Huns have achieved ruining the forests. Venetian got the timber for their buildings in the lagoons. Forest laws appeared in those areas in the sixteenth century. They were protection and tending decrees. Here also the most important starting decree came from Empress Maria Theresia in 1769. It is considered as the first handbook on forestry for those countries. Modern Laws on Forest was edited in the middle of the nineteenth century. The quality of the timber growing in those areas did attract many harvesting operators after the French Revolution. Consequently, over-exploitation did very deep and significant damages in some wide areas.

In Belgium, for example, on September 14, 1617 the first ordinance of the Archdukes Albert and Isabelle creating the corps of foresters was published.. A forest code was officially introduced in 1854. However the forests of Belgium were managed for a long time before 1830, the year of its independence. Before the occupation of what became the Belgian territory by the Celts; the Roman, Spanish, Austrian, French, and Dutch conquerors introduced various management rules or pillages. However, some very positive heritage remains from those occupations, like the forest of Soignes around Brussels. Apparently it is considered by botanists and foresters as the most beautiful beech forest in the world. The regulations were edited by the Dukes of Brabant (1300, 1459, 1491,...) More recently, great families left nice well-managed private forests, like the Dukes of Arenberg for example.

It is said that the Europeans were the first to replace the uncontrolled harvesting of the forest by a patrimonial management of the resource that protects against wood overcuts.

During the nineteenth century, the industry and the demography were sacking the forest to get fuel wood for domestic fires and blast-furnaces. Hopefully coal has saved the forest but, then, wood was necessary for the pits and timber production was largely conditioned to provide pit - props of various sizes.

European forests have also paid a heavy price for the successive wars in Europe. The troops overcut or clearcut large areas, while iron or copper alloy shrapnels and barbed wires remain in the stems and introduce dangerous working conditions when felling or sawing many years later.

Have we to underline also the damages introduced by the mines and other booby-trap systems of the second world war. Stands have been totally ruined and it took time to recover healthy timber.

The education programs for forest engineers in the Belgian Universities include teaching of management principles since their foundation.

It is necessary to introduce two main distinctions for the purpose of this report: *the treatment and the management of the forest.*

The treatment includes all the operations necessary to obtain continuously the best yield of the high forest, mixed forest, coppice and other types of tree stands.

Whatever the treatment can be, it is necessary to get the best of the possibilities in growth and shape and to carry out the best fitted operations in each part of the forest following soil and environmental conditions.

The management of the forest involves all the harvesting operations and will give the calendar of the fellings in order to guarantee an annual sustained and advantageous income. The planning of the type and the succession of the harvesting operations is fixed at the same time as the quantities delivered. Here comes the notions of exploitability of the trees and the different types of exploitability.

The management of the forest defines the cut area , its location, the felling directions, the skidding conditions, the place for the storage of the felled trees or logs, etc. The management of the forest requires repeated inventories and identification of the conditions. The state forest data and those of more and more private forest are now introduced into computers for treatment and analyses , also for administration purpose.

THE SHAPE OF THE EUROPEAN FOREST

Right away it is necessary to make a distinction between conifer and broadleaved forests. Most of the spruce, fir, and pine areas were essentially managed in regular high forest and mainly as mono-specific stands. In the past some clearcuts did happen but in most cases the thinning system was applied periodically during the life (revolution) of the stand.

I really don't know if it is the only case, but very early in the past in Switzerland, they started mixing the conifers in their mountain forests. So these forest became uneven in age and species. A specific treatment was applied for safety in areas with avalanches and in the hilly parts of the Alps. It was named the "mixing" systems.

Broadleaved forests are mostly mixed and even or uneven in age. To a large extend coppices provided fuelwood and charcoal potential. The demand of large and long logs did re-introduce the high forest by mixing or by conversion of coppices to a large extent.

A typical and interesting aspect for the actual views on the future must consider the silvicultural system called "the gardening method" applied essentially in broadleaved stands. These are mixing the species and the age classes following various methods: stem by stem, by groups, by lines, by strips, etc.

When natural regeneration is applicable like in climax forest, the stand offers a very charming outlook but is very difficult to keep healthy and harvesting is not easy with mechanized devices without severe damages sometimes.

New initiatives are promoted by the European Commission since 1979. The increase in the pressure exerted by the different publics has suggested new aims. Wood production must go with environment conservation, recreation structures, employment and life standard improvement. The forests must become multi functional. The richness in the climate diversity, topography, soils and history of the forests in Europe will encourage various approaches and different measures corresponding to each of the regions. A main contribution of the forest must remain its social role for urban citizens living in large cities and willing to have easy excursions into the forests. The role of the forest in the conservation of water, vegetation and animal life is essential and must help for keeping the landscapes. Each natural region in Europe must determine the ranking given to the many aims of the forest. Some will have to protect against erosions while others will only produce timber or different kinds of wood products.

Environment quality is related to the type of forests and to the diversity in the species existing in the stands. Sustainability must consider much more than nature, i.e. the normal composition of the flora and fauna for the different locations. Re-organizations will be necessary, new structures must be created and incitements must be given at least to private owners to succeed in such fundamental change.

The instruments of such a forest policy are numerous. First of all the forest authority must be managed efficiently and will use highly skilled personal acting with competence and perspicacity for the very long term. It is advised to have a real independent forest administration working in coordination with different Ministries involved in land management agriculture and industry or economic affairs. Forest legislation will be adapted in the participating countries. Eventually specific administrative procedures will implement the basic laws. Taxation and financial aids are other tools for the application of the European forest policy.

Research, development and application must increase and should be coordinated at the different levels. Education and vocational training will provide the requested personnel while continuing education will keep the high level requested.

The permanent consulting of the owners, managers, workers, delegates from the processing industry, trade spheres and greens or positive ecologists will allow to moderate the conflicts and objectively promote the proposed forest policy. Public relations will inform about the programs and the operations.

A detailed project has been compiled already in 1979 and implies wood production and conservation of the nature with protection of the human environment. Sustainability and diversity are the main basis for the future of the forest, all the forests, state, private, public, communities, etc.

An application model is given here for the state and under state service control forests in Belgium as example.

The French speaking Universities were asked to elaborate special technical instructions for the management of the forest. The forests on slopes, wet soil (hydromorphic) and peat are especially involved. On slopes, erosion must be avoided by keeping the canopy closed, by a correct management of the openings due to the harvest of the trees and by doing thinnings at a very young age. The mixing of species is advised and even age stands must be managed to come in the very near future to an uneven structure with adapted broadleaves for a large extend. Stumps will remain in place on the slopes after felling. Brushes and herbaceous vegetation must be sustained underneath the trees. Logging by air using skylines is advised and road net should offer densities of 15 - 25 m/ha when the slopes are >30%. The number and the location of the log yards will be especially adapted. On wet soils broadleaves mixed stands must be promoted. The mixed forest treated as a gardened high forest should be seen as an optimum. No clearcut is allowed and the keeping of the cover will favor evapotranspiration permanently. The choice tree species will look at the root systems and natural drainage is recommended. Special hauling strips should be managed in the stands. Humus process will be kept under continuous control.

The use of peat soils for sustained wood production is considered as nonsense.

Peat areas must be kept and even restored for ecological, aesthetic, ethic and socio-economic reasons. Biochemical quality of the water in the peat soils is considered as too important to allow any transformation or plantation.

Operations will request special and adapted machines. Reforestation after harvesting existing stands is not more allowed and some areas of scientific interest will be totally protected. No thinnings in existing stands are allowed. Natural spontaneous vegetation will be promoted.

In general wide spacings are advised at the plantation and thinnings will keep the trees at correct distance at each age. Compartments will be installed to facilitate the access to the trees for felling and skidding. Strict control is prescribed on mechanization. The harvesting instructions are given at the sale of the trees. Some type of equipment, skidder or tool may be forbidden while tracks are not more systematically under interdiction as it was imposed by the forestry code in times past. Mixed species is promoted mainly in areas planted with conifers.

For the private owners, incentives are given by the Forest Service of the Walloon Region in Belgium to promote the first thinnings, if some conditions are respected. The forest stand must reach less than an average 13m height for the hundred thickest standing trees.

The thinning may happen selectively or systematically (compartments to facilitate mechanical operations). The thinning must left 700 to 2000 trees after the felling following the density of the plantation (proportion figures are specified). Only one subvention is allowed for the life of the stand. The amount allowed is 260 dollars per ha with a maximum of 1,290 dollars per request. For grouped demands issued by at least three owners, an additional 65 dollars is allowed individually.

The demands must follow various administrative conditions specified in the decree issued by the Government of the Walloon Region on November 17, 1994. Some additional amounts are allowed when the forest area is located in rural areas recognized by the EU for special assistance.

Financial support is given by the Forest Service of the Flanders Region also to private forest owners for the planting or re-planting operations areas over 0,5 ha. The amounts are calculated following the categories of tree species as listed in appendix. The amounts are: category 1 = $3225/ha; category 2 = $2530/ha; category 3 = $1935/ha; category 4 =$1290/ha; category 5 =$645/ha, and for spontaneous regeneration, where and when possible: $645/ha.

THE BIODIVERSITY IN THE FUTURE FOREST: THE BELGIAN EXAMPLE

The advised forest species for improving the biodiversity may vary following the countries. The Belgian forest administration for the Walloon region advises the following species. (Latin names are translated into common names as given in "Trees of North America, a guide to field identification" by C. Frank Brockman, Collection Golden Press, New York):

for conifers (total = 15 species):

- Picea abies (spruce),
- Picea sitchensis (sitka spruce),
- Pseudotsuga menziesii (douglas fir),
- Larix decidua (larch spp.),
- Larix Kaempferi (larch spp.),
- Larix eurolepis,
- Pinus nigra ssp. nigra var. Koekelare (Austrian pine var. K),
- Pinus nigra ssp. Laricio var. Corsican (Austrian pine var. Corsican),
- Pinus nigra ssp. nigra var. Austriaca (Austrian pine),
- Pinus sylvestris (Scotch pine),
- Abies grandis (true fir),
- Abies procera (fir),
- Abies alba (fir),
- Thuya plicata (western red cedar),
- Tsuga heterophylla (hemlock)

for broadleaved (total = 26 species):

- Acer pseudoplatanus (planetree maple, sycamore),
- Alnus glutinosa (European alder),
- Betula pubescens (birch),
- Betula pendula (birch),
- Carya sp. (hickory spp.),
- Carpinus betulus (European hornbeam),
- Castanea sativa, (Spanish chestnut),
- Fagus sylvatica (European beech),
- Fraxinus excelsior (ash),
- Juglans regia (English walnut),
- Juglans intermedia (walnut),
- Juglans nigra, (black walnut),
- Liriodendron tulipifera (tuliptree),
- Populus canescens (aspen, cottonwood),
- Populus tremula (quaking aspen),
- Populus euramericana (cottonwood),
- Populus interamericana (cottonwood),
- Prunus avium (plum),
- Quercus robur (oak),
- Quercus rubra (northern red oak),
- Quercus petrea (oak spp.),
- Robinia pseudoacacia (black locust),
- Salix alba (willow),
- Sorbus torminalis (mountain-ash),
- Tilia platyphyllos (basswood),
- Tilia cordata (basswood)

For the Flemish region of Belgium, the tree species are specified accordingly to the level of subvention allowed. The species are proposed as follows:

category 1:
- Quercus robur (oak spp.),
- Quercus petrea (oak spp.)
- Fraxinus excelsior (ash spp.)

category 2:
- Fagus sylvatica (European beech)
- Prunus avium (plum spp.)
- Carpinus betulus (European hornbeam)
- Acer campestre (English field maple),
- Acer platanoïdes (Norway maple)
- Acer pseudoplatanus (planetree maple, sycamore),
- Tilia cordata (basswood spp.),
- Tilia platyphyllos (basswood spp.),
- Tilia vulgaris (linden, basswood spp.)
- Ulmus glabra or scabra (wych elm),
- Ulmus minor or campestris (English elm)

*when those elms are especially and officially accepted

category 3:
- Quercus palustris (oak spp.) ,
- Quercus rubra (northern red oak)
- Castanea sativa (Spanish chestnut)
- Juglans regia (black walnut)
- Alnus glutinosa (European alder)
- Betula pendula (European white birch),
- Betula pubescens (birch spp.)
- Salix alba (white willow),
- Salix fragilis (crack willow),
- Salix x rubens (willow spp.)

*all those Salix when accepted

- Populus nigra (Lombardy poplar)

*when and were accepted

Populus alba (white poplar),
Populus tremula (quaking aspen),
Populus canescens (aspen spp.)
Pinus sylvestris (scotch pine)

category 4: Robinia pseudoacacia (black locust),
Taxus baccata (yew)
Juniperus communis (common juniper)
Pinus nigra var. Corsican (Austrian pine var. Corsican)
Pseudotsuga menziesii (douglas fir)
Larix kaempferi (larch spp.),
Larix x eurolepis (larch spp.)
Alnus incana (alder spp.)
Populus spp. or Cultivated cottonwoods in mixing with indigenous broadleaved species.

category 5: Populus spp. (Cultivated cottonwoods)

When plantation happens with undercover species the following are accepted:

Salix spp. (willows spp.),
Sambucus nigra (elders spp.),
Sorbus aucuparia (European mountain ash),
Coryllus avellana (hazels spp.),
Ilex aquifolium (English holly),
Frangula alnus (not translated),
Viburnum opulus (honeysuckle spp.),
Evonymus europaeus (bittersweet spp.),
Cornus sanguinea (dogwood spp.),
Prunus padus (cherry/plum spp.).

CONCLUSIONS

Europe has a very long forest and silvicultural tradition deeply anchored in the minds of the owners and managers. The forest structures were largely influenced by crown and noble families. Their relations and their family connections have had an effect on the ways of managing their domains.

Such facts have introduced several different philosophies in the management systems. The successional rules and laws have deeply shaped the properties.

The breaking up of the estates was and is still significantly detrimental to good environmental forestry. However, the very long peace time since the second world war makes that more and more interest is put on the forest areas and the eyes of the general public are very critical. Notwithstanding most of the views are slightly too much romantic and idealized pictures or paintings of the past times are often taken as model for landscapes. rural areas, agriculture and for forestry also, of course.

New regulations seem to be influenced by the same ideas about "nature" and our era of abundance let us think about our environment more than before.

The recovering of the past configurations forces the young generation to use more efficiently the computers certainly but there is also a necessity to adapt the actual means to the "next" forests. The tending and the harvesting of diversified stands mixed by stems or by groups is rather a heavy technical problem when everything must remain untouched and if human ergonomic criteria must be considered.

The future European forests will seemingly look as close as Eden is represented in the early times. Have we to turn back to more manpower, to operations with animals and to more expensive equipments to fulfil the many tasks?

Let us stay more realistic for the future. The silvicultural management will keep the forest more close to the nature conditions than before that is evident and necessary for our well-being.

If we cannot any more find other forests in the world where "brutal" operations are allowed as it is actually, what should be done?

Again new techniques, adapted machines must be engineered.

The remaining problem is: who will have the money for the technical development or for buying the wood products harvested in accordance with the requirements edited for keeping the environment and the ecology?

This is a very exciting modelization task!!!

LITERATURE

Abeels, Pierre F. J., 1975 - 1995, personnel reports, documents and treatise of silviculture

Anon., 1982, Brief Glimpses of Danish Forestry, ED. Danish Forestry Society, 52 p.

Brochure Finish Ministry of Agriculture, 1985, Forestry in Finland, 17 p.

Bulletin des Communautés européennes, 1979, Politique forestière dans la Communauté, Luxembourg, 52 p.

Clicheroux, Emile, 1978, La forêt, deuxième richesse de Wallonie, Ed. Crédit Général, Brussels, 30 p.

ENGREF brochure, 1977, La politique forestière, Euro-impressions, Paris, 52 p.

FAO, 1995, State of the world's forests, Executive Summary, FAO, Rome, 4 p.

Goblet d'Alviella (Comte), 1974, Histoire des Bois et Forêts de Belgique, Ed. Culture et Civilisation, Brussels, 4 volumes, 420 p.

Hanns Siedel Foundation, unknown date, The Free State of Bavaria, Ed. H. Siedel Found., München, 223 p.

Leroy, Philippe, 1991, Des_forêts et des hommes, Press Pocket, 127 p.

Many contributors, 1991, L'homme et sa forêt, ENGREF, France, 64 p.

Michel, Henri, 1964, Aperçu sur les forêts communales en Belgique, Bull. du Crédit Communal de Belgique, 47 p.

Montagna, Giuseppe; Lassini, Paolo, 1983, Gli Alberi e il Bosco; Ed. Azienda regionale delle Foreste regione lombardia, 98 p.

Ostojic, Zarko; Drinic, Pero; and alii, 1986, The Forestry in Yugoslavia, Ed. Preradu Drveta Jugoslavije, Beograd, 258 p.

Plattner, Edwin, 1979, Austrian Forestry, Ed. Fed. Ministry of Agriculture and Forestry, Vienna, 26 p.

Skinnemoen, Knut, 1964, An outline of Norwegian Forestry, Ed. Det Norske Skogselskap, Oslo, 124 p.

x, 1995, Subventions à la forêt privée, Ed. Région Wallonne, Dir. Gén. des Ressources Naturelles et de l'Environnement, Div. de la Nature et des Forêts, Bruxelles, 47 p.

x, 1979, Eaux et forêts, Ed. Administration des Eaux et Forêts, Brussels, 33 p.

x, 1990, Het Bosdecreet, AMINAL, Brussels, 64 p.

x, 1982, The Norwegian forest owners' association, Ed. Norges Skogeierforbund, Oslo, 8 p.

x, 1990, Wald- und Forstwirtschaft in Niedersachsen, Ed. Niedersachsisches Ministerium für Ernährung, Landwirtschaft und Forsten, Hannover, 113 p.

MULTI-PURPOSE MANAGEMENT AND BIODIVERSITY: THE EXPERIENCE OF THE OFFICE NATIONAL DES FORETS (FRANCE) FOREST PLANNING OF THE ROMERSBERG STATE-OWNED FOREST[1]

by

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ABSTRACT: As throughout the world, sustainable forest management has been the focus of much lively discussion in France since the early 1990s. The upkeep, not to say reinstatement, of biodiversity is the main theme of such discussion. The Office National des Forêts, which manages 4.5 million hectares of public forests-i.e. one third of France's forests- is deeply involved in this area, by incorporating this new aspect of society's requirements in its choices and management methods.

To this end, several studies have been undertaken, in order to better describe the influence of forest management methods on biodiversity, and improve them where necessary.

The studies embarked upon in 1991 in the Romersberg state-owned forest, in Lorraine, are among the most comprehensive, where this theme is concerned, and have culminated in the formulation of a new forest management plan, which pays greater heed to biodiversity.

Key Words: sustainable forestry, biodiversity, forest planning, multi-purpose management.

HISTORICAL BACKGROUND TO FOREST MANAGEMENT IN FRANCE

To get a better grasp of the context of the Romersberg forest study, we must first briefly outline the already age-old history of forest management in France (Huffel, 1925; Badré, 1983).

Forests deeply marked by man

In France, as in Europe, people have been using forests for thousands of years either for their resources, or to turn them into farmland. So there is now virtually no virgin forest left, even in high-altitude mountainous regions, and forest stands are deeply marked by human activities.

Ever since the Middle Ages, population growth has ushered in both a thirst for new lands to feed people and heightened needs for construction timber and fuelwood, a principal energy source. This situation duly took the form of largescale land clearing and excessive logging in the remaining forests. Politicians then became conscious of the need to protect forests from farming pressures, on the one hand, and, on the other, to log these same forests in such a way as to conserve their wood production capacity, in the long term.

Many centuries of forest management experience

In France, one of the earliest official documents on this topic is 650 years old. In Article IV of the Brunoy Ordinance of May 1346 concerning the royal forests, king Philippe VI of Valois stated quite clearly: "The Masters of the Forests shall visit all the forests and woodlands that are there and carry out the sales to be held there, so that the said forests and woodlands may be maintained on a permanent and sustainable basis".[2]

This law was followed by many other laws and regulations, all deriving from the same principle. The Forest Code of 1827, which is still the basis of French forestry rules and regulations, is the culmination of this lengthy history. In introducing very strict rules about land clearance, including privately owned forests, the Code has effectively protected the forest and halted the drop in France's

[1] Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04.00, Marquette, MI, July 29-August 1, 1996.

[2] "Les maîtres des Forêts enquerront et visiteront toutes les forêts et bois qui y sont et feront les ventes qui y sont à faire, en regard à ce que lesdistes forêts et bois se puissent perpétuellement soutenir en bon état".

forested area - 8 million hectares at the beginning of the 19th century. The development of the use of charcoal, followed by rural migration to cities, subsequently enabled the forest to double its area, in less than two hundred years. It now accounts for one quarter of France's territory.

The Forest Code has also made forest planning obligatory for every state- and community-owned forest, setting the long-term targets of forest management and drawing up the management plan for the next 15-30 years.

A fundamental principle: multi-purpose management

French forestry policy is based on the principle of multi-purpose management, which has been tested in the field for at least three centuries. This principle is backed up by the Forestry Law of 4 December 1985, and, as far as state-owned forests are concerned, detailed in the national management directives updated by the Ministry of Agriculture on 17 July 1990. These directives define the basic objective of public forest management as the upkeep, and wherever possible, the improvement of the forest's capacity to acquit, in the best way possible, all of its ecological, economic and social functions.

It is not possible to conceive long-term sustainable management by setting targets for each individual forest in a rigid and definitive way. These targets in fact convey a current state of the balanced nature of society's requirements. The fact is that social requirements are evolving much quicker than forests. The best way of adapting to the development of society and its needs, without compromising the future of forests, thus consists of drawing up medium-term management plans, which take into account all the known functions of the forest - ecological, economic, and social. So, in management regulations, a major goal of wood and timber production must not exclude environmental protection and public access. Conversely, experience shows that maintaining a wood production function in a forest largely devoted to conservation provides a better guarantee against destruction than strict rules and regulations.

Development of forest uses and management methods

Multi-purpose management has helped to usher in a wide variety of management methods, which have complementary advantages, both for their adaptation to developing needs and for the upkeep of biodiversity.

- In the 17th and 18th centuries, the royal lowland forests were often managed as high forest to produce construction timber for the navy, while at the same time giving refuge to the large game, for the royal hunt.

- At the same time the community-owned forests, from which local people wanted to extract both timber for constructing their houses and fuelwood, were very often managed as coppices-with- standards. When it was time to cut the coppice every 20-25 years, this involved keeping trees (or saplings) earmarked to be retained to produce large trees - the reserves.

When metal replaced timber in ship construction, the royal forests, which had become state-owned forests, were shifted towards the production of quality timber. And when coal and oil replaced wood as the main source of energy, coppices-with-standards were gradually turned into high forest, taking advantage of the reserve trees.

These two management methods each had their advantages for maintaining biodiversity:

1. The state-owned forests were the last refuge for large lowland game, which has now managed to regain much larger areas.

2. The coppices-with-standards helped to maintain many secondary forest species, whose ecological and economic advantages are now recognized.

Needless to say, if the principle of multi-purpose forest management still holds good, forest uses are evolving and becoming more complex. To cope with this situation, the forester must accordingly adapt his basic management tool in an on-going way - and this tool is forest planning. To do this he must:

- have more dialogue with people who are involved with the different factors of social requirements and demand: officials, people in the wood and timber industry, scientists, associations, tourists...

- flesh out his forest analysis methods, and
- improve and enhance his silvicultural techniques .

The case of the Romersberg forest offers a response to these challenges.

FOREST MANAGEMENT AND BIODIVERSITY: THE EXAMPLE OF THE MANAGEMENT OF THE STATE-OWNED ROMERSBERG FOREST (MOSELLE)

The geographical and political context

A "pond district"

The state-owned Romersberg forest, which covers 420 hectares, is situated on the Lorrain plateau, in the département of Moselle, about 45 km east of Nancy. It has been the property of the State since the French Revolution. It has been undergoing conversion to high forest for about 100 years, and consists essentially of oak and beech. It lies on marly soils, often covered with silt, which are advantageous for forest production. But its main feature stems from its location at the heart of the small region known as the "pond district" on the eastern shores of the Lindre lake, known internationally for its ornithological interest. The "pond district" is part of the Lorraine Regional Nature Park (LRNP), which is keen to develop tourist activities in this area, which focus on the discovery and exploration of nature.

The Lindre lake and its protection

The ornithological interest of the Lindre lake has given rise to a project, put foward by nature conservation associations, to have it listed as a nature reserve. These associations are in fact worried about seeing its natural wealth whittled away by increased fishing and poorly supervised tourist development.

Several studies have been carried out in this area over the past 20 years, to define the boundaries of such a future reserve, and they have all concluded that it is necessary to include the Romersberg forest in it (ecolor. drae - 1985). But the project has not come to anything because of opposition from the mayors of the towns and villages concerned and from the département of Moselle, which owns the lake.

From confrontation to cooperation

The principal, and extremely active, Lorraine-based nature conservation association - called The Lorraine Site Conservancy (LSC) - has its headquarters a few km from here. Because the failure of conservation procedures has had the effect of heightening the vigilance and increasing the mistrust of environmentalists, these latter reacted actively in 1991, when a seed trees in one of the forest plots were felled.

The regional press was alerted and the ONF was accused of being bent on destroying the ecological wealth of this forest in the name of financial profitability. A banner was even unfurled in front of the journalists proclaiming: "Amazonia is in France too".

This attack took foresters by surprise. In fact, although they were aware of the plan to create a nature reserve, they did not think that they had damaged the biodiversity of the area by carrying out felling in a progressive natural regeneration. To clear the air, the ONF thus approached the LRNP and the LSC. With the backing of Professor Rameau, Professor of forest ecology at the Forestry School in Nancy (ENGREF), a study programme on the relationship between forest management and biodiversity was drawn up and spelled out in a three-way agreement between the LSC, the LRNP and the ONF. Funding from the Ministry of Agriculture and the Ministry of the Environment was requested and obtained for this programme.

Programme and findings of the studies undertaken

The framework for cooperation

It goes without saying that the study of the Romersberg natural forest heritage involved bringing together many scientific and technical disciplines. The work of the various specialists was thus incorporated within a steering committee. Because of this structure, fruitful exchanges have been successfully established between foresters and naturalists, with a view to drawing up a concerted forest management plan.

A detailed and multi-disciplinary analysis of the natural forest heritage

In the first instance, this involved a precise description and inventory of the sites, with a close look at the variety of stations and stands.

This preliminary phase to all French forestry management schemes was, in this case, dealt with in great detail by ONF foresters, and rounded off by two studies by Morhain (1991) and Gaudin (1992). It emerges from these studies that the Romersberg sessile oak and beech forest is well adapted to the dominant silty sites of the range. On the shores of the Lindre lake, the presence of wetlands of the alder-and-ash and elm types, accommodating in particular one of the rarest tree species in France - the fluttering elm (Ulmus laevis) - represents an area of major botanical interest. These stands cover about 15 hectares. On the rest of the range we find 185 hectares of old coppices-with-standards undergoing conversion and 220 hectares of young oak and beech high forest, showing every stage of development. The histogram below (Figure 1) illustrates the diversty of the stands found in the Romersberg forest.

This initial traditional and basic forestry approach was then enhanced by an analysis of the different animal populations in the range and their relationships with the various environments within the forest. This original study, part of the preparation of a management scheme, was carried out for insects - Lepidopterans (Courtois, 1994) and Coleopterans (Meyer et al., 1994) -, the Batrachia (Morhain, 1991), birds (Morhain 1991, and Muller 1993) and mammals-bats (Schwaab, 1993) and carnivores (Schweyer, 1994). The various factors of a detailed analysis of the natural environment were thus brought together in a four-year period. At this juncture, it became necessary to pool the considerable knowledge garnered, so as to turn a store of specific but fragmentary information into an overview of the animal biodiversity of the range and its relationship with forest management. After the specialists, the general forester came in (Degron, 1996). In a schematic sense, it emerged that six major factors underpinned the richness of the Romersberg animal biocoenoses:

1. The proximity of the Lindre lake and farmland is a key element in the frequentation of the range by birds of prey, bats, and certain carnivores.

2. The diversity of the types of stands (open environments, environments with shrubs and bushes, closed environments), which are home to various arrays of insects and birds.

3. The old trees, in particular, old oaks, which form favourite habitats for certain birds which live in hollows, Chiroptera, and certain insects. The ambiguity between the importance of old trees and old stands must be effectively removed - outstanding hollow-dwelling birds, such as the collared flycatcher (Ficedula albicollis) and the middle spotted woodpecker (Dendrocopos medius), do indeed need old trees.

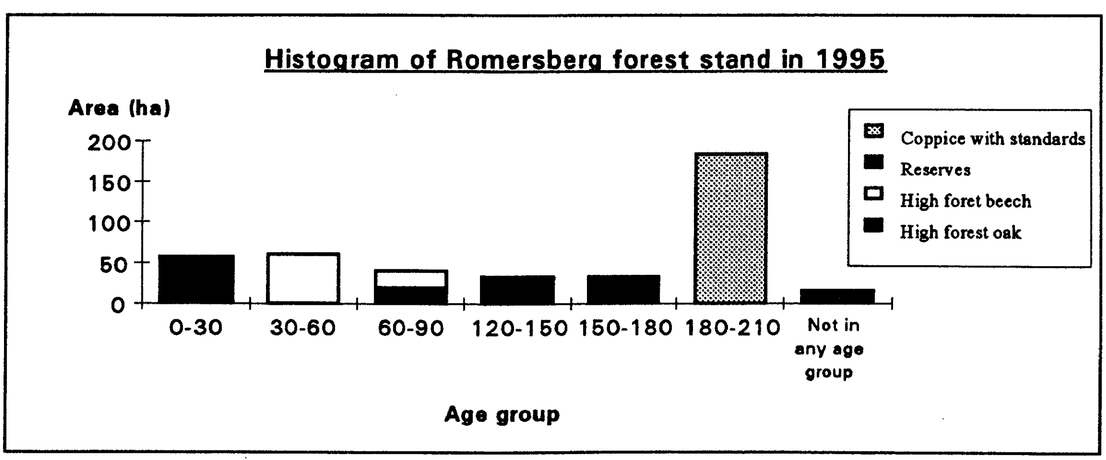

Figure 1. Histogram of forest stands.

4. Very old wood and dead wood, in different stages of development, house various groups of wood-eating and saproxylophagus insects. In the Romersberg range they are nowadays poorly represented, because, until the beginning of the 19th century, the forest was essentially logged for its coppices, without any reserve being set up (Degron, 1995a). The old wood in the range is thus barely 200 years old.

5. On the forest scale, an original bio-coenosis has been introduced or might be introduced in the small forest pools - 55 pools covering about four hectares in all.

6. The sets of badgers (Meles meles) have a certain biological importance as breeding sites for some protected carnivores, specifically the wild cat (Felis sylvestris).

Towards an overall and concerted management plan

The preliminary studies have shown that the maintenance of biodiversity was compatible, if not associated, with a form of silviculture directed at the production of quality timber. The conditions for taking into account the various elements making up the natural heritage were then drawn up. They were approved by the Romersberg steering committee. Using a coherent pooling of data, each specialized naturalist managed to find a sounding board for his particular concerns.

The forest manager's choices and methods: forest planning

Incorporating the ecological function in the production function

Bearing the above analysis in mind, the major choices for the Romersberg forest management scheme focus quite logically on two key points:

1. The production of quality oak wood.

2. A broad consideration of biodiversity factors.

The incorporation of the ecological function can be specified in terms of three precise objectives:

1. The sustainable maintenance of environmental diversity, which entails a tendency towards a balanced patchwork of stands in the forest legacy, which are also accessible environments. This primary objective also encompasses the maintenance of ecologically outstanding environments at the forest scale (stands of elm, stands of alder, mixed stands on the edge of ponds, forest pools, badger sets).

2. The maintenance of the current level - recognized as high - of outstanding bird populations in the range (collared flycatcher, middle spotted woodpecker).

3. A comprehensive enhancement of the accessibility potential, for animal life, of the range, associated with old wood and dead matter (development, in due course, of populations of wood-eating and saproxylophagous insects). Dead matter, poorly represented today in the range, must be regarded as a normal, natural component of the forest environment.

Integrated management methods: changes and continuity

To achieve these goals, several methods can be envisaged. Some are part and parcel of past management schemes, others represent an innovative input for an overall forest management structure. The general management framework still involves the conversion of coppices-with-standards to regular high forest, with oak as the target species. The regeneration programme for old stands must be as progressive as possible, to aim for the best possible equilibrium of the forest's make-up. These old stands will be logged over a 90-year period to avoid any abrupt drop in production. The method of the enlarged regeneration group must be used. A plot can thus be very progressively regenerated over 30 years, i.e. twice the application period of the management plan. Lastly, natural regeneration is to be encouraged.

Alongside this framework, which is very traditionally used in the management of France's lowland forests, several other measures can still be taken to incorporate specific restrictions associated with the natural heritage. In the case of wetlands, a conservancy-oriented management scheme for outstanding sites must be applied, which will make it possible to separate these environments quite distinctly from the general management of oak and beech forest. As far as hollow-dwelling animals and wood-eating insects are concerned, two original solutions may be introduced. First, it is necessary to select small areas for aging, or 10 percent of the area to be regenerated a priori, in the form of large copses covering about 1 hectare. The old stands thus selected will then be conserved until they have reached twice the loggable age of the target species (2 x 180 years = 360 years for oak). A priori, these small management units scattered throughout the range will be an open door for animal populations closely associated with very old wood and dead matter. Extra reserves will also be maintained; these will be of ecological importance in regeneration plots. With a density of two old oak trees per hectare in these management units, hollow-dwelling birds should thus be able to retain their habitat. These last two measures, which are altogether innovative, are the outcome of experiments. The goals that they represent are still to be achieved.

The economic consequences of these choices

To round off the scientific studies, it was necessary to assess the economic implications of the management choices. This study was carried out jointly by the ONF and the forestry and farming laboratory of the National Institute of Agronomic Research (INRA) (Siroux, 1996).

Two approaches have been proposed:

1. A theoretical approach, comparing the profitability of different silvicultural models applicable to the Romersberg forest, from the most intensive and artificial to the most extensive and natural.

2. A pragmatic approach, comparing the net revenues obtained by the previous management system and that proposed in the new management system.

The results are as follows:

1. For the theoretical approach, 5 possibilities were compared:
   - artificial silviculture for Douglas fir at 70 years
   - artificial silviculture of sessile oak at 110 years
   - natural silviculture for sessile oak at 180 years (previous management plan)
   - natural silviculture for sessile oak at 180 years with ageing plots (new management)
   - natural silviculture for sessile oak at 240 years.

The internal rates of profitability [IRP] are given in Table 1. As was to be expected, it was the most intensive model which obtained the highest IRP. The traditional silvicultural systems for oak differ markedly from the more intensive models. On the contrary, the difference is hardly noticeable between the old and new management schemes.

2. For the pragmatic approach, the difference between the net revenue obtained and the new management plan is more clearly defined.

For the next 15 years the loss of revenue due to the establishment of ageing plots is about 100F/ha/year (US$20) for a net revenue of about 1000F/ha/year (US$200), or 10 percent of the revenue. This percentage should be the same after the completion of the conversion phase to high forest in 90-100 years, and it will then represent about 350F/ha/year (US$70) for a planned net revenue of 3500F/ha/year (US$700). But in due course, between now and some 250 years hence, the impact of the aging plots on revenue will become very slight; the logging of 360-year-old trees, originating from high forest, and thus, a priori, of a much higher quality than trees originating from coppices-with-standards, will in fact obtain high revenues.

Table 1: The internal rates of profitability for different silvicultural systems

	Douglas fir	Oak 110 yrs	Oak 180 yrs	Oak 180 yrs +IV	Oak 240 yrs
IRP	2.97%	1.98%	1.61%	1.60%	1.45%

The maintenance of certain extra reserves after the completion of the regeneration phase will, for its part, have no more than a very slight influence on the revenue

Discussion

The economic studies that have just been described highlight a cost linked to a better consideration of biodiversity in forest management. In the short term, the forest manager's revenues thus drop by 10%. How are we to interpret this additional cost?

In a first approach, this extra cost can be interpreted as a consequence of the choice of extensive and natural silvicultural methods, resulting for the ONF from the application of the national management targets set by the State. This extra cost would thus be an evaluation of the value of biodiversity and accordingly a sound estimation of what society--represented by the State, and with the ONF as its guardian--is prepared to pay for "ordinary" biodiversity. In a more general way, it is thus important to define sustainable funding sources to meet this social demand. At the present time, the funding of such operations in state-owned forests is guaranteed by the profits made by the ONF's activities--mainly from the sale of wood. If this source of funding were to be inadequate, other ways could be envisaged, such as the payment of compensation by local authorities, or the development of products such as forest "eco-tourism".

In a second approach, the extra cost due to the better consideration of biodiversity can be interpreted as an investment. In fact, the maintenance of a high level of biodiversity helps to reduce health risks, helps to reduce the vulnerability of stands to climatic phenomena, and makes it possible to better stabilize revenues by the diversity of the products supplied (Barthod, 1994; Barthod, 1995). A precise estimation of the profitability of this investment is nevertheless quite difficult to make.

Whatever interpretation may be made, the most relevant and the most comprehensive measure for encouraging a consideration of biodiversity appears to be based on sound economic development of wood produced in an environment-friendly way, which leads quite naturally into the current debate about eco-certification, which we shall not go into here.

Conclusions about the Romersberg forest study

As of this writing, several conclusions may be drawn from this study.

An encouraging outcome from past management

Apart from the relative rarity of saproxylophagous species of insects, due to the virtual disappearance of large trees in the 18th century, the findings of the studies on different biodiversity factors can only be a source of comfort to foresters in terms of the outcome of their on-going efforts covering the past 200 years to improve the stands in this range. In fact, if few rarities have been discovered, which is not surprising for a forest situated on a relatively homogeneous and ordinary substratum, the level of biological diversity is high, particularly with regard to the birds and insect groups studied. For these species, there can be no doubt that the forester's activities, involving the establishment of a relatively balanced patchwork of stands of differing ages, has had a positive effect on biodiversity.

Much needed follow-up

The management measures proposed to take biodiversity more fully into consideration are, in some instances, relatively novel. Their experimental nature means that a follow-up study of their impact on target species must be undertaken. This is why, in 1996, there will be follow-up studies of bats and badgers. The amphibians in the three test pools will also be studied, as will nesting pairs of collared flycatchers in four plots that are representative of the forest. Lastly, a simple and reliable method for following up populations of saproxylophagous insects is currently being looked into.

Making use of a geographical information system [GIS]

The Romersberg forest has been one of the first forests, in France, to benefit from the use of a GIS for the formulation of its management plan, in particular for the visualization, in map form, of the findings of the many studies carried out. But the advantages of the GIS for the forest manager will come fully to the fore in the annual follow-up of all forest activities and operations, which will enable him to have a precise and constantly updated overview of the state of the forest. This is why all the ONF's management departments will be equipped with a GIS between 1996 and 1998.

Fruitful exchanges between foresters and naturalists

The work carried out since 1991 on the Romersberg forest, with the cooperation of scientists in various disciplines has lead all those foresters concerned to deal openly with these experts and become more aware of the variety and complexity of the natural environments they manage.

Conversely, by being closely associated with the formulation of a forest management plan, naturalists have been able to appreciate the very comprehensive nature of this management tool. They have learned a great deal about the forester's role, which is akin to that of a general practitioner responsible for weighing up different demands and requirements, and coming up with a multi-purpose forest management scheme.

This experience has thus been very formative for all those participating. Because of a better mutual grasp of the situation, it has been possible to introduce a spirit of constructive cooperation in Lorraine between foresters and naturalists, and there have been no further clashes since the 1991 dispute.

Investment for training

The high cost of the studies carried out in the Romersberg forest - about 1 million francs (US$200,000) - can also be justified as an investment in training. This forest is now used for visits and training sessions dealing with forest management and biodiversity. The types of audience vary a great deal: ONF foresters, cheek by jowl with owners and managers of private forests in France, foresters from abroad (Germany, Belgium, Poland), members of nature conservation associations, etc.

BIODIVERSITY AND PUBLIC FOREST MANAGEMENT BY THE ONF IN FRANCE

The management of the state-owned Romersberg forest is exemplary in terms of the scope of the studies and operations involved in its formulation. As a result the forest is thoroughly representative, in terms of management choices, of what the ONF is keen to implement in most of the forests it manages.

From the Romersberg example in particular to ONF-managed forests in general

In accordance with the law on nature conservation of 10 July 1976, the 1990 national directives on state-owned forest management specify that the forest forms the habitat of a large proportion of wild fauna and flora, and that, as such, it must fulfill the role of safeguarding biotopes and acting as a gene-bank.

If certain aspects of the management methods proposed are still at the experimental stage, the approach adopted in the Romersberg forest to introduce a multi-purpose form of management, incorporating biodiversity conservation, is now generally adopted for all forest management plans currently under review.

As from November 1993, the ONF head office has circulated to all its foresters technical instructions and handbooks dealing with "biodiversity considerations in forest development and management". These documents explain how to assess, conserve, develop, and monitor biodiversity, using an integrated approach at every stage of forest management. Their circulation has gone hand in hand with, and been followed up by, numerous training sessions on these topics, which represent a major investment.

A policy and coherent instruments for the conservation of forest biodiversity

At the same time, the ONF has also drawn up a coherent system for conserving biodiversity based on the value and scarcity of the natural environments and species in question.
In a schematic way, we may single out:

1. A general consideration of "ordinary" biodiversity in all forest development and management plans, akin to what is being done at Romersberg.

2. A definition of "series of special environmental and ecological interest" with a specific management plan for outstanding natural environments and species, where priority is given to the protection objective, but not to the exclusion of the various productive functions of, and public access to, the forest. This applies to the outstanding wetlands of the Romersberg forest.

3. The creation of "biological reserves", for the most outstanding "series of environmental and ecological interest", by a regional

scientific committee set up by the ONF. These reserves, which must be approved by the Ministry of Agriculture and by the Ministry of Environment, are also supervised by a steering committee made up of non-ONF scientists.

The ONF is also setting up a network of undeveloped nature reserves of a significant size (approximately 50-200 hectares). These are mainly earmarked for improving knowledge about the way forest ecosystems work, so as to be able to derive lessons for management. One of the basic principles of the French forest is in fact "To imitate nature and urge on her work"[3].

Forest management and development: a basic tool for sustainable management

But whatever the targets may be, they are all part and parcel of the forest management and development approach, which is in turn encompassed by the national management directives.

The main stages of forest management are:

1. Analyses of the environment and of economic and social requirements.

2. A summary of these analyses and needs and the setting of long-term targets.

3. The formulation of a medium-term management plan.

4. A follow-up to this plan by way of day-to-day programmes and operations.

In a general way, it would seem possible to apply this approach to the sustainable management of all natural areas, thus lending it an across-the-board universal value.

CONCLUSION: INTEGRATED FOREST MANAGEMENT

A consideration of biodiversity as part of forest management is very much part of the age-old tradition of multi-purpose management in France's forests.

It is in fact one of the ingredients of natural environments, and one of the factors in society's requirement that foresters should incorporate in their management choices, along with the production of quality timber, the protection of landscapes and countryside, land stabilization in mountainous areas and dunes, and public access.

The broadening and ever greater complexity of the factors determining both analyses and choices represent a major challenge for foresters.

They call for major investment in terms of money and, above all, human resources. They also make foresters look for compromises, and sometimes call into question old technical certainties. But a real and sincere openness to outside elements is vital to the forester. That general practitioner, in charge of the forest's health and well-being, is the better to safeguard and disseminate information about his unique role in the overall and sustainable management of forest and woodland alike.

REFERENCES

Badre L., 1983. Histoire de la forêt française - Paris. Arthaud. - 312 p

Barthod C., 1994. Sylviculture et risques sanitaires dans les forêts tempérées. 1ère partie. Revue Forestière Française, 6, 609-628.

Barthod C., 1995. Sylviculture et risques sanitaires dans les forêts tempérées. 2ème partie. Revue Forestière Française, 1, 39-53.

Courtois J.M., 1994. Contribution à une étude écologique forestière globale : Essai d'inventaire des Lépidoptères, étude de la variation de la diversité en fonction de divers traitements, choix de bio-indicateurs, conseils de gestion. Rapport intermédiaire. Parc Naturel Régional de Lorraine. - 84 p.

Degron R., 1995a. Historique de la forêt du Romersberg : une forêt de Lorraine sous l'emprise des salines. Revue Forestière Française, 5, 590-597.

[3] Quoted from : Louis Parade - Head of the Forestry School in Nancy from 1838 to 1864.

Degron R., 1995b. Synthèse des études écologiques de la forêt domaniale du Romersberg (Moselle - Division de Château-Salins) dans la perspective d'une proposition d'aménagement global du massif. Office National des Forêts. - 20 p.

Ecolor.drae de Lorraine. 1985. Propositions pour la création d'une réserve naturelle et conventionnelle dans la région des étangs de Lindre. Moselle. ECOLOR .- 62 p et annexes

Gaudin S., 1992. Contribution à une étude écologique forestière globale : typologie des peuplements de la forêt domaniale du Romersberg (Moselle). Mémoire de troisième année de l'E.N.I.T.E.F - 89 p et annexes.

Huffel G. 1925. Histoire des forêts françaises de l'origine jusqu'à la suppression des maîtrises des Eaux et Forêts - Nancy. Ecole Nationale des Eaux et Forêts - 178 p

Meyer M., Braunert C., Dolisy D. et Drugmand D., 1994. Etude des patrimoines naturels forestiers de la forêt domaniale du Romersberg (F-Moselle). Partie entomologique. Inventaires qualitatifs et quantitatifs des bio-indicateurs de milieux forestiers parmi les Coléoptères : Carabidae, Cerambycidae, Lucanidae, Staphylinidae. Rapport

Ministère de l'Agriculture, 1990. Directives nationales de gestion des forêts domaniales - 23 p.

Ministère de l'Agriculture, 1994. La gestion durable des forêts françaises - 78 p.

Ministère de l'Agriculture, 1995. Critères et indicateurs de gestion durable - 49 p.

Ministère de l'Agriculture, 1996. La politique forestière française - 20 p.

Morhain E., 1991. Forêt domaniale du Romersberg (Moselle). Contribution à l'étude de la valeur biologique et écosystémique. Proposition de gestion. Mémoire de troisième année de l'E.N.I.T.A. de Dijon. Conservatoire des Sites Lorrains - 62p et annexes.

Muller Y., 1993. Expertise avifaunistique de la forêt du Romersberg. Conservatoire des Sites Lorrains. - 40 p et annexes.

Office National des Forêts 1993 - Prise en compte de la diversité biologique dans l'aménagement et la gestion forestière - Instruction - 18 p

Office National des Forêts 1993 - Prise en compte de la diversité biologique dans l'aménagement et la gestion forestière. Guide - 32 p

Siroux H. 1996. Economie de la gestion de la biodiversité en forêt. Mémoire de troisième année de l'ENSA de Rennes. Institut National de la Recherche Agronomique - 37 p

Schwaab F., 1993. Etude des populations de Chiroptères de la forêt du Romersberg, 1ère partie Août 1991-Août 1993. Rapport intermédiaire. Parc Naturel Régional de Lorraine. - 44 p et annexes.

Schweyer J.B., 1994. Contribution à l'étude des carnivores de la forêt domaniale du Romersberg (F.-Moselle). Statut des carnivores et étude des populations de blaireaux. Rapport intermédiaire. Parc Naturel Régional de Lorraine. - 18 p et annexes.

STATE OF THE ART IN LOGGER EDUCATION: EMERGING ROLES AND RESPONSIBILITIES[1]

by

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ABSTRACT: Describes the current state of the art in logger education and training in the US. The paper highlights the increase in activity resulting from the Sustainable Forestry Initiative of the American Forest and Paper Association. The differences between programs of accreditation, certification and licensing are noted. Describes in brief detail what is being taught and the partnerships engaged in the education efforts. Funding arrangements are outlined for unique approaches. Future prospects are outlined for logger education.

Key Words: loggers, training, education, roles, responsibilities, and funding

INTRODUCTION

The level of activity in logger education and training has risen sharply in the last few years compared to the previous twenty that the author has been working with this issue. Part of the increase in activity can be attributed to the Cooperative Extension program of LEAP: Logger Education to Advance Professionalism which stimulated activities in various states with grants aimed at logger education. More recently, the Sustainable Forestry Initiative of the American Forest and Paper Association (AF&PA) called for landowner and logger education efforts by their member companies (AF&PA, 1995). Based on my assessment, some 35 states have logger education efforts now underway. Several of these states have had logger education efforts dating back to the mid sixties, and progressive companies and contractors have long recognized the need to provide education and training for their employees. This paper mainly addresses the most recent activities and highlights some emerging roles and responsibilities.

TRAINING OR EDUCATION?

Some would make a large distinction between the terms "education" versus "training"; however, they are typically used interchangeably by most people in the forestry sector. Some use the term "training" to describe the physical training of muscle patterns needed to perform the manual and control tasks in logging, while reserving the term "education" for changes in knowledge or attitudes that are largely mental and less visible. The fact that both training and education are needed to carry out logging tasks, such as felling trees, makes the semantic distinctions both cumbersome and hard to use. A compromise would be to concurrently list such programs as "logger training and education" programs when practical and emphasize the distinctions when necessary.

STATUS OF LOGGER EDUCATION AND TRAINING PROGRAMS

The author's best estimate of the current status of logger training and education programs are listed in Table 1. Each program is identified by state, program name/type, partial listing of cooperators, whether the program can be identified as an accreditation, certification or licensing program, and an abbreviated list of topics in the program. Admittedly, there are likely errors in this summary as the rate of change in these programs is phenomenal. In addition, where data were not available, I simply listed the status as "unknown". For some states where forestry is not a large part of the economy it may well be that nothing is happening in the area of logger training. Also, the table does not reflect programs well that are in the planning stages except where information has come to the attention of the author. Finally, Table 1 does not show national efforts of organizations like the American Pulpwood Association, the AF&PA or its individual member companies, or the Cooperative States Research, Education, and Extension Service (CSREES), all of whom have been actively supporting state and local efforts in logger education and training. The abbreviations at the end of the table are perhaps awkward but they allow quick state by state comparisons. The author welcomes suggested changes and corrections to the table.

ACCREDITATION, CERTIFICATION OR LICENSING

At last year's COFE meeting, I detailed the distinctions between accreditation, certification and licensing

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

(A,C,L) and will only briefly repeat them here. Accreditation refers to a process where the quality of the education is meeting some standard. Certification attests to the qualifications of individuals or products and often has an expectation of future performance associated with it. Licensing is a privilege to perform some function bestowed on individuals by government. There are more differences that help clarify the distinctions, and to confound us all, there are mixed combinations of these found in logger education and training programs (Garland, 1995).

WHAT TOPICS ARE TAUGHT?

Table 1 lists some of the topics being taught in the logger education and training programs, but of necessity they are highly abbreviated. Several types of training are needed for the owners and managers of logging firms and the individual loggers. What is more important is who decides what loggers need in the way of education. The educational design process should start with the needs of the learners not necessarily what some other group thinks the learner ought to know. A mixture of views on what loggers need usually produces a substantial list of needed education and training. Those providing this mixture include loggers themselves, owners/managers of logging contractor firms, industry purchasers, forest land managers, university and college educators, landowners, associations/organizations, regulatory agencies, and others.

Another way to look at training needs are to categorize them along these lines:

Entry level training

- JOB SKILL TRAINING (manual/tool skills, machine operator skills, etc.)
- INTEGRATED JOB SEQUENCE TRAINING (training for next job while in current one, cross training)
- CREW PRODUCTIVITY TRAINING
- WHOLE-CONCEPT TRAINING (how the workers job fits into the whole firm and forestry sector)
- MANAGEMENT TRAINING

For some of these, the emphasis is on the individual workers and their development, while others involve the crew and the entire firm. Owners and managers of logging firms might consider that they and their individual employees are on a "trajectory of development" over time. The trajectory may be guided and enhanced by education and training or the result of chaotic responses by the firm and individuals. For example, the firm has needs for topics in logging business management, and individuals need skills as machine operators (Timber Harvesting, 1996), The forestry sector needs workers who can use principles of ecology and silviculture so that loggers are in reality "APPLIED ECOLOGISTS" as they work in the woods.

Many states and organizations have efforts underway to develop curriculums that encompass more complete consideration of needed topics (APA, 1995). Other approaches recognize that job content of forestry jobs are changing and workforce needs of the future require different knowledge, skills, and abilities (Garland, 1994). The profile of logging jobs in the future will be quite different than those of earlier generations of loggers.

INNOVATIVE FUNDING SOURCES

Make no mistake about who pays for logger education and training. Ultimately the consumer of goods and services from the forest will pay for logger education and training if the free enterprise system will work as intended. However, during the start-up phase of increased logger education, the transfer mechanisms between landowners, loggers, mills, and consumers appears to be bumpy and inequitable (the playing field is not level). The costs and benefits of logger education and training are not allocated nor distributed well. The individual logging firm is the focus of the education and training decisions with a wide variety of organizations "helping " to influence the decisions.

Some of the funding sources used for starting logger education and training programs have been both necessary and innovative.

Initial "LEAP" grants totaling $300 thousand dollars spread across many states leveraged more than ten times that amount of logger training activities.

A partnership of MS loggers, industry, and university folks convinced the MS legislator to fund an Extension position to work in logger education, plus the industry assessed itself to pay for operating expenses.

Table 1. Status of Logger Education and Training Programs by State.

State	Program Name/Type	Cooperators	A, C, L	Topics
AL	Professional Logging Managers (PLM)	Ext., Auburn U. , AL Log. Assoc., AL For. Assoc.	A	S,FA/CPR,E&S,LBM, HS
AK	in progress			
AR	AR Prof. Timber Harvester Prog.	AR Forestry Assoc.& AR Timber Producers Assoc.	A	S, BMPs, LC,
AZ	unknown			
CA	Illness & Injury Prevention Prog.; Logger Training Prog.	Assoc. California Loggers (CA Div. of Forestry)	A, L	S, FA/CPR, LC, BMPs, Other
CO	in progress			
CT	CT For. Practitioner Certification	Div. of Forestry, Dept. of Environ. Prot. & Ext.	L	Exam for 3 classes of employees
DE	unknown			
FL	FL Master Logger Program	FL For. Assoc. & SE Wood Producers' Assoc.	A	S, LC, LBM, E&S, BMPs, Others
GA	GA Prof. Timber Harvester Program	GA For. Assoc., Ext., GA For. Comm., SE Wood Producers	A	BMPs, S, LC, LEAP, LBM
HI	unknown			
ID	ID LEAP Program	ID Assoc. Cont. Loggers & Ext., plus others	A	LEAP, BMPs, S, FA/CPR, Others
IL	Game of Logging	IL	C	FST
IN	Game of Logging	IN For. Ind. Council, DNR,	C	FST
IA	Game of Logging	IA DNR	C	FST
KS	unknown			
KY	KY Master Logger Program	KY For. Ind. Assoc., Ext. , Moorehead St. U., USFS, TVA, Bryan Equip. Sales	A	S, FA/CPR, LC, E&S, BMPs,
LA	Logging Safety Awareness	LA For. Assoc. & Ext., OSHA	A	OSHA, S, LC,
MA	MA Forest Laws: Timber Harvester License	MA Div. of Forests & Parks, Ext., Other agencies	L	Exam over LAWS, BMPs, E&S. Cont. Educ. required
ME	Certified Logging Professional (CLP)	ME Tree Found., ME For. Prods. Council, APA	C	S, FA, E&S, HS, FST, LBM
MD	MD Master Logger Program	MD Forests Assoc.	A	FA/CPR, BMPs, S, E&S,
MI	Logger Education (LEAP)	Ext. & Tbr. Prod. Assoc. of MI & WI, SFI-SIC	A	E&S, BMPs, Others
MN	Logger Ed. Workshops, MN Targeted Industries, Truck Drivers Training	MN For. Ind. Assoc., MN DNR, Ext., & Others	C/A ?	S, FA/CPR, OSHA, LC, BMPs, E&S, LBM, Others
MS	MS Logger Education	MS Log. Educ. Council, Ext., MFA, MLA, SFI-SIC, APA	A	Curriculum w/ S, LC, FA/CPR, OSHA, LAWS, E&S, LBM, Others,
MO	LEAP	Ext. & MO For. Div.	A	E&S, BMPs, Others
MT	MT Accredited Logging Professional (ALP)	Montana Loggers Assoc. & Ext.	A	FA/CPR, BMPs, E&S, LC, STEW, HS
NE	unknown			
NV	unknown			

State	Program Name/Type	Cooperators	A, C, L	Topics
NH	NH Certified Loggers & Forest Products Truckers	NH Timber. Own. Assoc., UNH Thompson Sch., Ext	A (C)	FA/CPR, FST, LAWS, S, LBM, LC, E&S, Others
NJ	unknown			
NM	unknown			
NY	Logger Education	New York Logger Training Board, Ext. & Others	A	S, FA/CPR, E&S, Others
NC	PRO-Logger Program	NC For. Assoc., Comm. Colleges, Ext., & Others	A & C	S, FA/CPR, E&S, LC, LAWS, LBM, Others
ND	unknown			
OH	Game of Logging, Logger Education	GOL, inc; Hocking College & OH For. Assoc.	C & A	FST, BMPs, STEW, Others
OK	Joined with AR program	OK SFI-SIC	A	see AR above
OR	OR PRO-Logger Prog. & OSU Logger Education (LEAP)	Assoc. OR Loggers, & Ext.	A	E&S, LC, S, FA/CPR, LBM, LAWS, HS, BMPs, Others by credit
PA	Timber Harvester (in reorganization)	Timber Harvesting Council of PA	?	Various programs were offered
RI	unknown			
SC	Timber Operations Professional (TOP) Program	SC For. Assoc. & Tech. Educ. System, & Ext.	A	S, LC, BMPs, LBM, CDL, Others
SD	Logger Education to Advance Professionalism (LEAP)	BH Women in Timber, Ext. & BH Timber Prod. Assoc.	A	S, LC, BMPs, LBM, E&S, & Others
TN	Master Logger Program	Ext., TN For. Assoc., TN Div. of For., TVA, USFS, Ind. & Others	A	FA/CPR, S, LC, E&S, LBM, BMPs,
TX	in progress	TX Loggers Council, Ext. & TFA	?	?
UT	unknown			
VT	Logger Education to Advance Professionalism (LEAP): VT Safety Advancement Prog.	Ext. & Cooperators; VT For. Products Assoc.	A, C	S, FA/CPR, LBM, E&S, BMPs, PROF., Others; FST, LAWS, GOL,
VA	Logger Education	Ext., VA Dept of For, VA For. Assoc.	A	S, LC, FA/CPR, BMPs, OSHA, E&S, LBM, HS, Others
WA	WA Accredited Logging Professional	WA Cont. Loggers Assoc., Ext., Other cooperators	A	WA S, LC, FA/CPR, BMPs/FPA, E&S, LBM, FST, Others
WV	Logger Education & Certification (licensing)	WV Forestry Association,. WV Div. For., Ext, Appalachian Hdwood Ctr.	L	FA/CPR, S, OSHA, LAWS, BMPs, GOL, Others
WI	Forest Industry Safety & Training Alliance (FISTA)	FISTA (non-profit org.) & Others; SFI-SIC	A	OSHA, S, LC, FST, GOL SKIDDER,
WY	LEAP	Ext. & Div. of Forestry	A	E&S, BMPs, S, LBM, Others

<u>ABBREVIATIONS</u>

A,C,L = Programs of Accreditation (A), Certification (C), or Licensing (L)
BH = Black Hills
BMPs = Best Management Practices or Forest Practices Regulations
CDL = Commercial Driver's License
DNR = Department of Natural Resources

E&S	= Ecology and Silviculture
Ext.	= State Cooperative Extension Service of the Land Grant Universities
FA/CPR	= First Aid, Cardio-Pulmonary Resuscitation
FST	= Faller Skills Training (may be GOL)
GOL	= Game of Logging (private sector program involving falling and skidder operator training)
HS	= Harvesting Systems Education
LAWS	= Laws and Regulations relating to logging operations
LBM	= Logging Business Management
LC	= Loss Control (education to deal with insurance and safety issues)
OSHA	= Occupational Safety and Health Administration (rules)
S	= Safety training and education (skills and safety program implementation)
SFI-SIC	= Sustainable Forestry Initiative- State Implementation Committee
USFS	= US Forest Service, Department of Agriculture
TVA	= Tennessee Valley Authority

A consortium in GA pulled together forestry associations, commissions, university, and loggers to fund logger education aimed at the entire logging firm not just individual workers.

The "Game of Logging"™ is a private sector logging skills provider

The Sustainable Forestry Initiative State Implementation Committee in MI helped fund increased logger education through university and association partnerships

The Certified Logging Professional program in Maine is dependent on subscriber fees for much of the program costs

A number of logger training program participants are receiving lower insurance rates as a result of training activities in ME, MN, NC, and elsewhere.

Grants from the Tennessee Valley Authority helped develop "Master Logger" Programs in the region

The OR PRO-LOGGER program depends on fees and the commitment of Associated Oregon Loggers to fund a training position

In MT some of the materials used to develop Extension's Stewardship Education for landowners through federal and state grants have helped the MT Loggers Association in their training

A more in-depth review of funding shows that start-up costs are needed to get the education and training efforts started, user fees can contribute part of the funding from firms and individuals, voluntary efforts can be extraordinary but are not sufficient to sustain programs, and partnerships that bring resources to the effort are highly valued.

ROLES AND RESPONSIBILITIES

The new era of increased attention to logger education and training is welcomed from those who have spent much of their careers emphasizing training investments in the logging workforce as means to improve individuals, firms and the entire forestry sector. I have some suggested changes and emphasis for the roles and responsibilities of those involved in the entire area of logger training and education.

INDIVIDUAL WORKERS should consider their own trajectory of development and the way logger education and training can be investments in their own development.

LOGGING FIRMS may need to rethink education and training as strategic investments that contribute as much or more than buying equipment. Training is not a fringe benefit to cut back when the market takes a downturn.

INDUSTRY might well give up its illusion of control over logging contractors and welcome them as partners whose success in logger education contributes to the success of the entire forest industry sector.

ASSOCIATIONS at the state and national level might recognize they are not expert in education and training and need to cooperate with universities, colleges, and various training providers to serve their members. Furthermore, real commitment to logger education takes substantial resources not just a title or part-time staff assignment.

EDUCATIONAL INSTITUTIONS need to think of long term staff commitments to logger education rather than hiring part-timers to work on the grants that run out in a few years.

STATE FORESTRY AGENCIES have recognized the value in logger training and education to implement best management practices and forestry regulations but may need to support broader logger training efforts.

EQUIPMENT MANUFACTURERS AND SUPPLIERS need to support the logger training efforts not just for operator training but their for their own employees who need similar education and training to support the entire forestry sector's efforts in ecology and silviculture, logging business management, etc.

LANDOWNERS AND MANAGERS need to seek loggers who have received education and training for preferential contracts to work on their lands.

PROFESSIONAL FORESTERS AND CONSULTANTS need not fear that loggers will be doing their work but that loggers will be able to better implement the forestry practices foresters have long advocated.

EXTENSION SERVICES in states with little commitment to logger education need to recognize the potential for the informal adult education that will enable loggers to conduct improved operations on our nation's forest lands.

The list might well continue as more and more organizations become involved in logger education and training, but real challenges lie ahead to align the positive forces and organizations to contribute to partnerships to improve logger education.

SUMMARY

From my experience over the years with logger training and education I have a sense of what has happened in the past--successes and failures. The concept of a trajectory of development for the forestry sector is still hard to see on a state-by-state basis. It is even harder to visualize when trying to aggregate all of the state efforts into a national picture. There is value in the many different approaches underway if the successful ones can be sustained. It will take greater commitment to sustain many of the logger training and education efforts in the future once the current wave of interest has crested. I am optimistic and the hazy trajectory of development that I see for the nation's loggers is headed upwards not downwards. COFE members can help contribute to that upward trajectory.

LITERATURE CITED

American Forest and Paper Association, 1995. Sustainable Forestry: Principles and Implementation Guidelines. AF&PA, Washington, DC. 10 p.

American Pulpwood Association. 1995. An Interim Report on the Status of Logger Training and Education Programs in Thirty Forested States. 95-A-2. APA. Washington, DC. 36 p.

American Pulpwood Association. 1995. Statewide Model Logger Training and Education Program. 95-A-2. APA. Washington, DC. April, 1995. 16 p.

Garland, J.J., 1994. Forestry Jobs of the Future: Matching Forest Needs with Workforce Knowledge, Skills, Abilities and Risks. Forest Engineering Dept., Oregon State University, Corvallis, OR 204 p.

Garland J.J., 1995. Accreditation, Certification and Licensing of the Forestry Workforce. Proceedings of the Council on Forest Engineering. Sustainability, Forest Health and Meeting the Nation's Need for Wood Products. June 5-8, 1995. p. 221-227.

Timber Harvesting, 1996. Training for the Future. Northwest Report. May, 1996. p. 46-48.

EVALUATION OF HARVEST PLANNING TRAINING[1]

by

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ABSTRACT: Interest in Best Management Practices (BMP)-related logger education and training has increased dramatically in recent years. Harvest planning is a critical component of forestry water quality BMPs. All states' BMP manuals recommend written timber harvest plans, and several states require them by law. The objective of this study was to evaluate the impact of harvest planning training and the use of written timber harvest plans on BMP compliance, landowner satisfaction and weather-related downtime in the Virginia Piedmont. Nine randomly chosen loggers (study group) from the Virginia Piedmont participated in two days of intensive harvest planning field training. Nine additional loggers were randomly chosen as a control group. Study group loggers prepared and followed written timber harvest plans for the 29 tracts they harvested during the 9-month study period immediately following the training. Study group loggers outperformed control group loggers (who did not receive harvest planning training or prepare written harvest plans) for mean BMP compliance (90% vs. 86%), mean landowner satisfaction (3.54 vs. 3.27 on a scale where 4.0 = well satisfied), and mean percentage of scheduled operating days lost due to weather-related downtime (10% vs. 13%). Absolute scores for all evaluation criteria for both groups were good, and the differences, though statistically significant, were relatively small, leading to conclusions that:

* Loggers in the Virginia Piedmont are generally doing a good job.

* They are planning their operations, whether a written plan is required or not.

* Harvest planning training and written harvest plans can marginally improve BMP compliance, landowner satisfaction and weather-related downtime, even for loggers who are already performing well.

Key Words: logger education and training, harvest planning, water quality Best Management Practices (BMPs), BMP compliance

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ENVIRONMENTAL CONCERNS AFFECTING FOREST OPERATIONS ON PUBLIC LANDS IN THE CENTRAL APPALACHIANS[1]

by

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ABSTRACT: Located in the central Appalachians, the Monongahela National Forest contains a variety of forested ecosystems that provide abundant supplies of high-quality hardwood timber and extensive recreational opportunities. Efforts to sustain these forested ecosystems have created a complex array of environmental concerns that affect forest operations. The 1986 Land and Resource Management Plan for the Monongahela identified several important areas of concern related to wildlife habitat, recreation, and water quality. Land-management objectives and prescriptions for addressing these concerns are discussed with respect to constraints on forest operations and the need to plan forest operations on broad spatial and temporal scales, apply conventional harvesting systems carefully, and identify opportunities to apply alternative harvesting systems.

Key Words: forest planning, timber harvesting, environmental impacts

INTRODUCTION

On public lands, forest operations that include road construction and timber harvesting are increasingly being met by a complex array of challenges, many resulting from increased public awareness of and concern for the environmental quality of public forests. During the 1960's and 1970's, some of these concerns resulted in federal legislation governing land-management planning on National Forests. This legislation mandated increased public involvement in decisions affecting the management of these forests. More recently, the planning and conduct of forest operations have become even more complex as public land-management agencies have embraced the concept of "ecosystem management." According to Salwasser (1994), the laws of the 1960's and 1970's regulating forest planning processes "did not anticipate the magnitude of shifts that would occur in how people value wildlands and natural resources as our society moved from rural to increasingly urban settings and lifestyles . . . and in general from utilitarian to preservation perspectives." To broaden the spectrum of issues included in the planning process and more effectively address environmental concerns associated with the former "multiple use" or ecosystem management paradigms, National Forest staffs now include specialists from several natural resource-related disciplines.

In this paper I provide a qualitative assessment of the environmental issues and concerns affecting forest operations on public lands managed for multiple uses, and discuss how forest operations are changing to satisfy changing public values.

The Monongahela National Forest, located in eastern West Virginia, is the general focus of this assessment. Although the Monongahela is but one of several National Forests in the Appalachians, its ecological diversity and variety of user demands imposed on the Forest provide an opportunity to identify a wide range of environmental issues. By giving the public a voice in forest management, the National Forest planning process helps identify important environmental concerns and forest values. Further, the Monongahela represents a large block of public land in a region where most forest land is privately owned and public concerns related to forest operations often are focused on National Forest lands. This was apparent during the controversy over clearcutting in the late 1960's and early 1970's. During that time, the Monongahela was a focal point in the national debate over management practices on public lands.

The more important categories of public uses and environmental concerns are identified in the Monongahela National Forest's 1986 Land and Resource Management Plan (USDA Forest Service 1986). Other important sources of information include white papers prepared by resource specialists targeting specific environmental issues, and interviews with resource specialists at the forest and district level.

THE FOREST

The ecological subregions encompassing the Monongahela include the Northern Ridge and Valley Section and the Allegheny Mountain Section (McNab and Avers 1994). With a variety of forest soils, elevations ranging from 300 to 4,800 feet, and average

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-Aug. 1,1996.

annual precipitation ranging from 30 to 60 inches, the composition of tree species and productivity of the Monongahela's forests are highly diverse. Forest types include red spruce, white oak-white pine, and northern hardwood types common to the Northern Forest Region, as well as the upland oak and central hardwood types common to the Central Forest Region (Eyre 1980). Collectively, hardwood types account for 90 percent of the Monongahela's forested area (DiGiovanni 1990). Potential growth rates range from 20 to 220 ft^3/acre/year. Much of the Forest originated following the heavy logging and frequent severe fires that occurred between 1880 and 1920. The second-growth forests now are maturing and sawtimber stands account for 76 percent of the Monongahela's 908,000 acres. Half of this sawtimber acreage contains more than 6,000 board feet/acre.

The demands on the Monongahela's resources are as varied as the forest itself. Located relatively close to several major metropolitan areas (within a day's drive for one-third of the nation's population) the forest provided 900,000 to 1,100,000 recreation visitor days annually from 1985 to 1994. Recreation activities range from berry picking and picnicking to rock climbing and whitewater boating. A National Recreation Area and five wilderness areas contribute to the Monongahela's attraction. Recreation resources of particular importance as emphasized by the public in the Forest Plan include 563 miles of hiking trails, 567 miles of coldwater streams that provide trout fishing, large remote areas that serve as habitat for wild turkey and black bear, and extensive opportunities for semi-primitive nonmotorized recreation.

The Monongahela is situated in a region with a large and growing forest products industry that is becoming increasingly important to the regional economy (Greenstreet 1994). In addition to the large number of hardwood sawmills producing factory-grade lumber and specialty products, large-capacity plants are being constructed in West Virginia to manufacture oriented-strand board and laminated veneer lumber from an abundant supply of soft hardwoods such as yellow-poplar and red maple. Demand for these structural products is due in part to a reduction in softwood timber supplies linked to environmental concerns over forest operations on western National Forests (Wiedenbeck and Araman 1993). The growing demand for the Monongahela's hardwood sawtimber is reflected by stumpage prices that, for several of the more desired species, increased by 300 to 800 percent from 1985 to 1995.

THE FOREST PLAN

The current Monongahela National Forest Plan identifies specific categories of resource uses and environmental concerns expressed by the public and National Forest resource specialists, and defines resource-management objectives and goals for addressing these concerns and uses. The resulting management prescriptions and guidelines represent the link between forest operations and environmental concerns and resource uses. Whether amenity or commodity driven, these management objectives define the operating environment for forest operations and the challenges to be met by resource managers in meeting these objectives. The Monongahela Forest Plan categorizes environmental concerns into several broad topical areas. Those with the greatest potential impact on forest operations include road construction, vegetation manipulation, recreation, and wildlife.

Following is the allocation of the total acreage available when the Forest Plan was developed in 1986, by management prescription:

- 78,000 acres of designated wilderness, no timber harvesting
- 125,000 acres for semi-primitive/nonmotorized recreation, excluding harvesting.
- 1,000 acres for developed recreation, excluding harvesting.
- 12,000 acres for research areas, harvesting allowed but area not included in timber base.
- 228,000 acres for intensive management, including motorized recreation, with 95,000 acres suitable for timber management.
- 387,000 acres managed primarily for remote wildlife habitat, with 236,000 acres suitable for timber management.

This distribution of acreage by management prescription demonstrates the priority given by the Forest Plan to maintaining remote habitat for wildlife species intolerant of disturbance, and providing opportunities for semi-primitive nonmotorized recreation. A total of 590,000 acres was allocated to these management objectives. For more than 70 percent of the 331,000 acres classified as suitable for timber management, the primary goal is providing habitat for wildlife species intolerant of disturbance. Management objectives also affect forest operations on the acres available for timber harvesting by limiting the frequency and extent of disturbance, prescribing long rotations to grow large sawtimber trees, reducing levels and standards of road construction, and requiring seasonal or permanent road closures.

A goal of the 1986 Forest Plan was to continue timber harvesting at pre-plan levels. To maintain this level of harvesting through regeneration and improvement cutting required a timber base of approximately 331,000 acres. The maximum production from this timber base is estimated at 53 million board feet (mmbf) per year for the first 10 years of the Forest Plan, increasing to 77 mmbf over 60 years as the second growth-timber matures. In 1986 there were 724,000 acres on the Monongahela classified as tentatively suitable for timber production, lands not withdrawn for wilderness or other purposes, or classified as unsuitable because of soil or regeneration concerns. Maximum production on these 724,000 acres is estimated at 165 mmbf per year. Actual harvest levels since 1986 have averaged approximately 36 mmbf per year. The difference between maximum and actual harvests from the 331,000-acre timber base can be attributed to a poor market for small trees and the time required to process environmental assessments. Changes in public values and environmental concerns that developed since the 1986 Forest Plan was completed also have constrained harvest levels.

Several additional environmental issues affecting forest operations are identified in the 1986 Forest Plan, and others recently were addressed in a series of reports prepared by resource specialists. Given the Monongahela's rugged terrain, areas of high precipitation, and numerous streams supporting native brook trout, soil disturbance and water quality are important issues. Consequently, there is considerable concern over the hydrologic and soil productivity impacts of logging steep slopes with conventional ground-based equipment. Developing and sustaining old-growth or mature forest areas and sustaining suitable habitat for neotropical migrant songbirds are equally important issues. Awareness of the existence of threatened, endangered, and sensitive plant and animal species has increased significantly since 1986, and any constraints that result from protecting the integrity of these populations affect all forest operations.

Although this paper is largely concerned with public land issues, many of the environmental issues identified in the Monongahela Forest Plan also are of great interest to private forest-land owners. A survey of West Virginia tree farmers found that most agreed that landowners should harvest timber. However, many also believed that cutting trees could result in the destruction of wildlife habitat, soil erosion, muddy streams, and a loss of recreation space (Egan et al., in press). Many of these same concerns were cited by nonindustrial private forest-land owners as reasons for not harvesting timber. Public concerns related to timber harvesting and water quality also resulted in the West Virginia State Legislature enacting the 1992 Logging Sediment Control Act, which includes specific guidelines for reducing erosion on logging roads, skid trails, and log landings (West Virginia Division of Forestry 1995).

EFFECTS ON FOREST OPERATIONS

The following sections provide a more detailed discussion of environmental concerns, Forest Plan objectives, and forest operations.

Timber management

Of the 724,000 acres tentatively classified as suitable for timber management in 1986, 331,000 acres were required to meet timber production goals. The remaining 393,000 acres were not needed to maintain pre-plan harvest levels but could be incorporated into the timber production base depending on resource-needs analyses of future revisions to the Forest Plan.

Although much of the public opposes clearcutting, even-age management was prescribed for 95 percent of the forest land suitable for timber production. When the Forest Plan was developed, there was strong public demand to maintain high populations of huntable wildlife species such as deer, bear, and turkey. Even-age silviculture provides more diverse wildlife habitat and regenerates shade-intolerant tree species that produce mast crops required to support large populations of these game species. Because these same tree species are valued highly by the timber industry, even-age management satisfies two major categories of user demand. However, growing concerns about the visual quality and biological diversity of clearcut areas is reducing the reliance on clearcutting as an even-age regeneration tool, and the Chief of the Forest Service has directed that clearcutting meet specific requirements when applied on National Forests.

Although uneven-age management addresses concerns about visual quality, it also requires cutting cycles of 15 to 20 years and more frequent disturbance of forest roads and skid trails. To minimize the soil disturbance associated with frequent entries, single-tree selection is prescribed only when it is desirable to maintain a continuous forest scene in areas with high levels of public activity.

To meet wildlife and recreation management objectives, most silivicultural prescriptions favor the production of large-diameter sawtimber trees over an entire rotation and seek to minimize the frequency of site disturbances. Accordingly, prescribed even-age rotations range from 100 to 200 years depending on site quality and the predominant tree species. Management prescriptions that permit intensive management apply to 25 percent of the forest under even-age management, generally to accelerate development of desired future conditions that enhance wildlife or recreation values. Prescriptions for the remaining areas under even-age management favor remote habitat. On the more productive sites, a maximum of two or three commercial thinnings is likely over extended rotations. On poorer sites, commercial thinnings might not be economically feasible. To further reduce the frequency of disturbance in remote habitat areas, only 40 percent of a specific management area may be disturbed in a single entry, and an interval of 10 years is required between successive forest operations.

Although even-age management predominates as a prescription, partial cutting accounts for much of the planned harvest. Extending rotations to grow larger trees and reduce the frequency of regeneration cuts requires periodic commercial thinnings to maintain stand vigor and harvest potential mortality. Accordingly, the Forest Plan indicates that selection cuts and commercial thinnings account for approximately 70 percent of the acres and 55 percent of the volume harvested. Further, to regenerate selected tree species, moderate the adverse visual impact of clearcuts, deferment and shelterwood cuts that leave residual sawtimber trees may become more popular as regeneration options.

With this level of partial cutting, one of the more important challenges to forest operations will be minimizing residual stand damage. Given long periods between harvest entries, the decay caused by logging damage will in time reduce residual stand volume and quality. Because hardwood sawtimber values depend on log quality, decay and degrade can result in significant economic losses. For example, veneer and grade 1 sawlogs of select species can be worth 5 to 10 times more than low-grade logs. Potential stand decadence resulting from extended rotations and logging damage also could pose problems related to wood utilization and logging safety when stands are regenerated.

Although longer rotations will produce larger trees, information from remnant old-growth stands indicates that these large hardwoods can be harvested with conventional equipment. Results of studies on a variety of old-growth hardwood sites show several trees reaching 40 to 50 inches in diameter at breast height (dbh), though most trees were less than 30 inches dbh (Abrams et al. 1995; McGee 1984). For some of the larger trees grown over long rotations on good sites, bucking at the stump may be required to keep log volumes within the range of payloads observed for Appalachian skidder and cable-yarding operations.

Barring extensive decay and degrade, harvesting large-diameter hardwoods with conventional ground-based systems should be technically and economically feasible. However, thinning young stands to accelerate desired future conditions, or presalvage and sanitation thinnings in immature stands at risk from gypsy moth defoliation (Gottschalk 1993) would require more efficient harvesting equipment and improved roundwood markets to be considered commercial operations.

Water quality

Recent surveys of 70 native brook trout streams on the Monongahela National Forest indicate that a majority of the spawning gravels sampled had loads of fine sediment that exceed levels affecting spawning success (Duffield 1995). Sediment also can reduce pool volume and winter carrying capacity, as well as macroinvertebrate production and diversity.

Research conducted on the Fernow Experimental Forest in West Virginia (Kochenderfer and Wendel 1980), indicates that with properly located and constructed skid trails, truck roads, and landings, there is little increase in sediment export from a watershed associated with timber harvesting. However, the concern voiced by resource specialists is that the cumulative effects of past forest operations and activities on adjacent private lands have resulted in stream sediment levels that are at or above the critical levels. As a result, harvesting operations that meet water-quality standards might contribute to cumulative effects and exceed the threshold level for sediment associated with sustainable populations of native brook trout. Although there is not concensus as to all aspects of the relationship between forest operations and the sustainability of brook trout, there is sufficient concern to increase research and stream monitoring to better understand this relationship.

Changes in forest operations related to water quality include increased applications of cable yarding, particularly on highly erodible soils which often support some of the more valuable timber stands. Helicopter logging is being planned in stands adjacent to streams with current high levels of sedimentation, and in stands that are not accessible with existing roads. A case study of helicopter logging in Appalachia showed that the relatively high costs will limit application of this technology to harvests that remove at least 2.5 to 3.0 mbf/acre of high-value sawtimber (Sloan et al. 1994). These authors also suggest that local market prices guide decisions on locating harvest-unit boundaries, marking cut trees, and levels of wood utilization.

Because ground-based logging is common on slopes up to 40 percent, and economics and locally available technology encourage the continued use of this technology, cable yarding has not been used widely on the Monongahela. Contacts with district timber managers indicate that 10 to 20 percent of the forest land suitable for timber production will not be logged with ground-based systems; thus, there is ample opportunity for the use of alternative harvesting systems. Soil surveys of three counties that encompass much of the Forest indicate that 31 to 54 percent of the land area has slopes of 35 percent or greater. To expand the timber base by reclassifying additional lands as suitable for timber production will require economically viable and environmentally sound alternatives for harvesting on steep slopes.

Recommended measures for protecting water quality include leaving filter strips to trap sediment and shade strips to maintain water temperature for fish. Recently implemented guidelines for managing riparian areas further limit vegetation management in riparian zones to protect plant communities. These constraints can have a significant impact on the planning and layout of harvest units and the selection of appropriate harvesting systems and system applications. Although stream crossings are permitted within filter strips, careful planning is required to minimize the number of crossings and to construct crossings to minimize the possibility of erosion.

Depending on slope and soil type, filter strips may extend up to 250 feet on each side of perennial or ephemeral streams. Avoiding soil disturbance in these large areas requires cable yarding or long winching distances for rubber-tired skidders. It has been suggested that on convex slopes, backing the skidder to the log rather than winching long distances might reduce soil disturbance (Hornbeck et al. 1994). Cable yarding to avoid the construction of skid trails and soil disturbance in the upper reaches of small drainages could prove a costly alternative. The distances from the spur ridges to the ephemeral streams in these small drainages may be only 200 to 300 feet. Yarding short distances reduces the volume yarded per corridor and yarder productivity due to the high proportion of time spent moving the yarder and rigging the skyline.

Forest roads

To comply with the wildlife and recreation management objectives of the Forest Plan, many logging roads are closed and seeded following timber harvesting so that they "generally appear as a grassy path through the woods." Closing roads to public travel also reduces both maintenance costs and the potential for stream sedimentation associated with road rutting and maintenance activities.

In keeping with the planned levels of road use and to reduce costs, the Forest Plan generally recommended construction of low-standard roads. These roads had an insloped 12-foot travel surface and vertical cut slopes when cuts were less than 6 feet. Except at perennial stream crossings, roads were drained with broad-based dips. Problems encountered with low-standard roads related to cut bank sloughing, narrowing travel surface, and difficult maintenance often resulted in excessive erosion and degradation of water quality.

To protect water quality, road standards have been raised to include a 14-foot travel surface and seeded cut banks with side slopes of 1 1/4 to 1. Culvert installations also were increased and now include road sections with grades greater than 10 percent and wet sites with erodible soils. Highly erodible sites also require immediate seeding of cut slopes and graveling of the travel surface. Erosion of the fill slope below broad-based dips has been controlled by covering the entire fill slope below the dip outlet with ½- to 3-inch rock containing no fine sediment. To control sedimentation related to the installation of large culverts, check dams constructed with logs, hay bales, and logging slash are installed in culvert drainages.

Wildlife

Although limiting forest operations in remote habitat favors selected wildlife species, such operations can play an active role in wildlife management. Timber harvesting can benefit many wildlife species by creating more diverse habitat. However, due to concerns with increasing harvesting revenue and the need to avoid no-bid or below-cost timber sales, timber harvesting often is concentrated on the better sites with high-value tree species. Improving habitat on poorer sites might require packaging timber sales to include poor and good sites, more efficient harvesting, or increasing revenue through improved utilization and roundwood marketing. Improving the economic feasibility of treating immature stands, such as thinnings or crop-tree release to favor mast-bearing trees, also would benefit wildlife. At higher elevations on the Monongahela, overstory removals that release the red spruce understory could help restore the habitat of the endangered Virginia northern flying squirrel.

Maintaining viable populations of neotropical migrant birds is a concern of land managers throughout the eastern hardwood region and one that could affect the planning and scheduling of forest operations on broad scales. An estimated 106 species of neotropical migrant birds use the Monongahela National Forest, and 89 species breed there (Wargo et al. 1995). Many of these species require interior forest habitat, which, in turn, requires maintaining large areas of closed canopy or mature forests to avoid excessive forest fragmentation. Edge habitat resulting from fragmentation contributes to nest parasitism by cowbirds and predation by other birds or animals that use edge habitat. Other management recommendations with potential impacts on forest operations include minimizing area in roads and landings, not cutting trees that overtop forest roads or clearing only one side, and seeding these roads to shade-tolerant plant species.

Old-growth forests

Effectively addressing concerns related to maintaining old growth or mature forest components, much like providing habitat for neotropical migrant birds, requires long-range planning and scheduling of forest operations at the landscape level. To provide habitat diversity, the Forest Plan provides for the maintenance and development of mature or old-growth conditions. Specific concerns related to old-growth management include maintaining stands large enough to create desired future conditions, spatial relationships between old-growth stands and other forest conditions, and fragmentation of potential old-growth areas by road construction or timber harvesting (DeMeo et al. 1995).

SUMMARY AND CONCLUSIONS

Environmental concerns regarding forest-land management that were identified in the Monongahela National Forest's Land and Resource Management Plan, are similar to those expressed by tree farmers in West Virginia. Concerns with the greatest impacts on the planning and conduct of forest operations relate to forest recreation, wildlife habitat, and water quality. Important attributes of management prescriptions favoring remote habitat for wildlife and semi-primitive nonmotorized recreation include growing larger trees over extended rotations, reducing the frequency of harvest-related disturbances, and reducing levels of road construction. Concern about water quality are addressed through improved road standards, guidelines for managing riparian areas, and the use of alternative harvesting methods.

The management objectives and goals linked to specific environmental concerns can affect forest operations at all levels, from long-range planning of harvesting activities to site specific applications of harvesting technology. Issues affecting old-growth forests, neotropical migrant birds, and remote habitat for bear and turkey clearly define the need to maintain appropriate spatial relationships between forest types or habitat conditions. Effective planning of forest operations on broad spatial and temporal scales will require the use of GIS technology and computerized tools that allow spatial analysis.

Efficiently controlling residual stand damage and soil disturbance will be among the most important performance criteria for timber-harvesting operations. Management prescriptions that limit the need to treat young stands and that focus most of the allowable cut on large diameter sawtimber stands generally favor the economic viability of harvesting operations. However, making periodic partial cuts over extended rotations will require careful logging to minimize decay-related losses of timber volume and value. Also, controlling soil disturbance and implementing riparian area guidelines will require careful planning and layout of truck roads, skid trails, and harvest units. With respect to harvesting economics, perhaps the greatest challenges will be harvesting poor sites to enhance wildlife habitat or cable yarding and helicopter logging on sensitive sites, and balancing increased costs and reduced stumpage payments against expected environmental benefits.

LITERATURE CITED

Abrams, M.D.; Orwig, D.A.; DeMeo, T.E. 1995 Dendroecological analysis of successional dynamics for a presettlement-origin white-pine mixed-oak forest in the Southern Appalachians, USA. Journal of Ecology. 83: 123-133.

DeMeo, T.; Concannon, J.; Pawelczyk, H. 1995. Clarification of the Forest Plan intent for designated old-growth areas on the Monongahela National Forest. Report on file with the Monongahela National Forest, Elkins, WV.

Duffield, D.J. 1995. Briefing paper on fine sediment effects on brook trout (*Salvelinus fontinalis*) in selected streams of the Monongahela National Forest. Report on file with the Monongahela National Forest, Elkins, WV.

DiGiovanni, D.M. 1990. Forest statistics for West Virginia--1978 and 1989. Resour. Bull. NE-114. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 172 p.

Egan, A.; Rowe, J.; Peterson, D.; Philippi, G. (In press). West Virginia Tree Farmers and consulting foresters: views on timber harvesting. Northern Journal of Applied Forestry.

Eyre, F.H. 1980. Forest cover types in the United States and Canada. Washington, DC: Society of American Foresters. 148 p.

Gottschalk, Kurt W. 1993. Silvicultural guidelines for forest stands threatened by the gypsy moth. Gen. Tech. Rep. NE-171. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 49 p.

Greenstreet, D. 1994. Economic impact of the wood products industry: West Virginia 1992. Morgantown, WV: West Virginia University, Center for Economics Research. 74 p.

Hornbeck, J.W.; Verry, E.S.; Dollof, C.A. 1994. Managing riparian areas in Northeastern forests: a quest for desired future conditions. In: Proceedings, 1994 Society of American Foresters/Canadian Institute of Forestry Convention; 1994 September 18-22; Anchorage, AK. Bethesda, MD: Society of American Foresters: 299-304.

Kochenderfer, J.N.; Wendel, G.W. 1980. Costs and Environmental impacts of harvesting timber in Appalachia with a truck-mounted crane. Res. Pap. NE-456. Broomall, PA. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 9 p.

McGee, C.E. 1984. Heavy mortality and succession in a virgin mixed mesophytic forest. Res. Pap. SO-209. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 6 p.

McNab, H.W.; Avers, P.E. 1994 Ecological subregions of the United States: section descriptions. Admin. Pub. WO-WSA-5. Washington, DC: U.S. Department of Agriculture, Forest Service. 267 p.

Salwasser, H. 1994. Ecosystem management: can it sustain diversity and productivity. Journal of Forestry. 92(8):6-10.

Sloan, H.; Tollenaere, J.; Croff, C. 1994. Technology advances in helilogging: a case study of the K-MAX in Appalachian hardwoods. In: Advanced technology in forest operations: applied ecology in action: proceedings of the meeting; 1994 July 24-29; Corvallis, OR. Corvallis, OR: Oregon State University: 237-245.

U.S. Department of Agriculture, Forest Service. 1986. Land and resource management plan, Monongahela National Forest. Elkins, WV: U.S. Department of Agriculture, Forest Service, Eastern Region. 265 p.

Wargo, J.; DeMeo, T.; Kipley, R.; Pawelczyk, H.; Santiago, J. 1995. Summary of neotropical migratory bird status on the Monongahela National Forest. Report on file with Monongahela National Forest, Elkins, WV.

West Virginia Division of Forestry. 1995. Guidelines for controlling soil erosion and water siltation from logging operations in West Virginia. Publ. WVDOF-TR-95-2. Charleston, WV: West Virginia Division of Forestry. 28 p.

Wiedenbeck, J.W.; Araman, P.A. 1993. Possible demands for eastern hardwoods resulting from harvest restrictions in the Pacific Northwest. Forest Products Journal. 43(10): 51-57.

PREDICTING THE OPERABILITY OF SOUTH CAROLINA COASTAL PLAIN SOILS FOR ALTERNATIVE HARVESTING SYSTEMS[1]

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ABSTRACT: Predicting the operability of timber sales (their relative ability to support the machine traffic of a logging system) is important to both long and short range wood supply planning. A system has been developed by Westvaco's Harvesting Research Project in South Carolina to measure the relative impact of alternative logging systems on a range of soils under different moisture conditions. This paper presents information from a database containing observations from over 200 operability plots. The data document the relative site disturbance associated with several alternative low impact logging systems. They also suggest that Time Domain Reflectometry (TDR)[2] technology may be a useful tool for predicting the operability of a site prior to moving equipment in.

Key Words: harvesting systems, site disturbance, operability, time domain reflectometry

INTRODUCTION

With current standard technology and under current environmental and aesthetic constraints, it is difficult to find sites which can support year-round logging in the lower Coastal Plain. The amount of relief logging sites available in a given year varies greatly due to volatile regional weather patterns and the location of annual timber sales.

As Westvaco moves to higher levels of self sufficiency from its landbase, the ability to operate year round on this land becomes more critical. Because operability estimates figure heavily in most harvest planning systems, verifying the information they provide is important. Furthermore, it is recognized that while operability estimates may provide a good guide as to the potential operability of alternative sites, additional information is needed when making day-to-day harvest planning decisions. Finally, it is already accepted that some alternative approaches to logging may be needed to deal with the operability problem. Measuring the relative benefits and limitations of harvesting system alternatives is crucial to determining the type and number of them to deploy.

The goal of Westvaco's Operability Calibration endeavor is threefold:

1. to verify operability predictions for Westvaco soil types,

2. to develop additional tools for predicting the operability of different sites under different conditions with different logging systems, and

3. to document and quantify the site disturbance associated with alternative logging systems.

BACKGROUND

Logging studies conducted by Westvaco as early as 1990 began to shape operability calibration. An inhouse study conducted between 1990 and 1992 clearly documented the limitations of standard rubber-tired equipment on a wet site. It also documented some of the limitations of operability estimates. While the soil map unit in question was rated to be of average operability, weather patterns between the period of June 1990 and February 1992 kept the logging site "inoperable" for over 450 consecutive days. This and other concerns sparked debate about how operability was defined, how harvest planning was done, and the need for low impact logging systems.

The study also focused attention on TDR (Time Domain Reflectometry) as a tool for predicting site operability. During the study, measurements were taken with a device called Trace (Soil Moisture Equipment Corporation), which relies on TDR to determine the volumetric moisture of a soil profile. It established that on two study sites operability improved when Trace moisture readings dropped below 40 percent. The speed and accuracy of TDR gave us the potential to capture a critical piece of information related to operability and test the value of that information on a range of soil types. By combining TDR moisture data with a measure of soil strength from a cone

[1] Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

[2] TDR measures soil moisture.

penetrometer we obtained quantifiable data related to operability.

In 1994, three important dimensions of an operability calibration effort were addressed. First, a consistent scale for rating the visible disturbance to a site was established by Harvesting Research with input from soil scientists and members of Operations. Next, logging system codes that classify the important components of alternative systems were developed. Finally, operability estimates and sale prioritization based on operability became a key part of the harvest planning process.

PROCEDURES

A calibration effort of this type requires a large number of observations. The three major factors alone (soil type, logging system, and moisture condition) create a large number of combinations. We needed a nimble data collection procedure that would allow us to establish disturbance plots on active sales, categorize the site condition, evaluate site disturbance, and record all pertinent data within 24 hours of initiating each plot. We also needed the capability to complete several plots in a day.

Rather than target specific soil types, we allow the routine progression of harvesting operations to dictate where we take plots. When an active operation is identified, we pull a copy of the sale map along with the soil information. Plot locations are chosen based on the planned logging activity for that day. Two types of plots may be established: "A" plots and/or "B" plots.

To establish an "A" plot the researcher finds an uncut portion of the sale where the felling machine will be working within the next hour. A square tenth-acre plot is established by pacing. Ten TDR and ten cone penetrometer measurements are taken at random locations within the plot. Volumetric moisture percent is recorded at each point. From the penetrometer, we record the depth from the surface (in inches) where the soil strength generates a reading of 250 psi. If 250 psi is not reached before 30 inches are penetrated, a value of 31 inches is recorded. (250 psi was chosen based on field experience. It is believed that this reading from the penetrometer we are using[3] is a reliable indication that the soil strength is high enough to support standard equipment without rutting.) Once these readings are taken, the researcher observes the progression of logging activities through the plot and records the disturbance level after each phase.

To establish a "B" plot the researcher finds an uncut portion of the sale immediately adjacent to a harvested area and establishes a tenth-acre plot. The uncut portion must be on the same soil type as the harvested portion. The harvested area must have been cut and/or yarded within the previous 24 hours. No significant weather events can have occurred during that period. The same procedure described for "A" plots is used to characterize the moisture and soil strength of the plot. The researcher then evaluates the disturbance level on the cut portion. Unlike the "A" plot where disturbance on the plot itself is monitored, the "B" plot assumes that disturbance adjacent to the plot is what would occur on the plot. This assumption is valid when the selection and timing constraints are adhered to. "B" plots have the advantage of generating results faster than "A" plots.

Plot disturbance is evaluated in the following manner. The procedure uses four traffic intensity categories (TI1 through 4) and five site disturbance categories (SD1 through 5).

The TI categories are defined as follows:

<u>TI1</u> Trees on the plot have been felled.

<u>TI2</u> Trees which stood on the plot have been removed. No other traffic has passed through the plot.

<u>TI3</u> Trees which stood on the plot have been removed and trees outside the plot have been yarded through the plot. Passes with a loaded machine are between three and ten.

<u>TI4</u> More than ten loaded machine passes have been made through the plot.

The SD categories are defined as follows:

<u>SD1</u> Little or no disturbance. Little evidence of machine traffic. Forest floor surface layer generally undisturbed. Compaction unlikely. Needles, limbs, and other forest floor debris intact.

<u>SD2</u> Compaction likely. Machine traffic obvious but little or no disturbed earth. Limbs, tops, and other forest floor debris may be scraped off. Stumps may appear to have "grown"

[3] Specifications of the penetrometer include: 30 degree cone of ½-square-inch base area, a shaft 31 inches long and ⅝-inch diameter, a proving ring, a micrometer dial, and a handle.

since the tree was cut. In addition to these visual signs, soil moisture content may be high enough to suspect compaction on this map unit.

SD3 Area is rutted. Ruts are less than eight inches deep. (BMP compliance becomes questionable at this level of disturbance. SD3 is generally out of compliance with Westvaco guidelines.)

SD4 Area is rutted. Ruts are eight inches deep or deeper.

SD5 Area is churned. The soil has been puddled.

The percent of the plot which is impacted can affect the disturbance category assigned to the plot. (Table 1.) Up to twenty percent of a plot's area can be disturbed to the next highest category and the plot still be assessed at the lower value. Up to five percent of a plot's area can be disturbed to a degree two categories higher and the plot still be assessed at the lower value. This is an "either/or" qualifier; there cannot be combinations of higher disturbance in a plot that receives a lower rating.

The lower traffic intensity categories in our dataset have more observations than the higher ones. Two key reasons for this include time constraints in the observation process and the fact that jobs operating on wet ground are often shut down before the higher levels of traffic intensity are reached. Although it is not always possible to observe the site disturbance level at every traffic intensity level on every plot, it is fair to assume that the site disturbance level reached on a plot for a given traffic intensity level will either stay the same or increase with additional trafficking. For example, site disturbance cannot be less at TI3 than it was at TI2 nor can it be higher at TI2 than it is at TI3.

The SD by TI information presented in the results section includes data which was logically derived as follows:

- if a site disturbance level of 5 is observed for a given TI level, SD5 is assumed for all higher TI levels.
- if a site disturbance level of 1 is observed for a given TI level, SD1 is assumed for all lower TI levels.
- if a site disturbance level of 3 is observed for a given TI level, a minimum disturbance rating of SD3 is assigned to the higher TI levels to indicate that observed disturbance would have been at least that high.
- if a site disturbance level of 4 is observed for a given TI level, a minimum disturbance rating of SD4 is assigned to the higher TI levels to indicate that observed disturbance would have been at least that high.

These derivations are important because they allow calculations on the extent of rutting to more accurately reflect what the observed data actually indicate. Derived data are coded separately from observed data in the database.

Logging system codes document the logging system that was used to harvest the plot. These codes create a unique description of each logging system, which includes its product, its in-woods machine mix, its loading and trucking strategy, its truck mix, its capital investment level and its manpower level. Unique fields in the operability database focus on the felling and yarding system since those two elements have the greatest impact on site disturbance.

Table 1. Categorization of Site Disturbance, SD1 through SD5.

SD	Allowable Area				
Rating	SD1	SD2	SD3	SD4	SD5
SD1	***	or 20%	or 5%		
SD2		***	or 20%	or 5%	
SD3			***	or 20%	or 5%
SD4				***	or 20%
SD5					***

Data recorded for each plot include:

- date
- person who established the plot
- rainfall history (past 24 hours, 15 days, and 30 days as recorded at the closest Southern Woodlands raingauge)
- location of the rain gauge
- timber stand information (district, map ID, stand number)
- logging system information (logger name, logger number, logging system code, feller type code, yarding type code)

- soil information (wvsoil number, soil type name, operability code, microsite verification - Y or N)
- presence or absence of standing water
- TDR device soil probe length
- target psi for the penetrometer
- 10 TDR and 10 penetrometer readings and their averages
- SD ratings by TI category
- plot type, A or B.

RESULTS

Regarding logging systems and moisture conditions the data collected thus far indicate three things:

1. There is a dramatic reduction in the operability of most soil map units in our lower Coastal Plain landbase when the average soil moisture in the surface 12 inches reaches 40 percent. At this moisture content, the only logging systems in the current local logging force that can predictably operate within current site disturbance guidelines are tracked feller bunchers combined with shovels or wide-tired skidders running on trees and treetop mats.

2. There is a transitional moisture range between 35 and 40 percent where operability may depend heavily on the soil type as well as the logging system. Logging under these conditions is likely to require low ground pressure equipment (at least rubber-tired equipment with tires or duals wider than 43 inches).

3. Operability is generally not a problem regardless of soil type or logging system when moisture in the surface 12 inches falls below 35 percent.

Figure 1 illustrates the dramatic difference in disturbance documented by our plots when moisture was below and above the 40 percent mark. It summarizes the entire dataset, including the plots logged with low ground pressure systems. Figure 2 breaks moisture into three categories and drops the ultra-LGP logging systems (i.e. - shovel system and systems running on limb mats). The graphs showing the percent of observations which were above SD3 and SD4 are intended to complement the graphs which show the average disturbance for all plots.

Tables 2 through 7 stratify the data by moisture condition and logging system. ND indicates that there are no data in that category. ID indicates inconclusive data.

The data also suggest that while the penetrometer is of value when assessing operability, as a stand-alone tool the information it yields is far from conclusive. There are correlations between penetrometer readings, moisture condition, and soil type, which can be shown when large numbers of observations are considered on average. However, there is too much variability among individual readings. If the penetrometer consistently yields 250 psi within a few inches of the surface it is probably a good indication that operability is good. Failure to do so, however, is not necessarily an indication that operability is poor.

CONCLUSIONS

Based on the trends exposed by this database, we have begun to use TDR to help us do three things:

- find operable sites sooner,
- avoid unnecessary equipment moves,
- match logging systems to site conditions.

Within the next year, the database will be analyzed to determine if the current operability estimates for soil types can be verified or improved based on soil moisure and disturbance observations.

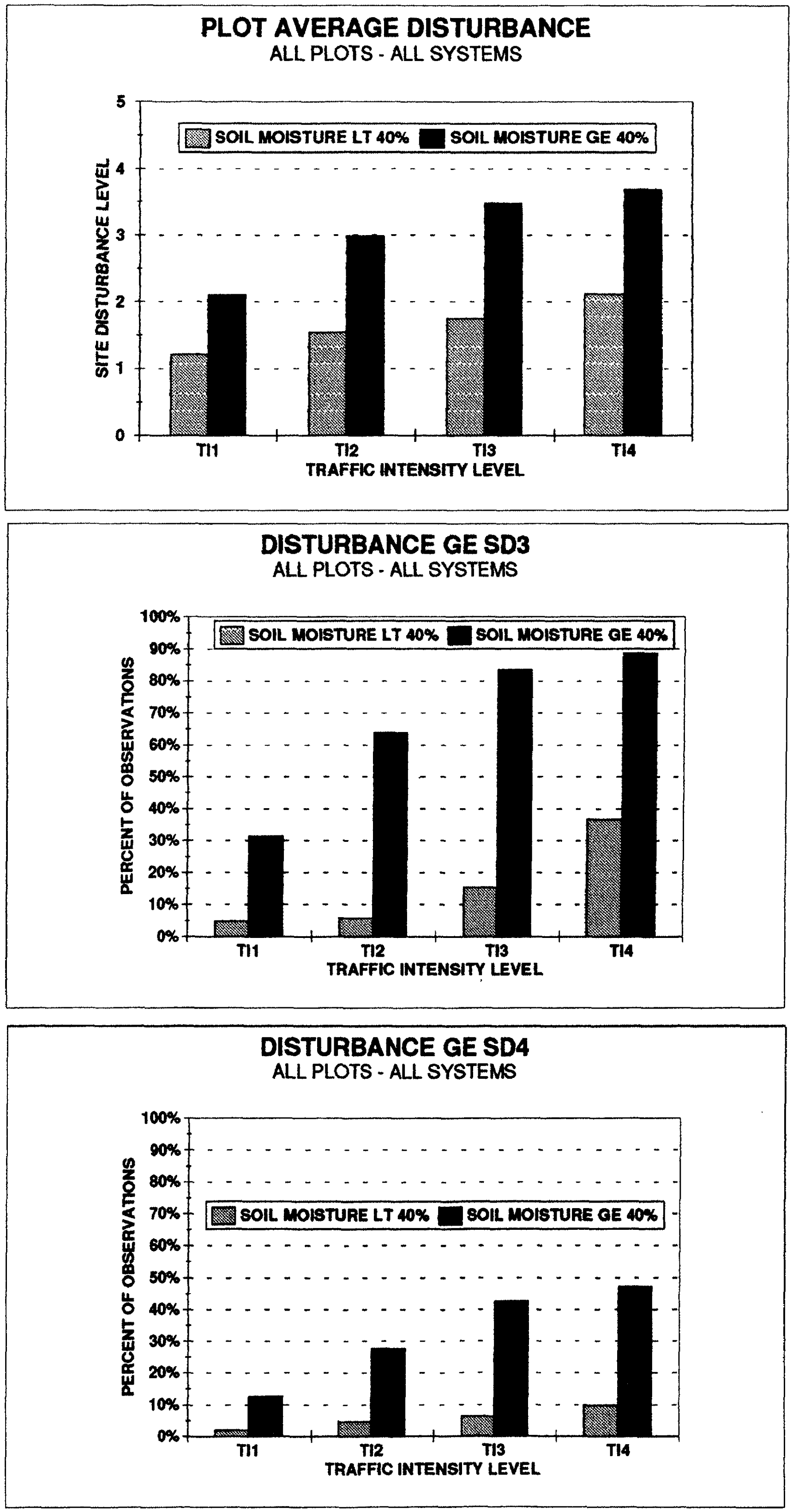

Figure 1. Disturbance results - soil moisture above and below 40 percent.

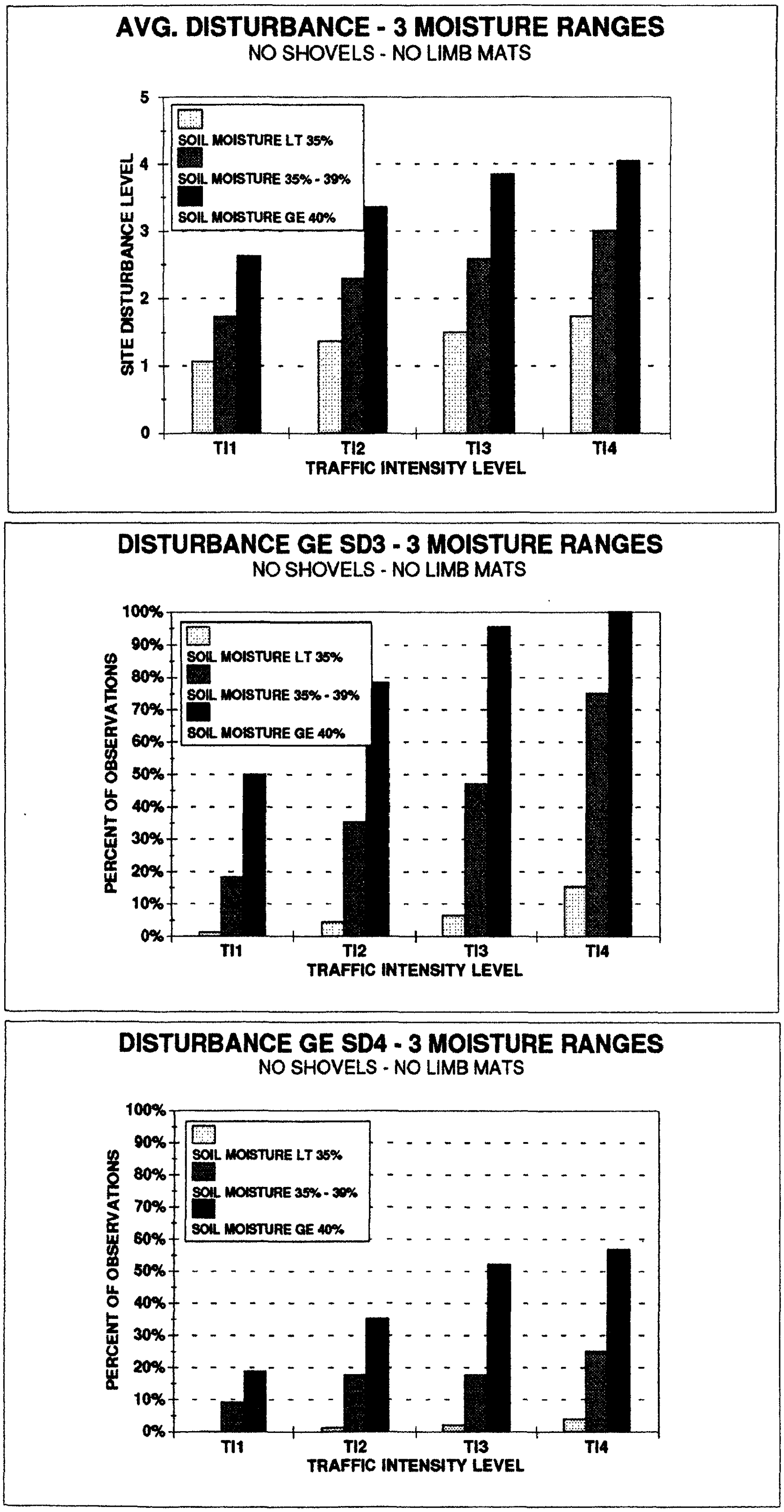

Figure 2. Disturbance results - soil moisture LT 35 percent, 35 to 39%, and GE 40 percent. No ultra-low ground pressure systems.

Table 2. Percent of observations in Disturbance Class 3 (SD3) or higher, surface soil moisture less than 40 percent.

	TI1	TI	TI3	TI4
Standard Ground Pressure Rubber-Tired Equipment	9%	19%	24%	42%
LGP Rubber-Tired Fellers, LGP Rubber-Tired Skidders	0%	0%	0%	0%
Tracked Fellers, LGP Rubber-Tired Skidders	0%	0%	6%	18%
Tracked Fellers, LGP RT Skidders on Limb Mat	ND	ND	ND	ND
Tracked Fellers, Shovel	ND	ND	ND	ND

Table 3. Percent of observations in Disturbance Class 4 (SD4) or higher, surface soil moisture less than 40 percent.

	TI1	TI2	TI3	TI4
Standard Ground Pressure Rubber-Tired Equipment	4%	9%	12%	19%
LGP Rubber-Tired Fellers, LGP Rubber-Tired Skidders	0%	0%	0%	0%
Tracked Fellers, LGP Rubber-Tired Skidders	0%	0%	0%	0%
Tracked Fellers, LGP RT Skidders on Limb Mat	ND	ND	ND	ND
Tracked Fellers, Shovel	ND	ND	ND	ND

Table 4. Percent of observations in Disturbance Class 3 (SD3) or higher, surface soil moisture greater than or Equal to 40 Percent

	TI1	TI2	TI3	TI4
Standard Ground Pressure Rubber-Tired Equipment	69%	76%	95%	100%
LGP Rubber-Tired Fellers, LGP Rubber-Tired Skidders	83%	86%	100%	100%
Tracked Fellers, LGP Rubber-Tired Skidders	0%	71%	91%	100%
Tracked Fellers, LGP RT Skidders on Limb Mat	0%	0%	50%	100%
Tracked Fellers, Shovel	0%	20%	20%	20%

Table 5. Percent of observations in Disturbance Class 4 (SD4) or higher, surface soil moisture greater than or equal to 40 percent.

	TI1	TI2	TI3	TI4
Standard Ground Pressure Rubber-Tired Equipment	31%	ID	ID	ID
LGP Rubber-Tired Fellers, LGP Rubber-Tired Skidders	33%	43%	50%	63%
Tracked Fellers, LGP Rubber-Tired Skidders	0%	14%	64%	70%
Tracked Fellers, LGP RT Skidders on Limb Mat	0%	0%	0%	0%
Tracked Fellers, Shovel	0%	0%	0%	0%

Table 6. Percent of observations in Disturbance Class 3 (SD3) or higher, surface soil moisture 35 to 40 percent.

	TI1	TI2	TI3	TI4
Standard Ground Pressure Rubber-Tired Equipment	33%	42%	67%	100%
LGP Fellers (RT or Tracked), LGP Rubber-Tired Skidders	0%	0%	17%	33%

Table 7. Percent of observations in Disturbance Class 4 (SD4) or higher, surface soil moisture 35 to 40 percent.

	TI1	TI2	TI3	TI4
Standard Ground Pressure Rubber-Tired Equipment	17%	17%	25%	ID
LGP Fellers (RT or Tracked), LGP Rubber-Tired Skidders	0%	0%	0%	0%

SOIL COMPACTION AND DISTURBANCE RESEARCH ON RECENT TIMBER HARVEST OPERATIONS IN OREGON[1]

by

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ABSTRACT: The Oregon State University Forest Engineering Department has conducted research on the effects of timber harvesting operations on forest soil compaction and disturbance for over 20 years. Building on this knowledge base, studies in recent years have focused on efforts to better understand the effects of equipment and treatments that are becoming increasingly common, including highly mechanized, ground-based systems, and commercial thinning and fuel reduction treatments. This presentation will provide an overview of the results of these diverse studies from throughout Oregon, and some important patterns that appear to be emerging among key site, equipment, and treatment variables.

Key Words: ground-based logging, mechanized harvesting, site productivity, skid trails, soil bulk density

[1] Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04.00, Marquette, MI, July 29-August 1, 1996.

TIMBER HARVESTER PERCEIVED COSTS AND BENEFITS OF APPLYING WATER QUALITY BEST MANAGEMENT PRACTICES IN MINNESOTA[1]

by

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ABSTRACT: As Best Management Practices (BMPs) become implemented, it is important to consider the net financial effect to timber harvesters. The few studies reported in the literature have focused on evaluating operational costs without assessing the extent of any benefits that may accrue to the timber harvester. A mailed survey of some Minnesota timber harvesters found that they are generally well-acquainted and willing to comply with Minnesota's water quality BMP program. While the BMP program was officially implemented in 1990, it appears that some practices were widely applied prior to program initiation. Practices applied before 1990 were probably those that provided obvious financial benefits to timber harvesters and/or landowners. Loggers who attended BMP continuing education workshops had higher BMP use rates than non-attendees. Fifteen percent of the respondents indicated that their operational benefits derived from applying water quality BMPs were at least equal to their application costs.

Key Words: costs, benefits, net financial effects, water quality, Best Management Practices, timber harvester

INTRODUCTION

Water quality Best Management Practices (BMPs) have been defined as a practice or combination of practices for preventing or reducing nonpoint source pollution to a level compatible with water quality goals. Minnesota's voluntary forestry water quality BMP program was implemented in 1990. A total of 97 recommended BMPs were developed by a committee composed of representatives from both the public and the private sector. Since 1990, more than 50 workshops have been conducted across the state, introducing timber harvesters and natural resource professionals to the program. In addition, a guidebook entitled "Water Quality in Forest Management: Best Management Practices in Minnesota" (Minnesota Department of Natural Resources, 1989) has been widely distributed.

From 1991-1993, compliance monitoring qualitative surveys were conducted on 261 harvested sites. Persons involved in compliance monitoring site visits included individuals from public agencies, wood-based industry, timber harvesters, non-industrial private landowners, and members of environmental and conservation groups. The average compliance rate across all ownerships in Minnesota between 1991-1993 was approximately 84 percent (Phillips et al. 1994).

Some timber harvesters believe that the application of BMPs increases harvesting costs without any benefit to their operation. They also believe that BMPs result in benefits that are only received by the public or the landowner and that the costs incurred by timber harvesters to produce these benefits should be reimbursed by some entity. Whether this perception is accurate is open to debate.

In spite of actions taken to implement BMP programs, there has been little research directed towards assessment of their net financial consequences (total costs minus total benefits) to a logging business. The focus of any studies which have evaluated financial aspects of BMPs has been on analyzing the cost of applying those practices. There has been only limited analytical focus on quantifying the financial benefits of BMPs to a timber harvester. Financial benefits could come in the form of factors such as increased productivity per day, an increased number of operable days on-site, or a reduced cost of maintaining equipment, roads, landings, and skid trails. This lack of information makes it difficult to accurately assess the net financial consequences of BMPs to a timber harvester. This paper reports the results of a study that assessed the change in application rate of selected water quality BMPs in Minnesota since 1990, the role of continuing education programming in changing BMP application rates, and the net financial effect to Minnesota timber harvesters of implementing water quality BMPs since 1990.

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

APPROACH

A questionnaire was mailed to logging-related business owner members of the Minnesota Timber Producers (TPA) and the Associated Contract Loggers (ACL). The questionnaire collected demographic information, evaluated changes in BMP use since the program's inception in 1990, and assessed the respondents' perceptions of the costs and benefits associated with water quality BMP use. It also asked whether they had attended a logger informational workshop in which the state water quality BMP voluntary program was the primary focus of the program.

The general practices and specific BMPs included in the questionnaire were taken from Phillips et al. (1994). Certain practices were excluded, namely practices that did not directly pertain to timber harvesting (e.g., mechanical site preparation, pesticide use, prescribed burnings), practices where respondents might infrequently report that they were improperly applying a practice (e.g., the practice "proper placement of clearing debris" might have few respondents indicate that they "improperly" applied the practice), and practices infrequently rated during the BMP audit process (e.g., "install silt fences where needed").

Respondents were asked to rate their use of forty specific practices. They were asked to indicate whether their operation: a) never applied the practice, b) used the practice less today than it did before 1990, c) hadn't changed its use of the practice since before 1990, or d) used the practice more today than it did before 1990. The response rates to these questions were tabulated in percentage form and were compared to the results of Minnesota's BMP compliance monitoring program (Phillips et al. 1994). The role of continuing education in changing the application rate of the forty practices was assessed by cross tabulating responses to participation in BMP workshops.

Respondents were also asked to specify whether their operations had experienced changes in costs and revenues since BMPs were implemented in 1990. Focusing on 14 BMP categories, respondents were asked to note the approximate percent increase as either one to five percent, six to 10 percent, 11 to 15 percent, greater than 15 percent, or "don't know." The response rates to these questions were tabulated and recorded in percentage form. Respondents were also asked to identify the sources of any changes in BMP applications. Five potential sources of increased costs were listed, namely: 1) increased number of days needed to complete harvest, 2) increased capital costs (e.g.; culverts, seeds), 3) increased cost of road, skid trail, or landing construction, 4) increased cost of road, skid trail, or landing maintenance, and 5) increased cost of maintaining equipment. Also listed were potential sources of increased benefits, namely: 1) increased productivity per day, 2) increased number of operable days on-site, 3) reduced cost of road, skid trail, or landing construction, 4) reduced cost of road, skid trail, or landing maintenance, and 5) reduced cost of maintaining equipment. An "other" source was also provided for both costs and benefits. Respondents were also provided with an opportunity to write open-ended comments at the end of the survey.

A total of 523 questionnaires were mailed by TPA and ACL. For a variety of reasons (e.g., some individuals are members in both TPA and ACL, there may have been some retired members on both mailing lists, the ACL list contained truckers) it was not possible to determine how many individual timber harvesters were actually sent a survey.

This study is one of the first attempts to quantify the costs and attendant benefits associated with timber harvester BMP use. It should be recognized however, that the data compiled here represents the self-reported *perceptions* of a select group of timber harvesters, rather than objective data reporting of the *actual* financial effects of these practices. While respondents may sincerely attempt to estimate the effect of BMP compliance on their net revenue, the information that they report generally represents a best estimate, as their business records do not usually collect data at the level of detail required for an in-depth analysis. In addition, a timber harvester disgruntled with BMP standards, regulations in general, or reduced profit margins, may bring bias into the surveying process. It should also be noted that the study made no attempt to evaluate whether practices are being better applied today than they were prior to 1990.

In assessing the results of the study, it is also important to consider that individuals who join timber harvester associations like the TPA and the ACL may be the more progressive members of the timber harvesting industry. They may also be larger scale operators. As a result, the views expressed may be representative of a specific type of timber harvester rather than of the industry as a whole. Timber harvesters who are not members of these organizations may, for example, have different operating constraints, cash flows, or motivations. Also, they may be smaller businesses or more part-time operators as compared to association members. As the size and demographics of the timber harvesting community in Minnesota are largely unknown, it is not possible to tell how accurately the respondents in the survey population represent the entire timber harvesting industry within the state.

RESULTS

A total of 200 questionnaires were returned of which 126 were completed. The majority of the responding timber harvesters were owner/operators of fairly small timber harvesting operations who work throughout most of the year in northern Minnesota. A majority of these individuals had been exposed to state water quality BMP information in the form of the BMP guidebook and/or an informational workshop (Table 1).

Eighty-five percent of the respondents indicated that they were either "very willing" or "fairly willing" to comply with the BMPs (Table 2). Most rated themself as being at least "fairly knowledgeable" about BMP practices. In fact, only about 20 percent of the respondents indicated that they referred to Minnesota's water quality BMP guidebook either "very often" (one percent) or "quite often" (18 percent). The relatively low rate of use of the guidebook may be due to a number of factors, including their reported high level of knowledge of the practices contained in the guidebook, judgement that the guidebook is technically inadequate in demonstrating the application of the various forestry practices, or a perception that the information contained in the guidebook is not different from forestry practices that are already being applied. Also a factor in the low rate of use of the guidebook is that respondents harvested a high percentage of timber on nonindustrial private forests where the voluntary BMP program had lower compliance levels than was noted on other ownerships (Phillips et al. 1994)

Table 1. Knowledge of Minnesota's water quality BMP guidebook and attendance at BMP informational workshops by responding timber harvesters. (The number of respondents [n] is noted for each item.)

	Response (percent)	
Item	Yes	No
Do you have a copy of the publication entitled "Water Quality in Forest Management: Best Management Practices in Minnesota"? (n = 126)	80	20
Have you ever attended a logger informational workshop in which the state water quality BMP voluntary program was the primary focus of the workshop? (N = 125)	67	33

Table 2. Perceptions of respondents to their knowledge of Minnesota's water quality BMP program and of their willingness to comply. (The number of respondents [n] is noted for each item.)

	Response (percent)				
Item	Very	Fairly	Somewhat	Not very	Not at all
Knowledge: How knowledgeable are you about water quality BMPs and the voluntary BMP program? (n = 125)	19	53	22	3	3
Willingness: How willing are you to comply with water quality BMP requirements? (n = 125)	40	45	12	2	1

Change in BMP application rate

Overall, relatively few respondents indicated that they never apply any of the forty specific water quality BMP practices included in the questionnaire or use them less today than prior to 1990. An average of seven percent of the respondents indicated that they never apply any of the practices, while one percent indicated the "use less" category, as compared to pre-1990. Low frequencies for "never apply" and "use less" categories might be expected given that practices selected for inclusion in the questionnaire were those that tended to be most frequently rated during the compliance monitoring field audit (Phillips et al. 1994). An average of 42 percent of the respondents indicated "no change" and 51 percent indicated "use more" in their use of specific water quality BMP practices since 1990. The "no change" category was selected most frequently for 14 practices and the "use more" category was selected most frequently for 25 practices. There was one practice where the "no change" category equaled the "use more" category.

It was interesting to compare the above results to the corresponding compliance monitoring field audit data (Phillips et al. 1994). Some of the practices which were rated frequently during the field audits had relatively low departure rates. Survey respondents frequently indicated that these were the practices for which they had not changed their operation. Widespread use of these practices before the introduction of the water quality BMP program in 1990 suggests that these particular BMPs provide obvious financial benefits to timber harvesters and/or landowners. As an example, the practice "minimize total road mileage required" was rated 166 times during the audit process and was not properly applied on only three percent of the sites. Correspondingly, 60 percent of the respondents indicated that there was "no change" in their rate of application of this practice after 1990. Similarly, the BMP practice "minimize total skid trail mileage required," which was rated 195 times, had a departure rate of only seven percent while 54 percent of the respondents indicated that there was "no change" in their rate of application. Although these results do suggest that some practices were widely used before 1990, it is not possible to tell whether or not the practices were implemented in the same way during the two time periods.

In contrast, there were several practices where respondents indicated that they used the practice more after the BMP program was implemented in 1990. These practices tended to be those which apparently did not provide direct benefits to loggers. As an example, for the practice "adequate storage and disposal for fuel, debris, lubricants, fluids and rinsate from equipment cleanup," which was rated 243 times and had a departure rate of 22 percent, 78 percent of the respondents indicated that they used the practice more after 1990. Similarly, for the practice "keep streams, lakes, and wetlands free of logging debris," which was rated 199 times and had a departure rate of 37 percent, 73 percent of the respondents indicated that they used the practice more after 1990.

In addition to the formal responses timber harvesters made to inquiries specified in the questionnaire, many provided written comments about their BMP use. Some examples of those responses are shown below.

> *"I have been logging for 50 years and during that time I have always tried to do what is best for the land and water. I do what the landowner wants."*
>
> *"Common sense equals most BMP practices. Therefore, we haven't done anything different since 1990."*
>
> *"We have always done most of this -- before BMPs were ever around."*

Role of continuing education

For each of the 40 BMP practices listed, those responding timber harvesters who had attended a workshop selected the "use more" category more frequently than those individuals who had not attended a workshop. Seventy-two percent of the time, the difference in the "use more" column between those who had attended a workshop and those who had not was 15 percent or greater. Forty-five percent of the time, the difference between these groups was 20 percent or greater. Timber harvesters who had not attended a BMP workshop selected the "never apply" category more frequently than those respondents who had attended a workshop for 25 out of the 40 practices presented. For four practices, there was no difference in the "never apply" category response between workshop attendees vs. non-attendees. For the other 11 practices, the difference between the two groups did not exceed seven percent. An assessment of those respondents who answered "never apply" was unable to identify any consistent pattern in their demographic information.

Net financial effects of applying BMPs

Respondents separately noted their perceived amount and source of additional costs and benefits of applying water quality BMPs. An average of 78 percent of the respondents perceived that they had experienced additional costs to apply one or more of the fourteen categories of water quality BMPs recommended in 1990. In descending order of priority, the most frequently cited sources of additional costs are noted below.

1. Increased cost of road, skid trail, and landing construction.

2. Increase in number of days needed to complete the harvest.

3. Increased cost of road, skid trail, and landing maintenance.

4. Increase in capital costs (e.g., culverts).

5. Increased cost of maintaining equipment.

An average of 36 percent of the respondents perceived that they had experienced additional benefits from applying one or more of the fourteen categories of water quality BMPs. The most frequently cited sources of additional benefits, in decreasing order of priority, are noted below.

1. Increased number of operable days on-site.

2. Increased productivity per day.

3. Reduced cost of road, skid trail, and landing maintenance.

4. Reduced cost of road, skid trail, and landing construction.

5. Reduced cost of maintaining equipment.

When asked to consider the net financial effect that implementing water quality BMPs had on the financial condition of their harvesting operations since 1990, eight percent of the responding timber harvesters indicated that benefits had exceeded costs (Table 3). Seven percent of the respondents indicated that benefits and costs were equal. The majority (85 percent) indicated that costs exceeded benefits. Of that majority, 21 percent reported that costs exceeded benefits by 1 to 5 percent, over half (51 percent) indicated that costs exceeded benefits by 6 to 10 percent, and 34 percent reported costs exceeding benefits by more than 10 percent.

Table 3. Perceived net financial effects to responding timber harvester operations of applying water quality BMPs in Minnesota from 1990 through 1994. (The number of respondents [n] is noted.)

Type of effect (n = 100)	Response (percent)
Returns exceed costs by:	
1 to 4 percent	1
6 to 10 percent	3
11 to 15 percent	3
More than 15 percent	1
Returns equal costs	7
Costs exceed returns by:	
1 to 5 percent	21
6 to 10 percent	30
11 to 15 percent	16
More than 15 percent	18

Further insight to the net financial effects on timber harvesting operations of using water quality BMPs since 1990 can also be gained from respondent written comments. Examples are noted below.

> *"BMPs are good for the forest and water quality, but they have been an extra cost because of longer skidding distance. They also require more extensive road systems and wider tires that use more fuel and cost more to operate. There have been no benefits to a logger with implementing BMPs, only extra costs."*

> *"It is probable that sale design and size have a greater impact on cost than actual practices. It is difficult to assign cost to a specific action, but average production per day is down. It may be unfair to assign all loss to BMPs."*

> *"It is good to improve logging practices for both loggers and the environment, but costs need to be met by forest agencies and companies."*

SUMMARY AND OBSERVATIONS

It is important to reiterate the limitations of this study. First, the data represents perceptions rather than actual data from the financial records of timber harvesters. There has been increasing discussion within Minnesota's logging community about the out-of-pocket costs of applying BMPs so some responses may include some respondent bias. Also, because the survey was only sent to members of Minnesota's two logging associations, the results may not be representative of all logging businesses within the state. Regardless, the information gathered by the study is a major step toward understanding both the benefits and costs to timber harvesters of applying water quality best management practices. Within this context, the study provides a number of useful insights

Timber harvesters are generally well-acquainted and willing to comply with water quality BMPs in Minnesota, although only a very modest portion of them refer to the Minnesota water quality BMP guidebook. While respondents indicated their use of 25 of the 40 practices has increased since 1990 when the BMP program was initiated, there was "no change" in their use of 14 practices. For many of the practices where the "use more" category was favored, there were relatively large departures reported by the field compliance monitoring program (Phillips et al. 1994). In contrast, departure rates were much lower for practices where the "no change" category was favored. Many timber harvesters apparently feel (and have always felt) that water quality BMP practices make sense from either a financial or an environmental point of view. Respondent open-ended comments support this finding.

Timber harvesters attending BMP continuing education workshops have increased their application of BMP practices more than those who did not attend any workshops. Workshops appear to be an appropriate mechanism to increase application rates. This influence would probably be most noticeable where the workshops present information about why it is important to apply specific practices, especially those where large departures might be anticipated. Field exercises demonstrating proper application may be the best way to show how to construct some of the practices.

Timber harvesters generally perceive that they incur additional costs when applying recommended water quality BMPs in Minnesota, and that these costs most often exceed any benefits (returns) that they might receive from their use. However, fifteen percent of the respondents indicated that their operational benefits derived from applying water quality BMPs were at least equal to their application costs. An increased number of operable days on-site and increased productivity per day were the most frequently cited benefits derived from applying water quality BMPs. Since so many timber harvesters suggest that they are applying BMPs today at rates that are similar to what occurred prior to 1990, there may in fact be little net financial effect on many logging operations that can be attributed to BMP application.

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LITERATURE CITED

Minnesota Department of Natural Resources. 1989. Water quality in forest management: Best Management Practices in Minnesota. St. Paul, MN: Minnesota Department of Natural Resources, Division of Forestry. 104 p.

Phillips, M. J.; Rossman, R.; and Dahlman, R. 1994. Best management practices for water quality evaluating BMP compliance on forest lands in Minnesota: A three-year study. St. Paul, MN: Minnesota Department of Natural Resources, Division of Forestry. 50 p.

A NEW CONCEPT AND APPROACH TO THE INTRODUCTION OF MECHANIZED, SILVICULTURAL OPERATIONS AND EQUIPMENT TO RURAL, TIMBER-BASED COMMUNITIES[1]

by

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ABSTRACT: Heightened awareness about the ecological fragility of the Pacific Northwest's forest systems resulted in significant curtailment of commercial timber harvesting and general forest management activities. The resulting withdrawal of huge timber volumes from wood markets resulted in significant economic losses for timber-based, rural communities. The socially- and politically-imposed reduction in timber and forest management activities is, in part, a result of neglected development of an appropriate knowledge and technology base in forest operations that addresses the ecological need of the forest sytems and at the same time is economically viable.

For ecological and silvicultural methods to succeed in the utilization, restoration and/or maintenance of forest systems, efforts in the arena of harvest technology development and transfer/training are desperately needed. Without it, rural communities will continue to deteriorate or resort to other, less desirable resources such as tourism development. Such development will ultimately destroy the fabric of those communities and with it the appeal of the landscape. With the increased complexities in equipment, combined with increased complexities in silvicultural prescriptions and ecological values, new approaches to the introduction of technology, knowledge and training are required.

A Forestry Training Center has been created to facilitate the introduction of advanced, technology and operational procedures from Scandinavian countries where such methods have proved successful. The Forestry Training Center provides operator training for new and developing equipment designed to make forest operations more efficient. Providing local contractors access to training operators reduces the risk of possible failures brought about by a general lack of an existing knowledge and training base. It also will provide for new opportunities of resource utilization without damaging ecological values.

The Center is being developed in four phases: organization, planning, staff-up, and operations. The Center has completed planning and development of its curriculum and operations plan and has initiated instruction of basic short courses. Operations of the Center will be supported by earned income. Significant capital equipment has been pledged to the Center. The Center is in the process of raising the remaining $525,000 it will take to capitalize operations.

Key Words: logger training, mechanized systems training, faller training in thinnings

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QUANTIFYING RESIDUAL STAND DAMAGE IN PARTIAL HARVEST OPERATIONS[1]

by

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ABSTRACT: Stand thinning and alternative silvicultural systems to clearcutting are increasingly important to Pacific Northwest forest managers. Stand damage studies were conducted on two cable thinning operations in 33-year-old Douglas-fir (*Pseudotsuga menziesii*) stands having residual stockings of 74, 148, and 247 trees per hectare (30, 60, and 100 trees per acre). The percent of residual stems damaged increased with decreasing residual density. Average scar sizes were significant, but lower than levels cited as major. Observed thinning damage from helicopter logging was smaller and higher on the stem, characteristics associated with lower incidence of decay. This paper reports and reviews four methods used in sampling stand damage.

Key Words: stand damage, thinning, Douglas-fir, skyline yarding, helicopter logging

INTRODUCTION

Forest managers in the Pacific Northwest United States and British Columbia, Canada are increasing the use of partial harvest silviculture to meet management objectives associated with ecosystem management, sustainable forestry, and social-political policies. Ecosystem maintenance goals can be addressed through partial harvests and thinning (DeBell and Curtis 1993, McComb et al. 1993).

Additionally, fiber supply and demand have increased small log utilization from thinnings. Thinning harvests of second-growth timber are principle among these partial cut silvicultural regimes. Thinning allows for mortality capture, an early return on investment, and concentration of growth on higher quality trees (Tappeiner et al. 1982).

However, partial harvest entries produce residual stand damage. This damage may adversely affect timber growth and value. The effects of harvesting practices on residual stands are well-documented for many forest types (Nyland and Gabriel 1977, Benson and Gonsior 1981, Aho et al. 1983, Kellogg et al. 1986, Fairweather 1991, Bennett 1993, Baumgras et al. 1995, Lanford and Stokes 1995).

Stand damage and resulting decay in young coastal Douglas-fir has not been intensively studied. Shea (1961) studied decay from 10-year-old logging scars in 114-year-old stands. Eighty-one percent of the wounds were within 1.4 meters (4.5 feet) from groundline. The average size was 1580 centimeters^2 (1.7 feet^2). Decay was found in 57 percent of the wounds. Ten-year volume loss on a tree basis was only 1.4 percent, but was 86 percent of the butt log volume increment.

Later Shea (1967) simulated logging wounds in a controlled experiment. From mature Douglas-fir trees, he removed bark squares having sides equal to 10, 20, and 40 percent of the circumference at 1.4 meters (4.5 feet). Unfortunately the planned 10 year study was shortened due to typhoon Freda (12 October 1962). He noted that during the first year considerable pitch was exuded, glazing over the exposed xylem. This effect was not consistent among trees. The smallest scars were frequently callused over after five years.

In another study, Hunt and Krueger (1962) also report low decay incidence and associated volume loss. Each of the previous three studies also evaluated western hemlock (*Tsuga heterophylla*). That species consistently had larger wounds and substantially more decay, with volume losses approaching or exceeding incremental volume growth.

Until now, the reported low incidence of stand decay associated with Douglas-fir partial harvests studies and the extensive use of clearcut harvesting for Douglas-fir stands over the past thirty years has made residual stand damage an insignificant concern. However, many of these clearcut stands are now of thinning age. Oswald et al. (1986) estimates there are 1.5 million hectares (3.7 million acres) of 20 to 60 year-old Douglas-fir type in the U.S. Pacific Northwest Douglas-fir subregion. They estimate an additional 257,000 hectares (635,000 acres) of this type in western British Columbia. The 0-20 age class adds an additional 1 million hectares (2.5 million acres) and

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

205,000 hectares (506,000 acres) in each region, respectively.

Silvicultural treatments are changing to address the new management objectives and to meet fiber requirements. One management objective on public lands is to accelerate the development of late successional stand characteristics. It is hypothesized that rapid growth of the dominants, after commercial thinning from below to low residual densities, coupled with underplanting of shade tolerant species will create multistoried stands (Tucker et al. 1993).

This hypothesis became an integrated research project in the Oregon coastal mountains during 1992. Harvesting studies to determine felling and yarding production and costs were conducted for three commercial thinning treatments on two sites in 1994. The results are reported by Kellogg et al. (1996). Stand damage was measured following cable logging on these sites. Additionally, a helicopter logging unit was evaluated for stand damage.

Objectives

The objectives of the overall study were:

1. Characterize stand damage sustained.
2. Quantitatively contrast damage between logging systems and treatments.
3. Identify the harvesting variables which affect residual damage.
4. Recommend practices to reduce damage during harvesting.
5. Investigate and identify sampling methods for quantifying damage.

This paper will summarize some of the preliminary results of objectives 1, 2, and 5. Final results for all objectives will be completed later in more detailed reports.

METHODS

Study sites and treatments

Two cable yarding sites were selected in the Coast Range of Oregon, near the towns of Hebo and Yachats on Siuslaw National Forest land. Both sites have a King site index (50 year) of 35.3 meters (116 feet), which is low site II.

Three different commercial thinning treatments were tested at each site, each leaving a prescribed number of residual trees per hectare (TPH) (trees per acre [TPA]):

1. conventional -- 247 TPH (100 TPA)
2. wide -- 148 TPH (60 TPA)
3. very wide -- 74 TPH (30 TPA).

The helicopter units at Hebo were inconsistently spaced between 197 and 296 TPH (80 and 120 TPA).

Site and stand characteristics before thinning are shown in Table 1.

The healthy dominant and co-dominant trees were marked to be left within each stand. The removed trees were selected from the mid-size diameter classes (18-41 centimeters [7-16 inches]). All trees less than 18 centimeters (7 inches) were cut as part of the silvicultural treatment

Harvest systems

Harvesting was performed by two cable logging contractors and a helicopter logging contractor during the period December 1993 to April 1994. Yarding equipment and operational differences are summarized in Tables 2 and 3. Stems at Hebo were limbed on three sides with tops bucked off. At Yachats, only the top side was limbed and the tree top was attached to the last log.

The helicopter used was a Sikorsky S-58T, having 2,272 kilograms (5,000 pounds) maximum external load capacity.

Table 1. Study site and stand characteristics before thinning.

Characteristic	Hebo	Yachats
Total size in ha (acres)	10.9 (26.9)	9.2 (22.6)
Treatment size in ha (acres)		
74 tph (30 tpa)	2.0 (4.9)	4.5 (11.1)
148 tph (60 tpa)	3.6 (9.0)	2.4 (5.9)
247 tph (100 tpa)	5.3 (13.0)	2.3 (5.6)
Aspect	Northwest, Northeast	Southwest
Percent slope	15-60	15-70
Species composition	99% Douglas-fir	93% Douglas-fir 6% Western hemlock
Stand age in years	33	33
Trees/ha (trees/acre)	588 (238)	791 (320)
Average dbh in cm (in.)	29.5 (11.6)	26.9 (10.6)
Volume in m^3/ha (ft^3/acre)	506 (7226)	514 (7343)
Basal area, m^2/ha (ft^2/acre)	44.3 (193.1)	48.4 (210.6)

Table 2. Summary of cable logging equipment and crew used at Hebo and Yachats.

Sites	Yarder	Tower height	Operating lines (diameter /length)	Carriage
Hebo	Thunderbird TMY 40	12.2 m (40 ft)	Skyline: 20 mm / 610 m (0.75 in / 2000 ft) Mainline: 12 mm / 610 m (0.5 in / 2000 ft)	Maki Mini Mak II Mechanical Slackpulling
Yachats	Koller K501	10.1 m (33 ft)	Skyline: 20 mm / 500 m (0.75 in / 1640 ft) Mainline: 12 mm / 600 m (0.5 in / 1965 ft)	Koller SKA 2.5 Manual Slackpulling

Table 3. Comparison of thinning operations at both sites.

Sites	Felling	Tail-trees used	Intermediate supports	Yarding height	Log suspension	Yarding distance (AEYD)
Hebo	Manual	1, rest mobile	none	above, within canopy	partial, often full	260 m (660 ft)
Yachats	Manual	26	10	under canopy	partial	250 m (820 ft)

Procedure

Residual tree damage was measured one year after harvest (summer 1995). The following characteristics were recorded for each damaged tree:

1. Diameter at breast height (DBH)
2. Scar width
3. Scar length
4. Scar area
5. Height to scar base
6. Bole quadrant location
   Bole quadrants were:
   1. towards landing
   2. towards corridor
   3. away from landing
   4 away from corridor
7. Gouge damage, depth penetrating sapwood
8. Gouge area
9. Distance from skyline corridor centerline
10. Distance from landing
11. Number of scars
12 Broken top defined as removal of the apical leader
13. Flag injury defined as half or more of the crown removed from the base of the live crown to the top on one side of the stem, causing the tree to resemble a flag on a pole.

Intermediate support trees and tailtrees were inspected for rigging related damage. Windfall trees were recorded. Root damage and branch damage were not evaluated.

All damaged trees (presence of a scar, any bark removed with exposed cambial layer) were numbered with paint in the cable units to avoid double counting and for testing the sampling methods. Each scar was measured for area. Small scars were traced onto loose leaf paper. Larger scars were traced onto several sheets and summed. The tracings were measured using a planimeter in the office. Scars which could not be reached were measured by Bettinger and Kellogg's (1993) method using a camera equipped with a 70-210 mm zoom lens. A scale was mounted to a 7.62 meter (25 ft) telescoping rod, placed near the scar, and a photo taken of the scar and scale for later analysis.

Sampling methods

The objective of the sampling method was to obtain an estimate of the percentage of total residual trees which are damaged as defined by some criteria in an efficient yet statistically sound manner for the entire stand.

At the cable sites, every tree was evaluated for damage (100 percent cruise). Four additional sampling methods were performed at the Yachats site. The four methods evaluated were:

1. Line-circular 0.04 ha (0.1 acre) plots
2. Random circular plots
3. Strip transects
4. Blocks centered on corridors.

All four methods were developed the same initially to determine the number of damaged trees to sample. First, an estimate of the percent damaged residual trees was obtained. Second, an estimate of the number of total residual trees was obtained. Third, we selected an appropriate allowable sampling error. The larger the acceptable error, the lower the required sampling intensity. An allowable error of 10 percent was selected as an appropriate level to balance accuracy and effort. Then the number of damage trees to be sampled was determined using equation (1) (Dilworth 1981):

$$n_o = \frac{N*p*(1-p)}{(N-1)*(d^2/z^2)+p*(1-p)}$$

where:

N = total number of trees in the unit,
n_o = number of damaged trees required in sample,
p = estimate of percent damaged trees in unit, (decimal)
d = allowable sampling error, decimal percent,
z = upper alpha/2 point on a normal distribution, where alpha is the probability of a type I error.

Plot methods

For the line-plot or random plot methods, an appropriate plot size was selected to yield a manageable yet representative sample (six trees per plot) as a function of the residual stocking. Then the number of plots required was calculated using equation (2):

$$plots = \frac{n_o}{ta*p*s}$$

where:

n_o = number of damaged trees required in sample,
p = estimate of percent damaged trees in unit, (decimal)
ta = residual stocking density in unit, trees per unit area
s = plot size in area

Line-plots

With the known number of plots and unit size, an appropriate line spacing and plot center spacing was selected to fit the required plots to the unit. In the 74 TPH (30 TPA) unit, a plot size of 0.08 hectare (0.2 acre) was used to achieve the representative sample per plot.

Random plots

A spreadsheet was created to generate random x,y coordinate pairs within the unit boundaries. Plots were selected until the number of plots required were located. Plots which overlapped each other or unit boundaries were dropped. Plots were then ordered into a continuous traverse. A traverse program was used to generate bearings and distances for each leg from the starting point to the end-point.

Strip transects

We divided the number of damage trees required for sampling from equation (1) by the estimated decimal damage rate to obtain the total number of trees to investigate. This number was then divided by the residual stocking density to determine the total strip area to be sampled by the cruise. With the known sample area and unit size, an appropriate line spacing and strip width was selected to fit the required total strip area to the unit.

Blocks on corridors

As with the strip method, we divided the number of damage trees required for sampling from equation (1) by the estimated decimal damage rate to obtain the total number of trees to investigate. This number was then divided by the residual stocking density to determine the total block area to be sampled by the method. Then each skyline road was divided into four equal sections with a line at 25, 50, and 75 quartile points of the total skyline corridor length. A block width was selected. A block was drawn extending from the midpoints with the adjacent corridors of the chosen width (one-half width above and below quartile points). The total block area, was summed and compared with the required total sample area. The block width was adjusted, as required, to achieve the sample area needed.

When sampling cruises were performed, only the damaged tree numbers were recorded because the data were previously collected. However, the time to perform (establish, locate, traverse) the various cruises was recorded.

The helicopter sites were systematically sampled as the total unit size was 33 hectares (82 acres). A line-plot method using 62, 0.04 hectare (0.1 acre) circular plots gave a 7.5 percent sampling intensity.

RESULTS and DISCUSSION

Cable logging damage

Many of the scars less than 2.5 centimeters (1 inch) in width completely healed over in the year following harvesting. The summary of the attributes sampled is shown in Table 4.

Damage incidence and scar size

As the thinning intensity increased, (residual density decreased) stand damage increased, on a percentage basis. However, damaged trees per unit area increased with increasing residual density, from 18 TPH (7 TPA) in the very wide treatment unit to 35 TPH (14 TPA) in the conventional treatment unit at Hebo. A similar, but higher, trend occurred at Yachats as there was a greater percentage of damaged trees by treatment than at Hebo.

Trees at both sites averaged approximately 2.5 scars per tree, with a slight increase in the very wide treatment at Yachats. Scar size by frequency follows an inverse J shape distribution. Average scar size increased with increasing thinning intensity. Additionally, the average scar at Yachats by treatment (240-490 cm^2 [37- 76 in^2]) was larger than the scar of corresponding treatment (150-195 cm^2 [23-30 in^2]) at Hebo.

Under the commercial thinning standards documented by the British Columbia Ministry of Forests (1983), trees with cumulative scar area less than 450 $centimeters^2$ (70 $inches^2$) do not incur a financial penalty. Greater damage incurs increasing penalties. Under these guidelines, depending on the treatment, 8-13 percent of the residual trees would be penalty trees at Hebo, while 18-39 percent of the residual trees would be penalty trees at Yachats.

The trend at Yachats to have more damage and larger scars is puzzling. The smaller yarding equipment and the rigging configuration used are conventionally associated with lower levels of damage. The inability to readily reposition the Koller carriage, as contrasted with the better carriage control at Hebo, is felt to be one important factor. The factors of crew incentive or diligence in minimizing stand damage must also be considered. It was not apparent if the timber sale

Table 4. Descriptive statistics of residual stand damage from commercial thinning at Yachats and Hebo

Study Sites (Logging System)	Unit (TPA)	Logging Damages # of trees (%)				DBH (in)	# of Scars per Tree	Scar Height (feet)	Scar Width (in)			Scar Length (in)			Scar Area (in^2)			Scar Area per Tree (in^2)			Scar Area (ft^2/ac)
		Total	Broken Top	Flag	Wind Throw	Average			Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	
Yachats (Cable)	30	49 (36.6)	1 (2.0)	0 (0.0)	1	15.1	3.2	7.5	5.8	1.5	44.4	16.6	1.2	253	76	2.8	864	257	5.2	1678	16.8
	60	142 (32.2)	2 (1.4)	0 (0.0)	19	14.2	2.3	4.8	5.5	1.2	20	12.3	1.2	130	59	2.8	829	134	4	1103	14.3
	100	227 (22.9)	2 (0.9)	0 (0.0)	3	14.2	1.9	5.5	4.9	0.8	31	8.7	0.9	111	36.6	3	588	70.1	3	717	8.1
Hebo (Cable)	30	75 (25.0)	18 (24.0)	3 (4.0)	0	13.8	2.5	7.7	4.1	0.5	18	7.8	0.8	44	30.4	2.6	367	75.1	7	822	2.7
	60	59 (17.3)	7 (11.7)	12 (20.3)	1	13.7	2.4	7	5.3	1	32	7.6	1.5	56	28.4	3	317	64.5	3.8	357	3.3
	100	81 (15.8)	3 (3.7)	1 (1.2)	0	12.7	2.8	7.1	3.7	0.5	11	7.0	0.8	78	22.8	2	234	63.2	4	578	5.9
Hebo (Helicopter)	100	69 (11.1)	10 (14.5)	6 (8.7)	1	13.3	1.7	17.7	4.6	0.8	56	7.4	2	36	23.9	4	155	41.4	4	291	2.4

Notes: - DBH are only for the damaged trees

- The data in cable units were collected by 100% sampling, but data for the helicopter units were collected by using line-plot sampling method.

- The percentages for Broken top and Flag are calculated based on the total number of damaged trees.

officers at either site were evaluating the operations for residual stand damage

Corridor proximity, height, and quadrant location

The majority of the gouge damage occurred along the corridors at both sites. The appearance of the gouged scars suggests multiple impacts. More than 60 percent of the damaged trees at Yachats and approximately 70 percent at Hebo were located within 6.1 meters (20 feet) of the corridor centerline.

The average height of the scars at Yachats varied from 1.5 - 2.3 meters (4.8 - 7.5 feet). At Hebo, scar height was more uniform around 2.2 meters (7.2 feet).

More than 50 percent of the scars where located in the quadrant facing the corridor at both Yachats and Hebo. Including the quadrant away from the landing, 75 percent of all scars occur in these 2 quadrants.

Non-scar damage

Both broken top and flag injuries were more prevalent at Hebo than Yachats, where they were almost non-existent. This is directly attributable to the rigging configuration and procedures used at Hebo. This was the first thinning operation by the operator with this equipment. They chose not to rig tailtrees in favor of rigging across the draw to a roadside mobile tailhold. As the skyline was raised and tightened, the resulting rubbing and siwash of the skyline on the trees removed live limbs and severed tree tops. On several occasions, the mobile tailhold had to be repositioned to bring the skyline into the yarding corridor.

At Yachats, the choice not to use tree plates or ballistic fiber rigging straps caused the rigging cables on the tailtrees and intermediate support trees to partially or completely crush or remove the cambial layer, resulting in girdling of the stem. One-third of the tailtrees and one-half of the intermediate support trees were dead one year after thinning.

Helicopter logging damage

Only 11.1 percent (95 percent CI, 8.5-13.5 percent) of the residual trees were damaged in the helicopter unit (Table 4). The average scar size was comparable to the lowest average cable yarding scar. The maximum scar area sampled was the smallest maximum seen in the entire study. More than 80 percent of the scars sampled were smaller than 195 $centimeters^2$ (30 $inches^2$). The average scar height was 5.4 meters (17.7 feet), 3 meters (10 feet) higher than in the cable yarded units. These scar conditions may have a lower risk of infection.

Broken tops and flag injuries accounted for 23 percent of the total stand damage in the helicopter units at Hebo. While decay potential is minimized, stem mortality may increase due to the loss of the live crown.

Sampling methods

Sampling intensity of the residual trees was 55, 20, and 10 percent respectively for the 74, 148, and 247 TPH (30, 60, 100 TPA) units. With a few exceptions, the four sampling methods evaluated performed acceptably (within the acceptable error rate) in estimating stand damage for the various attributes measured (Table 5). With this unreplicated case study (n=1), it is not possible to determine whether methodology alone caused an inaccurate attribute estimate.

Upon review of Table 5, the block method appears most variable among the methods, especially in estimating total scar area per tree. The line-plot method appears most consistent across the attributes estimated. All methods are highly variable in the 74 TPH unit (30 TPA) as a result of the high variability in stand damage. Likewise, all methods have more variability in estimating a highly variable attribute like scar size. All methods have higher accuracy with a more consistent attribute like percent damaged trees.

Ease of implementation is highest with the line-plot and lowest with the block and random plot methods (Table 6). Statistically, the random circular plots is the most robust (least potential bias), but the least efficient for forest sampling. The line-plot and transect require coverage of the entire unit for unbiased statistical inference to the entire stand, particularly when the stand lacks homogeneity.

The block on corridor method concentrates coverage in the area where damage occurrence and severity is the highest as evidenced in the damage study results. However, field implementation was difficult and the amount of area surveyed must be known to create an estimate for scar area per unit land area.

The line-plot method appears to be the most efficient in establishing, traversing, and implementing a stand damage survey while providing an acceptable estimate of residual damage.

Table 5. Comparison of four sampling results to the actual data taken from 100 percent sampling at Yachats

Units (trees per acre)	Sampling methods	Area (acre)	DBH (in.)	Damage (%)	Average Scars per tree (#)	Average Scar area (sq.in)	Average Scar area per tree (sq.in)	Scar area per acre (sq.ft/ac)
30	Actual	5.0	15.1	36.6	3.2	76.0	257.0	20.2
	Line	3.0	15.1	40.0	3.0	96.9	313.4	21.1
	Random	2.5	14.8	37.0	3.2	55.2	184.0	13.8
	Block	1.2	15.3	39.6	3.0	44.9	138.4	15.3
	Transect	2.8	14.9	35.7	3.1	83.6	268.0	18.5
60	Actual	9.0	14.2	32.2	2.3	59.0	134.0	15.3
	Line	1.6	14.5	34.8	2.0	64.6	128.8	16.8
	Random	1.7	14.9	37.0	2.4	82.2	196.0	28.9
	Block	1.4	14.7	38.4	2.9	65.3	192.7	28.2
	Transect	1.8	14.5	30.5	1.9	53.7	103.8	9.7
100	Actual	13.0	14.2	22.9	1.9	36.6	70.0	8.1
	Line	1.3	14.6	24.4	1.8	30.2	53.3	8.5
	Random	1.3	14.4	23.3	1.8	41.9	71.6	9.2
	Block	1.4	13.6	24.8	1.8	16.3	39.7	5.1
	Transect	1.3	15.3	23.2	1.9	30.2	56.8	9.9

Table 6. Advantages and disadvantages of the sampling methods.

Sampling Designs	Advantages	Disadvantages
Systematic Circular Plots (Line-Plot)	- Easy to find plots on the site. - The checker is certain to take exactly the same trees as the original cruiser if a stake is set to designate the center of the plot. - One person can collect data. - Easy to collect data - Takes the least time to establish and traverse.	- Difficult to precisely layout a circular plot on the slope.
Systematic Line Transects	- Easier to estimate a distance on either side of the center line than a radius circular plots. => easy to do layout	- Difficult to check unless the center line is definitely marked. - Requires at least a two-person crew.
Blocks along the Skyline Roads	- Samples damages along the skyline roads where occurrence and severity is highest.	- More difficult to set the blocks on the site than any of the other methods. - Hard to apply it to ground based systems. - Takes the most time for data collection. - Difficult to calculate the area sampled.
Random Circular Plots	- Eliminate bias - Every situation has the same probability to be selected. - Works well for both cable and ground based logging systems.	- Difficult to locate plots on the site. - The most difficult to do layout of plots on the map. - More difficult data collection than Systematic circular plots.

Management implications

Quantifying stand damage may provide information useful in managing for both fiber and non-fiber resources. Stand damage has negative fiber volume and value impacts. With current ecosystem management and sustainable forestry goals, stand damage may contribute positive impacts through immediate and progressive snag creation, roosting and nesting sites in broken topped trees, and diversity in micro-flora and fauna species associated with decay processes.

Conducting stand damage surveys for in-progress harvest operations would provide forest managers with the information needed to take corrective action to minimize impacts. The manager may also use the information in selecting habitat reserve trees. Growth and yield projections may be updated. Operationally, the manager can insure feasibility of future harvest entries through protection of tail and intermediate support trees.

Forest engineers, through harvest planning, can provide the best starting conditions to minimize damage during operations. The thinning operator ultimately controls stand damage occurrence.

SUMMARY

This study reported levels of cable thinning caused damage for a conventional thinning intensity and two higher intensities implemented for accelerating development of multistoried stands. Evaluation of recorded damage patterns suggest a matching of harvest equipment, techniques, and diligent operators can reduce damage. The line-plot cruise method can efficiently provide an acceptable estimate of stand damage.

LITERATURE CITED

Aho, Paul E.; Fiddler, G.; Srago, M. 1983. Logging damage in thinned, young-growth true fir stands in California and recommendations for prevention. Research Paper PNW-304. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 8 p.

Baumgras, John E.; Sherar, J.R.; LeDoux, C.B. 1995. Environmental impacts from skyline yarding in an Appalachian hardwood stand: A case study. In: Proceedings of the 18th annual meeting of the Council on Forest Engineering; 1995 June 5-8; Cashiers, NC. Corvallis, OR: Council on Forest Engineering: 87-96.

Bennett, Doug M. 1993. Partial cutting in a second-growth Douglas-fir stand in coastal British Columbia: Productivity, costs, and soil impacts. Technical Note TN-199. Vancouver, British Columbia: Forest Engineering Research Institute of Canada, Western Division. 12 p.

Benson, Robert E.; Gonsior, M.J. 1981. Tree damage from skyline logging in a western larch/Douglas-fir stand. Res. Paper INT-268. Ogden, UT: USDA, Forest Service, Intermountain Forest and Range Experiment Station. 15 p.

Bettinger, P.; Kellogg, L.D. 1993. Residual stand damage from cut-to-length thinning of second-growth timber in the Cascade Range of Western Oregon. Forest Products Journal 43(11/12): 59-64.

British Columbia Ministry of Forests. (Updated periodically). "Appendix 9-10B, Commercial Thinning, Summary of Standards, Schedule B (F.S. 763B)". In: Silviculture Manual, Volume 2. Victoria, BC, Canada.

DeBell, Dean S.; Curtis, R.O. 1993. Silviculture and new forestry in the Pacific Northwest. Journal of Forestry 91(12): 25-30.

Dilworth, John R. 1981. Log scaling and timber cruising. Corvallis, OR: OSU Book Stores, Inc. 468 p.

Fairweather, Stephen E. 1991. Damage to residual trees after cable logging in northern hardwoods. Northern Journal of Applied Forestry 8(1): 15-17.

Hunt, John; Krueger, K.W. 1962. Decay associated with thinning wounds in young-growth western hemlock and Douglas-fir. J.For.60(5): 336-340.

Kellogg, Loren D.; Olsen, E.D.; Hargrave, M.A. 1986. Skyline thinning a western hemlock-Sitka spruce stand: Harvesting costs and stand damage. Research Bulletin 53. Corvallis, OR: Oregon State University, College of Forestry, Forest Research Laboratory. 21 p.

Kellogg, Loren D.; Milota, G.V.; Miller Jr, M. 1996. A comparison of skyline harvesting costs for alternative commercial thinning prescriptions. Journal of Forest Engineering 8(1): in press.

Lanford, Bobby L.; Stokes, B.J. 1995. Comparison of two thinning systems. Part 1. Stand and site impacts. Forest Prod. J. 45(5): 74-79.

McComb, William C.; Spies, T.A.; Emmingham, W.H. 1993. Douglas-fir forests: Managing timber and mature-forest habitat. J.For.91(12): 31-42.

Nyland, Ralph D.; Gabriel, W.J. 1977. Logging and its effects in northern hardwoods. Applied Forest Research Institute Research Report No. 31. Syracuse, New York: New York State University, College of Forestry, AFRI. 18 p.

Oswald, Daniel D.; Hegyi, F.; Becker, A. 1986. In: Douglas-fir: Stand management for the future. Contribution No. 55. Seattle, WA: University of Washington, College of Forest Resources, Institute of Forest Resources: 26-31.

Shea, Keith R. 1961. Deterioration resulting from logging injury in Douglas-fir and western hemlock. Forestry Research Note No. 36. Centralia, WA: Weyerhaeuser Company, Forestry Research Center. 5 p.

Shea, Keith R. 1967. Effect of artificial root and bole injuries on diameter increment of Douglas-fir. Weyerhaeuser Forestry paper No. 11. Centralia, WA: Weyerhaeuser Company, Forestry Research Center. 11 p.

Tappeiner, John C.; Bell, J.F.; Brodie, J.D. 1982. Response of young Douglas-fir to 16 years of intensive thinning. Res. Bull. 38. Corvallis, OR: Oregon State University, College of Forestry, FRL. 17 p.

Tucker, Gabe; Emmingham, W.; Johnston, S. 1993. Commercial thinning and underplanting to enhance structural diversity of young Douglas-fir stands in the Oregon Coast Range. Newport, OR: COPE Report 6(2): 2-4.

DAMAGE TO RESIDUAL TREES DURING PARTIAL HARVESTS - MEASUREMENT, ANALYSIS, AND IMPLICATIONS[1]

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ABSTRACT: The use of thinning as a management tool is becoming significantly more popular in the Pacific Northwest and other regions of the United States. Thinning operations typically leave some portion of the residual stand in a damaged condition. This paper reviews the techniques for measuring that damage in a systematic manner, presents preferred measurement techniques based on past research studies, and presents current models for predicting volume losses based on scar size and scar age.

Key Words: thinning, stand damage, decay, thinning losses

INTRODUCTION

Thinning is an integral part of forest management for both public and private forest landowners in the Pacific Northwest. One of the most significant questions facing managers who use thinning treatments in their management is how residual stand damage affects the final harvest value of thinned stands. While a number of scientific studies have evolved to address these concerns, no specific techniques have been adopted by the forest industry to measure this damage, quantify the impact on yield, or predict the financial effects of harvest related stand damage.

Why should the forest industry be concerned about the question of damage? A recent survey of forest land managers in western Washington state indicates that public land managers have increased the acreage thinned on their managed lands by almost 200 percent in the past five years. Private land managers increased the acreage thinned on their lands by 232 percent in the same period. When asked to predict the level of increase or decrease in acreage thinned over the next five years, both public and private land managers estimated moderate to substantial increases in thinning levels (McNeel and Dodd, 1996).

In addition, land managers were asked if they subjected contractor thinning crews to financial penalties to control site disturbance or stand damage. Government respondents indicated that over 80 percent of their thinning contractors were subject to penalties if thinning damage or soil disturbance exceeded pre-defined limits. Industry land managers also used financial penalties 55 percent of the time.

A five percent level of stand damage was considered acceptable after thinning by most industry and government land managers, when using either cable or ground-based systems. The question of what constitutes damage was not addressed in the survey. However, the responses to the questionnaire suggest that there is no agreement on a standard definition as to what constitutes damage from thinning.

This survey identifies several concerns associated with thinning and stand damage. First, acceptable forest practices in the West are changing and, as a result, thinning is becoming much more popular as a management tool. Clearcutting, based on even-aged forest management, is far less acceptable now than five years ago on most federal lands. State lands have also reduced the amount of timber harvested using clearcuts. In contrast, thinning is widely accepted by many federal and state land management agencies in the region, as suggested by the reported increases in thinned acreage.

Another concern brought out by the survey is what constitutes damage to a tree during a thinning harvest. As indicated earlier, informal discussions with different industry and government land managers in the region suggest that consensus has not been reached on this question.

This paper presents an overview of current thinning related research dealing with stand damage. It

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includes a review of stand damage related to thinning or partial harvest operations and discusses the effect of thinning damage on the residual stand. Finally, techniques for measuring thinning related damage are discussed, with emphasis on projecting measured damage to estimate potential losses prior to the final harvest.

MEASURING STAND DAMAGE

A number of studies have been conducted in the western United States to evaluate stand damage after thinning. Aho and others (1983) examined damage in true fir (*Abies concolor* and *A. magnifica*), Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) stands three to 25 years after thinning. They found that conventional harvest systems using cable or grapple skidders and, in one case, a cable yarder caused damage levels ranging from 22 to 50 percent of the residual stand. Wound location in these stands was consistent, being located primarily at the base of the tree in contact with the ground.

In another study by Ostrofsky et al. (1986), mechanical harvesting systems were evaluated to determine where damage originated in the thinning process when using conventional mechanized systems. Most damage was reportedly from felling and bunching operations, averaging 62 percent of all damage observed in the study. Skidding produced 29 percent of the damage on average.

As part of their analysis, Ostrofsky et al. (1986), used regression analysis to determine how trail spacing affected damage levels. A general conclusion supported by their study was that, as distance from the trail increases and as tree size decreases, the probability of damage decreases. As with other studies, trees located closest to the trail had the highest probability of being damaged.

McNeel and Ballard (1992) examined residual stand damage in a young Douglas-fir plantation thinned with a harvester-forwarder system. Their study indicated that damage from using the cut-to-length system was minimal, that most of the scars created during the harvest were 40 cm^2 (16 $inch^2$), and that damage was substantially less than that observed with conventional thinning systems.

Bettinger and Kellogg (1993) also evaluated a cut-to-length system in a natural stand of western hemlock and Douglas-fir in western Oregon. Their study measured total damage levels of 12.85 ft^2 per acre. Average scar size was reported to be 18.4 $inch^2$ per tree for Douglas-fir and 9.3 $inch^2$ in western hemlock. Height measurements indicated that over 82 percent of the damage occurred within seven feet of the groundline for this system. The authors suggest that the location and type of damage (primarily scarring) occurred as a result of the processing associated with cut-to-length operations.

Wiley (1968) summarizes the findings of several authors relative to reducing losses from injury and disease, primarily in western hemlock (*Tsuga heterophilia*). These include:

1. Minimize yarding, skidding, and forwarding injuries, especially those located near the groundline where decay has a greater chance to enter the tree.

2. Use of equipment specifically designed for thinning and careful planning in skid trails is advised, as is the use of carefully laid out trails or yarding corridors.

3. Trees with wounds greater than 366 cm^2 (1 ft^2) should be removed during the thinning harvest.

4. Openings in the stand should be kept small to avoid the occurrence of sunscald.

Similar findings have been reported in case studies in northern forests. Cline et al. (1991) found that the most significant factor affecting the amount of residual stand damage in partial harvests was the amount of pre-harvest planning and the level of skill possessed by operators of the harvesting equipment. The study examined 18 different harvest operations in partial cuts within northern hardwoods. The systems used during these harvests included a feller-buncher and either a cable or grapple skidder.

EFFECTS OF FUNGAL DECAY AND INSECTS

Decay and insect infestation are the two most prevalent post-harvest problems for damaged residual trees. One study of a western hemlock stand that had been thinned at three year intervals over a ten year period, starting at age 47, found decay present in 61 percent of the trees with wounds created through thinning (Hunt and Krueger, 1962).

The surface area for the wounds with decay present averaged 0.97 ft^2 in size, while the average size of those trees with wounds but without decay was 0.19 ft^2. *Heterobasidion annosum* was the predominant decay causing fungus present in those trees with wounds. The findings were similar to those presented by Wright and Isaac (1956) in old growth western hemlock, and the authors concluded that there was little difference in susceptibility based on stand age in western hemlock.

Hunt and Krueger (1962) also examined two Douglas-fir stands of similar age subjected to similar thinning regimes to determine the effect of thinning damage relative to subsequent decay for this species. Their findings indicate that Douglas-fir is less susceptible to decay following thinning damage. Comparison of losses in the Douglas-fir stands with that measured in the one western hemlock stand in the study indicated that, on a per-tree basis, Douglas-fir trees lost about 33 percent of the volume lost in western hemlock trees with similar types of wound.

Projected losses of volume also indicated more loss in the western hemlock. Hunt and Krueger found that the western hemlock stand had lost about 5.5 percent of the net annual periodic increment of 185 ft^3 through decay. In contrast, the stands of Douglas-fir lost between 0.1 and 2.7 percent of the net periodic annual increment for the two stands under study.

H. annosum was also found to be a problem in stands subjected to pre-commercial thinning. A study by Chavez et al. (1980) compared the level and extent of decay associated with plots of trees that had been thinned to those that had not been thinned. Infection levels for the thinned plots taken 11 years after thinning were very high, with decay present in about 85 percent of the residual stand. In contrast, the trees left unthinned had infection levels of only 12 percent.

Decay columns, the distance that decay was measured vertically in the trees, averaged between 3.4 and 4.1 meters for the thinned plots. The control plots averaged much smaller values, between 1.0 and 2.3 meters. The study concludes that western hemlock is very susceptible to *H. annosum* infection, that the stands can be significantly affected by this infection, that decay caused through infection can have a significant effect on potential products, and that effective treatment for *H.annosum* is necessary to minimize potential losses to decay.

Wright and Isaac (1956) present regression estimators with associated graphs for predicting volume losses relative to age after wounding and initial or present scar surface area for old growth western hemlock (Table 1). These prediction equations were partially verified in other studies, conducted predominantly in younger (30 to 90 year-old) stands of western hemlock, by Shea (1967), Hunt and Krueger (1962), and Wiley (1968).

Insects are also a problem after thinning. Wounds release organic compounds that often attract boring or tunneling insects to the tree. In one study conducted by Blanche et al. (1985), thinning damage was simulated in loblolly pine (*Pinus taeda*) to determine the effect of different types of damage on insect infestation. Two damage treatments, root pruning and scarring, were imposed individually and in combination to determine their effect on resin flow from the trees. Measurements were also taken on monoterpene components in the produced resin, since it was hypothesized that monoterpene increases tree susceptibility to insect (bark beetle) infestation. The study concluded that bole scarring provides more resistance to insect attack than root pruning (or root damage).

A second study relative to insect attack after thinning operations was reported by Nebeker and Hodges (1985). They emphasize that a number of biological factors should be included when developing a thinning strategy. The paper points out that *Ips* engraver beetles typically colonize in the slash created during thinning operations and infest standing residual trees after the thinning is completed. Natural enemies of the engraver beetle are thought to keep these attacks in check, however. The study further suggests that, in the South, thinning should be conducted in the winter months to reduce the potential for beetle infestation. This suggestion, however, runs contrary to the suggested time to thin when concerned *H. annosus* root rot.

A last study on insect infestation after thinning is provided by Witcosky et al. (1986). In this case, however, the concern is over the black stain root rot (*Verticicladiella wagneneri*) which is sometimes spread in Douglas-fir via the root bark beetle (*Hylastes macer*). The study demonstrated that thinning increased the abundance of insects carrying root rot, and that root damage in the residual trees provided an adequate infestation point for the fungus. Spring was considered to be a better time to conduct thinning operations due to low insect presence.

DAMAGE MEASUREMENT TECHNIQUES

Researchers have developed a variety of approaches for measuring stand damage. For practical application, however, selected measurement techniques should provide an accurate representation of the extent of damage in a residual stand after thinning, while also providing the forester with enough data to develop projections of potential losses from decay and/or mortality. Using standard cruise based plots allows the forester to project measured damage within plots to provide a representative measure for the entire stand.

A variety of methods for measuring damage are reported by researchers. However, common data collection themes are present in many of the reported studies. Typically, these include the following damage related factors:

Height of wound

Height of the wound is usually a defining factor in predicting the probability of subsequent decay. Different approaches have been taken to classify damage relative to height. The most simplistic is the approach taken by Stone and Coulter (1975) who defined two classes; butt - from 0.5 meters above groundline to groundline, and upper stem - from 0.5 meters to the top of the tree. McNeel and Ballard (1992) reported the general location of stem damage on the bole, but did not provide exact measurements or define height-of-wound categories in their study of cut-to-length thinning related damage in a Douglas-fir plantation. Nichols et al. (1994) used exact height measurements from the groundline in partially harvested stands of northern hardwoods.

Bettinger and Kellogg (1993) measured each wound in their study of thinning in a natural Douglas-fir and western hemlock second-growth stand. They also classified the extent of scarring on a percentage basis to provide a better understanding of the height of wound across the treated stand.

Froehlich (1976) reported two classes of wounds, those under one foot from the groundline and those over five feet from the groundline, suggesting perhaps that wounds between these two points were not recorded or simply did not occur in his study of thinning damage from skyline and tractor thinning in young Douglas-fir stands. Sidle and Laurent (1986) classed only those wounds above a one-foot stump height in their study of spruce stands mechanically thinned in southeast Alaska. Wright and Isaac (1956) classed wounds based on two categories, either above DBH (where DBH = 4.5 feet from groundline) or below DBH.

Ostrofsky et al. (1986) specified location of the wound, but only with respect to the roots, bole, or crown in their study of thinning damage in northern hardwoods. Cline et al. (1991) used a similar approach in their study of whole tree partial harvests in northern hardwoods.

Siren (1982) studied damage during a thinning in a Swedish forest caused by a grapple processor and classed the damage as either root, root collar, or bole damage. Bruhn (1986) and Meyer et al. (1966) classified damage based on whether the damage occurred at the root or on the bole in a study of partial harvests in northern hardwoods. A number of other studies have examined stem damage almost exclusively, but did not consider height of the scar as a classification criteria.

Height of scar should be considered when collecting stand damage information, since the butt log usually contains the most valuable wood products. Damage should be considered more severe, for wounds of similar size, as height of wound decreases. The probability of infection by different fungi is evidently much greater for wounds low to the ground. As noted by Wallis and Morrison (1975) who studied decay in western hemlock stands that had been thinned between five and 25 years prior to the study, most decay found during their study was located in the butt log (<16 feet). Wiley (1968) also suggests that great care be taken during thinning operations to minimize damage near the groundline, *where decay enters most frequently*. Another study by Aho et al. (1983) found that the presence and extent of decay were significantly related to wound location; wounds closer to the ground had a greater probability of decay being present and higher levels of decay when decay was present.

Tree diameter

Tree diameter was a criteria in nearly all of the studies examined and cited in the previous section. Tree diameter is a critical component of any damage related survey, since diameter can be used to estimate current value of the tree. However, when projecting potential losses and/or decay spread over time for damaged trees, diameter is not really a critical factor in the prediction process (Wright and Isaac, 1956; Wiley, 1968).

Scar size

Scar size, as discussed later in this paper, has a strong correlation with subsequent decay and volume losses. Undoubtedly, scar size also has a significant relationship with value loss as well, although few studies have been conducted to directly support this hypothesis.

Most researchers have used scar size to quantify thinning related damage. Froehlich (1976) classed wounds into two categories; those with scars of a size greater than 9 $inch^2$, and those with scars greater than 27 $inch^2$. Bruhn (1986) separated scar sizes into four categories, based on width in two cases, where the wound was greater than either four or seven inches in width. The wound was classed differently if the wound area exceeded 50 $inch^2$. A last category was gouge wounds, where the wound extended into the cambium more deeply than could be explained by a scraping type wound. Gouge wounds were considered to be the most critical type of wound with respect to potential decay. In a similar manner, Bettinger and Kellogg (1993) measured wound depth and classed wounds into two categories, those less than or equal to 0.25 inches and those greater than 0.25 inches in depth. Wounds with the greater depth were considered to be less resistant to decay.

McNeel and Ballard (1992) simply computed a mean wound size in square inches to describe damage. Both the mean and the mode (most common observation) were provided. Sidle and Laurent (1986) classed stem scars based on wound size, providing percent estimates of wound size by 0.5 ft^2 classes, up to wounds over 1 ft^2. A mean wound size was also provided in the results.

Ostrofsky et al. (1986) provided the mean width and length for wounds on different thinning sites, and a measure of the ratio of wound width to tree circumference in percent. Stone and Coulter (1975) also used tree circumference as a means of classifying wound significance. Butt damage, for any point 0.5 meters from the ground and below, was classed into 0.25 of the tree circumference, 0.25 to 0.50 of the circumference, and greater than 0.5 of the tree circumference. The utility of this approach is not readily apparent, since most, if not all, of the ratios in the Ostrofsky study fell into a range of 19 to 23 percent. The Stone and Coulter study classed 67 percent of the damaged trees into the 0.25 circumference category, also suggesting little sensitivity to damage severity.

The damage that occurs to a given tree may be located in two or more wounds. For most of the studies where this factor was considered -- many did not mention this fairly common situation -- the wound areas were added together as if a single wound existed. While this is an expeditious manner to handle multiple wounds, there may be some bias to exaggeration in some cases. Location-based weights applied to wound size estimates could be used to factor out this bias, although no studies reviewed in this paper have considered such a weighting system.

The importance of scar size measures cannot be overemphasized. In western hemlock, studies suggest that initial scar size is strongly correlated to potential decay losses over time (Wright and Isaac, 1956). Correlations of this type are currently available for only a few other species, however, leaving foresters with little information beyond the extent of scarring within a stand.

Some rules of thumb can be developed, however, by reviewing past studies of other species. For example, Hunt and Krueger (1962) found that scarring in Douglas-fir, although of similar severity to that in western hemlock, produced significantly lower levels of decay, about one third of that produced in thinned western hemlock.

Root damage

Root damage caused by thinning operations is the least measured variable associated with stand damage measurements. Two concerns are addressed in this section; measuring root related damage, and quantifying the effect of root damage on tree growth.

Sidle and Laurent (1986) present measurements for root damage caused during thinning harvests in Sitka spruce and western hemlock stands in Southeast Alaska. Root damage was classified into several categories comprised of root collar scars (unmeasured), root scars of different sizes (ranging from 0.1 ft^2, 0.1 to 0.5 ft^2, 0.5 to 1.0 ft^2, and scars greater than 1.0 ft^2), and split or severed scars.

Nilsson and Hyppel (1968) found, during their study of root damage in Norway spruce in Finland, that only five percent of all damaged roots over 1 meter away from the bole produced decay. Based on these results, Siren (1989) suggests that damage evaluations of root systems should be limited to distances equal to or less than one meter from the bole.

Wasterlund (1983) studied the effect of thinning damage to root systems caused by trail rutting, although these studies were limited exclusively to Scandinavia. Siren (1989) summarizes these findings and presents a formula developed by Wasterlund to predict root area of a single tree based on tree age. He further provides estimates developed by Wasterlund predicting the increment losses caused by root damage (as a percent of the root system damaged) for Norway spruce (on good and bad sites) and for Scots pine. Increment loss projections were small, ranging to 0.7 percent loss (per annum?) for spruce on a poor site. On good sites, increment loss tends to be less, ranging to only 0.3 percent (per annum?) for damage occurring to 70 percent of the root system.

Measurement factors

The following summarizes what has been considered important in different studies for measuring damage in thinned stands:

Height of wound

More weight should be placed on wounds lower to the ground, than placed on those located 1.5 to 2.0 meters above groundline. Several studies specified a strong correlation between height of damage and the eventual presence of decay.

Size of wound

Size of wound can often be correlated to subsequent decay rates in certain species. To facilitate measurement, wounds can be classed into size categories. Some researchers have separated categories every 0.5 ft^2 with some success. Other studies suggest that wound width may be the most significant factor in determining the probability of decay losses. The majority of studies reviewed indicate that both width and length of the scar are required for adequate estimates of decay losses.

Wound width/circumference ratios

This approach was used twice, with little added information obtained for the effort. This may be of little value in most data collection schemes.

Root wounds

While not adequately researched in North America, root damage has been shown to be a significant factor to the introduction of decay in some Scandinavian species. Limiting damage assessments to a distance of one meter or less around the tree is suggested in one study. Another study classed root damage as either root scars (of various sizes), or split and/or severed roots.

Species

An obvious concern when trying to predict decay losses. Species such as western hemlock, Sitka spruce, and most eastern hardwoods have received a large amount of attention from researchers because they are much more sensitive to damage and subsequent decay. Other species, such as Douglas-fir and the southern pines, are relatively robust and exhibit few damage related problems after thinning.

Based on the reviewed papers, field techniques collecting damage information for later analysis to predict volume losses should probably consider wound location, wound size, species, and percent of root damage when collecting damage information. Some studies, not cited here, suggest that bent trees also should be measured as potentially damaged, although this seems more of a problem in eastern hardwood forests.

ANALYTICAL TECHNIQUES FOR ESTIMATING DECAY LOSSES

At least two studies have addressed questions regarding decay after a thinning wound has been created. Wright and Isaac (1956), examined the growth of decay over time in western hemlock and Sitka spruce. While the study results have been cited in several papers as being suitable for use in measuring decay levels in young stands (less than 50 years old), most of the study data was collected from old growth stands of hemlock and spruce. Their results are provided in graphical form in Figures 1 (western hemlock) and 2 (Sitka spruce) for changing wound size and age.

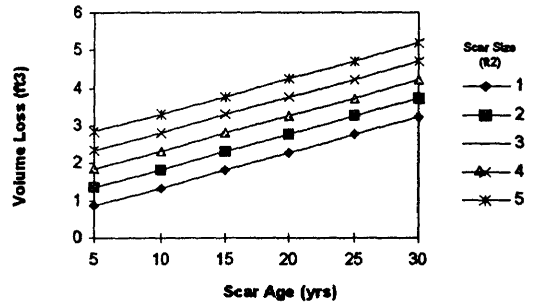

Figure 1. Volume losses from thinning scars in western hemlock (From Wright and Isaac, 1956).

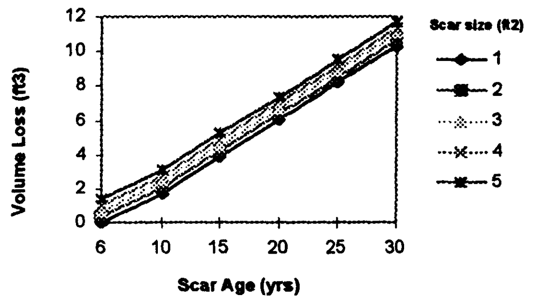

Figure 2. Volume losses from thinning scars in Sitka spruce (From Wright and Isaac, 1956).

A second study by Aho et al. (1983) examined decay in second-growth white and red fir in northern California. They also provide estimates of decay, based on wound size and age of the wound (Figure 3).

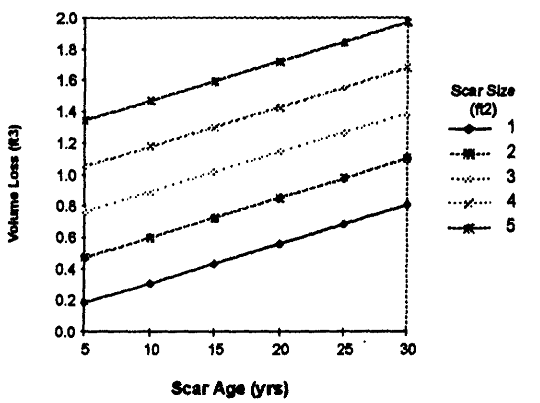

Figure 3. Volume losses from thinning scars in red and white firs (From Aho et al., 1983).

The two studies have interesting similarities. First, data requirements for estimating volume losses were limited in both studies to size of wound (typically present size) and age of wound. No other variables were required in either study to generally predict volume losses.

From an economic perspective, volume and quality losses after thinning, but before final harvest, are the most critical concerns. These volume loss prediction equations provide economists with the basic tools to estimate product loss and the subsequent dollar losses incurred through thinning damage. Currently, no economic-based tool exists in the Pacific Northwest to provide these estimates. They are, however, desperately needed to assist foresters in determining the appropriate rules and strategies for implementing thinning based management.

As noted previously, Wasterlund (1986) developed predictors for estimating increment losses caused through root damage. Measurement of the percent of root area damaged are necessary to develop these predictions. Shea (1967) examined scarred and severed root damage in Douglas-fir three and five years after thinning damage had occurred and found decay fungi present, but little rot. Shea observed that the most significant problem after severing of the root system was windthrow. No studies were obtained that estimated decay losses caused by root damage from thinning harvests.

Estimates of volume loss from decay alone can be developed for some species based on scar measurements. Estimates of value loss through stain and decay are not as easily obtained. Further research is needed that evaluates damage from an economic perspective to provide a better understanding of the potential benefits associated with different thinning strategies. A limited model predicting volume losses over time after thinning could probably be constructed using results presented in current and past literature.

Bettinger and Kellogg (1993) conducted an analysis of volume loss based on equations developed by Wright and Isaac (1956) to predict the potential cubic foot volume losses associated with cut-to-length thinning in second-growth Douglas-fir and western hemlock. However, the analysis did not examine the potential economic losses associated with decay caused by thinning. The report does provide readers with a general approach to determining volume and, potentially, value losses from thinning damage.

CONCLUSIONS

As noted by Froehlich (1976), "While most of us are interested in keeping any [thinning related] impact as low as possible, it appears that most efforts in this direction will increase thinning costs. We must be certain that any added costs will produce a true reduction in damage to soil and trees, not just a reduction in the visible impact."

Information is provided in the cited studies to help foresters develop their own thinning strategies. Damage can be alleviated in our forests when thinning, if we are willing to take on the added costs. If, however, we prefer to reach a balance between value gains from improved growing conditions and value losses from thinning damage, we must continue to explore different management options and promote the research needed to help direct our management efforts.

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LITERATURE CITED

Aho, P.E., G. Fiddler, and M. Srago. 1983. Logging damage in thinned, young-growth true fir stands in California and recommendations for prevention. USFS Research Paper, PNW-304.

Bettinger, P. and L. Kellogg. 1993. Residual stand damage from cut-to-length thinning of second-growth timber in the Cascade Range of western Oregon. For. Prod. Jrnl. 43(11/12): 59-64.

Blanche, C.A., T.E. Nebeker, J.D. Hodges, B.L. Karr, and J.J. Schmitt. 1985. Effect of thinning damage on bark beetle susceptibility indicators in loblolly pine. USFS Gen.Tech. Rpt. No. 54. New Orleans, LA. (54): 471-79.

Bruhn, J.N. 1986. Damage to the residual stand resulting from mechanized thinning of northern hardwoods. USFS Gen.Tech. Rpt. No. 113. St. Paul, Minn.(113): 74-84.

Chavez, T.D., jr., R.L. Edmonds, and C.H. Driver. 1980. Young-growth western hemlock stand infection by Hetrobasidion annosum 11 years after precommercial thinning. Can. J. For. Res. vol. 10: 389-394.

Cline, M.L., B. Hoffman, M. Cyr, and Wm. Bragg. 1991. Stand damage following whole-tree partial cutting in northern forests. NJAF 8: 72-76.

Froehlich, H.A. 1976. The influence of different thinning systems on damage to soil and trees. For. Comm. Bull. London. 55: 102-5.

Hunt, J., and K.W. Krueger. 1962. Decay associated with thinning wounds in young-growth western hemlock and Douglas-fir. J. For. 60:336-340.

McNeel, J.F. and K. Dodd. 1996. Survey of commercial thinning practices in the coastal region of Washington state. For. Prod. Jrnl. (In Press).

McNeel, J. and T. Ballard. 1992. Site and stand impacts of harvester-forwarder thinning operations in a Douglas-fir plantation. Jrnl. For. Engr. 4(1):23-29.

Meyer, G., J.H. Ohman, and R. Oettel. 1966. Skidding hardwoods - articulated rubber-tired skidders versus crawler tractors. J. For., 64:191-196.

Nebeker, T.E. and J.D. Hodges. 1985. Thinning and harvesting practices to minimize site and stand disturbance and susceptibility to bark beetle and disease attacts. USFS Gen.Tech. Rpt. New Orleans, LA. Aug 1985. (56): 263-271.

Nichols, M.T., R.C. Lemin, jr., and W.D. Ostrofsky. 1993. The impact of two harvesting systems on residual stems in a patially cut stand of northern hardwoods. Can. J. For. Res. 24: 350-357.

Nilsson, P.O. and A. Hyppel. 1968. Studier over rotangrepp i sarskador hos gran. Svergies Skogsvardforbunds tidskrift 66. pp. 675-713.

Ostrofsky, W.D., R.S. Seymor, and R.C. Lemin, jr.. 1986. Damage to northern hardwoods from thinning using whole- tree harvesting technology. Can. J. Res. 16:1238-1244.

Shea, K.R. 1967. Effect of artificial root and bole injuries on diameter increment of Douglas-fir. Weyerhaeuser Forestry Paper No. 11. 11 p.

Sidle, R.C. and T.H. Laurent. 1986. Site damage from mechanized thinning in southeast Alaska. NJAF 3(3):94-97.

Siren, M. 1982. Stand damage in thinning operation with a grapple loader processor. (English Summary) Folia For. Helsinki (528).

Siren, M. 1989. Cost of thinning to the stand - How to evaluate. IN Machine design and working methods in thinnings. Proceedings of IUFRO P4.02.01 Conf. in Hyytiala, Finland, Sept. 17-22, 1989. pp. 23-40.

Stone, R.J.C., and I.M. Coulter. 1975. Mechanical damage to retained Pinus radiata in a first thinning operation - a comparison of two extraction methods. For.Tech. Ppr., Brit. Col. For. Serv., Victoria, BC. Dec 1975. 23:11-13.

Wallis, G.W., and D.J. Morrison. 1975. Root rot and stem decay following commercial thinning in western hemlock an guidelines for reducing losses. The Forestry Chronicle, Oct.:203-207.

Wasterlund, I. 1983. Kanttradens tillvaxtforluster vid gallring p.g.a. jordpackning och rotskador i stickvag. [Growth losses in border trees caused by soil compaction and root damage along main trails during thinning.] Sveriges Skogvardforbunds tidskrift 2. pp. 95-107.

Wiley, K.N. 1968. Thinning of western hemlock: A literature review. Weyerhaeuser Forestry Paper No. 12. 12 p.

Witcosky, J., T.D. Schowalter, and E.M. Hansen. 1986. The influence of time of precommercial thinning on the colonization of Douglas-fir by three species of root-colonizing insects. Can-J-For-Res. 16(4):745-49

Wright, E. and L. Isaac. 1956. Decay following logging injury to western hemlock, Sitka spruce, and true firs. USDA Tech. Bull. 1148. 33 p.

HOW TO MANAGE THINNING WITH LOW DAMAGES OF STANDING TREES - EXPERIENCE FROM THE MODEL[1]

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ABSTRACT: With the new Forest Act (1993), the Public Forest Service of Slovenia was founded, and at the same time the forest enterprises started to work as companies with mixed capital. The traditional connections between the silvicultural part of forest management and forest operations were broken due to different interest and positions of foresters employed in public or private domain. This could be a thread also to the quality of forest work, especially to the damage of the standing trees in forests where clearcuts are forbidden. This paper deals with a problem of how to avoid increasing damages despite the fact that present silvicultural practice and present technology of logging are not very well connected.

Key words: models, forest damage, thinning, forest operations, silviculture

INTRODUCTION

The demand for a really - not only declaratively - conatural and sustainable forest management is gaining strength in Slovenia as well as in other parts of the world. It is only a matter of time before the products from very well managed forests will prevail on the market. The products will carry special mark (certificate) which will prove the ecologically acceptable forest technology and silvicultural treatment. In auditing the suitability of certain practices, the silvicultural treatments as well as ecologically sound technology will play the most important role. The market will value only the complete (joint) result from silvicultural and technical production process. There are long debates about how to improve the intensive forest management based on the principles of sustainability, multifuncionality stability, and biodiversity. These discussions touch conatural forest management in which a variety of human interest will also find harmony with natural resources and their limits.

During the rotation period of the stand we normally perform thinnings to improve growing conditions and tree quality to maintain stability and forest health, and to improve other non-market forest functions. Every treatment in certain stands brings costs and, beside first thinnings ,also some timber volume.

The comparison of the timber prices and costs of the production is so obvious that we often forget the forest damage (in the stand and on the forest soil) which is the third serious consequence of every treatment. If we look at the problem with the eyes of an average woodowner, it is normal to expect that the benefit from better forest condition (i.e., growth, stability and health) must prevail over the loss because of the lower quality of damaged trees and overall poor nonrationality. In this context the benefits represent the complex of different commodities that we can get from the proper forest management, including nonmeasurable benefits from a healthy multifunctional forest. We shall limit ourselves on the possibilities of how to decrease logging damages of the remaining trees in the stand. In this paper we shall not discuss damages to forest soils.

Damages in forest stands accumulate during the rotation period (Košir/Cedilnik, 1996), but at the same time, some disappear because of the natural vitality of the trees. Some of the damaged trees are removed in the next thinning but the majority of the wounds remain in the stand and cause wood decay, and as a consequence of this, resistance against different biotic and abiotic factors diminish and tree value is lowered. This problem is not new as Ivanek (1976) in his study has already calculated for the pure spruce stand the level of 76 percent damaged trees in the stand at the end of the rotation period. The theoretical model described in the paper by Košir/Cedilnik (1996) has revealed an even more pessimistic picture that has not been proven by actual field observations. It is obvious that the great vitality of trees and the variability of the forest ecosystem erase many of the visible damages. Yet many of them start the hidden processes of destruction with different negative consequences for the life of the tree and the stand.

[1] Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

PRESENT TECHNOLOGY

The technological model that dominates in moderate terrains in Slovenian forests is not optimal but it is adapted to typical conditions and the technological level of development in Slovenia. For the purpose of this paper, we assume the technology has not changed during the whole rotation period or - and this is essential - the logging damages from different technologies are comparable. As an example, we can assume motor-manual felling with a power saw, partial bucking at the stump, bunching and skidding with a tractor on a temporarily designated and permanent skidding tracks to the forest road. Final bucking is performed along the forest road. Wood hauling is done with a truck equipped with grapple loader and semitrailer.

This kind of model demands a high level of forest roads and skidding tracks network density if we assume a tractor is working alone planned skidding tracks only. Necessary density of forest skidding tracks is between 120 and 200m/ha and it depends upon the form of relief and the type of network in the cutting unit. The length of the timber extracted is 12m at most. In the early stages of stand development we can talk about the stem or half-stem method (age of 40 to 50 years). In the late phases we buck the stem on shorter lengths because the danger of high share of damaged remaining trees; but at the end of the rotation period we can again buck longer timber as the density of the stand is lower. In this case we have to do final bucking along the forest road.

On steep terrain the forest cable systems are in use - mostly skidding uphill with different types of mobile tower yarders but in the alpine areas the long-distance gravity cable cranes are popular as well. The cable crane corridors are planned in advance in parallel or fan shaped system of forest opening.

In the early development phases of the stand we think about the small adapted agricultural tractors and/or small cable cranes. When logging in late phases, the forest steering frame skidders and heavy cable cranes dominate.

Operational planning has its role in careful and professional work preparation where different restrictions and directions (time and season of forest operations, method of bucking the trees, etc.) because of possible impacts on environment are also a part of it (Košir, 1992, 1994).

In everyday life we use many different forest technologies of logging but many of them are important only on a local level, and therefore in this paper we have not paid attention to them.

ACCUMULATION OF THE DAMAGES ON TREES DEPENDS ON THE NUMBER OF THINNINGS

There is a number of studies dealing with damages in stands after logging and the ways to prevent them. The first authors in Slovenia were Krivec (1975), Ivanek (1976) and many others. Looking at the problem from present time, we have to consider great differences in research results, which can not be explained with different observations only but are also caused by different approaches and measuring scales of the researchers. All authors have put a great stress on prevention against damages in stands but they rarely mentioned the upper limit of - the so called - tolerable share of damaged trees.

For conditions similar to Slovenian, Butora and Schwager (1986) estimate the level of tolerable damages to be 15 percent (intensity of thinning 25 percent). This level is still very high from the point of view of the new and old damages. Majority of studies deals with new damages, connected with observed working processes, and ignore the problem of damages caused by past forest operations. Description of theoretical increase of damages in stands was done by Košir and Cedilnik (1996). They have included some assumptions that limit the practical use of the model. However, these assumptions do not eliminate the warning of consequences because of the bad present forest practice.

The intensity of thinning was defined as a proportion between the number of marked and the total number of trees in the stand. In the model the share of damaged trees after *i* thinning depends on the probabilities that the tree has been chosen for felling, and that the tree has been damaged in any of the past thinnings. The damage on the tree was understood as a wound or a broken part of a tree or a sum of many small wounds that exceed 10 cm^2, as it was the standard for field research. They also assumed the damaged trees could not have some greater probability to be chosen for cutting in the next thinning. This assumption was however examined through computer simulation program to check its influence on the final result. They also assumed the new damages were equally distributed among the trees in the stand and were not in any connection to the old damages. It is obvious they also supposed the technology did not change in the rotation age or better - that the share of damaged trees in the stand in single thinning depended only on the intensity of thinning.

In the calculations they used the following definitions:

N_0	number of trees in the stand at the beginning (before first thinning),
N_i	number of trees after i thinning and before $(i+1)$ thinning (i = 1, 2, 3, ...),
P_0	number of damaged trees before the beginning with thinnings (original stand),
P_i	number of damaged trees after i thinning and before $(i+1)$ thinning (i = 1, 2, 3, ...),
M_i	number in i thinning damaged standing trees,
S_i	number in i thinning removed trees,
Δ_0	share of the damaged trees before the thinnings began (original stand),
Δ_i	share of the damaged trees after i thinning,
ε_i	thinning intensity in i thinning,
δ_i	share of the damaged trees in i thinning,
r_i	share of the undamaged trees in original stand,
d_i	share of the damaged trees in original stand,
p_i	increment of the share of the damaged trees between two thinnings.

The share of damaged trees after n thinnings (the end of rotation period) is therefore:

$$\Delta_n = 1 - (1- \Delta_0) . \prod_{i=1}^{n}(1 - \delta_i) .$$

If the shares of the damaged trees δ_i have their positive lower limit α ($\delta_i \geq \alpha > 0$), the value of Δ_n after numerous thinnings approaches 1, which means 100% of damaged remaining trees in the stand:

$$\Delta_n \geq \quad 1 - (1- \Delta_0)(1 - \alpha)^n \quad \xrightarrow[n \to \infty]{} \quad 1 .$$

Theoretically, the share of the undamaged trees is also important in relation to the original stand which is:

$$r_i = (1- \Delta_0) . \prod_{i=1}^{n}(1 - \varepsilon_i) (1 - \delta_i) .$$

as well as the share of the damaged trees in relation to the original stand which is:

$$d_i = \prod_{i=1}^{n}(1 - \varepsilon_i)[1 - (1- \Delta_0) . \prod_{i=1}^{n} (1 - \delta_i)] .$$

where: n = 1, 2, 3, ...

We can also calculate the increment of the share of the damaged trees between two thinnings:

$$p_i = \delta_n .(1- \Delta_0). \prod_{i=1}^{n-1} (1 - \delta_i) .$$

The use of these equations has some restrictions, have their origin in accepted assumptions. Among the most serious is the assumption of the relation between ε_i and δ_i which could be true in limited range of both parameters. We already know from experience that ε_i depends on the state of the stand - the number and distribution of the function carriers and accepted silvicultural goals. On the other hand, the δ_i depends also on the stand density, technology, season of the year etc. The observations show that δ_i changes in dependence on the development phase of the stand. In practice we can therefore expect the correlation between these two parameters because both are partially influenced by the same factors.

We must also suppose that before the first thinning in the stand we do not have damages caused by human activity ($P_0 = 0$ and $\Delta_0 = 0$), while in this stage we have not fell the trees in the young forest or make other logging activities that could cause the damages. Assumption that the past wounds on the trees do not influence criteria for present selection for cutting is also important. Normally, this is true for majority of cases, as many characteristics of the tree (vitality, quality and form, functions, etc.) and its position in a stand influence much more on this selection than wounds.

The problem of the model was also the estimation of the parameter δ_i. The observation of different authors proved that the shares of damaged trees in the stand due to present technology often fall beyond 20 percent. In the model the δ_i was put in dependence on the intensity of thinning ($\delta_i = 2\varepsilon_i/3$), which was lower than normally expected, but very close to the tolerable level suggested by Butora and Schwager ($\delta_i = 0.15$ when $\varepsilon_i = 0.25$).

However, the results from our studies show some lower intensities of the thinnings and some higher shares of damaged trees in the remaining stands, mostly due to skidtracks building on difficult terrain (Papac, 1992, Šolar, 1994).

The results of the model are based on normal stand development with normal thinning intensities through the whole rotation age of beech and spruce stands on very good and very poor sites. As an example we show the case of beech forest on a very good site in Figure 1.

The observation of Figure 1 shows us the following hints:

- the chance the tree remains undamaged in relation to the original forest decreases very rapidly and approaches 0;
- the total share of damaged trees (new and old damages) after *i* thinning increases, and after each thinning gets closer to 1 (100% of damaged trees);
- the increment of the share of damaged trees is the greatest in the first thinnings when we perform logging in more or less untouched stand, and it approaches 0 when we thin in later stages of stand development.

The results of model analysis of all four stands are shown in Figure 2 where only the total share of damages in the remaining stand is included. The following conclusions can be made:

- The shares of damaged trees increase with the greatest angle in young development phases. Later the growth of these shares is lower but on very high level. The reason lies in the fact that in the late thinnings more and more wounded trees are damaged again.
- Damages increase very rapidly in stands where the intensity of thinnings is the highest (very good sites), and at the end of rotation period - which is longer - they reach a higher final level as well.

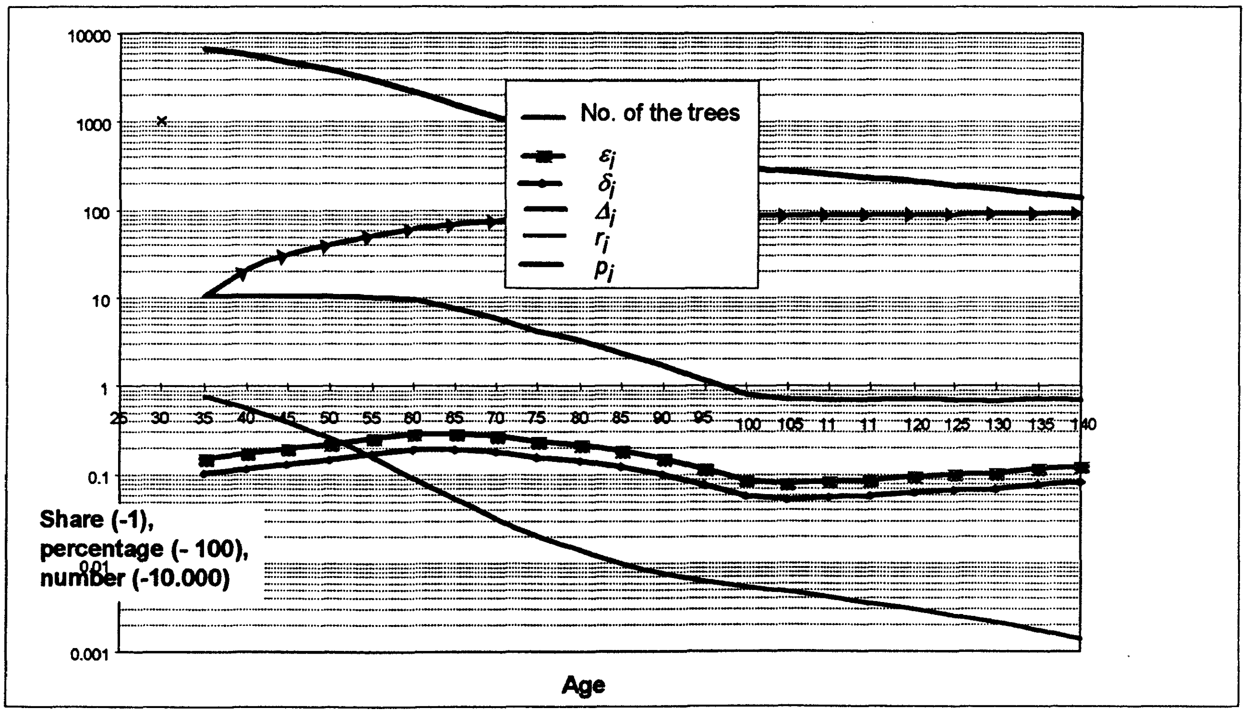

Figure 1. The shares of damaged and undamaged trees and the increment of the damaged trees share in beech forest on a very good site.

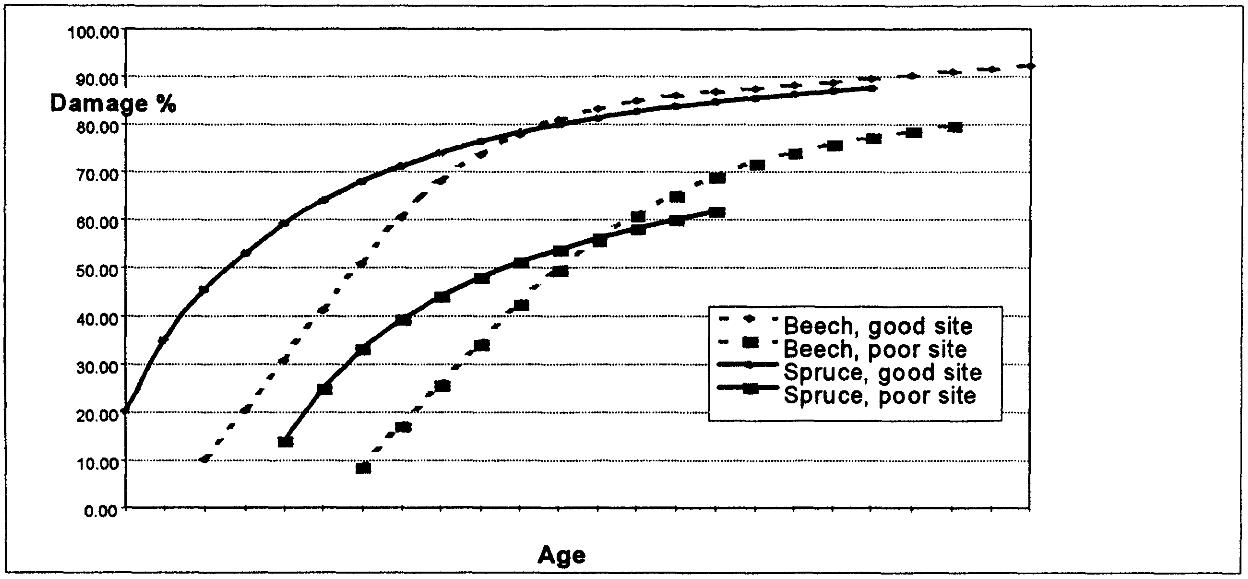

Figure 2. The shares of damaged trees in the model stands.

- In stands on very good sites we reached 50 percent of damaged trees already after 3 to 6 thinnings; in stands on the sites of low productivity this level of damages is reached after 7 thinnings.

- More than 75 percent of damaged trees in the stand is reached on very good sites after 9 to 10 thinnings, while on poorer sites this level is overjumped after the 13th thinning or not at all.

- That means at the half of rotation period we have on very good sites around three quarters of damaged trees. At the same time on the poor sites there is only one quarter of damaged trees in the stand.

- On average, thinnings in the last quarter of the rotation period do not contribute significantly to a higher level of damages in the stand as it is evident that the majority of damages happened in the early stages of stand development.

The present observations on actual research plots can not find damages that happened decades ago. Those wounds have already disappeared due to the process of natural reaction of the trees or they have resulted in wood decay, which is often hidden in the stem. The observed frequency of tree damages is therefore lower than it could be expected on the basis of the model prediction. However, it is obvious we have to pay a very high price for poorly coordinated practice of silviculture and forest operations.

SILVICULTURAL AND ECONOMIC ASPECT

Different damages of the tree have an impact on tree vitality and lower market value of the timber when the tree is cut. This is not true only for mature stands but even much more for thinnings (Ivanek 1976) where we remove significant share of wood biomass (in the model stands about 65 percent of the wood is removed during the thinnings).

If we understand the major factor which influences the total share of damages - beside parameters ε_i and δ_i - is the length of rotation period - and with this connected number of thinnings, than we can conclude the decreased value of the intermediate yields as well as the impact on the average age and annual value increment (Kotar, 1979) is greater with those tree species that reach culmination of the average age increment later (e.g., beech) than with the species where the culmination begins earlier (e.g., spruce).

This consideration holds true even if the relative value lost due to decay (proportion between more valuable and low price assortments) would be the same with included tree species, which depends -

beside the tree species - upon the place and type of wound, season, and the site. If we talk about beech, the lose in value of timber in a tree is greater than with spruce, and this is why the impact of the damages on the average value increment and its culmination is greater than with spruce.

If we continue with considerations in the same course, we could find that the culmination of the value increment in damaged stands is obviously lower, and it begins at the earlier stage of the stand development. This has serious silvicultural consequences. Accumulation of the damages in stands with longer rotation period with later culmination of the average value increment is greater because of higher number of thinnings. This is obvious - in the middle aged stands where we have already caused at least half of damaged trees - we can not count on extraordinary quality of timber. The consequence of damages in stands is therefore also a pressure to shorten the rotation age in such forests.

POSSIBLE IMPROVEMENTS

We could ask ourselves what the possibilities of improvement of the present forest practice are. We counted a number of choices among which many of them are well known, and yet we do not perform them from different reasons.

- **Close connection of the silviculture and forest operations:** The basic demand of rational forest management is a very tight connection of silviculture and forestry technique, especially on the operational level. When we decide about the long term silvicultural goals, we should also think about the operational aspects of the measures. Necessary conditions for their realization must be provided. Otherwise, this is just wishful thinking. Forest infrastructure is a basic condition for forest operations. The question of moving timber from stump to roadside is the most complex problem despite the troubles which could begin with felling the trees, if we have not thought of practical consequences when marking the trees. When the tree hangs we do not have unlimited choices how to fell it to the ground. In most cases, a tractor with a winch tries to come closer to the tree just to help the worker, and this is enough for a problem with damages. Many silvicultural plans are quite good until we do not take a closer look at the structure of selected trees. We can often find unprofessional marking of thin undergrowth and already eliminated trees while the function carriers are not free of their competitors. There is also another practice - too strong intensity where the main target of selection is just function carriers. Silvicultural plans have also the possibility to put on forest operations specified restrictions - like the maximum length of the bucked timber, about the season of logging, protection of certain function carriers, etc.). This is also the reason why we can not rely on old silvicultural plans. Before every logging we have to update old plans and adapt them to the new situation.

- **Calculation of the ecological work preparation.** The ecological view of the operational planning of forest operations has its roots in silvicultural planning. Here we have to take into account the costs of prevention or later sanation of the caused damage. This is also the way to define financial consequences of improper work as well as the way to clearly point out who is responsible for what.

- **Professional layout of skidtracks and cable crane corridors of necessary density.** When marking trees, we must think of the transportation border, which is possible only when we know the position of the skidtracks or cable crane corridors. This especially holds true for gentle terrain where the skidtracks building is unnecessary. On such terrain the skidtracks should be designed in advance and clearly visible on the terrain. If we leave the operator to find the best way to the felled timber, any attempts to avoid unnecessary damages will not be successful. The only way to insist on the proper direction of felling trees is the workers who know the position of tractor when bunching trees. The analysis of the dynamics how the damages appear during felling and skidding in time showed (Krè, 1993) the majority of damages appear at the beginning of the work when a worker does not have enough room. Later - after a couple of hours - the damages appear randomly on much lower but quite stabilized level. Low density of skidtracks means the operator will leave the existing skidtracks to make his work easier, more efficient and/or even possible. When work is finished it is too late for analyzing particular cases if we know the basic planning was not good. On the other hand - in high density of designated skidtracks - we have chances to make pressure on the operator who drove through the stand to the stump.

- **Winter season.** It is already well known that the damages during the winter season are much lower than in the summer (proportion on the basis of the number of damaged trees are between 1 : 1.5 to 1 : 2; if we take the surface of the wounds for the basis, the proportion is significantly higher). The suggestion for winter logging is therefore very popular among the people from Public Forest Service. However, it is impossible to expect the forest enterprises or woodowners to do all work during the winter season only. The best season for forest operations is influenced also by timber prices on the market - demand and supply of certain quality and volume. The stands of best quality on best sites that have also some other conditions as location and terrain characteristics, are normally the most suitable for winter season.

- **Shorter timber bucking in middle-aged stands.** The problem of the bucking and its influence on the share of damages start in transition of stand in the middle age. At this time the tree lengths exceed some 15m and the stands are very dense. Long timber causes many more damages despite very careful work preparation. It is wise to extract shorter timber but it is also good to look at the economy of skidding, and to select on the same compartment cutting units where - because of specific conditions - we could buck longer assortments.

- **Less thinnings that are better prepared.** It is better to go to the forest for logging as little as possible. Continuous driving through the forest with tractor and hunting for small and disperse volume of timber cause damages without touchable silvicultural and economic results. The allowable ten years cut could be reached in one or many cuttings. If we admit that every presence of forest operations in the stand is connected to damages, we shall try to keep a time distance between two thinnings close to the silvicultural and forest protection demands. In the middle aged stand thinnings are 6 to 8 or even 10 years apart. More frequent thinnings can make an impression on intensive and careful forest management, but they are really bad for the forest and are economically inefficient.

- **Trees beside the skidtracks and forest roads.** In many cases, a forest offers chances of natural protection of function carriers against the damage. Many authors have already suggested the function carriers that must remain undamaged should be marked in a special way. This measure is reasonable in the stands of high quality. When function carrier has several competitors, we can choose a tree for cutting which will probably cause no damage. We can also think of bunching and leave one or more trees between function carrier and skidtrack despite this tree being a competitor. This is reasonable if we could protect a function carrier not to be damaged. When it is necessary to cut down such a tree, we can cut it on high stump which will protect its neighbors also after removing the tree. It is the same matter with the trees along the skidtracks and forest roads that have been, until now, damaged many times, and are obviously of low quality. They may stay just of the same reason - they are excellent protectors of the remaining stand. In special cases we can protect selected remaining trees with some of the artificial bumpers but this is normally more an exception to the rule. For this type of protection piles of branches could suit as well if they are not on the skidding lines.

- **Cure of wounds on the damaged trees.** In very qualitative stands we can think of the protection of the wounds with special chemicals to prevent the tree against fungi.

This is also economically reasonable (Ljubec, 1993).

- **Choice of technology.** There is a number of discussion of the environmentally friendly logging technologies. In this place, we should stress that the future is in modern, technically perfect working machines with proper additional equipment adapted for hard-working conditions such as in the natural environment. It is important we do not try to use the same technology in every stand and to realize that significant details are important too. Tractor chains, for example, are good because they decrease the use of tires and make skidding more efficient, but they also cause heavy wounds on roots and lower parts of the stump. Remote control of the winches and tractor is also good because the worker can be closer to the timber and can avoid different obstacles and standing trees, which could cause delay and wounds as well. Sometimes it is also wise to think about the use of cable skidding, which is - truly more expensive - but on a long term much friendlier to the forest. The worker as an individual human being with his social surroundings is among the most important targets when we want to improve the quality of work. There are numerous ways how to increase his motivation and efforts for better quality of work, where the care for environment is becoming a part of it.

- **Operational control.** Operational control is a part of total quality management system of modern forest enterprise. It also has to be a part of the information system of the organization and it means proper and sufficient documentation of visits, documented comparison with operational plans, especially with the statements dealing with ecological aspect of work preparation. Control is in the hands of production managers of the forest enterprise, but it must be performed through activities of the Public Forest Service as well. Operational control must be frequent enough to maintain the proper level of work quality. In successful work organization it could be a matter of working group if there are mechanisms to trigger the motivation of workers to take care of every aspect of their activities. During the working process, in most cases, the mistakes can be corrected pretty easily while after the work is finished this could be done with many more troubles. The final control after finishing a cutting unit is necessary not only to estimate the real state of the stand and economic situation but also to get experience and learn for the future.

- **Incentives and discouragements.** Both are primitive but very strong factors of motivation as for the enterprise and the workers. Punishment comes after the damage has been already done while award for qualitative work could prevent the forest against the bad treatment. There are also many possibilities for discouragement of worker as well as the whole enterprise to do bad logging. The value of damaged function carrier could be calculated in money or in volume units, which is later included in the final balance according to the contract between the woodowner and enterprise that has done the logging. In fact, every damage of the function carriers has also its value in money, which could be subtracted from the earnings of the loggers. However, it is normal to expect a certain share of the so called normal damage that occurs due to many reasons and despite high professionality of workers. On the other hand, if we say that 5 percent of function carriers is the upper limit of normal damage, every better work must be stimulated with better wages.

DISCUSSION

The procedure described in the paper is aimed at the problem of accumulation of damages on the remaining trees in the stand after many successive thinnings. This kind of practice is becoming a rule today, though it is not ecologically and economically proven. The model is adapted to an even-aged forest. For selection forest the results will certainly be different.

The reasons for this kind of practice are partially objective (removing the trees attacked by bark beetles and other causes such as snowfall, windfall, etc.), but there is also a philosophy to work in the forest intensively in time but with less intensity of thinning. It is not the matter of this article to discuss this practice, which could be proven by examining the marking over several past years. We intended to make a warning and to point to the important interdependence between silvicultural and logging practice, and to stress the necessity of improving the professional approach in operational planning and control on every level.

Present practice of forest operation working processes is under permanent critics, and it is good to know that many exits to better work are opened through a permanent development of techniques and organization. It is evident that this development should suit not only the economy but also ecology as only both together can mean sustainable forest management.

The use of model is limited with many assumptions. This proves our limited knowledge of many very important processes in practical work in the forest. The influence of the forest work to the environment is a complex problem where damages of standing trees are only a part of it.

The results of the model should be understood primarily as a warning. Careful and professional selection of trees for marking has an important influence on final success. But at the same time, if we make thinnings too often the share of damaged trees will rise to an unwished proportion. This tendency was proved by many field observations, though the found shares were of different reasons lower than it was predicted from the model.

The possibilities of prevention against the damages of standing trees have already been discussed (Košir, 1992, 1994) but there is still a lot of space for invention and fresh ideas.

SUMMARY

During logging in thinnings the damages of remaining trees are accumulating in dependence on the intensity of thinning, the share of damaged trees in each thinning and the number of thinnings in rotation age. In this paper the theoretical increasing of damages for four model forests is calculated by use of simple equations and several assumptions. In the model we calculated some lower shares of damaged trees in the remaining stand, which were found in field observation. And yet we find that after several thinnings in model stands the damaged trees prevail with the tendency to reach after many thinnings 100 percent. If the intensity of thinning is in a certain period prescribed by the forest management plan, we can expect more damages of the remaining trees in the stand if we take allowable cut in more cuttings than if we respect rationality and pure silvicultural aspects. It is necessary to think of a better connection between silviculture and forestry techniques, especially on the operational level - planning and control.

REFERENCES

Butora, A./Schwager, G. 1986. Holzernteschaden in Durrchforstungsbestanden. Berichte 288, Eidgenossische Anstalt fur das forstliche Versuchwesen, Birmensdorf, 51p.

Ivanek, F. 1976. Vrednotenje poškodb pri spravilu lesa v gozdovih na Pohorju. IGLG, Strokovna in znanstvena dela 51, Ljubljana, p.142-147.

Košir, B. 1992. Ekološki vidik priprave dela. Gozdarski vestnik, 50, 4, Ljubljana, p.207-215.

Košir, B. 1994. Naèini in pogoji pridobivanja lesa, doloèeni z gozdnogojitvenim naèrtom. In: Strokovna izhodišèa za pripravo pravilnikov o gozdnogospo-darskem, gozdnogojitvenem in lovskogojitvenem naèrtovanju, Zbornik posvetovanja ZGD, Ljubljana, p.83 - 94.

Košir, B./Cedilnik, T. 1996. Model narašèanja poškodb drevja pri redèenjih sestojev. Zbornik gozd. in les., 48, Ljubljana, p. -

Kotar, M. 1979. Prirastoslovje. UL, BF, Odd. za gozdarstvo, Ljubljana, 196p.

Krè, J. 1993. Analiza nastanka ran v sestoju pri procesu pridobivanja lesa. UL, BF, seminarska naloga, Ljubljana, 20p.

Krivec, A. 1975. Racionalizacija delovnih procesov pri seènji in izdelavi ter spravilu lesa glede na delovne razmere in poškodbe. IGLG, Zbornik gozd. in les., 13/2, Ljubljana, p.145-193.

Ljubec, M. 1993. Sanacija poškodb gozdnega drevja z zašèitnimi premazi. UL, BF, Odd. za gozdarstvo, Ljubljana, dipl. naloga, 88p.

Papac 1992. Prostorska in èasovna predstavitev nastanka poškodb pri seènji in spravilu lesa s traktorjem. UL, BF, Odd. za gozdarstvo, Ljubljana, dipl. naloga, 79p.

Šolar, S. 1994. Nastanek poškodb v sestoju po miniranju ter seènji in spravilu lesa. UL, BF, Odd. za gozdarstvo, Ljubljana, dipl. naloga, 75p.

SUSTAINABLE FOREST MANAGEMENT IN GREY ALDER STANDS AS ENERGY AND BUFFER FORESTS IN ESTONIA[1]

by

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ABSTRACT: For sustainable management of grey alder *(Alnus incana)* stands their silvicultural, economic and ecological aspects were analysed. Alder forests present interest as biomass energy sources. Grey alder stands form 4.4 percent of closed and 11 percent of private forests in Estonia. Due to an increase in the area of abandoned agricultural lands, the share of grey alder is growing. Annual volume increment of grey alder stands is higher than that of other domestic tree species. Riparian grey alder stands are evaluated as buffer zones to protect waterbodies against pollution. Grey alder stands serve as perspective energy forest stands with the maximum productivity at an age of 10 to 20 years. From the point of view of both productivity and nutrient retention, their optimal harvesting age is 12 to 15 years. No additional N and P leaching was found from heavily loaded riparian grey alder stands; thus fast growing young grey alder stands do not represent an additional source of nutrients, and they can act as effective buffers on stream banks and lake shores.

Key Words: grey alder (*Alnus incana*), energy forestry, short-rotation forestry, buffering capacity

INTRODUCTION

Estonia is in transition from a centrally-planned political and economic system to a system oriented to political democracy with a market economy. Further structural reforms and investments are required to ensure environmentally sound economic development. The energy sector is, in this respect, a priority area in Estonia.

Although the environmental impact from using alternative fuels is mainly favorable, domestic biofuels are still utilized to a very limited extent. Substitution of fossil fuels is largely limited to the production of wood for heating.

Estonia is situated in an intermediate zone between the boreal coniferous forest and the deciduous, broad-leaved forest. More than 47 percent of the total area of Estonia is covered by forests. Grey alder (*Alnus incana*) forests present interest as potential biomass energy sources. Grey alder occurred in Estonia along watercourses flowing off the melting ice sheet. It is a strong pioneer species, especially on abandoned agricultural lands and is common in all Baltic States, Poland and Scandinavia. Grey alder as a short-rotation species has many biological and economic advantages: it grows rapidly, is symbiotically N_2-fixing by the actinomycete *Frankia*, and has only a few pests and diseases. Storm damage in grey alder stands is of relatively little importance compared to other tree species. Under normal conditions the wind mainly fells over-aged trees with a rot weakened trunk. Decomposition of alder litter enhances soil properties.

After cutting, a new alder generation emerges by coppicing from the root system, thus artificial reforestation is not needed. Stands of grey alder produced by sprouts are usually so dense, that seedlings of other tree species cannot grow under them. Grey alder seedlings withstand direct sunlight and frost. In young developing stands, grey alder grows faster than the other tree species. However, growth slows down earlier than in other tree species; maturity is reached at an age of 40 to 50 years. Harvesting can be performed with ordinary equipment (e.g. power-saw).

In recent years the area of abandoned agricultural lands has increased. Various authors estimate this area to be in the range of 70,000 to 300,000 hectares in 1994 (Tullus et al. 1995). Recently, grey alder forest resources were estimated in state forests in

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Estonia, and a forest inventory is in process on private lands. Due to an increase in the area of abandoned agricultural lands, the real area of grey alder stands may be larger than presented in this paper.

For sustainable management of grey alder stands an analysis of their silvicultural, economic and ecological aspects is needed. In the present study the dynamics of annual volume increment in grey alder forests was investigated with the aim to create yield tables and to determine the rotation period. Also, grey alder was compared with two main tree species of high productivity - Norway spruce (*Picea abies*) and silver birch (*Betula pendula*) in different site types. One of the aims was elucidation of maximal productivity of natural grey alder stands. For the development of rational methods of afforestation of abandoned agricultural lands by grey alder, an experimental plantation was established where various planting material was used.

Alder forests are typical riparian ecosystems in Europe which can retain and transform nutrient fluxes from adjacent intensively exploited territories. Therefore, riparian alder stands are commonly evaluated as buffer zones to protect waterbodies against pollution. Pollution by nutrients, causing several problems in relation to waterbodies and groundwater quality, is the most important environmental issue in rural areas of Estonia. However, only a few thorough studies have been carried out to investigate the buffering capacity of alder forests, with the results indicating contradictory findings (Knauer and Mander 1989; Binkley et al. 1992; Vought et al. 1994). Due to the fixation of atmospheric nitrogen by root nodules, alders have been expected to act as an additional source of nitrogen pollution of waterbodies. To clarify the influence of both internal and external loading in riparian alder forests, a study was carried out in two grey alder stands of different loadings in southern Estonia: one (14 years) in the natural conditions without any significant nutrient input via groundwater/over-land flow, the other (40 years) downhill from an intensively fertilized arable land in the vicinity of a large pig farm. The main hypothesis was that significantly more nutrients would be leached from riparian grey alder stands with a considerable external nutrient load (manure application in upland field, ammonium deposition) than from the unloaded stands. The hypothesis was tested in 1994-1995. Some preliminary results of this comprehensive study are presented in this paper.

MATERIAL AND METHODS

Estimation of grey alder forest resources in Estonia

Data of the Estonian Forest Survey Centre are analysed for the area, total standing volume, mean annual increment (MAI), current annual increment (CAI), age distribution and cutting of grey alder forests (Estonian Forest Survey Centre, 1995). MAI and CAI of grey alder are compared to those of other principle and main tree species.

The area of a grey alder stand is mostly small, on an average of 1 hectare in Estonia. The distribution of different site types of grey alder forests (2,224 stands) was analysed in private forests in Harju (North-Estonia), Rapla (West-Estonia), Võru and Valga (South-Estonia) counties. The share of grey alder is bigger in *Filipendula*, *Aegopodium*, *Oxalis* and *Hepatica* site types.

Study area and test sites for assessment of the buffering capacity

Two different riparian grey alder stands were selected: one (14 years) in the unpolluted Porijõgi River catchment (for area description see Mander et al. 1995), the other (40 years), in the vicinity of the Viiratsi pig farm (32000 pigs), Viljandi County. The physio-geographical conditions of the Viiratsi study site are similar to those of the Porijõgi River catchment. In both study areas, transects were established along topo-edaphic gradients in autumn 1993. In the less polluted Porijõgi test site, the following spectrum of communities, in the order of going downhill, were analyzed: abandoned (formerly cultivated) grassland - wet meadow (dominated by *Filipendula ulmaria*, *Aegopodium podagraria*, *Cirsium oleraceum*, and *Urtica dioica*) - grey alder stand. In the heavily polluted Viiratsi test site, the transect was established through the following communities: arable land (fertilized by pig slurry) - eutrophic grassland strip (*Elytrigia repens*, *Urtica dioica*) - young grey alder stand with wet meadow pattern (*Filipendula ulmaria*) - old grey alder forest. In landscape profiles, piezometers (3 rows in the Porijõgi transect and 5 rows in the Viiratsi study site, 3 replicates in each row) and study plots were established on the boundaries between the plant communities. Main nitrogen (N) and phosphorus (P) cycles and budgets were assessed. In this paper some preliminary results of the soil water quality, tree biomass, production and nutrient uptake, nitrogen fixation and denitrification are presented.

Productivity and uptake estimation

Dimension-analysis techniques (Bormann, Gordon 1984) were used to estimate the above-ground biomass and productivity of grey alder forests. In all test sites (ages 10, 14, 18 and 40 years) we first measured diameter at breast height (DBH) on 50 to 100 trees. Using a random procedure based on DBH distribution, 5 to 17 model trees per plot were felled. The height and crown length of all model trees was measured. Three to five model branches per model tree were randomly sampled (at intervals equal to the crown length divided by 4-6) to collect data on the following branch components: generative organs, buds, leaves, primary branch growth, and secondary branch growth. In 10-year-old and 18-year-old stands the model trees were felled in March and April of 1996, respectively, with the stem and branches being collected. All model branches were divided into 3 diameter (d) fractions: $d < 5$ mm, 5 mm $\leq d < 10$ mm and $d \geq 10$ mm; all current year shoots constituted an additional fraction. From each fraction a subsample was taken to estimate the dry weight percentage. Dead branches were collected and weighed. All mass data are on an oven-dry (70° C) basis. Production of branches consisted of primary and secondary growth. The secondary growth was estimated by dividing branch overbark mass (without primary growth) by branch age.

Each bole was cut into 50 cm sections. Disks from the base of each section and at height of 1.3 meters were taken and the diameter outside bark and fresh mass of each section were determined. The discs were measured for bark thickness and width of the last 3 to 5 annual rings, and number of annual rings and mean annual increments were calculated. Subsamples for estimating bark and wood proportions and their dry weight percentages were obtained.

The relative increments of the wood and bark of an overbark fraction were assumed to be equal. In riparian buffer stands (14 years and 40 years), root systems for 6 and 3 out of the sampled 17 and 5 trees, respectively, were excavated and divided into five fractions: stump, coarse roots: $d \geq 20$ mm, 5 mm $\leq d < 20$ mm, and fine roots ($d < 2$ mm). In case root craftings occurred between trees, the length of the connecting root was divided into parts proportional to tree diameter. Nodule mass was estimated separately in June and July 1995. Around randomly selected 10 alders, a ring layer of the width of 50 cm was marked, and divided into four equal segments. From each of these segments all nodules down to a depth of 10 centimeters were sampled and stored in a freezer; DBHand the tree perimeter on the ground level were measured for all trees. For the remaining study plot area 15 cores of 147 millimeters in diameter down to 15 centimeters depth were taken. However, nodules were not found deeper than 10 centimeters. Immediately after sampling the core samples were washed (tree nodule samples after thawing) and living and dead fractions of nodules collected. For estimating the below-ground production, it was assumed that shoot/root ratios for tree biomass and production were equal.

For the analysis of N, P, energy and ash contents, subsamples from all tree compartments were collected. The age of a stand was estimated on the basis of model trees except for the oldest stand where 30 cores were taken with an increment borer at DBH; 40 percent of trees in the 40-year-old stand were infected with stem rot.

Regression equations for tree compartments had the following form:

$$\ln y = a + b \ln DBH \quad (1)$$

where y is the oven-dry mass of tree compartment (kilogram) and DBH - diameter at breast height (centimeter); all equations had very high correlation coefficients and low levels of significance ($p < 0.0001$ in all cases), the parameters a and b are presented in Table 1. Stand characteristics are presented in Table 2.

Field experiments and laboratory analysis

In riparian grey alder study sites, water samples were collected and groundwater depth was measured once to twice a month by piezometers. Filtered soil water samples were analyzed for NH_4-N, NO_2-N, NO_3-N, total Kjeldahl nitrogen (TKN), PO_4-P, total Kjeldahl phosphorus (TKP), SO_4, Fe, and Ca (APHA 1981) in the laboratory of the Estonian Agricultural University. Soil bulk density, texture class, and field capacity were determined for each 20 centimeters of soil profile (up to 1.5 meters in depth). Hydraulic conductivity was estimated by using tracer (chloride) and pumping experiments (Freeze and Cherry 1979). Groundwater discharge was estimated on the basis of both Darcy's law and by gauging with weirs installed in groundwater seeping sites. TKN and TKP of plant samples were estimated.

Table 1. Parameters of regression equations (1) used in dimension analysis for estimating the mass of tree compartments (kg); r^2 - coefficient of determination, s.e.e. - standard error of estimate.

Age (years)	Tree compartment overbark (kg)	a	b	r^2	s.e.e.
10	Stem	-2.939	2.369	0.993	0.08
	Branches	-6.506	3.305	0.993	0.09
14	Stem	-2.492	2.399	0.992	0.07
	Branches	-6.064	3.123	0.925	0.31
18	Stem	-3.179	2.680	0.994	0.14
	Branches	-4.412	2.281	0.960	0.32
40	Stem	-2.406	2.354	0.984	0.14
	Branches	-3.891	2.353	0.947	0.33

Table 2. Stand characteristics of test sites. Mean age, dbh, height, basal area, above-ground overbark biomass and production are given for alders.

Age (years)	Trees per ha	A lders per ha	DBH (cm)	Height (m)	Basal area (m^2 ha^{-1})	Biomass (t ha^{-1})	Production (t ha^{-1} yr^{-1})
10	15900	15900	3.7	8.3	29.8	65.1	9.6
14	6110	5240	8.9	11.0	33.4	89.6	9.5
18	3530	3530	10.1	15.0	28.0	83.2	7.5
40	1810	1390	16.4	16.7	35.1	128.4	5.5

Experimental plantation

An experimental plantation was established on abandoned agricultural land in Spring 1995. Naturally regenerated seedlings, root coppices and stem cuttings were used as planting material. Spacing was rectangular with 70 centimeters between plants in rows and 100 centimeters between rows, the stand size was 0.08 hectare. After the first growing season all survived plants were measured for the diameter at stem base, height and height increment. Leaf, bark, wood and soil samples (by 10-centimeter layers down to a depth of 50 centimeters) were collected in August 1995 and estimated for nitrogen, phosphorus, and potssium.

RESULTS

Grey alder resources in Estonia

Managed forests occupy 47 percent of the total area of Estonia or 2.0 million hectares (Estonian Forest Survey Centre 1995). 4.4 percent of closed forest area (1.845 million hectares) is covered by grey alder stands. Grey alder timber forms 4.0 percent of the total standing volume in closed forests, accounting for 6.7 percent (619,500 m^3) in the total volume increment. The mean annual volume increment of grey alder stands is higher compared to that of other tree species (Figure 1).

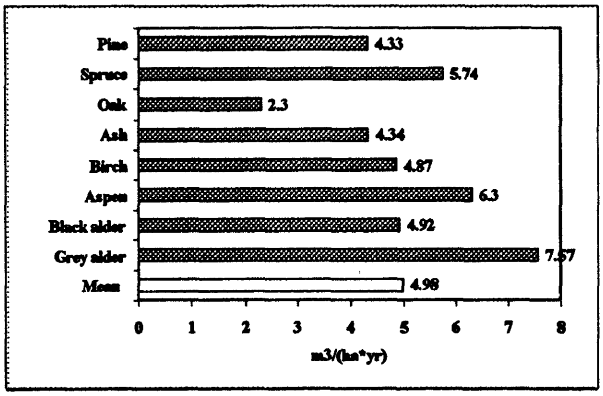


Figure 1. Mean annual increment (m^3 stem over-bark) per hectare by prncipal tree species.

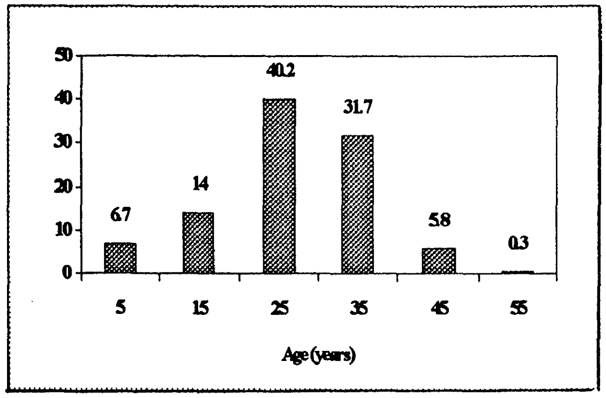


Figure 3. Distribution of grey alder stands by age classes.

When considering heating energies equivalent to the mean annual increment of the main tree species in closed stands, the production of grey alder stands is the highest (Figure 2). To calculate heating energies, the effective heating value of a grey alder stem with bark (moisture content 40 percent) was taken 1.737 Mwh solid m^{-3} (Nurmi 1993); the corresponding heating values of other trees are given in (Hakkila 1989). In Estonia, grey alder grows on relatively fertile soils, but its growth is inhibited by the high mean age of stands (29 years) considering the age distribution of grey alder stands (Figure 3).

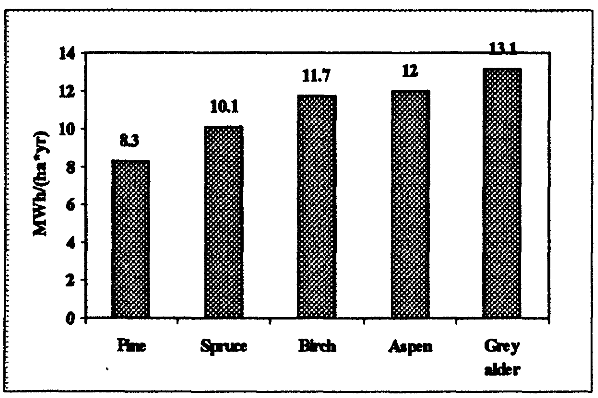


Figure 2. Mean annual increment of main tree species in closed stands by heating energy.

According to mean figures, 11 percent of standing volume and 26 percent of annual timber production are formed by grey alder in private forests. However, the situation varies in districts depending on landscape structure and soils. The share of grey alder is bigger in *Filipendula*, *Aegopodium*, *Oxalis* and *Hepatica* site types. In these site types it reaches the maximal CAI at a much younger age and it is definitely higher than in the case of Norway spruce and silver birch (Figure 4). Growth is the highest at the age of 10 to 20 years. At this age also MAI of grey alder is higher than that of spruce and birch (Figure 5). Fluctuations in the curves of CAI and MAI are caused by variability in stand density. After 20 years the growth of grey alder slows down, thus natural alder stands should be harvested earlier.

Cultivation of grey alder

Propagation of grey alder by stem cuttings failed, and there was no survival after the first growing season. The survival of plants of both generative and vegetative origin was high; 94.1 and 93.5 percent, respectively. The height increments ± standard deviations of planted seedlings and root coppices after the first growing season were 52.0 ± 23.2 cm and 35.0 ± 21.3 cm, respectively. Thus planting material of generative origin should be preferred.

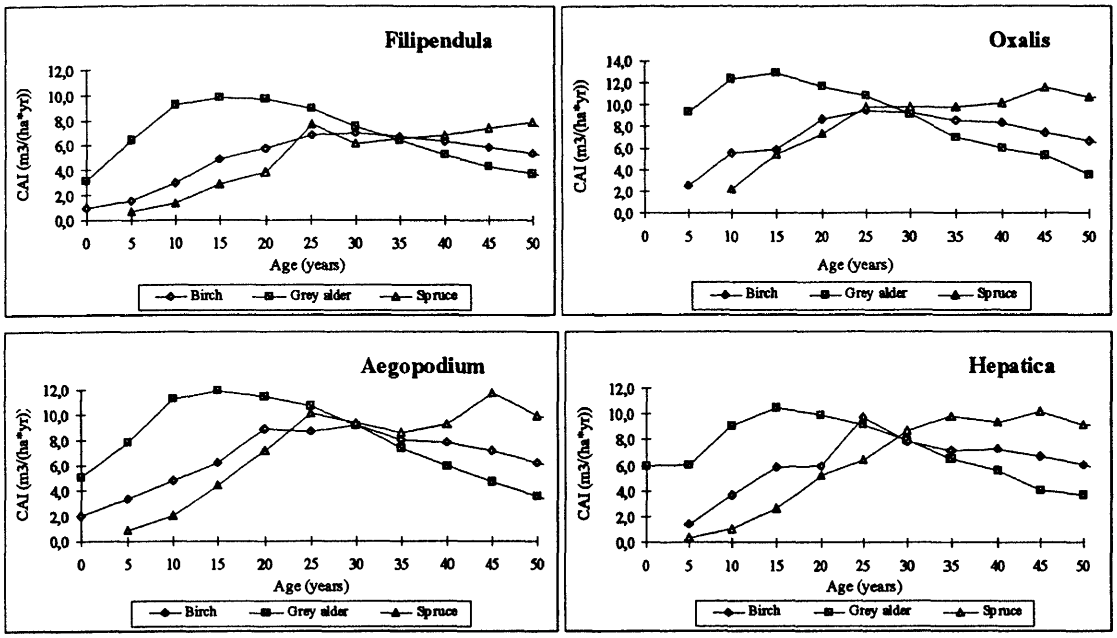


Figure 4. Current annual increment of silver birch, grey alder and Norway spruce stands.

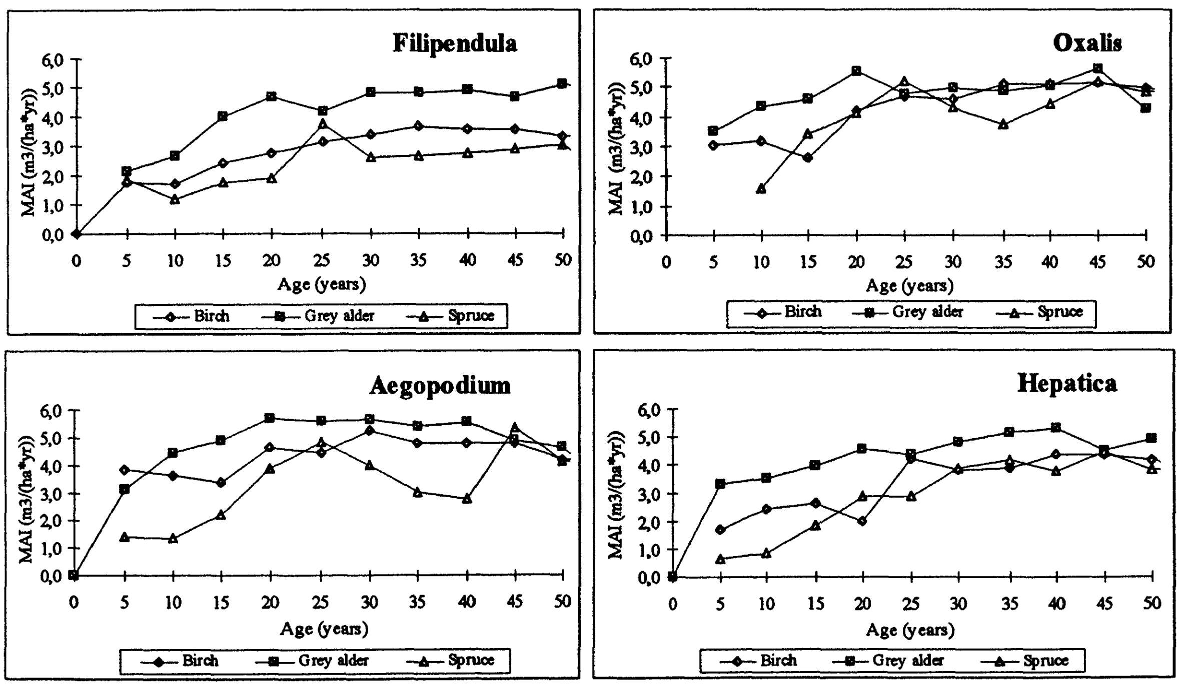


Figure 5. Mean annual increment of silver birch, grey alder and Norway spruce stands.

Biomass production and nutrient uptake

The percent increment of stem biomass (ΔB) of a stand in the *Aegopodium* site type is described by the following equation:

$$\Delta B = 101.9\ A^{-0.869} \qquad (2)$$
$$r^2 = 0.99,\ s.e.e. = 0.06,\ p < 0.005,$$

where A - stand age (years), r^2 - coefficient of determination, s.e.e. - standard error of estimate and p - level of significance.

Biomass, net production and nutrient uptake values in riparian grey alder stands are presented in Lõhmus et al. 1996). The total biomass value in the less polluted Porijõgi stand was 115.5 t ha^{-1}. In the 40-yearr old Viiratsi stand, the toal biomass value was 158 t ha^{-1} due to the larger diameter and height of stems and larger amount of branches. On the contrary, due to intensive growth, the net production was higher in the Porijõgi test site (17.3 and 10.6 t ha^{-1} yr^{-1}, respectively). Nitrogen and phosphorus uptake by grey alders was relatively high in both study sites. Owing to higher productivity, total N and P accumulation in both above-ground and below-ground biomass was significantly higher in the Porijõgi stand (204.8 kg N ha^{-1} yr^{-1} and 15.1 kg P ha^{-1} yr^{-1} in Porijõgi, and 140.2 kg N ha^{-1} yr^{-1} and 10.8 kg P ha^{-1} yr^{-1} in Viiratsi). Nitrogen content in wood and leaves was approximately the same in both test sites. However, P concentration in the total biomass of the older and heavily-loaded Viiratsi grey alder stand was 13.5 percent higher than in the younger and less polluted Porijõgi stand. In the older stand, a half of the assimilated P was allocated into leaves, in younger stand this share is only one-third.

Nutrient retention

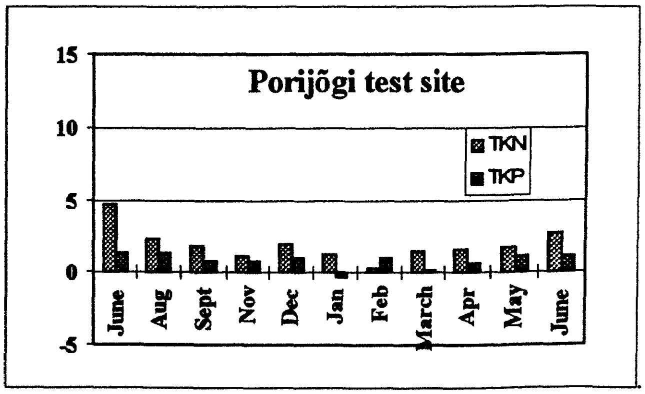
Retention of N and P was calculated according to Equation 3. In Porijõgi, groundwater filtration was calculated for 200 m^2 plots, in Viiratsi the calculation area was 800 m^2. Nutrient removal efficiency (difference between inflow and outflow values; percent) and retention capacity (g m^{-2} d^{-1}) are presented in Fig. 6. The retention value (R) was calculated as follows:

$$R = [(Q_{in} * C_{in}) - (Q_{out} * C_{out})]/A \qquad (3)$$

where Q_{in} and Q_{out} - inflow and outflow values (m^3 d^{-1}), respectively; C_{in} and C_{out} - concentration values (mg l^{-1}), respectively; A - plantation area treated with wastewater (m^2).

Nitrogen

Despite the significantly higher nitrogen load in the Viiratsi riparian buffer zone (eutrophic grassland - young alder stand - wet meadow - old alder stand) as compared to the Porijõgi site (set-aside grassland - wet meadow - alder forest complex (0.4-4.3 and 2.0-62.1 mg N l^{-1}, respectively), the output concentrations were at comparable levels (0.4-2.1 and 0.5-3.0 mg N l^{-1}, correspondingly). Atmospheric N deposition in Porijõgi and Viiratsi was estimated to be 10 and 15 kg N ha^{-1} yr^{-1}. The extremely high TKN content in Viiratsi soil water was caused by pig slurry application in the adjacent field in July and August 1994. Due to intensive fertilization over many years, soil in this field is compacted and the soil microfauna disturbed. That is why the N content in the upland soil water was always high during the first part of the study period (from June 1994 to July 1995). In the Porijõgi catchment, however, N input



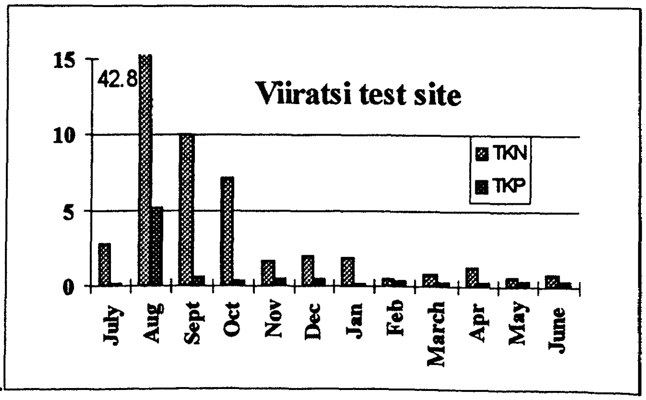


Figure 6. Total Kjeldahl nitrogen (TKN) and total Kjeldahl phosphorus (TKN) retention in the less polluted Porijõgi test site and the heavily-polluted Viiratsi test site (g m^{-2} d^{-1}).

decreased during the last three years since agricultural activities ceased in the upland field (see Kuusemets et al. 1996). According to high loading, the retention value in Viiratsi was relatively high: 0.48-42.8 kg N ha^{-1} yr^{-1} (Figure 6). In Porijõgi, it was 0.24-4.6 kg N ha^{-1} yr^{-1}. High buffering capacity in the Viiratsi study site can be explained by the following factors: (1) a relatively high denitrification value which is, however, lower than that measured in Porijõgi; (2) a relatively high plant uptake which is also lower than the corresponding value of Porijõgi; (3) lower N_2 fixation.

The denitrification value varied between 12 and 21 μg N m^{-2} hr^{-1} in the Porijõgi test site. In Viiratsi, this value was 3-14 μg N m^{-2} hr^{-1}. Still, in the adjacent wet meadow and set-aside grassland uphill from the forest, this rate was higher (4-57 and 5-41 μg N m^{-2} hr^{-1}, in Porijõgi and Viiratsi, respectively). Despite the relatively small number of analyses, main tendencies in denitrification intensity are comparable with the results of other investigations: (1) main denitrifying activity was observed in spring and late summer (Struwe and Kjøller 1990; Weller et al. 1994); and (2) higher denitrification activity was found in the upper part of the slope (see also Duff and Triska 1990; Pinay et al. 1993; Jordan et al. 1993; Weller et al. 1994). The latter tendency can be explained by significantly higher nitrate concentration in soil water. Struwe and Kjøller (1991) found up to 100 times higher denitrifying activity in slurry incubations than in the black alder forest. Most probably, due to the application of pig slurry in Viiratsi the real denitrification values can be higher than those revealed by our observations, since our measurements were not carried out immediately after the slurry application.

Atmospheric N_2 fixation in the soil of the alder stand in Viiratsi was significantly lower than in the Porijõgi test site (0.2-2.8 and 0.6-15 μg N m^{-2} hr^{-1}, respectively). The highest values were recorded in July. Surprisingly, the highest N_2 fixation values (up to 21.3 μg N m^{-2} hr^{-1} in Porijõgi and 17.9μg N m^{-2} hr^{-1} in Viiratsi) were observed in May in wet meadows and grassland communities without symbiotic N_2 fixers. Lower N_2 fixation in the loaded Viiratsi test area can be accounted for by the predomination of N assimilation over N_2 fixation in the presence of high mineral N concentrations in the root medium of actinorhizal plants (Troelstra et al. 1992). However, our investigations show that N_2 fixation in soil forms an insignificant part of the whole N budget in both study plots.

Phosphorus

Similarly to N relations in ground water, P concentration in the output from the intensively loaded Viiratsi test plot was not significantly higher than in Porijõgi, varying from 0.2 to 0.55 mg P l^{-1} and 0.08 to 0.65 mg P l^{-1}, respectively. However, P input values on the border of arable land and eutrophic grassland in Viiratsi are significantly higher than on the border of the *Filipendula-Aegopodium* wetland and alder forest and in Porijõgi, 0.6-7.09 and 0.42-1.05 mg P l^{-1}, accordingly (Mander et al. 1996). Again, high P values in Viiratsi are caused by slurry application in the adjacent field. According to high loading, the retention value in Viiratsi was high (0.12-5.2 kg P ha^{-1} yr^{-1}; (Figure 6). In Porijõgi, it was 0.13-1.3 kg P ha^{-1} yr^{-1} with a slight P leaching in winter (0.13 kg P ha^{-1} yr^{-1}). The high P retention rate in the Viiratsi study site can be explained by the following processes: (1) uptake by alders, and (2) accumulation in the soil.

Considering the relatively low plant uptake and low leaching values, we suggest that the main portion of retained P accumulates in the soil. In the long-term perspective this very high load cannot be compensated by Fe, Al and Ca phosphate precipitation. This is, evidently, the key process in P retention in Viiratsi. Also, some investigations suggest that permanently high N concentration in soil can cause P leaching (Andrusch et al. 1992). On the other hand, our earlier investigations demonstrate that riparian alder forests are effective buffers for phosphorus (Mander et al. 1995). Even in riparian wetlands P can be retained due to micro-scale oxygenation variability within the wetland and, probably, owing to phosphorus inactivation by nitrate (Andersen 1982).

Our results suggest that due to lower uptake in older *Alnus incana* stands (> 20 years), it is important to harvest these stands earlier. From the point of view of both productivity and nutrient uptake, the optimal harvest age is 12 to 15 years.

CONCLUSIONS

(1) Grey alder stands serve as perspective energy forest stands, with the maximum productivity at the age of 10 - 20 years, which is higher than for other tree species.

(2) From the point of view of both productivity and nutrient retention, their optimal harvesting age is 12-15 years.

(3) No additional N and P leaching was found within heavily loaded (application of pig slurry on upland soils, atmospheric NH_4 deposition) riparian grey alder stands. Thus, fast growing young grey alder stands do not represent an additional source of nutrients and they can act as effective buffers on stream banks and lake shores.

ACKNOWLEDGMENTS

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LITERATURE CITED

Andersen, J.M. 1982. Effects of nitrate concentration in lake water on phosphate release from the sediment. Wat. Res. 16: 1119-1126.

Andrusch, T.; Hupfer, M.; Luther, D. 1992. Chemical and microbial binding forms of phosphorus considering the availability of nitrate in sediment-water systems. Int. Revue ges. Hydrobiol. 77: 109-120.

APHA 1981. Standard Method for the Examination of Water and Waste Water, 15th edition, American Public Health Organization, Washington, 1134 pp.

Binkley, D.; Sollins, P.; Bell, R.; Sachs, D.; Myrold, D. 1992. Biogeochemistry of adjacent conifer and alder-conifer stands. Ecology 73, 6, 2022-2033.

Bormann, B.T.; Gordon, J.C. 1984. Stand density effects in young red alder plantations: productivity, photosynthate partitioning and nitrogen fixation. Ecology, 2: 394-402.

Duff, J.H.; Triska, F.J. 1990. Denitrification in sediments from the hyporheic zone adjacent to a small forested stream. Can. J. Fish. Aquat. Sci. 47: 1140-1147.

Estonian Forest Resources. Estonian Forest Survey Centre. 1995, 42 pp. (In Estonian).

Freeze, R.A.; Cherry, J.A. 1979. Groundwater. Prentice Hall.

Hakkila, P. 1989. Utilization of residual forest biomass. Springer-Verlag, Berlin, 568 p.

Jordan, T.E.; Correll, D.L.; Weller, D.E. 1992. Nutrient interception by riparian forest receiving inputs from adjacent cropland. J. Environ. Qual. 22: 467-473.

Knauer, N.; Mander, Ü. 1989. Studies on the filtration effect of differently vegetated buffer stripes along inland waters in Schleswig-Holstein. 1. Information : Filtration of nitrogen and phosphorus. Z. f. Kulturtechnik und Landentwicklung 30, 6: 365-376. (In German, with summary in English).

Kuusemets, V.; Ivask, M.; Mander, Ü. 1996. Phytomass, caloricity and nutrient variation in riparian ecotones of agricultural landscapes in Estonia. Landscape and Urban Planning. (In press).

Lõhmus, K.; Mander, Ü.; Tullus, H; Keedus, K. 1996. Productivity, buffering capacity and resources of grey alder forests in Estonia. (In press).

Mander, Ü.; Kuusemets, V.; Ivask, M. 1995. Nutrient dynamics of riparian ecotones: A case study from the Porijõgi River catchment, Estonia. Landscape and Urban Planning 31, 333-348.

Nurmi, J. 1993. Heating values of the above ground biomass of small-sized trees. Acta Forestalia Fennica 236: 1-30.

Pinay, G.; Roques, L.; Fabre, A. 1993. Spatial and temporal patterns of denitrification in a riparian forest. Journal of Applied Ecology 30: 581-591.

Struwe, S.; Kjøller, A. 1990. Seasonality of denitrification in water-logged alder stands. Plant and Soil 128: 109-113.

Struwe, S.; Kjøller, A. 1991. Denitrification in wet forest soil systems in-situ and in slurry experiments.- For. Ecol. Manage. 44 (1): 41-52.

Troelstra, S.R.; Wagenaar, R.; Smant, W. 1992. Growth of actinorhizal plants as influenced by the form of nitrogen with special reference to *Myrica gale* and *Alnus glutinosa*. J. Exp. Bot. 43: 1349-1359.

Tullus, H., Uri; V.; Keedus, K. 1995. Grey alder as an energy resource on abandoned agricultural lands. In: Land Use Changes and Nature Conservation in Central and Eastern Europe. Abstracts of the International Conference. Palanga , Lithuania, June 5-8. 55-56.

Vought, L.B.-M.; Dahl, J.; Pedersen, C.L.; Lacoursière, J.O. 1994. Nutrient retention in riparian ecotones. Ambio 23: 342-348.

Weller, D.E.; Correll, D.L.; Jordan, T.E. 1994. Denitrification in riparian forests receiving agricultural discharges. Mitsch, W.J. (Ed.).Global Wetlands: Old World and New. Elsevier Science B.V. p. 117-131.

CUT-TO-LENGTH HARVESTING ON A SMALL WOODLOT IN NEW ENGLAND: A CASE STUDY[1]

by

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ABSTRACT: This paper presents results from a case study of a cut-to-length (CTL) harvester with a forwarding system used on a small suburban woodlot. It was a cooperative effort between the Northeastern Forest Experiment Station; the Vermont Department of Forest, Parks and Recreation; and the Colchester School District, Colchester, Vermont, to demonstrate that using a CTL harvester with forwarding to thin small suburban woodlots, municipal parks, and environmentally sensitive areas is feasible. The average productivity of the harvester was about 49.88 m^3/8-hour day, within the range that the operator had experienced on similar sites and on larger commercial operations. If we assign two product value levels of \$12.95/m^3 and \$17.88/m^3, the break-even tree size was 0.176 m^3 and 0.136 m^3, respectively. Other considerations in using the CTL system on small suburban woodlots, such as profitable tree size, ecosystem sustainability, and environmental concerns are discussed.

Key Words: cut-to-length, harvesting, thinning, small woodlot, ecosystem wildlife, logging

INTRODUCTION

Fully mechanized cut-to-length (CTL) harvesting systems are becoming more popular as an alternative to manual felling, bucking, and limbing (Araki 1994, Brinker and Tufts 1990, Harrison 1995, Meek 1995, Kellogg and Brown 1995). Mechanized CTL systems offer several advantages, one of which is safer working conditions (Greene et al. 1984). The system eliminates the chopper and chain-saw interaction, particularly in dense stands where one would expect an increasing number of hangups. The CTL system can be used to more efficiently remove and pile the trees, eliminating the danger and difficulty in felling trees in dense stands. The forwarding/skidding operation is also improved because the trees are neatly piled allowing for larger, safer payloads to be transported and avoiding or minimizing the challenges that go with skidding manually felled trees.

Cut-to-length systems also allow for increased tree utilization resulting in precise uniform log lengths; less log end splitting and breakage; and cleaner, well-limbed logs (Gingras 1994). Cut-to-length systems when used with forwarders also can serve to reduce some of the soil disturbance and compaction that goes with manual felling and conventional skidder logging (Seixas et al. 1995). Application of CTL systems results in less residual stand damage because trees and logs are not being pulled through the stand and the CTL system can directionally fell trees (Leech 1989, Tufts 1991). Another advantage to CTL systems is that the delimbing takes place in front of the machine, and the limbs and slash can be used as a mat for the machine to travel on, thus reducing soil disturbance and compaction (Meyer 1984, Pawlett 1985, Seixas et al. 1995).

Cut-to-length systems have some disadvantages, the principal one being the high initial cost of purchasing such machines. Cut-to-length systems also may not be able to delimb large hardwoods and forwarding on steep slopes has limitations. In addition, fuel loading is increased in the CTL systems creating forest fire hazard conditions (Hartsough et al. 1994).

This article is a report on a case study of a small CTL system with forwarding used on a small woodlot in New England. The study was a cooperative effort between the Northeastern Forest Experiment Station, the Colchester School District, and the Vermont Department of Forest, Parks and Recreation.

The principal objective of the study was to evaluate the productivity of CTL harvesting with a forwarding system in thinning a small woodlot where minimizing the environmental impact was a high priority. Also it provided the opportunity for the high school students to participate in a class project in their environmental studies program.

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

STUDY AREA

The study area is located on the Colchester School District properties in the town of Colchester, Vermont. The test site is a 31-acre tract and is identified as stand No. 4 on the school's map. It is a typical small woodlot that is characteristic of the suburban area along Lake Champlain.

The stand was primarily white pine and red oak. The timber quality was classed as good. The topography of the site is nearly flat except for a small area in the back section of the lot where the side slope was about 3 percent. The soil on the site is dry and sandy and is an Adams-Windsor soil classification. Main skid trails were located and marked by a district forester from the Vermont State Forest, Parks and Recreation Department and averaged about 365.76 m in length.

The long-range management objective is to grow high-quality, large-diameter white pine and red oak, provide a wildlife area in a suburban environment, and provide a forested area for the high school students to apply knowledge gained from their environmental studies program.

The stand prescription was primarily a thinning to reduce the basal area to the B-level, as prescribed by Lancaster and Leak (1978) for white pine and Sampson et al. (1980) for northern red oak in New England.

EQUIPMENT

Cut-to-length harvester or feller processors as they are sometimes called usually perform three basic functions: (1) felling the stem, (2) delimbing, and (3) bucking the stem into predetermined length in the stand. Most CTL harvesters located in the Northeast are the single-grip type rather than the heavier more expensive double-grip type. The single-grip harvester is normally faster and more versatile and, therefore, more adaptable to smaller woodlots that are prevalent in the Northeastern region.

The single-grip harvester that was used in this study was a Peninsula design roller processing saw head model number RP1600[2] (Figure 1). The maximum cutting diameter is 35.56 cm and the min-max limbing diameter is about 1.27 cm and 22.86 cm, respectively. It was mounted on a modified 988 John Deere 70 tracked excavator platform. The hydraulic system on the 55-hp excavator was modified to include a 48-gallons/minute hydraulic pump system. The hydraulic system on most excavators is not specifically designed for harvester heads and, therefore, requires higher gallons/minute pumps as was the case for this machine.

The woodlot timber volume to be removed was estimated from a 100 percent cruise. Each tree was marked, measured, and tallied separately. There were 256 trees marked with yellow paint spots below stump height and tallied as sawlogs. In addition, 63 trees were marked with blue paint spots and tallied for pulpwood, and 402 trees marked for firewood. Topwood in the sawlog trees was included in the total pulpwood volume at the conversion rate of 1.27 m^3 of pulpwood /3.48 m^3 of sawlog volume. Also, 62 trees were marked with a blue "G" and were girdled by two parallel chain-saw cuts and left standing for wildlife habitat improvement. Volume removals by species and product are shown in Tables 1 and 2.

As stated earlier, the stand was marked for a heavy thinning to bring the density back to the B-line or about 100 square feet of basal area. This was primarily accomplished by removing the white pine, red oak, and hemlock sawlogs generally across all diameter at breast height (DBH) classes in the sawlog category. Because the stand had several m^3 of white pine, hemlock, and hardwood sawlogs with stump diameters that were beyond the capabilities of the harvester, a majority of the sawlog volume was cut using the conventional chain-saw and rubber-tired skidder method. In addition, a small area was logged for demonstration purposes using a team of horses and chain saw. No time or motion data were taken on the chain saw and rubber-tired skidder system or the horse operation.

The CLT system was divided into two phases for time study purposes. Phase 1 included the cutting and processing of individual trees, and phase 2 was forwarding the material to a landing. The sequence of events in phase 1 was as follows: The operator positioned the processing head on the tree to be cut, the accumulator arms were used to grip the tree while severing the tree from the stump with the chain-saw type cutter head. Spiked feed rollers pulled the tree through the delimbing knives to remove the limbs. The operator selected the cutting length, usually 2.44 m or 4.88 m with the on-board computer, and then cuts-to-length the tree into individual products. The process continued, creating bunches of six to eight cut-to-length stems/bunch. The bunches were then picked up and forwarded to the landing.

[2]The use of trade, firm or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

Figure 1. The modified 1988 John Deere tracked harvester with a Peninsula design roller processor saw head.

Table 1. Sawlog and pulpwood volume by species number of trees, and average DBH.

Species product	Volume (m^3)	Number of trees	Average DBH (cm)
Sawlogs			
White pine	112.75	157	38.20
Red oak	13.78	44	38.86
Beech	1.25	5	32.00
Paper/birch	.21	1	30.48
White oak	.21	1	30.48
Hemlock	.49	1	35.56
Red maple	12.18	47	33.27
Total	140.87	256	34.21
Pine-pulpwood	12.74	63	21.08
Pine topwood-pulpwood	40.78	--	--
Total	53.52	--	--

Table 2. Hardwood fuelwood volume, number of trees, and mean DBH.

DBH (cm)	Number of trees	Volume (m^3)
15.2	119	18.35
15.2-20.3	248	42.05
25.4	128	32.62
30.5	29	18.35
35.6	18	15.29
40.6	5	6.37
45.7	1	2.55
Total	548	135.58

Time and motion data were taken on the harvester and forwarder machine over a 5-day period. The goal was to estimate the time required to create a bunch with the harvester within a standard error of 10 percent or less at the 95 percent confidence interval. The bunch time is based on the total time to create a bunch, which includes the cycle time elements of cutting, felling, delimbing, bucking, and travel time between bunches. Timing began when the first stem was cut to create a bunch and ended when a new bunch was created. The number of trees were recorded for each bunch including the length, large-and small-end diameter for each piece in the bunch. The total ft^3 volume for each individual bunch was calculated by the formula for ft^3 content of poles, piling, and small round wood products as described in the "Forestry Handbook" (Wenger 1983). This has the form:

$$V = 0.2618L\frac{(D^2+d^2+Dd)}{144},$$

Where:

V = Volume in $feet^3$,
D = Large-end diameter in in.,
d = Small-end diameter in in.,
L = Length, and
144 = Constant.

Stems less than 5.08 cm in diameter were classed as being unmerchantable, but were included in the total cycle time. Delays were recorded to the nearest 1/10 minute and the cause of delay was noted. The effect of tree size in terms of m^3 and productivity of the harvester was evaluated with regression analysis. We also recorded turn time and the total volume to forward the bunches to the landing with the Valmet 524 forwarding machine (Figure 2). The total turn time for the forwarder included the cycle time elements of outhaul (travel empty), load time, inhaul (travel loaded), unload time, and travel distance from bunch to landing. Times were recorded to the nearest 1/10 minute and delay times were recorded as to the cause of delay. The volume/turn (load) was estimated by "stick measuring" (a 2.44-m stick, measuring the width, length, and height) the pile at the end of the day. The volume/turn was estimated by simply dividing the total volume at the landing by the number of turns. The timing for each forwarding element was as follows:

1. Outhaul--Time begins when operator clamps the back of the forwarder with the clambucket after unloading.
2. Loading--Time begins when the operator moves the loader (clambucket) and loading of stem begins.
3. Inhaul--Time begins when the forwarder moves toward the landing site after loading.
4. Unload--Time begins when the clam picks the first stem from the forwarder bunks and continues until the bunk is empty and the operator clamps the back of the forwarder with the clam bucket, starting the cycle over again.

Figure 2. The Valmet 524 forwarder with 2.44-m log bunks.

RESULTS

Harvester productivity

Table 3 shows the productivity of the CTL harvester for the study period. The CTL harvester produced 8.31 m^3/productive machine hour (PMH). The average number of trees processed was approximately 51.5 trees/PMH, which created about 16.5 bunches/PMH. The machine utilization rate (MUR) during the study period was 75 percent. Applying the 75 percent MUR over the 8 hour scheduled work day, the CTL system produced about 49.88 m^3. This fell within the range that the operator had estimated for the machine's production capability.

Table 4 shows the characteristics of product size and average bunch volume. The bunches created during the study period contained an average of 0.505 m^3 of material. The average piece size contained within the bunches was about 12.70 cm at the small end, and 16.51 cm on the large end. The average length of the pieces was 4.53 m^3, and each bunch contained about 6.0 pieces. The average tree volume was 0.165 m^3, and the average piece volume was 0.076 m^3.

Table 3. Production data for single-grip harvester CTL system.

Production factors	Volume
m^3/SMH	6.24
m^3/PMH	8.31
No. bunches/PMH	16.47
Trees processed/PMH	51.53
m^3/Scheduled 8-hour day	49.88
MUR	75%

Table 4. Characteristics of product size and bunch volume.

Variable	Average volume/unit
Volume/bunch (m^3)	0.500
Small end diameter (cm)	12.700
Large end diameter (cm)	16.500
Length (m)	4.530
Volume/piece (m^3)	0.076
Number of pieces/bunch	6.00
Volume/tree (m^3)	0.155

Tree size was analyzed to determine its effect on CTL machine productivity. The study data indicated a significant relationship with an R^2 of 68 percent. Figure 3 demonstrates the affect of tree size on machine productivity in PMH. Tree size was the most significant variable for the harvester's productivity that we observed during the study.

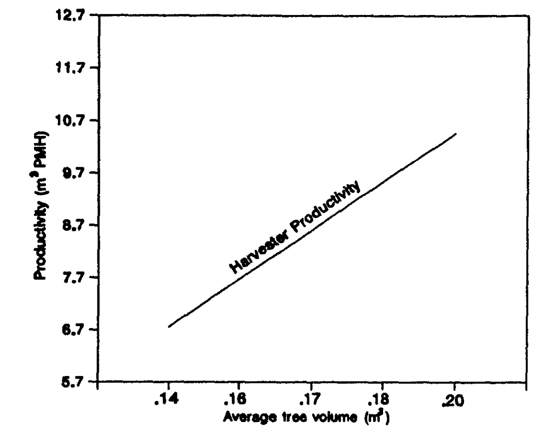

Figure 3. Effect of tree size in m^3 on harvester productivity.

We estimated the daily and annual production capability of the CTL harvester over several tree volume scenarios using data from Table 5 . If we use 0.169 m^3 for the average tree volume, which is only slightly higher than we found in the study, the average daily production is 51.65 m^3, which again is well within the range that the operator had estimated. The annual production for the same average tree volume shows an average yearly production of 12,913.90 m^3/year, assuming 250 scheduled days/year.

Figure 4 shows the break-even point (BEP) tree size for two levels of product value. At the first product price level (BEP1) of \$12.95/m^3, the logger could operate in stands with tree size of 0.175 m^3 and larger. Stated another way, at the \$12.95/m^3 product value rate, trees of 0.175 m^3 and larger will begin to show a profit and stands with tree sizes smaller than 0.175 m^3 would show a loss; therefore, it would not be a profitable stand for the logger to harvest. At the second product price level (BEP2) of \$17.66/m^3, the logger could operate at a profit in stands with tree size of 0.136 m^3 and larger. Stands with tree size less than 0.136 m^3 would not be a profitable stand to harvest. Tree size is an important variable and is a critical factor in stands with tree size less than 0.169 m^3. If we look at the cost curve segment in Figure 4, from tree size of about 0.113 m^3 to 0.198 m^3 you can see that it

Table 5. Estimated daily and annual production capability for the cut-to-length system in thinning hardwood stands.

	Average tree volume (m^3)			
Production	**0.11**	**0.14**	**0.17**	**0.2**
Daily (m^3)[a]	29.44	40.54	51.66	62.77
Annual (m^3)[b]	7355.00	10135.70	12913.91	5689.30

[a]8 Scheduled-hour day.
[b]250 Scheduled days/year.

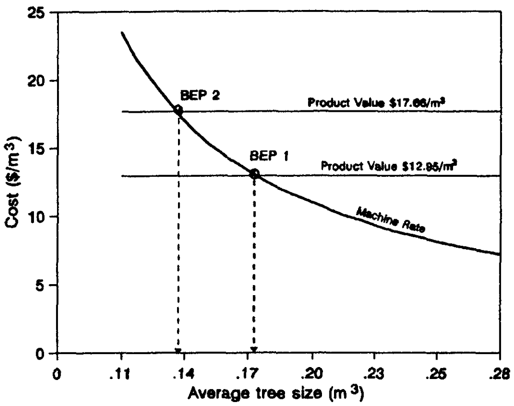

Figure 4. Break-even points (BEP) for CTL harvester

decreases at a decreasing rate (steeper slope) and then begins to flatten out beyond tree size of 0.283 m^3 and larger. This suggests that loggers generally would make a profit if they bid on stands when tree size is greater than 0.169 m^3. This of course will change as the market price of the product fluctuates.

Forwarding productivity

The Valmet model 524 forwarder, which is a bidirectional 4-wheel machine that was equipped with a small clam loader and 2.44 m log bunk, was used to transport the bunches created by the harvester to a roadside landing. Although the productivity of the forwarder was not a primary objective of the study, we were able to time 15 turns of the machine. The cycle time elements observed were inhaul, loading, outhaul, unload, and delay time. The average time for each element is shown in Table 6. The average outhaul time over the average distance of 5.97.44 m was 5.95 or 12.36 percent of the total productive time. Loading time required the most time and averaged 28.5 minutes or 59.19 percent of the total productive turn time. The inhaul required an average time of 7.3 minutes/turn or about 15.16 percent of the total productive time. Unload required 6.40 minutes/turn or about 13.29 percent of the productive time. The average total productive cycle time was 48.15 minutes over an average haul distance of 597.41 m. The average delay time was 9.6 minutes/cycle, which gives a MUR of 83.8 percent. The average volume transported by the forwarder to the landing was 12.74 m^3. Like most forwarding activities, the fixed time or terminal time accounts for the major proportion of the total turn time; in this case it accounted for 72.4 percent of the total turn time.

Table 6. Average total time and cycle time by element for the Valmet 524 forwarder.

Cycle Time Elements	Average Time (min)	% of Total Productive Time
Outhaul	5.95	12.4
Loading	28.5	59.2
Inhaul	7.3	15.2
Unload	6.4	13.3
Total cycle time	48.15	100.0
Delay time	9.3	
Total cycle time with delay	57.45	
Average volume/turn (m^3)	12.74 m^3	
Machine utilization	0.838	
Average distance	597.4 m	

DISCUSSION

The case study demonstrates that a small CTL system can operate in small woodlots in a suburban setting while maintaining the environmental and aesthetic advantages. The productivity of 49.88 m^3/day in this small woodlot was well within the range of productivity that the operator had experienced in larger operations.

Many small municipal parks and public woodlots in the Northeast suburban area need some form of forest management to increase tree growth and meet sustainable ecosystem goals. These sites must be harvested in such a way as to minimize the environmental impact and maintain a high degree of aesthetic value to the public. It seems that CTL systems within the size range of the equipment used in this study meet these requirements and should be considered as an economically feasible harvesting method for such woodlots. We also observed a higher than usual MUR on both the harvester and the forwarder, 75 percent and 83.8 percent, respectively.

However, we feel that these are not out of the range to be expected on sites that are flat with little or no terrain obstacles that are typical of small suburban woodlots especially along the Champlain Valley of New York and Vermont. Cut-to-length systems usually have a high machine rate cost, and side slope and tree size limitations; however, they will operate at a profit over a wide range of woodlots that require thinning as long as the woodlot contains multi-products such as pulpwood, fuelwood, and some medium- to high-grade sawlogs.

We revisited the post-harvest site and noted that very little residual stand damage resulted from the harvesting activity. The study gave students at the high school a chance to observe a commercial harvesting operation and to be involved in a post-harvest evaluation of the soil and site disturbance resulting from the harvest activity.

LITERATURE CITED

Araki, Dennis, R.P.F. 1994. At-the-stand and roadside log processing in Alberta: A comparison. FERIC Spec. Rep. No. 5R-96. Vancouver, BC: Forest Engineering Research Institute of Canada, Western Division, V6T124. 29 p.

Brinker, Richard W.; Tufts, Robert A. 1990. Economics of cut-to-length harvesting system in second thinning. In: Proceedings of the Council on Forest Engineering, 13th annual meeting; 1990 August 12-16; NC: Outer Banks: 84-88.

Gingras, J.F. 1994. A comparison of full-tree versus cut-to-length systems in the Manitoba Model Forest. FERIC Spec. Rep. SR-92. Quebec, Pointe-Claire: Forest Engineering Research Institute of Canada Canada. 16 p.

Greene, Dale W.; Lanford, Bobby L.; Stokes, Bryce J. 1984. Productivity of the Valmet 940 Gp Grapple processor in southern pine plantation thinning. Proceedings of the Council on Forest Engineering/IUFRO, University of Maine, Orono. August 11-18,1984. p.105-108.

Harrison, Bob. 1995. Mechanized CTL is part of the answer. Canadian Forest Industries, July - August. p. 40-44.

Hartsough, Bruce R.; McNeel, Joseph F.; Durston, Thomas A.; Stokes, Bryce J. 1994. Comparison of mechanized systems for thinning ponderosa pine and mixed conifer stands. Pap. No. 94-7513. 1994 International Winter Meeting sponsered by ASAE.

Kellogg, Loren D.; Brown, Cameron G. 1995. Using a single-grip harvester and skyline yarding system in a forest health improvement application. Proceedings of the Council of Forest Engineering, 18th Annual Meeting, June 5-8, 1995, Cashiers, NC. p. 130-142.

Lancaster, Kenneth F.; Leak William B. 1978. A silvicultural guide for white pine in the Northeast. Gen. Tech. Rep. NE-41. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.

Leech, Peter E. 1989. Rottne Log-Length Logging System. Proceedings of the Southern Regional Council on Forest Engineering. 1st Annual Meeting, May 3-4, 1989. Auburn, AL. p. 125-132.

Meek, Philippe.1995. Concentrating on a slash distribution solution. Canadian Forest Industries, July-August p. 46-49.

Meyer, Robert L. 1984. Rottne Forwarder and Harvester/Processor. Tech. Release 84-R-97. Washington, DC: American Pulpwood Association. 2 p.

Pawlett, Steve. 1985. Swedish harvesting system debuts in New Brunswick. Canadian Forest Industries. 105(10): 13-14.

Seixas, Fernando; McDonald, Timothy P.; Raper, Randy L. 1995. Effect of slash on forwarder on soil compaction. Proceedings of the Council of Forest Engineering, 18th Annual Meeting, June 5-8, 1995, Cashiers, NC. p. 77-86.

Sampson, T.L.; Barrett, J.P.; Leak, W.B. 1980. A Stocking Chart for Northern Red Oak in New England. Institute of Natural and Environmental Resources, University of New Hampshire, Durham, NH.

Tufts, Robert A. 1991. Productivity and cost of the Norcar 600 Harvester. Proceedings of the ASAE Forestry and Environment Conference, June 5-6, 1991. New Orleans, LA. p. 85-92. Forest Engineering. 1st Annual Meeting, May 3 - 4, `1989. Auburn, Alabama. p.125-132.

CABLE YARDING AS A LOW-IMPACT ALTERNATIVE ON SENSITIVE SITES IN THE LAKE STATES[1]

by

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ABSTRACT: Ground-based forest operations can cause adverse impacts to the soil and residual stand. Skyline cable yarding is a harvesting technology that can lessen impacts on steep slopes and flat, wet sites. The purpose of this study was to evaluate the yarding productivity, cost, residual stand impacts, and site impacts associated with a Christy cable yarder operating on steep slopes in the midwest. The Christy yarded an average of 4112 board feet per scheduled hour at a cost of about US$26 per thousand board feet. Felling and limbing productivity and costs were not evaluated in this study. Damage to the residual stand was approximately equivalent under the cable yarding and conventional cable skidding systems. Skyline cable yarding did result in substantially less damage to the soil.

Key Words: cable yarding, cost, productivity, site impacts, residual stand damage, forest harvesting

INTRODUCTION

Timber harvesting is becoming highly controversial in some areas of the United States due to the negative effects it can have on the forest. Potential impacts include soil compaction and displacement, residual tree damage, sedimentation of water courses, and changes to wildlife habitat, aesthetics, and recreational opportunities. These impacts are becoming less acceptable to a growing suburban population that places a greater value on the forest for recreation and other noncommodity values than as a source of wood products.

In response to these concerns, a number of states have developed Best Management Practices (BMPs) or have passed forest practices legislation that specify suitable practices to lower site impacts from forestry operations. Satisfying the stipulations of these BMPs will require the development and use of new, "light on the land" technologies. This may help convince a skeptical public that timber harvesting can be compatible with other forest values.

Harvesting systems that have less impact will also find application on difficult sites. There are many sites in the midwest where operability is severely limited using conventional logging techniques due to either steep or wet ground. Building roads and operating conventional ground-based equipment in these areas is very unproductive, costly, and normally results in undesirable environmental impacts. Systems that are economical and environmentally viable on steep slopes and unstable soils are needed. This will reduce the negative impacts associated with harvesting, permit better use of forest resources, and help maintain sustainable ecosystems.

Skyline cable yarding is an extraction system uniquely suited to harvesting timber on steep slopes and unstable soils. In its' simplest form, this method consists of a yarder with two large powered winch drums, one carrying the skyline and one carrying the mainline. Also part of the yarder is a tall, guyed spar through which these winch lines are strung to provide lift. The skyline is pulled out and fastened to a tailhold, which is usually a large tree at the end of the yarding corridor. A carriage runs along the skyline carrying the mainline with chokers out to the logs. Logs are pulled to the yarder by powering the mainline winch drum.

The main advantage of this system is that heavy machines do not traverse the site, typically reducing soil impacts. Also, the log is usually transported to the landing with at least one end off the ground, further lowering soil impacts. Cable yarding can also reduce the total length of haul road needed to harvest the tract, which lowers the costs and impacts associated with road building.

[1] Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996

LITERATURE REVIEW

The skyline cable yarding system is commonly used on steep slopes in the western mountain regions, but has not been used extensively in the east since the early 1900s (Peters 1984). It was discontinued in the east after most of the old growth timber was harvested. Increasing log sizes and environmental concerns have brought renewed interest in cable yarding in the east for harvesting difficult sites.

Matics (1980; 1982), Keesee (1982), and Norton (1982) report the use of cable yarding by the forest industry in the southeast. Research by the Forest Service and others shows the level of interest in cable yarding in the southeast (Fisher and Peters 1982). Cable yarders studied include the Ecologger (Fisher et al. 1980a), the Urus yarder (Fisher et al. 1980b), the Clearwater yarder (Koten and Peters 1985; Sherar and Tillman 1984), the Koller K-300 yarder (Stuart and Rossi 1984), the Appalachian Thinner (Biller and Fisher 1984), and the Bitterroot Miniyarder (Cubbage and Gorse 1984; Baumgras and Peters 1985). All of these studies were done in steep slope applications.

Very little work has been done on skyline cable yarding systems in the Lake States. Conditions closest to that found in the Lake States were found in a study in Upstate New York (Koten and Peters 1985). It is gener-ally believed that the Lake States has very few sites that justify the use of cable yarding systems. However, Ziemer (1980) estimates that the potential area available for cable yarding is about 4.4 million acres, which includes both steep terrain and flat, wet sites. Cable yarding could help ensure compliance with BMPs and promote ecosystem management on these problem sites.

OBJECTIVE

The purpose of this research was to evaluate the productivity, cost, and site impacts associated with cable yarding on steep slopes in the Lake States and determine the extent to which this type of harvesting assists landowners and operators in meeting BMP requirements. A similar study of cable yarding on flat, wet aspen sites is currently being conducted, but will not be reported here because the results are still being analyzed.

METHODS

Several study sites of various sizes were selected on Minnesota Department of Natural Resources (MN DNR) land in southeastern Minnesota. The stands contained mostly oak on steep terrain carved out by tributaries of the Mississippi River. The stands were marked for either partial or clearcutting as prescribed by MN DNR foresters. Marked trees on each site were chainsaw-felled prior to yarding by the local cooperating logger. The felled trees were yarded uphill to a landing using a Christy SWY3[2] double-drum cable yarder owned by the U.S. Forest Service (Figure 1). Yarded stems were extracted from the corridor with a crawler tractor.

The performance of the yarding operation was evaluated using continuous time study techniques over a two-week period for both a Forest Service and a local logging contractor crew. In addition to the detailed timing data collected, the corridor distance to stop, height of stop, lateral ground distance to stop, lateral yarding angle, number of stems per turn, and individual log measurements were collected.

Pre-harvest stand and site data and post-harvest disturbance data was collected by University of Minnesota personnel. It was done both on cable-logged sites and similar sites that were logged with conventional ground-based equipment. Pre-harvest information was collected on the overstory, ground cover, and physical attributes of the site. Sample plots were located using a systematic, random sampling pattern.

Overstory trees greater than 4.5 inches diameter at breast height (dbh) were sampled using one-tenth acre circular plots. Information recorded included dbh (nearest inch), species, merchantable height, and canopy class. Using the same plot centers, ground cover was sampled using 10 square meter circular plots. Ground cover was classified as litter, mineral soil, downed woody material, and rock. The aspect, slope, and slope position were also recorded for each plot.

Post-harvest disturbance data was collected using 40 meter line transects at random azimuth orientations from the pre-harvest sample plot centers discussed

[2] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. It does not constitute an official endorsement or approval of any product or service by the United States Department of Agriculture, the University of Minnesota, or the Minnesota Department of Natural Resources to the exclusion of others which may be suitable.

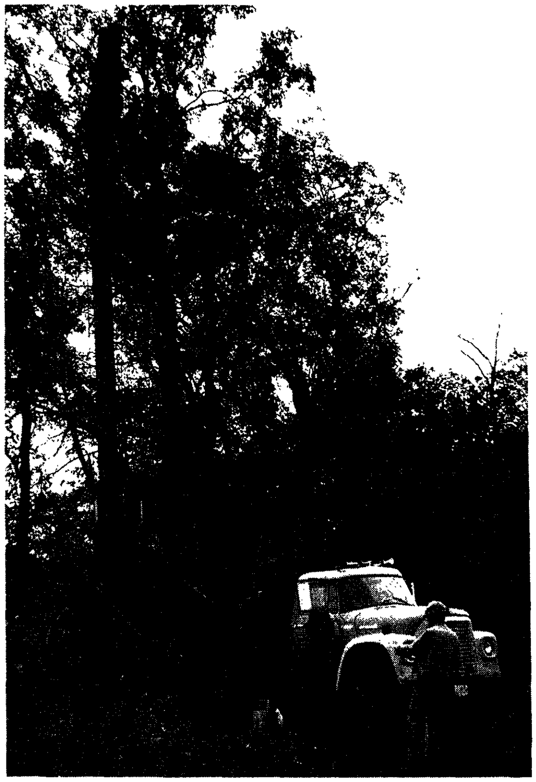

Figure 1. The Christy double-drum skyline cable yarder used in this study.

above. The types of disturbance present along each transect that resulted from logging operations were measured to assist in the assessment of vegetation changes after harvest. Soil disturbance severity was noted as low, moderate, high or none. The cause of disturbance was noted as winching, skidding or felling. The soil layer exposed was classified as organic or mineral and rut depth (if rutted) was measured. The understory disturbance was classified as low, moderate, or high and the slash cover rated as light, moderate, or heavy.

Residual stand damage was determined by conducting a 100 percent survey in the partially-cut cable-yarded and conventionally-skidded areas. Information collected includes the following: location on the slope, distance to the skid trail or yarding corridor, tree dbh, species, cause of the damage, location on the tree, scuff size, height and diameter of broken branches, potential crop tree or not, and other types of tree damage (uprooted, pinned, broken, leaning).

RESULTS

Four study sites were selected in southeastern Minnesota (Table 1). Slopes across the four sites averaged 46 percent with a slope length of 300 feet. The soils are generally a silt loam and are considered highly erosive.

Stand attributes measured during the preharvest assessment of the four study sites are presented in Table 2. Red oak accounted for the majority of the volume on all four sites, ranging from 66 to 96 percent of the total (average for four sites is 83 percent). Eighteen other species were identified (trees greater than 4.5 inches dbh) on at least one of the four sites.

Productivity and cost

The amount of time spent on various activities while cable yarding steep slopes in southeastern Minnesota is presented in Table 3 for the Forest Service crew, the local logging crew, and for the two combined. Ancillary Work Time included supportive work activities that allow the work to continue, such as re-choking stuck logs, clearing brush, re-setting the carriage stop, etc. Preparatory Time included setting up and rigging the yarder, clearing the new corridor, rigging the tail tree, etc. All times were observed except Rest and Meal Time and Service Time, which were assumed in order to account for expected long-term variability and provide for data comparability.

Overall average cycle time for both crews combined was about 9 minutes per cycle with an equipment utilization rate of about 47 percent. Average cycle time for the Forest Service crew (9.66 minutes) was more

Table 1. Attributes of the four study sites in southeastern Minnesota.

Site Attribute	Brightsdale	Caledonia-1	Caledonia-2	Diamond Crk	Overall
Area-acres	12.0	5.5	6.0	5.6	29.1
Slope Range-%	40-60	20-40	45-70	30-52	20-70
Slope Length-ft	200	300	450	350	300
Soil Type	Fayette silt loam	Lamoille Elbaville silt loam	LaCrescent cobbly silty clay loam	Fayette silt loam	
Type of Cut	clearcut	clearcut	some of both	partial cut	
System Used	cable	cable	some of both	cable	
Crew	FS crew	FS crew	local crew	local crew	

Table 2. Attributes of the deciduous overstory prior to harvesting on the four study sites.

Site Attributes	Brightsdale	Caledonia-1	Caledonia-2	Diamond Crk	Overall
Trees-#/ac	160	137	161	150	154
Basal Area-ft^2/ac	115	102	100	122	111
DBH-inches	10.3	10.5	9.7	11.1	10.4
Volume-bd.ft/ac	9518	6186	5773	9233	8061

Table 3. Average times for cable yarding steep slopes in southeastern Minnesota.

	Forest Service Crew		Local Crew		Combined	
Time Element	Minutes	Percent	Minutes	Percent	Minutes	Percent
Productive:						
Clear and raise skyline	0.17	1.8	0.27	3.2	0.22	2.5
Carriage to stop	0.29	3.0	0.30	3.6	0.30	3.3
Walk to line	0.12	1.2	0.15	1.8	0.13	1.4
Outhaul and hook	1.36	14.1	1.11	13.1	1.23	13.7
Clear and signal	0.27	2.8	0.09	1.1	0.17	1.9
Lateral yard	0.69	7.1	0.61	7.2	0.65	7.2
Carriage to landing	1.08	11.2	1.10	13.0	1.09	12.1
Walk and unhook	0.40	4.1	0.53	6.3	0.47	5.2
Total Productive Time	4.38	45.3	4.16	49.3	4.26	47.3
Other:						
Ancillary Work Time	1.03	10.7	0.57	6.7	0.78	8.7
Preparatory Time	1.78	18.4	1.55	18.4	1.66	18.4
Rest and Meal Time	1.50	15.6	1.32	15.6	1.40	15.6
Service Time	0.97	10.0	0.85	10.0	0.90	10.0
Total Other Time	5.28	54.7	4.29	50.7	4.74	52.7
Total Cycle Time	9.66	100.0	8.45	100.0	9.00	100.0

than a minute longer than for the local logging crew (8.45 minutes). This can be attributed mainly to a slightly larger lateral yarding distance and smaller piece size, which increased Outhaul and Hook and Ancillary Work Times because more cycles required multiple stems to acheive the optimum payload.

The productivity, cost, and other attributes associated with cable yarding are presented in Table 4 for the Forest Service crew, local logging crew, and both crews combined. The combined average yarding productivity was about 4112 board feet per scheduled hour (SH), which is similar to that observed in other studies of this equipment (Koten and Peters 1985). The local logging crew outproduced the Forest Service crew by about 660 board feet per SH, due mainly to larger piece size. Overall average yarding cost was about US$26 per thousand board feet, also comparable to previous results (Koten and Peters 1985).

Regression analysis was used to evaluate the effect piece size, number of pieces per turn, corridor yarding distance, and lateral yarding distance had on the productive time per cycle. The coefficients developed from this regression are presented in Table 5, along with the associated correlation coefficients. The four variables explained from 29 to 49 percent of the variation in the cycle times. Most of this was explained by corridor and lateral yarding distances. These coefficients and regression constants can be used to estimate productive yarding time for different values of these variables, or in sensitivity analyses.

Table 4. Yarding productivity, cost and other attributes.

Attribute	Forest Service Crew	Local Crew	Combined
Total Volume-mbf	86	108.4	194.4
Total Cycles	142	173	315
Ave. Volume per Cycle-bd.ft.	606	627	617
Total Pieces	203	202	405
Volume per Piece-bd.ft.	424	536	480
Ave. Yarding Distance-ft	280	310	298
Ave. Corridor Distance-ft	218	253	238
Ave. Lateral Distance-ft	62	57	60
Productivity-bd.ft. per SH	3764	4448	4112
Hourly System Cost-US$/SH[1]	106.48	106.48	106.48
Yarding Cost-US$ per mbf	28.29	23.94	25.89

[1]Includes yarder, bulldozer, and three operators.

Table 5. Regression coefficients and other statistical attributes associated with the observed productive yarding times.

Attribute	Forest Service Crew	Local Crew	Combined
Coefficients for:			
Corridor Distance	0.00546	0.00578	0.00529
Lateral Distance	0.01237	0.01917	0.01496
Pieces per Cycle	0.20610	0.77207	0.45832
Volume per Piece	0.00299	0.00706	0.00419
Regression Constant	1.96	0.36	1.31
Standard Error	1.16	0.87	1.03
Correlation (r^2)	0.29	0.49	0.37
Number of Observations	142	173	315

Residual stand damages

Partial cut operations were conducted with both a skyline cable yarding system and a conventional cable skidder system. A primary consideration in partial cut harvests is the amount of residual stand damage caused by the logging system. Both felling and yarding/skidding damages were assessed (Table 6). In each case, the number of potential crop trees that were damaged was also noted.

No significant difference in residual tree damage was noted between cable yarding and ground skidding (14 vs 16 boles damaged, respectively). The major difference between the damage caused by the two systems was in the "other bole damages" category caused by felling. The felling crew for the conventional cable skidding system caused 22 other bole damages compared to only 4 for the cable yarding system. The crews performing the felling were not necessarily the same crew for both operations; therefore, the only explanation for this difference is the expertise among the sawyers.

Site disturbance

After harvesting was completed, the degree of soil disturbance was assessed using the line intersect method. Five cable-logged sites and two conventionally-logged (cable skidded) sites were assessed. In this study, the total amount of soil disturbance by cable yarding was about 25 percent of that caused by conventional skidding. Soil disturbance on the five cable yarded sites occurred on 1.5 to 10.5 percent of the total area and was mainly a function of landform (i.e., greater log suspension results in less soil disturbance). Soil disturbance on the two cable skidder sites, on the other hand, was consistent and ranged from 18.5 to 20.5 percent of the area. amount of organic soil exposed was only slightly more for the cable skidder sites (average of 3.7 percent) than for the cable yarded sites (average of 1.8 percent). However, conventional cable skidding on these steep slopes caused significantly more mineral soil to be exposed (average of 15.8 percent) than cable yarding (average of 6.0 percent). This difference can be attributed to the impact of the cable skidder as it climbed the slope. The difference is significant relative to the impact soil disturbance has on sedimentation and water quality on these highly erosive slopes of southeastern Minnesota.

DISCUSSION

Although steep terrain is not usually associated with Lake States forests, Ziemer (1980) estimates that as much as 100,000 acres may be in steep ground. The conventional method of harvesting these steep sites is with ground-based cable skidders or crawler tractors. The weight distribution of crawler tractors allows operation without prepared trails, while rubber-tired skidders require trails cut into the hillside. The yarding productivity of ground-based cable skidders on these steep sites may be greater than that observed in this study for skyline cable yarding (4112 board feet per SH). Likewise, the usual yarding cost for cable skidding is less than that observed for cable yarding (US$26 per mbf). The cost of felling and limbing, which were not included in this study, are assumed to be the same for both cable yarding and conventional harvest systems.

These costs, however, do not include the costs associated with excessive soil disturbance, which results in sedimentation, site degradation, and negative aesthetic effects. Skyline cable yarding systems produce similar levels of residual stand damage in

Table 6. Residual stand damage from cable yarding and conventional cable skidding in partial cut stands on steep ground of southeastern Minnesota.

	Cable Yarded			Conventional Skidded		
Cause of Damage	Scuffed Boles	Broken Branches	Other[1] Damages	Scuffed Boles	Broken Branches	Other Damages
Felling	1	6	4	3	5	22
# Crop Trees	0	0	0	0	3	9
Yarding/Skidding	13	0	1	14	0	2
# Crop Trees	0	0	0	4	0	0
Total	14	6	5	17	5	24

[1]Other damages include uprooted, leaning, broken, and pinned trees.

partial cuts as ground-based cable skidding systems, but cause significantly less soil disturbance (5 vs 20 percent of the area in this study). The level of soil disturbance caused by a particular extraction system rather than the direct operational cost is likely to be the limiting factor on these steep, erosive sites in the future.

This is also true for forested wetlands in the Lake States, of which Ziemer (1980) estimates there are 4.3 million acres. Ground-based harvesting in these wet areas can cause serious soil displacement due to the low bearing capacity of the soils. Some areas are inaccessible by equipment except in winter. Cable yarding systems can reduce soil impacts in these areas and extend the harvest season. Research is currently underway to compare cable yarding with ground-based technology on flat, wet sites in Minnesota. Both wet aspen and swamp conifer sites are being considered for evaluation.

Although the skyline cable yarding system is not the most economic system available to harvest difficult sites at present, it may be in the future as the application of other more intrusive systems is constrained by BMPs or through regulation. Even now, some landowners are not allowing ground- based cable skidder operations on their land, but would allow a cable yarding operation due to differences in soil and aesthetic impacts.

LITERATURE CITED

Baumgras, John E. and Penn A. Peters. 1985. Cost and production analysis of the Bitterroot miniyarder on an Appalachian hardwood site. Research Paper NE-557. Radnor, PA; Northeastern Forest Experiment Station, USDA Forest Service.

Biller, Cleveland J. and Edward L. Fisher. 1984. Whole-tree harvesting with a medium capacity yarder. ASAE Paper No. 82-1591. St. Joseph, MI: American Society of Agricultural Engineers.

Cubbage, Frederick W. and August H. Gorse IV. 1984. Mountain logging with the Bitterroot miniyarder. In Proc. Mountain Logging Symposium, Morgantown, WV: West Virginia University; p. 80-91.

Fisher, Edward L., Harry G. Gibson, and Cleveland J. Biller. 1980a. Production and cost of a live skyline cable yarder tested in Appalachia. Research Paper NE-465. Broomall, PA: Northeastern Forest Experiment Station, USDA Forest Service.

Fisher, Edward L., Donald L. Gochenour, and Cleveland J. Biller. 1980b. Significant factors affecting performance of a Urus cable yarder. ASAE Paper No. 80-1547. St. Joseph, MI: American Society of Agricultural Engineers.

Fisher, Edward L. and Penn A. Peters. 1982. Analysis of eastern United States cable harvesting operations. ASAE Paper No. 82-1602. St. Joseph, MI: American Society of Agricultural Engineers.The amount of organic soil exposed was only slightly more for the cable skidder sites (average of 3.7 percent) than for the cable yarded sites (average of 1.8 percent).

Keesee, Kenneth C. 1982. Small tree steep slope harvesting. In Proc. Harvesting Small Timber: Waste Not, Want Not, Syracuse, NY, 28-30 April 1981. Proc. P-81-32. Madison, WI: Forest Products Society; p. 86-88.

Koten, Donald E. and Penn A. Peters. 1985. Cable yarding on environmentally sensitive areas in New York State. In Proc. 8th Annual Council On Forest Engineering Meeting, 18-22 August 1985, Tahoe City, California; p. 79-83.

Matics, H.E. 1980. Why Westvaco uses cable yarders in the Appalachians. In Proc. Cable Yarding Conference, Asheville, NC: Tennessee Valley Authority; p. 84-87.

Matics, H.E. 1982. Westvaco cable logging program, the future situation. In Proc. Appalachian Cable Logging Symposium, Blacksburg, VA: Polytechnic Institute; p. 15-24.

Norton, David. 1982. Owens-Illinois cable logging program. In Proc. Cable Logging Symposium, Blacksburg, VA: Polytechnic Institute; p. 25-32.

Peters, P.A. 1984. Steep slope clearcut harvesting with cable yarders. In Proc. Harvesting the South's Small Trees, Biloxi, MS, 18-20 April 1983. Proc. 7340. Madison, WI: Forest Products Society; p. 69-78.

Sherar, James R. and David A. Tillman. 1984. The Clearwater Yarder. In Proc. Mountain Logging Symposium, Morgantown, WV: West Virginia University; p. 337-349.

Stuart, William B. and Michael K. Rossi. 1984. Production study of the Koller K-300 cable yarder operating in the mountains of Virginia. In Proc. Mountain Logging Symposium, Morgantown, WV: West Virginia University; p. 350-362.

Ziemer, I. 1980. Preliminary study to establish the feasibility of cable yarding in the Lake States. Final report for Cooperative Agreement 13-564 (FS-NC-3701-77-03) 42p. On file with: USDA Forest Service, 410 MacInnes Drive, Houghton, MI 49931-1199.

VALUE MAXIMIZATION OF FOREST STANDS THROUGH OPTIMAL INVENTORY AND CROSS-CUTTING METHODOLOGIES[1]

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ABSTRACT: The Irish sawmilling industry is experiencing a phase of extremely tight profit margins, caused by a temporary over-capacity in production, leading to high stumpage prices, and by the need to penetrate international markets. Emphasis has consequently been placed upon maximizing value recovery from harvested stands. This paper outlines the research undertaken in the development of a decision support system for a medium-size mill. The work has focussed, initially, on the development of cost-effective inventory methods and data analysis software. Future efforts will concentrate on the integration of these modules with existing mill monitoring software and with the computerized data collection systems of harvesting machinery. The initial phase of the project has already shown potential for achieving significant increases in value recovery.

Key Words: value recovery, pre-harvest inventory, cross-cutting strategy, log-product yield.

INTRODUCTION

The total forest area of the Republic of Ireland has increased from a mere 100,000 ha in 1922 to 565,000 ha in 1995, which equates to 8 percent of the land surface. Exotic, even-aged monocultures, comprised predominantly of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) (62 percent) and Lodgepole pine (*Pinus contorta* Dougl.) (21 percent), dominate commercial forestry in Ireland. Afforestation, initiated in 1923, remained on a modest scale for six decades until the mid 1980's when, for the first time, attractive financial incentives encouraged significant non-state involvement. Total new planting for 1995 stood at 23,700 ha, 73 percent of which was undertaken by the private sector. An afforestation target of 30,000 ha per annum is expected to be achieved by and maintained beyond the turn of the century.

The current annual timber harvest of over 2.1 million m^3 is projected to rise by 33 percent to 2.8 million m^3 by the year 2001, and by a further 32 percent, to 3.7 million m^3, within a decade of that date, at which time output from the forest products industry will be valued at over IR£400m annually (Coford, 1994).

Most of the harvesting is undertaken using the shortwood system. The felling, delimbing, and cross-cutting actions are performed either by harvesting machine or by motor manual means, with extraction invariably by forwarder. The level of mechanization continues to rise rapidly; harvesters are now employed in almost 50 percent of all clearfelling operations.

Sawmilling industry

Coillte Teoranta, the Irish Forestry Board, is currently the principal supplier of round wood to the 100 sawmills spread throughout Ireland. The company routinely advertises stands available for purchase. The advertisements include estimates of important stand parameters, on the basis of which competing mills tender for the lots. Final payment for timber purchased from Coillte is calculated based upon a weight-volume ratio specific to each sale. The weight of all log shipments are recorded at millgate and sample logs are removed from a portion of consignments. The weight of each log is determined and its volume calculated based upon diameter and length measurements. Division of the volume by weight produces a correlation specific to each log. These values are subsequently averaged to provide a volume-weight ratio applicable to an entire sale.

The Irish sawmilling industry remains in the development stage. The availability of grant aid for the purchase of machinery in the 1980's encouraged the expansion of existing mills and led to significant rise in the number of new mills. The resultant increase in processing capacity created the current, temporary, imbalance between supply and demand. The continual increases in timber production will alleviate, and eventually bridge, this gap, although Coillte's recent adoption of shorter, financial rotations has further restricted the supply of large sawlog grade material.

By comparison with international competitors, Irish mills are limited in size. Only the country's two largest mills produce more than 100,000 m^3 of sawn timber per annum. Mills also experience high stumpage

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prices, over-capacity in processing, frequently operating on a single shift basis, and a depressed market for residues. The mills do not, therefore, share the advantages of a low cost position and large production and distribution scales enjoyed by those in competitor nations.

Given projected future increases in timber production, it is estimated that the volume of exports will need to rise significantly in order to avoid over-supply of sawngoods on the domestic market. Demand for sawn timber is expected to increase only gradually in Europe. However, Irish sawmills have penetrated foreign markets, especially Britain, as demonstrated by the increase in annual exports of construction timber, fencing timber and pallets, from 17,000 m^3 to 250,000 m^3, in the decade 1982-1992.

Recent trends in international exchange rates, however, in which the value of the Punt has strengthened with respect to Sterling, have reduced the competitiveness of Irish exporters in the principal market for their products. This has forced many to reduce margins still further.

In the long-term, when a greater balance exists between timber supply and processing capacity, the scope will arise for reducing unit costs. In the interim, however, alternative means of improving competitiveness and profitability must be sought. Interest in maximizing value recovery from harvesting operations stems directly from the challenge now faced by Irish sawmills, to actively compete in the export market.

The project described in this paper aims at the development of a decision support system for the sawmilling industry, linking standing timber to mill specifications and demands, with the ultimate aim of maximizing value recovery.

BACKGROUND TO THE PROJECT

Sawmills require detailed information on the volume, grade, number and size distribution of logs, which the felling of a forest stand could, given various product specifications and cross-cutting strategies, potentially yield.

At present, the information available to sawmills on standing timber lots is considered rather crude and inappropriate for the emerging needs of the industry. Coillte provides estimates of mean diameter at breast height, mean volume and total volume for timber lots available for purchase, in addition to a breakdown of volume into assortment categories derived from generic stand assortment tables (Table 1). The absence of relevant inventory data restricts the scope for comprehensive analysis of stands with regard to the quantity, quality and dimensional properties of potential product assortments, and also limits the mill manager's capacity to determine the optimal methods for manufacturing these products. In addition, the planning of forest operations is frequently undertaken in the absence of any detailed knowledge of industrial demand, a combination of circumstances that leads, inevitably, to sub-optimal utilization of the timber resource.

In order, therefore, to optimize the exploitation of the raw material, a system must be developed that provides a means of obtaining, relaying and manipulating information on standing timber to yield predictions of the dimensions and value of potential log assortments.

The reliance of timber producers upon even-aged monocultures, coupled with the adoption of intensive management regimes involving short rotations and standardized spacing and thinning practices, conspire to limit the variation in stem size and quality within individual management units. Ireland's plantation forests, therefore, yield uniform logs which lie in the lower size categories of commercial softwoods.

Table 1. Sales details: an example of the parameters provided by Coillte Teoranta for timber lots available for purchase.

Sub Compt.	Harv. Area	Species	Plant Year	Yield Class	Mean DBH	Trees (/ha)	Volume (/ha)	Total Volume	7-14	14-20	20+
33071Q 3	1.6	DF	1962	18	22	143	50	80	16	33	31
	2.0	SS	1962	24	24	144	67	134	12		
Sale Totals	3.6				23	144	59	214	28	75	111

The range of log sizes and grades that are cut from stems is comparatively limited. Fixed log specifications are frequently adopted for a given stand, reducing the flexibility of and increasing the danger of serious wastage in the cross-cutting action. However, this practice, combined with the uniform logs produced from intensively managed plantation forests, also reduces the complexity of the decision-making process and simplifies the task of developing a model that will predict potential log dimensions.

Research and development has provided numerous new technologies that will, increasingly, contribute toward more efficient exploitation of the forest stand through improvements in the collection, transfer and processing of data, and in the monitoring of operations.

At present, for example, the majority of harvesting machines are equipped with computerized measurement and cross-cutting systems. The inclusion of such devices gives rise to an enormous potential for achieving more accurate and optimal bucking, and for continuous monitoring of product volumes and critically, dimensions. Once collected, such information can be employed to determine recovery and product mix and, in so doing, to test the accuracy of inventory predictions and, if deemed necessary, to allow management to intervene to alter cutting strategy.

The electronic calliper, an increasingly widespread and valued management tool, provides for the rapid collection, the storage and the downloading of data. If employed correctly, the instrument can provide accurate diameter measurements in a variety of mill and stand situations.

LITERATURE REVIEW

The linear programming model developed by Smith and Harrell (1961) represents an early attempt at determining the optimum bucking strategy to be adopted for a stand. Their approach, however, failed to include the effect of log supply and end-product demand constraints on the value of each cross-cutting strategy. This became a key component of later procedures.

MicroMARVL, the Method for the Assessment of Recoverable Volume by Log-types (Deadman & Goulding, 1979; Deadman, 1990), was developed in New Zealand, where it now receives widespread use as a means of predicting the volume and dimensions of log grades that a stand could potentially yield. The system involves a two-stage process consisting of a field cruise inventory and subsequent computer analysis. The former entails the recording of the breast height diameter and total height of sample trees and the partitioning of their stems into intervals of uniform quality, independent of potential log specifications. The analysis stage simulates the consequences, for each stem, of felling, breakage and cross-cutting in accordance with a user-defined cutting strategy, which details the permissible sizes, grades, and the value for each log-type. A dynamic programming optimization algorithm maximizes the value of the logs derived from the latter action. Compatible volume-taper equations (Goulding & Murray, 1976) are employed for the estimation of log diameter and volume.

Eng et al. (1986) also addressed this challenge of prescribing, subject to constraints, an appropriate cross-cutting strategy for an entire forest stand. They developed a Dantzig-Wolfe decomposition procedure with a principle linear program and dynamic programming subproblems to link data on stem frequency, size and quality to projected demand for a series of log types. The dynamic programming algorithm, as in the MicroMARVL system, determines the bucking strategy that maximizes the value of each sample stem. The linear program selects one of a number of potential cross-cutting patterns for the various stem classes so that financial return is maximized given constraints on the supply of raw material and end-product demands. Mendoza and Bare (1986) adopted a similar approach, while Sessions et al. (1989) developed an heuristic procedure for determining a series of log prices which, when employed for optimizing the bucking of single trees, achieves near maximum stand value subject to log length constraints.

Other computer-based models include the Purdue Forest Data Processing System (Moser, 1970 & 1972), STX (Grosenbaugh, 1974) and the North-eastern Forest Data Processing System (Wilson & Peters, 1967).

Demaerschalk (1971, 1972) developed the theory of compatible taper equations, which he defined as those which, when integrated, produce an estimate of total volume equal to that derived from an existing volume equation. The equations, which are normally used to predict stem diameter as a function of breast height diameter, distance from tip and total height, are especially valuable in cross-cutting optimization models and in estimating potential recovery by log-type based upon pre-harvest inventory data. Gordon (1983) compared compatible polynomial taper equations in the first, second, third, fourth and fifth powers for accuracy and precision with other models that included a higher power term. The latter provided more accurate estimates of merchantable volume, butt log volume and inside bark diameter, although bias, which varied with height, remained associated with predictions of diameter. Cao et al. (1980) assessed two methods, volume ratio models and taper equations, of estimating merchantable volume to specified top diameter or height limits. The non-compatible taper equation developed by Max and Burkhart (1976) emerged as the most appropriate for representing stem profile. A segmented polynomial model, similar to the Max and Burkhart equation and containing elements of Goulding and Murray's (1976) equation, was found to be a valuable multipurpose taper equation, providing sound diameter and volume predictions.

PROJECT DESCRIPTION

Objectives

In order to maximize the value of forest stands, it is first necessary to perform the following tasks:

1. Design an efficient field procedure, employing modern tools, to collect data on the dimensional properties of a standing timber lot prior to harvesting.
2. Develop a computer model to analyse inventory data and so forecast the dimensions of potential log assortments, to which values, based upon production and market constraints, can be assigned.
3. Design a control method that provides feedback information during the actual harvesting operation, allowing for the monitoring and, if necessary, the adjustment of the production process.

The outcome of completing these steps will be an integrated decision-support system that will allow management to determine the optimal approach to harvesting individual stands and to reveal, also, the consequences of adopting alternative approaches.

Palfab Ltd.

This research project is undertaken in conjunction with Palfab Ltd, a privately owned softwood sawmill. The direction of the work is, therefore, governed by the practices of Palfab and toward finding solutions to the problems it encounters and toward developing a system specific to the needs of the mill. Palfab Ltd is a medium-size mill with an annual throughput in excess of 70,000 m^3. It operates on a double shift basis. Construction timber, produced with the MEM "Teletwin" system and "Cobra" multisaw, is the principal commodity. In addition, approximately 20 percent of incoming logs are sawn as palletwood with the MEM "Quad" system. The company currently serves a mainly Irish customer base.

Palfab, through a contracted firm, mechanically harvests over 90 percent of the logs it processes from standing timber lots. The balance are purchased at forest roadside. Coillte Teoranta supplies almost 95 percent of all timber. Standard practice involves cutting just one predetermined sawlog length per stand, with occasional recourse to an alternative length (Table 2).

Table 2. Palfab's log specifications: the minimum permissible small end diameters (s.e.d.) and log lengths for Pulp, Pallet and Sawlog.

Product	Minimum s.e.d. (cm)	Lengths (m)
Pulpwood	7	3.1
Palletwood	12	2.5, 3.1
Sawlog	16	3.1, 3.7, 4.3, 4.9, 5.5
	18	3.1, 3.7, 4.3, 4.9, 5.5

Inventory procedure

The initial period of research centred on the evaluation and development of appropriate inventory procedures.

In order to investigate the potential for eliminating the need to fell and measure sample trees, required for the development of true local volume tables, an attempt was made to relate lower stem taper to that of the entire stem. The establishment of such a relationship would facilitate the prediction of total volume and volume assortments based upon a limited number of diameter measurements on the lower bole.

A site within a partially harvested Sitka spruce (*Picea sitchensis* (Bong.) Carr.) stand was selected for the study. With the aid of a calibrated pole and an electronic calliper, diameter measurements were taken on 20 randomly selected trees at heights above ground of 1.0, 1.3, 1.5 and 2.0 m. These trees were immediately felled and partially delimbed to facilitate the measurement of diameter at 1.0, 1.3, 1.5, 2.0, 5.0, 7.5, 10.0, 15.0 and, provided stems were of sufficient length, 17.5 m. In addition, the total length of the stem was also recorded for all trees felled.

The data were submitted to a dynamic programming model compiled in FORTRAN (Nieuwenhuis, 1989) to determine optimal cross-cutting strategy based upon stem dimensions and user-defined assortment values. This analysis would reveal how similar, in terms of the products yielded, the stem predicted from the lower bole measurements was to the actual stem, as measured when felled.

Focus subsequently moved towards determining the most appropriate means of representing stem profile, as regards accuracy and parsimony, and on the subsequent development of "in place" local volume tables. The inventory methodology by which this information is to be obtained is under development.

An area containing trees representative of the surrounding stand was selected for the purpose of collecting stem profile data. The diameter at breast height was measured, in millimetres, for all trees with the aid of an electronic calliper. The point at which this measurement was taken was marked on the standing tree so as to provide a means of determining stump height and all trees received a unique number to allow for future identification. The area was subsequently felled and the stems delimbed to facilitate the measurement of diameter. Measurements were taken at 0.5 m intervals to 6.0 m and at 1.0 m intervals thereafter to an approximate top diameter of 7 cm. This latter is the normal limit of merchantability in Irish forestry. The total height to tip was also recorded. Sixty-eight trees were measured, of which fourteen suffered crown breakage during felling.

The data were submitted to the SAS system (SAS, 1985) for statistical analysis. Linear, non-linear and segmented regression analyses were performed. The non-linear approach was taken to achieve a greater fit at the upper and lower extremes of the stem. The segmented model was then developed in an attempt to accommodate a change in profile occurring at quite consistent junctures on the stems of many of the sample trees.

Data analysis system

A computer spreadsheet has been designed in Microsoft Excel using the Visual Basic programming language to provide a framework for applying a rate of taper to a stand of trees of known diameter at breast height (DBH). Combined with a single length and a minimum permissible small end diameter per assortment, and an average stump height for the stand, the software allows one to determine volume recovery per product. The programme also averages the volume and small end and mid diameters of all pallet and sawlogs. The logs are then assigned to one of a number of size categories based upon their small end or mid diameters. This package represents the first stage in the development of a decision support system that will eventually allow management to maximize the value of a forest stand, given the properties of that stand and the desired log specifications.

RESULTS

Employing the dynamic programming optimisation model, a comparison between the optimal product assortment, the resultant value of the stem, and the extent to which that stem was utilized, for the felled stem data and the data of the lower bole measurements, revealed no similarities, the latter grossly over-estimating product recovery and stem value. These results would appear to support the expectation that, due to the prominent buttress, predicting the profile of Sitka spruce stems from the accessible lower bole is extremely difficult.

Utilizing the sample tree data from the second trial, the initial linear regression approach modeled diameter, the dependent variable, as a function of DBH and stem height. Both DBH and stem height were found to be highly significant. The model was found to account for over 91percent of the variation occurring in diameter.

The polynomial model introduced an additional independent variable, the square of stem height, to the two included originally. This curve, with an R-square value of 0.93, described more accurately the profile of the basal and uppermost portions of the stems than the linear model.

Determining, initially by trial and error, the most appropriate break-point for a segmented polynomial model is curently underway. Although the lines more accurately reflect the profiles of the sample stems, the reduction in the size of the data set for each line has reduced the associated R-square values. Figures obtained to-date are in the range 0.81-0.88.

FUTURE DEVELOPMENTS

It is envisaged that further studies will be required before the most appropriate means of representing stem profile can be confirmed. Segmented regression would appear to more accurately describe stem shape, though its adoption will depend greatly on the consistency of any established break-point and on the ease of its use. The inventory methodology by which the relevant data are to be collected may then be designed and tested. It is of paramount importance that any proposed inventory procedure strikes the correct balance between the cost of its implementation and the value of the information it generates. The possibility may exist for the development of a robust equation to define the profile of Sitka spruce stems, applicable to all stands of that species, though the application required to achieve this may be beyond the scope of this study.

The existing software package will continue to be refined and expanded to incorporate the selected taper equation(s) and multiple log length and diameter specifications, and to include an appropriate down-grade factor. The system must ultimately identify the most appropriate log type, from those currently in use, to be cut from a forest stand. The introduction of greater flexibility to the cross-cutting strategy will also be investigated. Allowing recourse to an alternative, 'fall-back' log-type would doubtless improve recovery, although the necessity for greater organisation and monitoring, and the need to sort merchandise, may increase operational costs. The current paucity of bucking patterns employed by Palfab will be addressed with the system by examining the ambit for altering current log specifications or for adopting new log-types to futher optimize utilization of the resource.

Establishing a link between the dimensions of a log and the products that it yields is of critical importance if mill-yard stock levels and market demand for sawn timber are to be accommodated when determining log specifications. Recognizing this, Palfab have already begun to monitor lumber recovery from the various log size categories. Utilizing fully the mensuration and communications capabilities of the harvesting machines employed by Palfab will allow for the continuous exchange of up-to-date information between forest and mill. The harvester can provide feedback on volume recovery and product mix, to which management can respond, by altering mill set-up or perhaps redefining the cross-cutting strategy for the stand. The final product, an integrated decision support system, should provide management with a reliable and dynamic tool for extracting maximum value from a forest stand (Figure 1).

CONCLUSIONS

The prototype cross-cutting software is already receiving widespread use from Palfab and yielding promising results. The inclusion of multiple log specifications, a down-grade factor and a statistically sound representation of stem profile, whether site specific or generic, should improve its value further.

The relative uniformity of Irish plantations and cross-cutting practices provides an ideal context for the development of systems for maximizing the value of standing timber lots. The potential for increasing volume recovery and improving profitability is very real, and with mills facing the prospect of competition in a "slow growing, highly competitive, price-sensitive commodity market" (Simons, 1991), very necessary too.

ACKNOWLEDGEMENT

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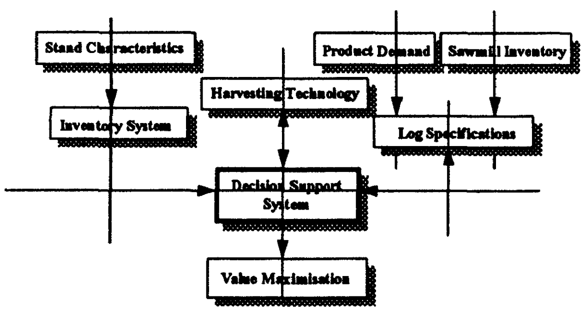

Figure 1. A schematic representation of the components of the decision support system

LITERATURE CITED

Cao, Q.V., Burkhart, H.E. and Max, T.A. 1980. Evaluation of Two Methods for Cubic-volume Prediction of Loblolly Pine to any Merchantable Limit. Forest Science 26(1): 71-80.

COFORD. 1994. Pathway to Progress: A Programme for Forest Research and Development. Council for Forest Research and Development. Dublin, Ireland. 132pp.

Demaerschalk, J.P. 1971. Taper Equations can be Converted to Volume Equations and Point Sampling Factors. Forestry Chronicle 47(6): 352-354.

Demaerschalk, J.P. 1972. Converting Volume Equations to Compatible Taper Equations. Forest Science 18(3): 241-245.

Deadman, M.W. and Goulding, C.J. 1979. A Method for Assessment of Recoverable Volume by Log Types. New Zealand Journal of Forestry Science 8(2): 225-239.

Deadman, M.W. 1990. MicroMARVL Preharvest Inventory - User Guide. N.Z. Forest Research Institute, Software series No. 7. Rotorua, New Zealand.

Eng, G., Daellenbach, H. and Whyte, A.G.D. 1986. Bucking Tree Lengths Optimally. Canadian Journal of Forest Research 16: 1030-1035.

Gordon, A.D. 1983. Comparison of Compatible Polynomial Taper Equations. New Zealand Journal of Forestry Science. 13(2): 146-155.

Goulding, C.J. and Murray, J.C. 1976. Polynomial Taper Equations that are Compatible with Tree Volume Equations. New Zealand Journal of Forestry Science 5: 313-322.

Grosenbaugh, L.R. 1974. STX 3-3-73. Tree Content and Value Estimation using Various Sample Designs, Dendrometry Methods and V-S-L Conversion Co-efficients. USDA Forest Service, Research Paper SE-117. 117pp.

Max, T.A. and Burkhart, H.E. 1976. Segmented Polynomial Regression Applied to Taper Equations. Forest Science 22(3): 283-289.

Mendoza, G. and Bare, B. 1986. A Two-stage Decision Model for Bucking and Allocation. Forest Products Journal 36(10): 70-74.

Moser, J.W. 1970. A Forest Data Processing Service for Indiana Landowners. Purdue University Agricultural Experiment Station, Research Bulletin No. 864. 28pp.

Moser, J.W. 1972. Purdue Data Processing Program Documentation. Purdue University Agricultural Experiment Station, Research Bulletin No. 891. 44pp.

Nieuwenhuis, M. 1989. Operations Research in Forestry. Irish Forestry 46 (1): 51-58.

SAS Institute Inc., 1985. SAS User's Guide, SAS Institute Inc. Cary, North Carolina, USA.

Sessions, J., Olsen, E. and Garland, J. 1989. Tree Bucking for Optimal Stand Value with Log Allocation Constraints. Forest Science 35(1): 271 -276.

Simons. 1991. The Irish Timber Industry - An Export Development Plan for the 1990's. Prepared for Coillte Teoranta, Irish Timber Council, Industrial Development Authority and Coras Trachtala. Simons Strategic Services Division, Vancouver, British Columbia, Canada.

Smith, G.W. and Harrel, C. 1961. Linear Programming in Log Production. Forest Products Journal 11(1): 8-11.

Wilson, R.W. and Peters, R.C. 1967. The North-eastern Forest Inventory Data Processing System. USDA Forest Service, Research Papers NE-61 and NE-70 to NE-80.

PROGRESS REPORT ON THE DEVELOPMENT OF AN INTEGRATED VALUE MANAGEMENT SYSTEM[1]

by

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ABSTRACT: Research carried out during the 1980's and early 1990's by NZFRI identified that the New Zealand forest industry can potentially improve the value recovered during its log-making operations by over US$50 million per year. In 1994 research began on the development of a computer vision system which could be used to automatically describe the geometry and quality characteristics of felled tree stems. The tree characteristics can then be analysed by NZFRI's log-making optimisation software, AVIS, to determine the most valuable way to cut up each tree while still meeting marketing and operational constraints. This paper provides a report on NZFRI's Integrated Value Management System and describes the current status of its prototype computer vision system.

Key Words: bucking, image processing, plantation forests, allocation

INTRODUCTION

There has been rapid growth in harvest in New Zealand plantation forests since 1985, as well as a large increase in the number of domestic and international customers purchasing wood. This in turn has led to a proliferation of log grades with different specifications and values.

Log production management has become increasingly complex and sophisticated. For example, some forest companies have to match markets, logging crews, and forest stands for over fifty log types. One company reports a four-fold increase in the number of log types between 1985 and 1990 and up to eighteen log types being manufactured on the landing at any one time (Duggan 1993).

A representative from one of New Zealand's larger forest companies recently stated that up to US$1.5 million improvement in his management region's annual revenue could be gained if they were able to capture an additional one per cent in value recovery (Duggan 1993). Nationally, it is estimated that value recovered could be improved by over US$50 million per year.

To ensure that the forest industry achieves the highest return on investment possible, the New Zealand Forest Research Institute (NZFRI) began research into improving value recovery in the early 1970s. The AVIS (Assessment of Value by Individual Stems) optimal bucking software system was one of the early products of this research effort (Geerts and Twaddle 1984). In the intervening years since the development of AVIS, NZFRI has seen the growth of a strong commitment from the forest industry to improving value recovery, including a significant investment in research and development (Murphy *et al.* 1991).

Improved value recovery will give the forest owner more return from each hectare, thereby, allowing more expenditure on techniques that will help ensure long term sustainability of the forest.

The development of tools for improving optimal bucking is one of NZFRI's R&D goals. This paper provides a report on the current status of our prototype computer vision system and how it will fit within NZFRI's Integrated Value Management System. It also briefly describes our research on allocation of cutting patterns to stands and logging crews.

NZFRI'S INTEGRATED VALUE MANAGEMENT SYSTEM

AVIS has been the primary tool for monitoring and measuring value recovery from single stems since the early 1980s. Use of the AVIS dynamic programming algorithm as a key part of a larger system for optimising log production in real time was proposed by Murphy (1987) who suggested that "one could envisage a value control system with a market feedback mechanism whereby the prices driving the decisions about individual trees are influenced by the aggregate supply and demand of logs ... The log-makers would [periodically] transfer the log product information they had gathered on their hand-held micro-computers onto

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a mini-computer or mainframe computer .... [and] summarised information would then be combined with current market information to calculate updated product [relative] prices". In the late 1980s NZFRI began to develop such an integrated value management system.

A feature of NZFRI's Integrated Value Management System was that every stem would have to be assessed and optimally made into logs. It was, therefore, considered necessary that stem data be automatically captured. Murphy and Cossens (1995) describe three types of electronic callipers, developed by NZFRI and other companies, which automate data capture of stem geometry. However, stem quality still needs to be subjectively determined and manually entered in conjunction with these callipers. This has led to the development of a prototype computer vision system which will handle both stem geometry and stem quality data capture.

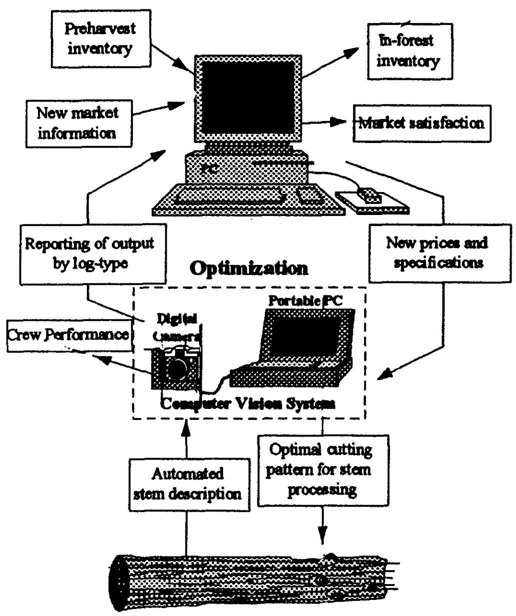

Figure 1. NZFRI's Integrated Value Management System.

In addition, the need to feed back updated product specifications and prices to each of the computer vision units in the forest has led to the exploration of several approaches to optimising cutting pattern and stand allocation for logging crews.

Since the development path for NZFRI's Value Management System may extend into the early 21st century, our development process stresses modularity with the intention of producing some components that can also stand alone.

COMPUTER VISION SYSTEM

Research into the application of computer vision systems to the optimal log-making problem was begun in late 1993. This work is still in its early stages.

The geometric information (eg., diameter, sweep, ovality and length) will be captured through the use of stereo images, obtained with digital photography, as the log-maker walks the length of the stem. It is intended that the series of images will be used to generate a complete stem model, based on images of at least 50% of the stem circumference, using modified image analysis procedures developed by Lane (1994).

The same images will be used to assess externally visible qualities (eg. pruned zone, knot size, scarring, splitting, etc.) along the length of the stem. Although this is likely to be a more difficult task than simply capturing geometric information it was thought to be a vital capability for two reasons: 1) assessment of quality could be speeded up, and 2) consistency of quality assessment could be improved.

Design and implementation

The software structure of the computer vision system has been divided into three operational modules that reflect the different tasks it performs. As a sequence of overlapping images is entered into the computer, each image will be processed sequentially by the correlation module and the quality assessment module. The results of these two operations will then be passed to the mensuration module to construct the geometric stem description, which can be fed into the AVIS optimiser to compute the optimal bucking pattern for that stem.

Correlation module

The correlation module will use image processing techniques to remove the background from each image. It will then segment the image in order to isolate and classify stem features, such as bark fissures, that fall into the region of the image that overlaps with the previous image. These features can then be matched to their complements found in the previous image.

The matching algorithm is an extension of an earlier algorithm developed by Lane (1994). Each individual stem feature will be classified parametrically as a collection of geometric nodes connected by vectors forming a description of the feature that is insensitive to variations in scale and rotation. Each feature is represented by a node in a graph structure that contains all the features for a particular image. The feature graphs of two adjacent, overlapping images are then roughly correlated and the matches refined by comparisons of the individual feature descriptions. This approach takes advantage of both the consistent spatial distribution of the stem features between images as well as the individual feature characteristics.

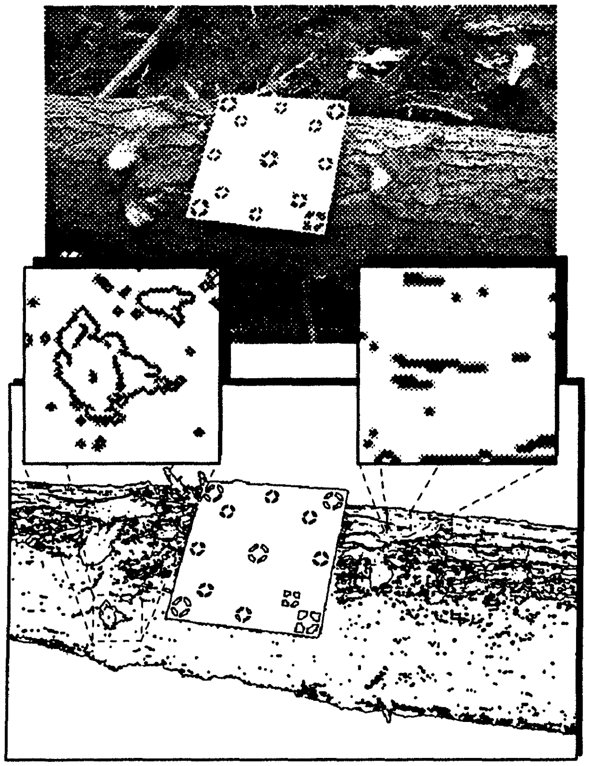

Figure 2. Image processing will reduce the image information to individual matchable features such as knots (left inset) and bark fissures (right inset). Note the calibration target.

Quality assessment module

The quality assessment module will perform an active filtering operation on each image to detect image signatures indicating the presence of knots or other stem features that have a bearing on stem quality. In general, knots appear as roughly elliptical marks in the image, which can be detected, for instance, through a sequence of image processing transformations. The edges of each suspected knot will be determined in the same process. Each suspected knot signature will be confirmed by checking the adjacent image for a similar signature. Some heuristic knot recognition criteria based on knot position, orientation, size, and color will be applied as well.

Mensuration module

Once gathered, the correlation and knot location data will be passed to the mensuration module which transforms the images into a single coordinate frame and generates a three dimensional map of the stem surface. This process is carried out as follows: the image coordinate pairs that correspond to the locations of matched stem or knot features will be processed photogrammetrically by a relative orientation algorithm. This provides the orientation information used to transform all of the images into a single reference frame, and given approximate parameters for the camera positions for each image, a rough scale estimate for the three dimensional locations of the matched features is computed.

The relative orientation results are used as the initial conditions for a bundle adjustment algorithm, currently under development, which refines the computed feature locations using the image signatures of a few calibration targets (see Figure 2.) of known size to compute an exact scale. Note that the calibration targets are distributed at rough intervals along the length of the stem before the images are acquired and appear in several adjacent pairs of images.

The cluster of spatial coordinates computed by the bundle adjustment will be used to determine stem geometry as well as stem cross sections at regular intervals along the stem. In keeping with industry standards, each cross section will be approximated by best fit ellipses which indicate the orientation and dimensions of the major and minor diameters of the stem at that location.

Work to date has concentrated on the mensuration module as its reliability and accuracy are paramount if the system is to perform as required. Current development and testing of this module is being done using synthetic image sequences rendered from a generic stem description with texture mapped bark and knots, and stem features. Features are being matched manually with the aid of a graphical user interface, shown in Figure 3, which runs under XWindows on a 486dx2-66 PC running the Linux operating system.

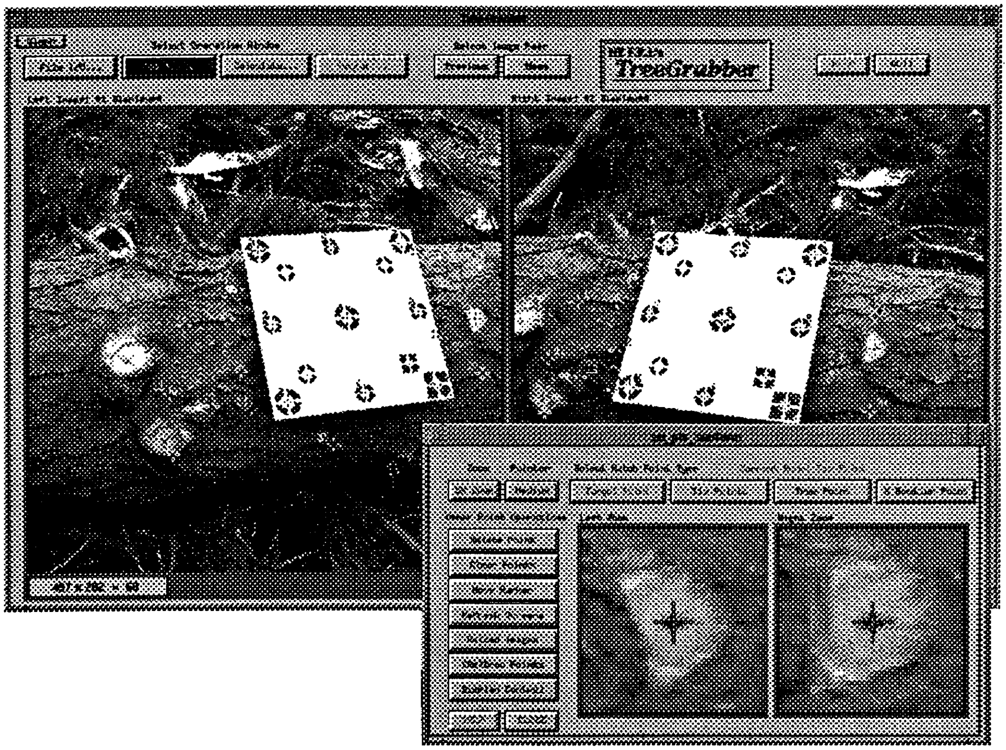

Figure 3. Screen capture of the XWindows interface showing stem images with matched feature points and zoom windows.

INTEGRATED PRODUCT OPTIMISATION

Although much of the research to date has focused on automating the data capture, some research has begun on constrained market optimisation and how to generate new prices and allocate log grades to individual logging crews.

As mentioned above AVIS optimises the value recovery from single trees, but what is "optimal" for the single tree is seldom "optimal" for the forest company, which must satisfy market demand and operational constraints. Many forest owners in New Zealand have negotiated log sales that require a given percentage of the volume be delivered in logs of a specified length and that average small end diameters must be greater than a given value. Constraints on the minimum or maximum amount of volume of a given log-type are also common.

The importance of developing a value management system which can optimise the combined value recovery performance for a forest company's logging crews was demonstrated in a recent pilot study by one of the authors when he found that value recovery could be improved by between 14 and 22% by choosing the best set of products and prices (cutting pattern) for a logging crew's cut. In an earlier study, Ferrow and McKewen (1980) found that over a third of the potential value of a sample of trees was unrealised by another New Zealand company due to failure in planning to match cutting patterns with stands and markets.

Two approaches to allocating cutting patterns to stands have been explored; iterative linear programming/ dynamic programming and tabu search heuristics. Each of the approaches has slightly different features and advantages. In particular, the LP/DP approach generates it own sets of cutting patterns from an initial cutting plan, whereas the tabu search heuristic requires user-supplied cutting patterns from which it selects an "optimal" solution.

Linear programming

Cossens (1996) has recently developed an iterative LP/DP model, which is capable of selecting cutting patterns to be used in each stand and provides values for log products that would result in efficient forest resource allocation during harvesting. The model also considers demand requirements over multiple time periods.

A dynamic programming algorithm in the MARVL (Method for the Assessment of Recoverable Volume by Log-type) inventory system (Deadman and Goulding, 1979) is used to generate new columns for a Dantzig Wolfe (DW) linear programming decomposition formulation (Dantzig and Wolfe, 1961).

The DW algorithm has been successfully implemented, using the C programming language and has been tested on two small problems. The program generates new cutting patterns and values as well as demonstrates iterative progress towards a maximum solution. Output from the model includes the proportion of time that generated cutting patterns should be used. Two of the useful features of decomposition are that (1) near optimal solutions can be easily evaluated, allowing a manager the option of selecting a solution that requires fewer changes in cutting patterns, and (2) the algorithm can be terminated if convergence is too slow.

Further development is underway to turn the model into a production tool. Improvements include the development of a matrix generator, modifications to allow automatic interaction with MARVL, restriction of product combinations and strategies and crew allocation to stands.

Tabu search heuristics

Whereas the LP/DP formulation should "guarantee" an optimal solution to the problem, a heuristic may only provide a "good" solution. However, heuristics are being applied to an ever widening range of forestry problems today because of their ability to solve difficult problems in a reasonable amount of time (Sessions 1985, Guignard et al. 1993, Laroze and Greber 1993, Mendoza et al. 1993, Ogweno 1995).

Glover (1989) presents the fundamental principles underlying tabu search as a strategy for combinatorial optimisation problems. He presents tabu search in a simple form that discloses two of its key elements: that of constraining the search by classifying certain of its moves as forbidden (ie, tabu), and that of freeing the search by a short term memory function that provides "strategic forgetting".

An algorithm that combines tabu search principles with a simple improvement-swapping heuristic has been developed for allocating logging crews and user-supplied cutting patterns to stands for a single time period. Individual logging crew productivity is taken into account.

A limited set of market and operational constraints have been included. These include constraints on: volume production (minimum and maximum); percentage requirements for given log lengths; minimum average small end diameter targets; and "preferred" and "no-go" stands for individual logging crews.

The algorithm has been implemented on an 8Mb 486dx2-80 CPU in Visual Basic (Version 1) as the TABU program. Tests have been carried out on up to 60 stands, 12 logging crews and 5 cutting patterns (each with 5 log-types). The user can specify the number of iterations over which improvements in value are searched for. The "best" solutions have usually been found within one or two minutes. An example of the output from a simple 10 stand, 5 crew, 5 cutting pattern problem is shown in Figure 4.

LOGGING CREW AND
CUTTING PATTERN ALLOCATION

03-25-1996 08:46:04

Number of Iterations is 10
Number of Tabu Moves is 5
Number of Logging Crews is 5
Name of Stand File is c:\native.std
Name of Crew Productivity File is c:\native.prd
Name of Crew Preferences File is c:\native.prf
Name of Initial Feasible Solution File is c:\native.ini
Name of Constraint File is c:\native.con
Name of Output File is c:\native.out

******* BEST SOLUTION REPORT *******

Crew Name	Stand Location	Cutting Pattern
Rimu	S65	3
Kahikatea	S72	4
Matai	R69	2
Totara	M866	5
Kauri	S64	1

Objective function = $ 495610

Peeler Volume = 1074 tonnes
Export long % = 74 %
Average SED for domestics is 31.7 cm

Figure 4. Example output from Tabu Search Heuristic.

SUMMARY

Development of a computer vision system for automatically assessing tree stem geometry and qualities is at an early stage.

The data captured by the computer vision system will be used by the AVIS dynamic programming algorithm, which has had over a decade of testing and application, to optimise single stems.

To ensure that the single stem optimisation also meets market and operational constraints new procedures are being developed to allocate the best cutting patterns and stands to each logging crew. Computer vision, single stem "optimisation" of all stems, and a market feed-back mechanism will be three of the key components of NZFRI's Integrated ValueManagement System.

LITERATURE CITED

Cossens, G.P. 1996. Optimisation of short term log allocation. Lincoln, New Zealand: Lincoln University. 124 p. M. Applied Science thesis. (submitted March 1996).

Dantzig, G.B.; Wolfe, P. 1961. The decomposition algorithm for linear programs. Econometrica 29:767-778.

Deadman, M.W.; Goulding, C.J. 1979. A method of assessment of recoverable volume by log types. New Zealand Journal of Forestry Science 9(2): 225-239.

Duggan, M. 1993. Value materialisation opportunities in harvesting. In: Quality issues in processing and harvesting. Proceedings of a seminar held in Rotorua, June 1993. New Zealand Logging Industry Research Organisation. Rotorua.

Ferrow, G.; McKewen, B.J. 1980. The determination of the profit sacrificed in felling, extraction and log allocation processes. Hamilton, New Zealand: University of Waikato. 91 p. Bachelor of Management Studies dissertation.

Geerts, J.M.P.; Twaddle, A. 1984. A method to assess log value loss caused by cross-cutting practice on the skidsite. New Zealand Journal of Forestry 29(2): 173-184.

Glover, F. 1989. Tabu Search - Part I. ORSA Journal in Computing 1(3): 190-206.

Guignard, M.; Chajakis, E.; Ryu, C. 1993. Lagrangian bounds and heuristics for integrated resources planning in forestry. In: Proceedings of an international symposium on system analysis and management decisions in forestry. Valdivia, Chile; March, 1993: 350-363.

Lane, D.C. 1994. A prototype system for automated step-wise close-range digital image matching and three dimensional terrain reconstruction. Seattle, WA: University of Washington. 140p. MS(ME) thesis.

Laroze, A.; Greber, B. 1993. Using Monte-Carlo simulation to generate rule-based bucking patterns. In: Proceedings of an international symposium on system analysis and management decisions in forestry. Valdivia, Chile; March, 1993: 153-165.

Mendoza, G.; Carnieri, C.; Luppold, W. 1993. Heuristic and analytical solution procedures for optimal cutting of lumber: an overview. In: Proceedings of an international symposium on system analysis and management decisions in forestry. Valdivia, Chile; March, 1993: 343-349.

Murphy, G.E. 1987. An economic analysis of final log manufacturing locations in the steep terrain radiata pine plantations of New Zealand. Corvallis, OR: Oregon State University. 420p. Ph.D. thesis.

Murphy, G.E.; Twaddle, A.; Cossens, G.P. 1991. How to improve value recovery from plantation forests: research and practical experience in New Zealand. In: Forestry operations in the 1990s: challenges and solutions. Proceedings of the 14th annual meeting of the Council on Forest Engineering; Nanaimo, British Columbia; July 1991: 30-38.

Murphy, G.E.; Cossens, G.P. 1995. New tools for maximising value recovery from plantation forests. In: Applications of new technologies in forestry. Proceedings of the Institute of Foresters of Australia Sixteenth Biennial Conference, Ballarat, Victoria, April 1995: 185-190.

Ogweno, D.C.O. 1995. Integrated optimisation of operational and tactical planning of log production. Christchurch, New Zealand: University of Canterbury. PhD. thesis.

Sessions, J. 1985. Network analysis using microcomputers for logging planning. In: Improving mountain logging planning, techniques and hardware. Proceedings of a joint symposium of the IUFRO Mountain Logging Section and the Sixth Pacific Northwest Skyline Logging Symposium, Vancouver, British Columbia, May 1985: 87-91.

THE COST OF PRODUCT SORTING DURING HARVESTING[1]

by

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ABSTRACT: Integrating harvesting with the sorting of multiple products is a reality that many companies and their contractors must adapt to. This separation of products can be performed at several stages during harvesting. This reports combines the results of published and unpublished studies to describe the advantages and disadvantages of separating two or more products using the various machines in full-tree, tree-length and cut-to-length harvesting systems. The cost of separating six products is simulated with three different harvesting systems.

Key Words: harvesting system, integrated harvesting, sorting, economic analysis, costs, value-added, fiber quality

INTRODUCTION

Today, integrated harvesting of multiple forest products is a reality that many industrial wood users, notably harvesting contractors, must adapt to. This multiproduct harvesting implies the sorting of various products to maximize the value and quality of the raw material and to satisfy the requirements of different users.

Separating stems into different products in the forest during harvesting operations entails a cost for whoever must perform this work. This additional cost arises in part from potential decreases in the productivity of the machines that must now include a product separation phase in their work cycles and from the creation of piles that will permit loading and hauling of the separated products. The value added by producing separate products does not generally provide any direct benefits to the person responsible for the sorting. Therefore, it is important to accurately quantify the related costs to equitably reward the person who assumes this responsibility and to evaluate the economics of carrying out a specific type of sorting.

The goal of this paper is to describe the magnitude of the costs related to multiproduct harvesting. The data in this report come from published and unpublished studies conducted by the Forest Engineering Research Institute of Canada (FERIC), as well as studies produced by other research organizations. The last part of this report presents a cost simulation that compares the separation of six products using three harvesting systems.

SORTING OPTIONS

Product separation can be carried out in several places, including at the stump, at roadside or in a satellite mill, depending on the operational context. Figure 1 illustrates the in-woods sorting possibilities for the most common harvesting systems in eastern Canada

The separation of stems into two or more products can be done based on several criteria, which depend on the specific requirements of the mills. Stems can be sorted:

1. by species or species group;
2. by quality criteria (e.g., form, defect, decay, etc.);
3. by size criteria (e.g., diameter, length); and
4. by end-product (e.g., lumber, pulp, veneer, other).

Choosing the best method of carrying out the sort is constrained by (1) the harvesting system used, (2) the configuration of the haul trailers, (3) the structure of the forest, and (4) the number of products to separate.

PRODUCT SEPARATION INTEGRATED WITHIN FULL-TREE OR TREE-LENGTH SYSTEMS

The phases in full-tree or tree-length harvesting that lend themselves to sorting are mechanized felling, cable skidding, mechanized delimbing, and truck loading.

Sorting with feller-bunchers

Feller-bunchers can sort full-trees simply by creating separate bunches. The usual method involves forward or backward carrier travel just before placing a tree in a bunch. Since feller-bunchers work rapidly, they cannot be expected to perform anything more than a coarse separation of species or sizes (Figure 2). Also, the creation of separate bunches increases carrier movement, and this could reslt in more rapid wear of

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

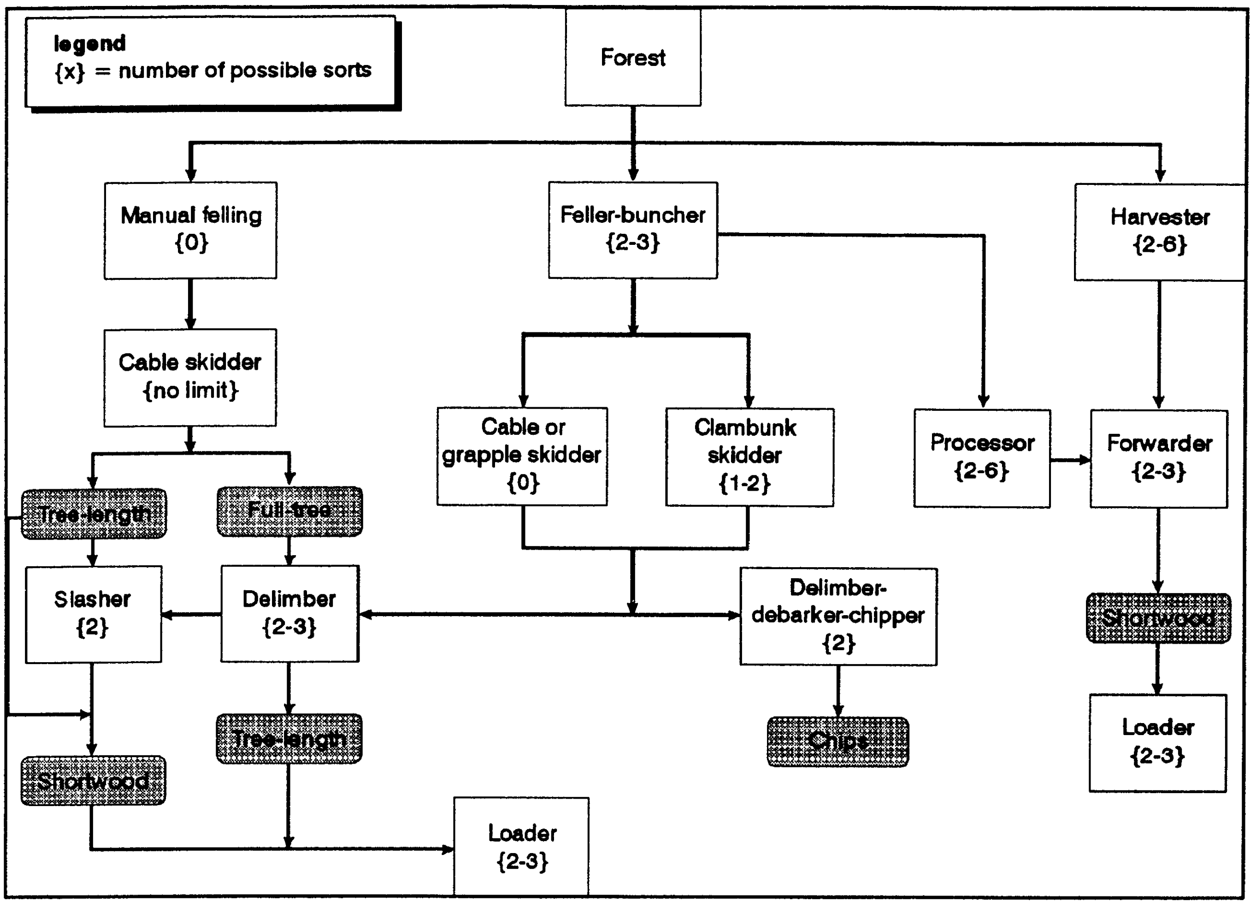

Figure 1. Options for multiproduct sorting using current harvesting systems in eastern Canada.

Figure 2. Size sort with a feller-buncher

the drive components, and more pronounced rutting in soft ground. Based on FERIC studies, the productivity reductions resulting from the sort of two or three products amount to about 5 and 10% respectively.

Sorting during skidding

In the context of mechanized felling, it is not realistic to separate products using grapple skidders or cable skidders because of the amount of work involved. Although a clambunk skidder could use its loading boom to separate species, this would be unproductive and thus expensive because few stems would be loaded simultaneously into the bunk.

In manual felling, cable skidders can be used to separate stems by species into distinct piles at roadside, simply by unhooking the chokers holding the stems in front of the appropriate piles (Figure 3).

Several factors can affect the time required to create sorted piles. The most important are the number of piles, the distance separating the piles and the space available for maneuvering around the piles.

Figure 3. Unchoking stems into separate piles by species using a cable skidder.

Sorting with stroke delimbers

Stroke delimbers are often used for separating two, three or even four products. Since the stems are typically handled one at a time, it is easy to lay them in different locations. Roadside processing permits sorting that would more heavily penalize the productivity of multi-stem machines working on the cutover like a feller-buncher.

The main problem posed by separation of stems into different products using a delimber is the crowding of the landing by the separate piles of tree-lengths. In effect, since the species are randomly distributed in the undelimbed piles of stems, it is difficult to plan the best position of the stems other than those of the primary product, which typically occupies a position perpendicular to the road. Depending on the available space, on the configuration of the road and ditches, and on the number of products, the secondary products can be placed:

1. in separate piles, parallel to the primary pile;
2. on top of the primary pile, but positioned some distance back from the edge of the pile, overhanging the edge of the pile, or diagonally atop the pile;
3. in the ditch, parallel to the road and in front of the primary pile; and
4. on the opposite side of the road.

FERIC studies have found that the productivity losses associated with sortting two and three products with stroke delimbers are in the order of 10 and 15 percent respectively.

Sorting with slashers

The separation of logs with similar characteristics can occur during the slashing phase. In effect, the slasher can process each bolt according to particular specifications and can create distinct piles. In practice, the limited mobility of the slasher's carrier limits to two or three the number of distinct piles that can be created. In addition, it is often tempting to process several stems simultaneously to increase productivity, but this has the effect of reducing the proportion of the higher-value products. FERIC estimates that the productivity reductions associated with the creation of two products with a slasher are in the order of 30 percent when compared to the production of pulpwood only.

SEPARATION OF PRODUCTS INTEGRATED WITH CUT-TO-LENGTH HARVESTING SYSTEMS

Cut-to-length harvesting systems lend themselves well to product separation, whether at the stump (by the harvester or the processor) or at roadside (with the forwarder or processor).

Sorting with single-grip harvesters

As with a delimber, a single-grip harvester can easily separate its products because it usually handles only a single stem at a time. While processing the felled stems, it is easy to move the harvesting head slightly to create two, three or four distinct piles, with no detectable loss of productivity. This has been demonstrated in several studies in the Nordic countries (Mikkonen 1977, Kuitto 1980, Bjurulf 1992).

Sorting with a processor

A processor can operate at roadside, but typically works on the cutover behind a feller-buncher or a manual faller. In eastern Canada, there are two main processor configurations: a single-grip processor whose processing head is mounted at the end of an articulated boom and a two-grip processor whose processing unit is mounted on the carrier.

The ease of separating products with single-grip processors is comparable to that with a single-grip harvester. The creation of different piles is more difficult with two-grip processors, since this requires back and forth movements of the machine or rotation of the processing unit. Moreover, the slashed logs fall from relatively high above the ground, and tend to bounce. It is thus more difficult to control the exact position of each log. Bjurulf (1992) measured a very slight 2 percent productivity loss during the separation of four products with a two-grip machine.

Sorting with a forwarder

Thanks to its articulated boom, a forwarder can also be used to carry out some sorting of products. Three scenarios are possible. In order of increasing cost, these are:

1. separately transporting products that have been entirely sorted beforehand by the processor or the harvester;
2. carrying out an additional separation working from piles already partially sorted by the harvester; or
3. conducting product separation entirely at the time of loading or unloading.

The results obtained by Bjurulf (1992) show an increase in time caused by product separation of 15 and 20 percent for sorting two and three products respectively, after partial sorting by a harvester. This is a result of increased loading and unloading times, but also of the increased number of trips per trail when the volume of a single product is insufficient to provide a full load.

The feasibility of transporting more than one product in a single trip depends greatly on the operator's skill, as well as on the log length and the distribution (volume and position) of the various products. Several scenarios for product separation are possible. In order of decreasing feasibility:

1. One product can be loaded while the forwarder moves to the back of the block, and the second during the return to roadside. Thus, the products are separately along a horizontal plane in the load bunk during loading.

2. One product can be placed to the left of the bunk and another to the right; that is, the products are separated along a vertical plane within the bunk. The forwarder's load bunk can also be modified (e.g., with the addition of pickets) to help keep the products separate.

3. For short logs (less than 3 m), one product can be placed at the front of the load bunk and one at the rear.

COMPARATIVE ANALYSIS OF THREE SORTING SCENARIOS

This section presents a simulation of three different product-separation scenarios that a manager can choose among to supply six products to six different mills. This type of situation is common in eastern Canada.

For this simulation, it is assumed that the harvest occurs in a mixedwood forest containing 30 percent trembling aspen (0.30 m3/stem), 20 percent jack pine (0.20 m3/stem) and 50 percent spruce-fir (0.15 m3/stem). The six products to be separated are:

1. 2.5-m aspen logs for waferboard;
2. 5.0-m aspen logs for veneer;
3. 5.0-m spruce-fir sawlogs;
4. 2.5-m spruce-fir pulpwood;
5. 5.0-m jack pine sawlogs; and
6. 2.5-m jack pine pulpwood.

The three production options include one full-tree system and two cut-to-length systems:
a feller-buncher and grapple skidder, with a delimber and a slasher;

1. a feller-buncher and a two-grip processor with a forwarder; and
2. a single-grip harvester with a forwarder.

The results of the simulation appear in Tables 1, 2 and 3. The costs for each product ($CAN/m3) reflect the effect of separating the products and of the average volume per species or product.

The net cost at roadside is lowest with the full-tree system. The simulation gives an additional cost of $CAN 1.77/m3 for the separation of six products, which is 14.5% more than the baseline cost of $CAN 12.20/m3 if all the volume is transformed into pulpwood. The separation into sawlog and pulpwood piles at the time of slashing is the factor that contributes most to this increase.

The cut-to-length system that uses a feller-buncher and a processor sees a cost increase of $CAN 1.33/m3 for separating six products, an increase of 8% over the baseline cost without product separation. The use of a single-grip processor, which is less expensive than the two-grip machine in the simulation, would reduce the overall cost of this system.

Table 1. The costs of sorting products in the simulated full-tree harvesting system

	Cost ($CAN/m3)			
	Without sorting	Aspen products	Jack pine products	Spruce-fir products
Feller-buncher, separation of aspen and softwoods (base productivity - 5%)	3.97	3.73	4.47	4.47
Grapple skidder[a]	2.68	2.12	2.96	2.96
Delimber, separation of jack pine/spruce-fir (base productivity - 10%)	2.91	2.46	3.27	3.72
Slasher, separation of pulpwood and sawlogs (base productivity - 30%)	2.64	3.45	3.77	3.96
Total cost	12.20	11.74	14.47	15.11
Weighted total cost	---		13.97	
Additional (sorting) cost	---		1.77 (+14.5 %)	

[a] At a 100-m skidding distance.

Table 2. The costs of sorting products in the simulated cut-to-length harvesting system with a feller-buncher and a processor

	Cost ($CAN/m3)			
	Without sorting	Aspen products	Jack pine products	Spruce-fir products
Feller-buncher, separation of aspen and softwoods (base productivity - 5%)	3.97	3.73	4.47	4.47
Processor, separation of softwoods and two aspen products (base productivity - 2%)	7.24	6.13	7.48	8.61
Forwarder, separation of softwood pulpwood and sawlogs (base productivity - 15%)[a]	5.29	5.29	6.22	6.22
Total cost	16.50	15.15	18.17	19.30
Weighted total cost	---		17.83	
Additional (sorting) cost	---		1.33 (+8.0 %)	

[a] At a 150-m forwarding distance.

Table 3. The costs of sorting products in the simulated cut-to-length harvesting system with a single-grip harvester

	Cost ($CAN/m3)			
	Without sorting	Aspen products	Jack pine products	Spruce-fir products
Single-grip harvester, separation of softwood species and two aspen products	10.57	7.79	10.22	12.39
Forwarder, separation of softwood pulpwood and sawlogs (base productivity - 15%)[a]	5.29	5.29	6.22	6.22
Total cost	15.86	13.08	16.44	18.61
Weighted total cost	---		16.52	
Additional (sorting) cost	---		0.66 (+4.2 %)	

[a] At a 150-m forwarding distance.

Of the three systems that were simulated using the study's assumptions, the cut-to-length system with a single-grip harvester was the least affected by the product separation, with a cost increase of $CAN 0.66/m3, which amounts to 4.2% of the baseline cost (without product separation). This result is attributable to the fact that the harvester's productivity is almost unaffected by the creation of distinct product piles during processing.

CONCLUSIONS

In this report, the results of several studies were combined to determine the costs and feasibility of various options for sorting products at the stump or at roadside using machinery commonly used in the main full-tree and cut-to-length harvesting systems in eastern Canada. Table 4 summarizes the productivity correction factors for each machine in terms of the number of products to sort.

Table 4. Correction factors for sorting[a]

	Number of products to sort		
	2	3	4
Machine			
Feller-buncher	-5%	-10%	n.a.
Delimber	-10%	-15%	n.a.
Slasher	-30%	n.a.	n.a.
Single-grip harvester	0%	0%	0%
Processor (two grip)	-2%	-2%	-2%
Forwarder	-15%	-20%	n.a.

[a] n.a. = not available.

Cut-to-length harvesting systems, particularly those that use single-grip harvesters or single-grip processors, are the best adapted for carrying out multiple-product sorting at the lowest additional cost. It is thus not surprising that the popularity of these systems is increasing in the current context of integrated multiproduct harvesting. In contrast, full-tree harvesting systems remain the least expensive and can also be modified to permit the separation of different products, particularly if there are relatively few products to separate. In this case, the feller-buncher or the delimber can be used effectively.

REFERENCES

Bjurulf, A. 1992. Sorteringklossen. [Sorting costs during harvesting.] SkogsForsk, Uppsala, Suède. Rapport 1992-10-07. 30 p.

Kuitto, P.J. 1980. Puutavaran lajittelun tuotos - ja kustannussvaikutukset. [Output and cost effect of the sorting of timber.] Metsateho, Helsinki, Finlande. Rep. 362. 18 p.

Mikkonen, E. 1977. Puutavaran ljittelu monitoimikoneilla. [Timber sorting with multi-purpose machines.] Metsateho, Helsinki, Finlande. Rep. 344. 26 p.

INTERNATIONAL STANDARDS FOR FOREST EQUIPMENT[1]

by

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ABSTRACT: There are many current standards and standards activities which affect the design and application of forest equipment. Within the standards-setting community there are also efforts to achieve greater harmonization and utilization of standards products. This paper reviews how standards for forest equipment are developed and maintained, and identifies important committees and advisory groups. Standards affecting forest equipment are described with discussion of the impact of standards on designers and users. Finally, current coverage of standards is analyzed to identify key areas for future standards development which will benefit the forest engineering community.

Key Words: forest equipment, terminology, machine design

INTRODUCTION

What would the world be like without standards? Standards affect every aspect of our daily lives from the foods we eat to the things that we use. Standards give consumers confidence in the products they purchase, insure compatibility between products from different manufacturers, define minimum acceptable levels of product performance or safety, and promote a growing economy through more unrestricted trade. Consider the benefits of standard weights and measures, standard symbols for signs and operating controls, standard dimensions for connectors, and standard conventions for coding electrical signals. Standards make life simpler and increase the capabilities of the goods and services we use.

While forestry is affected by general standards such as oil viscosity (SAE weight), hydraulic fittings specifications, or bolt dimensions, there is a growing need for the development of specific standards with the forest industry. Global marketing of forest equipment requires common terminology and specification definitions. New technologies and new applications of existing machines require consideration of acceptable safety standards. The proliferation of third-party attachments such as harvester heads would benefit from standardized connections to the primary machine. Comparison of equipment performance and evaluation of environmental effects requires standardized methods and tests.

People in the forest engineering community need to understand the benefits of using standards as well as participate in the development of useful documents for furthering the industry. The objective of this report is to provide some background information on the standards process and to illuminate the potential application of standards for forest operations.

STANDARDS DEVELOPMENT

Organizations

In more specific terms, "Standards are documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics, to ensure that materials, products, processes and services are fit for their purpose." (ISO, 1996). There are basically two types of standards--voluntary consensus documents and regulatory documents. Voluntary consensus standards are generally developed by the parties that will be affected such as a committee of industry representatives. Through the standard document, the committee defines generally accepted practice or design. After the document is published users are free to conform or not as they choose.

A regulatory standard, on the other hand, is associated with some penalty for non-compliance. An employer who violates the OSHA logging safety standard, for example, can be fined. A manufacturer who does not meet European Community (EC) requirements is unable to import products into the European Community. Regulatory standards, rather than defining commonly accepted practices, try to set minimally acceptable performance limits.

Standards are constantly being developed by many organizations around the world (Table 1). Specific documents are usually produced by a focused standards-developing-organization (SDO). The American Society of Agricultural Engineers (ASAE), for example, is an SDO that concentrates on documents affecting agricultural operations. The Society of

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

Table 1. Some standards developing organizations engaged in forestry standards work.

Organization	Web address
American Society of Agricultural Engineers, FE-01 Forest Engineering Executive Committee	http//www.asae.org
American National Standards Institute	http//www.ansi.org
Society of Automotive Engineers, Machine Technical Committee, SC4	http//www.sae.org
Occupational Safety and Health Administration	http//www.osha-slc.gov
International Standards Organization (ISO) Technical Committee 23, Tractors and machinery for agriculture and forestry	http//www.iso.ch

Automotive Engineers (SAE) works on standards affecting the mobility industries. Individual SDO's are represented by national standards groups such as the American National Standards Institute (ANSI) and the Deutsches Institut für Normung (DIN). At the international level, consensus standards are developed through the International Organization for Standardization (ISO), a worldwide federation of national standards bodies.

Society of Automotive Engineers

Historically, SAE has been the primary organization for standards affecting mobile machinery in the U.S.. Through various committees, SAE develops and maintains documents which affect passenger vehicles, trucks, buses, off-highway mobile equipment, and aerospace vehicles. These standards include topics such as common symbols, dimensioning, test methods, and terminology. Most of the standards which affect forestry are developed under the guidance of the Construction and Agriculture (CONAG) Council (Figure 1).

CONAG is made up of seven Technical Committees which cover specific functional areas. Each Technical Committee is turn composed of several Subcommittees. For example, the Machine and Operator Protection Technical Committee coordinates documents relating to general operator protection. This Technical Committee has nine subcommittees which generate documents. Standards specific to forestry machinery are generated by Subcommittee 4 of the Machine Technical Committee.

American Society of Agricultural Engineers

While SAE has worked on machine-specific standards, ASAE has taken the lead on standards for implements

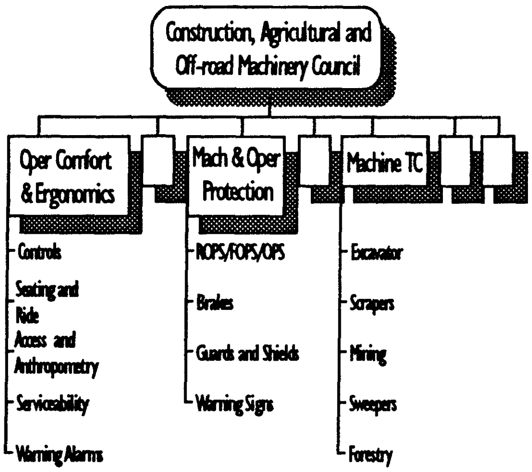

Figure 1. Organizational structure of the CONAG Council of the Society of Automotive Engineers (SAE).

("behind the hitch"). ASAE standards cover topics specific to agriculture such as irrigation systems, tractor performance testing, food processing and handling, and design of structures. Like SAE, there is a hierarchial structure of committees. Specific standards documents are generated by subcommittees within divisions. A Committee on Standards (T-1) coordinates and reviews the standards activity of the Society. Forestry documents are developed in the Forest Engineering Group of the Emerging Technologies Division.

International Organization for Standardization

ISO was established in 1947 to facilitate the international exchange of goods and services. Headquartered in Geneva, Switzerland, ISO coordinates the work of 2700 technical committees, subcommittees, and working groups. ISO standards cover a wide range of topics including quality management systems (ISO 9000), paper sizes (ISO 216), symbols for road signs and automotive controls, and the SI measurement system. Each country is represented by one member body on ISO document work. ANSI, for example, is the official representative for the United States.

Like SAE and ASAE, ISO has a hierarchial structure of subject-specific Technical Committees and Subcommittees. Technical Committee 23(TC23) maintains nearly 250 standards for tractors, machines and equipment used in agriculture and forestry. There are 13 subcommittees operating under TC23. While forest machines are included in the scope of many of these subcommittees, most forest equipment documents are developed in Subcommittee 15 "Machinery for forestry", Subcommittee 17 "Manually portable forestry machinery", or Subcommittee 14 "Operator controls, operator symbols and other displays, operator manuals."

Document development

Consensus standards are developed in an iterative process of drafting, balloting, and review. A standard originates in a group such as SAE as a new work item. There may be a formal process to assign the work item to an appropriate subcommittee for development. At the subcommittee level, a document sponsor assumes direction for developing an initial draft. The draft is circulated, discussed, and redrafted until the subcommittee feels that a consensus has been reached. The document then starts a process of balloting through the organizational levels. After each ballot stage the document may be referred back to the originating committee for rewriting. Finally, the successful document is approved by the executive committee and published.

Publication is not the end of the process, however. Every standards document is maintained throughout its lifetime. Requests for revision of documents can be prompted at any time by changes in technology. Periodically, standards documents must be reviewed by the originating committees and revised or reaffirmed. Eventually, some documents become obsolete and are eliminated.

In the development and revision process documents may evolve through several classifications. SAE, for example, designates documents as Information Reports or Standards. This type of classification is intended to differentiate between documents which are simply good information and those which identify generally accepted engineering practice. ASAE has designations for Data Documents, Standards, and Tentative Standards. A document may start out as an information report and be elevated in the next review cycle to a standard.

While all of the organizations discussed in this report follow similar processes, international standards add an additional level of review and balloting. A national standard, such as an ASAE document, can be proposed as the basis for an ISO document. In this situation, a new subcommittee begins to review and redraft and ultimately publish the document. When the final ISO document and the original are reasonably similar, the document may be dual-numbered by both ISO and the originating society.

The consensus standard development process depends heavily on appropriate representation and involvement in the subcommittees. These groups must have the technical expertise to address issues that arise. At times standards development is also negotiation, as committee members compromise on accepted definitions or design criteria. The final product is only useful if companies and customers are willing to apply the document. Thus a standard must meet a practical need in an effective manner.

EXISTING FORESTRY STANDARDS

Table 2 lists representative documents that apply to forest machines. Terminology and specification standards are important to manufacturers and customers for describing forest equipment. SAE J1209 and ISO 6814 define basic names for forest machines. Individual components of particular machines are defined in other nomenclature and specification documents. Common dimensioning and specifications ensure that customers can compare machines between manufacturers. For example, skidder grapple opening is defined in SAE J1112.

Safety standards, such as SAE J1084 and ISO 8084, define minimum performance requirements for forest equipment. Manufacturers can test and certify their products to meet these criteria and customers are assured that some level of protection is provided. Safety standards cover glazing and cab enclosure, roll-over protective structures, and falling-object protective structures. The SAE standards are also specifically incorporated in the OSHA logging safety standard.

Table 2. Some standards for forest machines.

Sponsor	Document	Title
SAE	**J1209**	Identification Terminology of Mobile Forestry Machines
	J1109	Component Nomenclature-Articulated Log Skidder, Rubber-Tired
	J1110	Specification Definitions-Articulated, Rubber-tired Log Skidder
	J1111	Component Nomenclature-Skidder-Grapple
	J1112	Specification Definitions-Skidder-Grapple
	J1353	Nomenclature-Clam Bunk Skidder
	J1824	Specification Definitions-Clam Bunk Skidder
	J1354	Nomenclature-Forwarder
	J1823	Specification Definitions-Articulated Rubber-tired Forwarder
	J1254	Component Nomenclature-Feller/Buncher
	J1255	Specification Definitions-Feller/Buncher
	J2055	Identification Terminology and Component Nomenclature-Knuckleboom Log Loader
	J1158	Specification Definitions-Winches for Crawler Tractors and Skidders
	J1440	Off-Road Tire and Rim Classification-Forestry Machines
	J1084	Operator Protective Structure Performance Criteria for Certain Forestry Equipment
	J1040	Performance Criteria for Rollover Protective Structures for Construction, Earthmoving, Forestry and Mining Machines
	J185	Access systems for Off-Road Machines
	J1178	Braking Performance-Rubber-Tired Skidders
	J1212	Fire Prevention on Forestry Equipment
ISO	**6687**	Machinery for forestry--winches--performance requirements
	6814	Machinery for forestry--mobile and self-propelled machinery--identification vocabulary
	6815	Machinery for forestry--hitches--dimensions
	6816	Machinery for forestry--winches--classification and nomenclature
	8082	Self-propelled machinery for forestry--roll-over protective structures--laboratory tests and performance requirements
	8083	Machinery for forestry--falling-object protective structures--laboratory tests and performance requirements
	9518	Forestry machinery--portable chain saws--kickback test
	11169	Machinery for forestry--wheeled special machines--vocabulary, performance test methods and criteria for brake systems
	11850	Machinery for forestry--mobile and self-propelled machinery--safety
	3789-4	Location and method of operation of operator controls--Part 4. Controls for log loaders
	3767-4	Symbols for operator controls and other displays--Part 4. Symbols for forestry machinery

Standards also provide data for forest equipment designers. SAE J185 identifies design practices for access systems. Minimum, maximum, and pre-ferred dimensions of steps, door openings, hand-holds, and platforms are provided. SAE J1212 out-lines design practices that can minimize the risk of fire on forest machines. ISO 3789 identifies stan-dard control functions and layout for log loaders.

Standards can also define common test methods for evaluating equipment performance. SAE J1503 describes a method and required equipment to quantify the performance of air-conditioning systems in off-road machines. Standard test methods are available for drawbar pull, braking performance, machine slope operation, gradeability, vibration measurement, etc.

By being aware of existing standards affecting forestry equipment, manufacturers can reduce design time and ensure compatibility with generally recognized engineering practice. Alert consumers can utilize existing standards by checking product specifications carefully and comparing products on the basis of accepted definitions. The OSHA Logging Safety Standard, for example, puts the burden on the employer of ensuring that equipment access systems meet the specifications of SAE J185.

NEED FOR FUTURE STANDARDS

Changing technology, increased emphasis on safety, and concern about environmental effects of forest operations will continue to drive the production of future standards.

The development of harvesting heads and cut-to-length equipment has led to a need for standard nomenclature and specifications for these devices. As third-party manufacturers produce heads and attachments for forestry prime movers, there may also be a need for standards defining attachment points and dimensions. The conversion of excavators to forestry use, for example, would be considerably simpler if a common attachment point could be defined similar to the three-point hitch for farm tractors.

Safety issues are also increasingly important. Falls from forest machines are a common cause of accidents and the access system is typically involved. SAE J185, mentioned previously, is currently being revised and elevated to a standard. Standards relating to operator enclosures are also being reviewed to keep up with the growing use of glazing materials. The review of operator protection standards is critical as new hazards are being introduced into the forest workplace. Current standards were not intended to protect against flying debris from sawheads, for example.

Assessment of the environmental effects of forest operations is also a growing trend. Manufacturers describe ground pressure and weight distribution as selling points for equipment. However, a common standard for defining the ground pressure of a rubber-tired forest machine is not available. Standards are also needed to define commonly accepted methods of assessing the environmental effects of forest operations. Studies of soil compaction and disturbance and residual stand damage use a variety of methods making comparison of different systems difficult.

Finally, covering all of the areas of standards development, is the issue of global harmonization. There is a drive to promote national standards to the ISO level. Currently, four SAE forest equipment standards are being revised as draft ISO documents. At the international level it becomes even more difficult to achieve consensus on issues such as terminology and performance requirements. Since each country only has one vote, it is also more difficult to define the process. North American skidder manufacturers, for example, may supply a majority of the global market, yet they only have two votes on the ISO Subcommittee. For equipment manufacturers, compliance with global standards can be a requirement for exporting.

CONCLUSION

Standards for forest operations have the potential to improve the safety and efficiency of the forest industry. However, in order to fully realize this potential, equipment manufacturers and customers must be aware of standards and how they are developed. There are also opportunities to become involved in the standards development process--draft documents and revisions are constantly circulating for comment and review. New standards to meet recognized needs can also be proposed to standards developing organizations.

There will be an expanding interest in standards development as a part of international trade. National standards groups are developing consensus documents that can be elevated to ISO standards. Hopefully a dynamic standards-developing community will be a positive contribution to the forest industry.

LITERATURE CITED

ISO. 1996. Introduction to ISO. International Organization for Standardization. http://www.iso.ch/ infoe/intro.html. (Access 4/10/96).

APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS IN FOREST ENGINEERING[1]

by

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ABSTRACT: The current application of geographic information systems (GIS) in forest engineering is presented. Proposed in this paper is the objective of the research needed on GIS applications in forest engineering in China. The research should focus on data design of forest engineering GIS, methods of data collection and data input, spatial and attribute data base design, and application projects of forest engineering GIS. As an example of the application projects, the function of the GIS application system is analyzed in accordance with the requirement of a skyline yarding design. The method of system development is presented. Finally, the application perspective of forest engineering GIS is discussed and the existing problem is raised.

Key Words: forest engineering planning, geographic information system (GIS), computer-aided design (CAD), skyline yarding

BACKGROUND

Research on the application of geographic information systems (GIS) in forest engineering started over 10 years ago. Reisinger and Davis (1985) utilized a computerized GIS to classify terrain in a forested area, establishing a terrain classification system with the criteria of ground strength, surface roughness, and slope. The terrain classification system was applied to the evaluation of trafficability of a logging area. Liu and Sessions (1993) applied digital terrain models to forest road planning. By identifying all feasible road segments and evaluating their variable and fixed costs, the optimal road path was determined. The computer-aided harvesting planning system developed by Cullen (1992) was based on an ARC/Info geographic information system. It functioned to determine harvesting and skidding region, to analyze logging possibility, to choose the skidding and hauling system, to set up an operation time table, to evaluate the economics of logging techniques, and to work out the optimal production combination.

Heinimann (1994) studied the building of a spatial decision support system based on GIS to help the selection of an adequate harvesting system in planning. Tucek (1994) used an IDRISI GIS package in the opening up of forest stands, utilizing the digital terrain model (DTM) to plan forest access and forest roads. Epstein (1994) developed a PLANEX software program, applying the data and the digital terrain model of the ARC/Info system. The software determined the optimal road and landing locations to access scheduled harvest areas, arriving at a minimum cost sum of road construction, landing construction, equipment setup, yarding and skidding operations.

Pan (1989) introduced an analysis method for developing digital terrain models. By quantitatively evaluating the factors affecting terrain features such as ground elevation, slope, relief energy, and valley density, a specific computational method was given for the exploitation of forests and for planning the road network.

Zhou (1992) studied the application technique of GIS in forest logging planning. Some methods of computer aided map analysis were put forward for planning forest utilization, selecting the annual logging area, and forest road planning. In western countries, the research on geographic information systems for forest engineering has achieved initial results with some practical systems developed (Cullen 1992, Epstein 1994, Tucek 1994). In China, study in this field has been initialized. However, a practical forest engineering GIS and its application system are still lacking.

Looking forward to the future of forest engineering GIS, we can expect its application will focus on the simulation and optimization of logging systems, computer-aided design in forest engineering, decision support to forest engineering planning and management, and on the area of comprehensive system analysis.

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

STUDY OBJECTIVE AND CONTENTS

The objective of this study is to develop the geographic information system and its application in accordance with the requirement of forest engineering planning and design. Through the efficient connection of GIS and forest engineering computer-aided design (CAD), the GIS and CAD techniques can reach a practical level, improving forest engineering planning and design.

Forest engineering planning and design demands detailed spatial and attribute data in the area of interest. The geographic information in large scales (up to 1:500) is required to be practical, which differs largely from the GIS used in ordinary management of forest resources. The major issues to be considered are noted below:

Design of GIS spatial and attribute data

The map scale required by forest engineering is generally between 1:500 and 1:10,000, which can be separated into two categories for different purposes: large scale of 1:500 to 1:2,000 and smaller scale of 1:5,000 to 1:10,000.

Data are classified into survey data and investigation data to suit the needs of forest engineering planning and design. Survey data include seven categories: boundary, road, water system, natural landforms, vegetation, pipe and electric line, and survey control points. There are six categories of investigation data: unit centers, man-made independent features, soil, condition of vegetation, stands, and notes.

The specific data items relate to points, lines, and areas. They should be selected in accordance with the requirement of forest engineering, production, managemnent, planning and design. The data items can be increased or deleted as long as the data structure is flexible and universal. The data items are number-coded to suit data input, processing, and output.

Data collection and digitized input

Three methods are used to collect and input data of logging areas.

On-the-spot collection and input

In the logging region, survey and investigation data are gathered and initially stored in portable microcomputers. The result from field work is then transferred to the permanent GIS data base in the.

Input from field records

Data can be input to the GIS data base directly from manual field records when limited by working conditions in the field.

Map digitization

Existing topographic maps and forest maps of special subjects can be input to the GIS data base through digitizers.

GIS data base

The data of points, lines, and areas are stored in spatial vector files. The attribute data are stored in a relational data base. The data searching, inquiring, retrieving, and processing routines are conducted by built-in linkages between the vector and attribute data bases. The PC version of the XMGIS package by Nanjing University is being used in the project. The package offers the function of map digitizing, map editing, data conversion, raster and vector spatial analysis, digital terrain analysis, and map output. The GIS data are stored in vector data files of points, lines and areas. dBASE type data bases facilitate the development of application software of specific subjects and functions requested by users.

Application projects

As required by the forest engineering planning and design, the study is focused on following projects.

Logging area division

Divide a forest farm into compartments, sub-compartments and cutting units successively. Schedule the harvest area and draw up their spatial and temporal distribution. With resources data calculated and natural environment analyzed, predict the variation of resources, environmental factors, and economics during a working plan period.

Investigation and design of harvesting and regeneration

Based on the spatial and attribute data from the forest engineering GIS, work out the resource statistics, technique scheme, technological design, and preparation of an operational design. Finally, compile all required files of investigation and design the plan.

Hauling Design

On the basis of the GIS, the following work should be completed: road network planning, route selection of roads, landing setting, development of an engineering budgetary estimate, selection of hauling route and hauling vehicle, calculation of hauling productivity, and an economics analysis.

Yarding and chuting design

Draw up yarding operation areas. Select landings, skyline corridors, and chute routes. Analyze terrain and simulate the running of skyline yarding and chuting. Fulfill the engineering design of the skyline and chute system.

The scheme of the GIS application system is shown in Figure 1.

SKYLINE YARDING DESIGN

The cutting unit in a specific year is shown in Figure 2 from the logging area division. A detailed design is required when skyline yarding system is employed.

Setting yarding operation unit

Determine the boundary of the yarding operation units in accordance with the requirement from the logging area division. Calculate the unit area and the timber volume.

Setting landing

According to the distribution of existing roads and operation units, determine the landing location with the whole yarding operation unit within the yarding extent of the skyline.

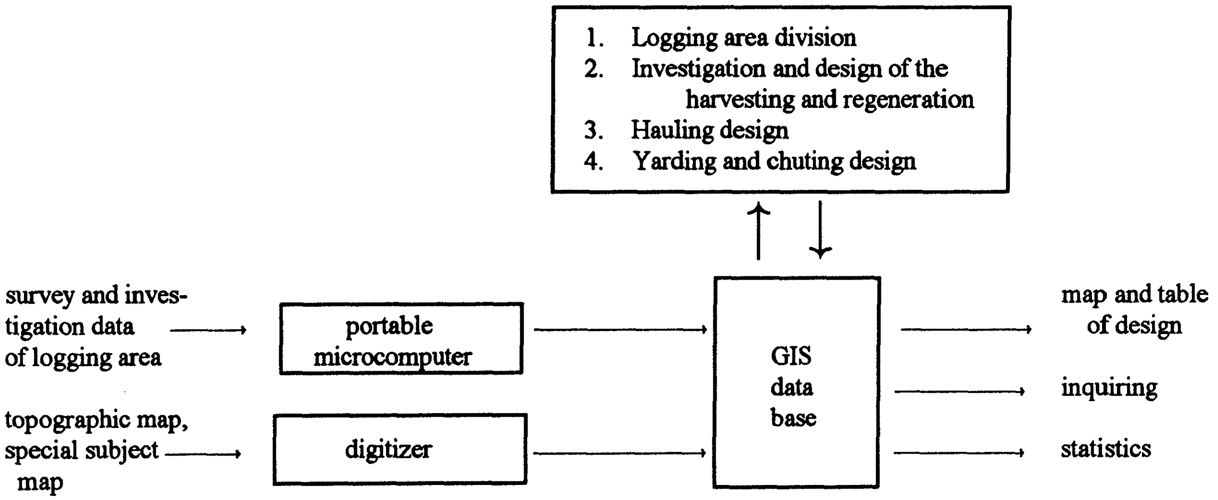

Figure 1. GIS system diagram for forest engineering.

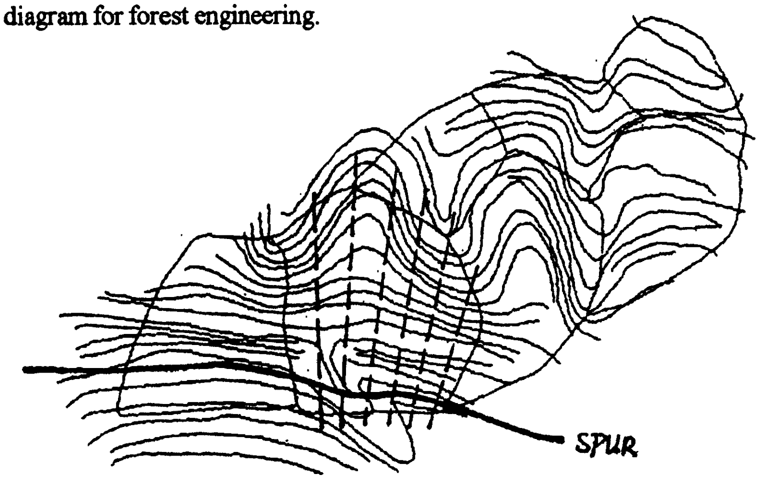

Figure 2. Skyline yarding area.

Slope calculation

Retrieve the topographic map of the yarding operation unit. Calculate the ground slope within the unit. Calculate the extreme slope and average slope. Analyze the variation of slope in the unit.

Drawing skyline corridor

Draw the skyline corridors from the landing chosen based on the extent of skyline and a given lateral yarding distance. Determine the position of alternate tail holds.

Analyze skyline profile

Compute skyline span, slope, and ground undulation for selected yarding corridors.

Skyline yarding simulation

The inhaul simulation of skyline is emphasized. By selecting different skyline systems and system parameters, the optimal equipment model and running parameters can be determined through analysis in accordance with the skyline yarding strategy (full suspension, partial suspension, etc.) (Zhao 1991).

Technical economics analysis

Based on the selected system and the resources condition, compute yarding trips, inhauled timber volume, and yarding productivity for each skyline corridor. Furthermore, the average productivity and yarding cost over the whole yarding operation unit are computed.

Output of design

1. Topographic map and stereo perspective view of the operation area.

2. Map of roads, landings, and skyline corridors in the area.

3. Profiles of skyline corridors in the yarding operation unit.

4. Simulation (Table 1) and animation display (Figure 3) for inhaul operation of the skyline.

5. Summary of skyline yarding design for the operation unit (Table 2).

Table 1. Inhaul simulation of the skyline.

D (m)	Hc (m)	α (°)	β (°)	Tc (kN)	Tm (kN)	Tsla (kN)	Tsl1 (kN)	Tsl2 (kN)	Vm (m/s)
325	1.0	88.5	0.0	19.84	28.87	9.20	18.41	18.44	0.0
325	4.3	68.5	0.0	15.54	37.89	22.39	46.27	46.32	-0.5
300	5.1	67.9	0.0	14.54	35.52	21.02	43.42	43.46	1.3
275	4.7	62.1	0.0	14.57	36.70	22.17	46.29	46.34	1.4
250	7.3	56.2	0.0	13.10	35.01	21.93	46.26	46.30	1.4
225	10.9	39.2	9.0	11.51	33.23	21.73	47.82	47.86	1.5
200	14.3	32.1	0.5	12.43	33.55	21.14	48.10	48.14	1.6
175	14.8	30.3	24.7	14.49	35.61	21.14	49.28	49.31	1.6
150	10.5	33.7	16.8	16.11	34.63	18.53	43.72	43.76	1.6
125	6.6	42.9	3.3	17.99	36.88	18.90	42.82	42.85	1.4
100	7.6	43.6	5.1	16.23	36.67	20.45	45.19	45.22	1.3
75	9.4	41.5	7.9	15.65	37.52	21.87	48.20	48.23	1.3
Min.	1.0	30.3	0.0	11.51	28.87	9.20	18.41	18.44	-0.5
Max.	14.8	88.5	24.7	19.84	37.89	22.39	49.28	49.31	1.6

Inhaul time = 173.9 seconds (2.90minutes)
Ave. speed of mainline = 1.4meters/second (85meters/minute)

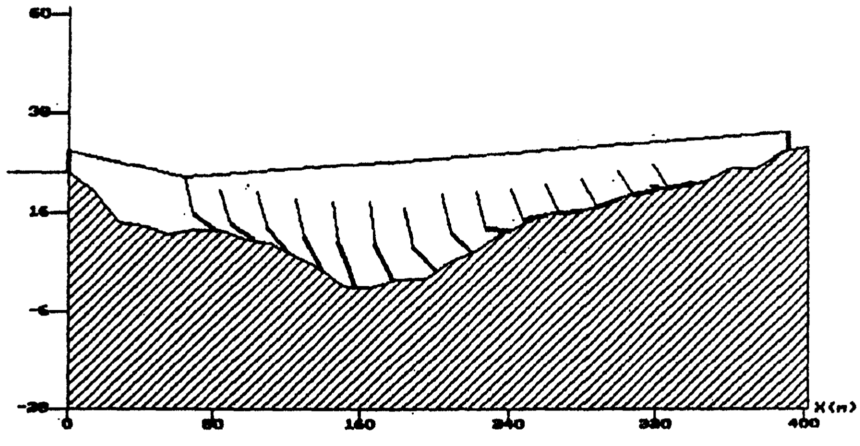

Figure 3. Animation display of the inhaul operation.

Table 2. Summary of skyline yarding design.

Yarding Corridor	Skyline Span (m)	Skyline Slope (%)	Yarding Area (ha)	Volume (m^3)	Ave. Yarding Distance (m)	Trip	Ave. Payload (m^3)	Ave. Round Trip Time (min)	Total Time (h)
1	350	-6	1.75	167	181	90	1.85	30.5	45.8
2	395	-5	2.07	197	207	113	1.74	33.6	63.3
3	395	-5	2.03	194	203	127	1.53	31.3	66.3
4	380	-10	1.85	176	195	94	1.87	31.0	48.6
5	340	-9	1.71	163	179	99	1.64	29.5	48.7
6	270	-6	1.30	124	144	78	1.58	24.7	32.1
Sum	--	--	10.71	1021	--	601	--	--	304.8
Average	361	-7	1.79	170	188	100	1.71	30.5	50.8

DISCUSSION AND SUMMARY

The analysis and implement of a skyline yarding design in the study has shown feasibility of the GIS application in forest engineering planning and design. The method developed can be directly applied to the engineering design in practice. The geographic information system is able to provide necessary information for engineering planning and design, including the terrain, topography, resources, road and water system. Thus, the data required for computer-aided design in forest engineering are guaranteed.

The computer-aided design based on GIS can provide detailed analysis for the operation system in changing conditions, which is specially suitable for the forest engineering design with diversity and complexity. The GIS technique sets a practical basis for simulation and optimization in forest engineering.

Since forest engineering planning and design requires a large number of data of various types, the acquisition and renewal of forest data is still the key to the success of GIS application. In order to increase the efficiency of data acquisition, data must be transfered from small-scale to large-scale, which makes full use of the existing small-scale map in forestry. It is also of great benefit to explore new methods for efficient and reliable investigation and survey in the logging area.

LITERATURE CITED

Cullen, J. 1992. Computer-aided harvesting planning system: an integrated forest engineering tool kit. In: Proceedings of the 15th Annual Council on Forest Engineering Meeting; 1992; Oregon, USA:81-98.

Epstein, R.; Weintraub, A.; Sapunar, P.; Sessions, J.; Sessions, J.B. 1994. PLANEX-software for operational planning. In: Proceedings of International Seminar on Forest Operations Under Mountainous Condition; 1994 July 24-27; Harbin, P. R. China:52-57.

Heinimann, H.R. 1994. Conceptual design of a spatial decision support system for harvesting planning. In: Proceedings of International Seminar on Forest Operations Under Mountainous Condition; 1994 July 24-27; Harbin, P. R. China:19-27.

Liu, K.; Sessions, J. 1993. Preliminary planning of road systems using digital terrain models. Journal of Forest Engineering 4(2):27-32.

Pan, X.D. 1989. Forest terrain model and terrain feature analysis. Journal of Northeast Forestry University 17(4):87-91. (in Chinese)

Reisinger, T.W.; Davis, C.J. 1985. Using a geographic information system to determine operable area--a trafficability approach. In: Proceedings of the 8th Annual Council on Forest Engineering Meeting;1985 August 18-22; Tahoe City, California, USA.

Tucek, J. 1994. Using the GIS environment for opening- up of forests. In: Proceedings of International Seminar on Forest Operations Under Mountainous Condition; 1994 July 24-27; Harbin, P.R. China:58-65.

Zhao, C. 1991. Simulation for inhaul operation of a cable yarding system. Journal of Nanjing Forestry University 15(3):66-70. (in Chinese)

Zhou, H. Z. 1992. Forest logging planning and geographic information system. Journal of Forest Engineering (Harbin, China) 29(3):1-5.(in Chinese)

A MODEL FOR PREDICTING NET REVENUE FROM HARVESTING OPERATIONS IN COASTAL SECOND-GROWTH FORESTS IN BRITISH COLUMBIA[1]

by

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ABSTRACT: The Forest Engineering Research Institute of Canada and the University of British Columbia are currently developing an interactive model, written in Microsoft Visual Basic, to predict the net revenue of harvesting Coastal second-growth forests in British Columbia. The model is intended to provide harvest planners with a tool to conduct economical analyses of various harvesting scenarios in Coastal second-growth stands.

Timber revenue is determined from cruise data, log sort description, information and log values input by the user. Based on these data, the model determines the combination of log sorts that will result in maximum revenue from each sampled (cruised) tree, and then projects the results to the entire setting.

A number of harvesting productivity functions, relating the productivity of harvesting equipment to the stand characteristics, reside in the model. The user selects the desired components of the harvesting system, and the model then determines productivity and costs for each phase. The user has the option to override the model's productivity and cost estimates, should he/she find that these estimates are not appropriate for the particular setting being analyzed.

The model is currently being tested on two different harvesting sites in British Columbia, Canada.

Key Words: timber revenue, cost, Harvest System Evaluator, productivity, modeling.

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

COMMERCIAL ASPEN THINNING: SYNTHESIZING HARVESTING SYSTEMS AND SILVICULTURE NEEDS[1]

by

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ABSTRACT: Across northern North America, including the Lake States, aspen is a commercially important tree species. Despite relatively fast growth, merchantable yields are sub-optimized due to extreme competition in early stages of development and by merchantable tree mortality as stands reach 25 to 40 years of age. Thinning strategies to improve productivity have not been practical due to low stumpage values and harvest equipment that was not suited to the task. This poster presentation reports on trial results of commercially thinned 30-year-old aspen. The trials demonstrate that quality results at marginally economical rates are possible by using a combination of proper harvest equipment and silviculture design. A harvest of 7 cords per acre underscores the potential to increase total fiber yields by salvaging anticipated mortality, increasing future merchantable volumes, and developing value-added products sooner. Applied only to the best aspen sites, commercial aspen thinning could add significantly to aspen supplies. Pulp quality, potential for genetic improvement, and impacts to non-timber values are also discussed.

Key Words: aspen thinning, aspen management.

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[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

WOOD UTILIZATION OPTIONS FOR ECOSYSTEM MANAGEMENT[1]

By

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ABSTRACT: The shift to ecosystem management is changing silvicultural objectives and practices on National Forests. Land managers are seeking silvicultural solutions to a variety of issues that include restoring wildlife habitat, maintaining healthy and aesthetically pleasing forests, reducing the risk of catastrophic fires, and restoring ecological diversity. These changing management objectives are also affecting the species composition, quality, and quantity of woody material available for removal. To develop the information and methods required to evaluate current and future utilization opportunities for woody materials that may be removed under ecosystem management regimes, a national research project was initiated in 1994. This research is being conducted by multidisciplinary teams with members from the USDA Forest Service Forest Products Laboratory and the Pacific Northwest, Southern, and Northeastern Research Stations in cooperation with National Forests in Regions 6, 8, and 9.

Regional research teams have identified specific ecosystem conditions, desired future conditions, and alternative silvicultural treatments to attain the desired conditions. This research is currently focused on dense small-diameter softwood stands in the West, uneven-aged pine/mixed hardwood stands in the Piedmont region, and mixed hardwood forests in the Central Appalachian region. To evaluate wood utilization options under alternative ecosystem management regimes, these teams are now: (1) collecting information to link silvicultural treatments to the characteristics of the wood removed, (2) identifying opportunities for allocating wood removed to higher valued products, (3) investigating alternative forest operations for removing woody material, and (4) estimating the economic feasibility of alternative treatments.

Key Words: wood utilization, ecosystem management, silviculture

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI., July 29-August 1, 1996.

HW-BUCK: A COMPUTERIZED OPTIMAL BUCKING DECISION SIMULATOR FOR TRAINING HARDWOOD LOG BUCKERS TO IMPROVE VALUE RECOVERY[1]

by

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ABSTRACT: It is widely recognized that the value of the products produced when hardwood stands are harvested is critically dependent on the quality of decisions made when bucking the logs. Unfortunately, maximizing the value of the logs produced is extremely difficult because of the complexity of the hardwood log grading rules. This difficulty is compounded by the irregular shape and widespread occurrence of defects in hardwood stems. The underachievement of field bucking practice, relative to the optimal stem conversion selected using operations research techniques, was recently estimated to be between 28 and 35 percent. This poster will present a computerized decision support system to help train field log buckers to make better decisions. This "bucking game" presents the trainee with a log to be bucked. The picture of the log includes stem shape and defect location, size, and type. The log can be rotated to view the entire stem. The trainee selects cuts to buck the log, after which the results of the bucker's cuts are presented along with the optimal bucking pattern.

Key Words: optimal hardwood bucking, computerized decision simulator

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

TEMPORARY STREAM AND WETLAND CROSSING OPTIONS[1]

by

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ABSTRACT: As forest management activities intensify, there is an increasing potential to negatively impact streams and wetlands and to increase nonpoint source pollution. This paper summarizes information about many of the options for temporary stream and wetland crossings and reviews some of the reported impacts associated with using some of those options.

Key Words: Temporary, portable, stream crossings, wetland crossings, impacts.

INTRODUCTION

Forest management activities are intensifying in many areas to meet a variety of demands. These increasing demands have the potential to negatively impact streams and wetlands[2] and to increase nonpoint source pollution. Road and skid trail crossings of streams and wetlands have the greatest potential to impact these water resources.

There are a variety of temporary[3] or portable stream and wetland crossing options for use during timber harvesting and hauling operations that can help meet the increasing demands in an environmentally and economically acceptable manner. These options include both commercial and home-made devices that are either transported to or built on-site. Increased awareness of these options for reducing nonpoint source pollution and damage to streams and wetlands can help minimize the cost of protecting these valuable resources.

When planning forest operations, the first priority for protecting streams and wetlands is to avoid crossings. When crossings are needed, their number should be minimized. Appropriate strategies must be used to mitigate impacts from crossings. Some of the criteria to consider when evaluating which crossing option to select include site conditions, effectiveness for reducing impacts, avoidance of the use of fill, maintenance requirements for both the option itself and for the crossing, rehabilitation requirements when the crossing is removed, safety, season of use, length of time the crossing will be in place, fluctuations in water levels during use, frequency of use, cost to purchase, install, and remove the option, the ease of installation and removal, and applicable regulations.

The purpose of this paper is: (1) to summarize information about many of the temporary stream and wetland crossings options, and (2) to review some of the reported impacts associated with using these options. It attempts to provide a broad overview of the temporary stream and wetland crossing options. There are likely several additional excellent options that are not included in this paper. Arnold (1994) and Mason (1990) provide excellent descriptions of many specific products, including design specifications, drawings, and photographs. The authors recommend that you contact local vendors and logging contractors for more complete information, including price, for specific products they may utilize or market.

TEMPORARY STREAM CROSSING OPTIONS

Stream crossing options include fords, culverts, bridges, and pipe fascine (bundled pipe). A brief description of each option is presented below. The *Logging and Sawmilling Journal* has established a World Wide Web homepage (http://www.forestnet.com) that contains information about stream crossings, including sections on planning, protecting aquatic resources, crossing structure options, revegetation, and removal. All portable stream crossing options may need to be cabled to a nearby tree or be able to pivot on one side to prevent floodwaters from moving them downstream.

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[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

[2]For the purposes of this paper, wetlands are areas that contain soil with poor load-bearing capacity and high moisture content or standing water. These areas are frequently effected by seasonal fluctuations in water levels.

[3]For purposes of this paper, a temporary crossing is one that is used for a maximum of three (3) years before it is removed.

Fords

A ford is a stream crossing which utilizes the stream bed as the roadway without significantly altering the shape of the stream channel. They are formed by lowering the road grade to the stream level from bank to bank. They are best suited to locations where the stream bank approaches are low, the bottom is solid (or can be made solid), the channel is straight, and the normal flow is low. While many potential fords have a stable natural base of bedrock or coarse gravel, imported rock, concrete pads/panels, tire mats, or other stabilizing systems may be needed to reinforce other crossings.

Some jurisdictions may permit the use of pole fords in small streams. They are constructed by placing poles, brush, or small logs parallel to the stream channel.

A vented ford is formed by partially lowering the road grades for passing floods and providing culverts for day-to-day flow (Adamson and Racey 1989). They are suitable where the flow may exceed a fordable depth either seasonally or following storm events.

Tufts et al. (1994) describe a plastic ford which was constructed over poor load-bearing soils using geotextiles and cellular confinement systems.[4] The ford included nonwoven geotextile, GEOWEB® panels, a well-graded rock that was less than 0.75-inch diameter to fill in and around the GEOWEB®, and larger diameter rock that was 4 to 8 inches in diameter in the bottom of the creek to increase the strength of the crusher run rock layer. Tufts et al. (1994) also include steps for installing a plastic ford.

Culverts

A culvert is a metal, concrete, or polyethylene pipe, a wooden box, or a hollow log. It may be round, oblong, or arched. An arch culvert has concrete footing walls along each side, into which the steel arch is fitted. A culvert must be sized to pass anticipated maximum flow levels. Temporary installations that are removed seasonally may only need to accommodate estimated seasonal peak flows. Year-round installations will need to consider specified storm event frequency requirements (e.g., 10-, 25-, 50-, or 100-year peak flows). Consultation with an engineer or hydrologist is advised.

[4] A cellular confinement system is an expandable honeycomb plastic panel into which different types of fill material (e.g., soil, gravel, stone) can be added. The panels confine the fill into small compartments, holding them in place.

Culverts have been the mainstay in stream crossings because of their portability, availability, and relatively low-cost. Low-cost culvert transportation systems have been developed (Ewing 1992). Installation and removal of small culverts can be accomplished with a bulldozer or backhoe. An excavator may be needed to install or remove larger culverts.

A single large diameter culvert is preferable to several smaller ones. Some jurisdictions may permit logs or brush to be placed around the culvert to avoid the use of fill and to make it easier to remove. Corrugated steel culverts are used most frequently. Corrugated polyethylene pipes, hollow piling, well casings, gas pipeline, and hollow logs may be acceptable alternatives in some cases. Stjernberg (1987) discusses some of the problems associated with plastic culverts and how those problems can be reduced or avoided by following proper installation procedures.

Culverts come in a variety of diameters and lengths and are generally available from a number of local suppliers. Used culverts may be available from highway and local road authorities or construction companies. A local pipeline, drilling, or construction company may have used well casings, piling, and gas pipeline available. The diameter of those products may be too small to avoid repeated clogging or to accommodate expected water flow.

Bridges

Bridges can be constructed from ice or fabricated from timber, steel, concrete, or rubber. Some designs use two of those materials (e.g., a steel superstructure with a wood running surface) and may be in modular panels or hinged to facilitate handling, transport, and installation/removal. Bridges usually disturb streams less than culverts. However, they may be uneconomical or impractical on low-volume forest roads.

Little site preparation is normally required when installing a temporary bridge crossing. Abutments on both sides of the stream crossing are needed when the stream bank is unstable and/or when required by local statutes.

Some bridge crossings consist of two side-by-side tracks made of logs, beams, or panels, often with a left between them. This design may be less expensive as compared to a crossing that is continuous across its entire width. However, it may result in degraded water quality if debris falls through the gap when logs are skidded or trucks cross the bridge.

Ice bridges

During the winter, an ice bridge offers a low-cost bridging alternative. It may be created across a stream when the ice is thick enough or the stream bed is frozen enough to protect the stream bed. An ice bridge is constructed by packing snow into the crossing area and adding water to create a thick layer of ice. This process may need to be repeated over a period of several days to create an adequate width and depth of ice for safe use. It is easiest to create an ice bridge across a stream that has a low flow velocity.

In some jurisdictions, it may be permissible to place brush down before creating the ice bridge. This is generally undesirable because the brush is often not removed. If brush is used as a base, it should be securely cabled to a tree or other nearby secure structure to avoid its being washed downstream and to facilitate removal when the bridge melts.

The following formula has been developed to estimate the minimum ice thickness required to support a load for an ice bridge above a flowing river or stream or on a lake (Haynes and Carey 1996):

$$h=4(P)^{1/2}$$

Where: h = ice thickness in inches,
P = the load or gross weight, in tons.

Timber bridges

Timber bridges can be classified as being non-engineered or engineered. Non-engineered bridges include log or roundwood stringer bridges and plank bridges. Log stringer bridges can be built from trees felled in the area of construction, railroad ties, or from demolition materials. Plank bridges use log stringers or cants for the superstructure and lumber for the running surface. Crossing a narrow stream can sometimes be accomplished by bundling log stringers together with chains or cable. If care is used during installation, removal, and transport, timber bridges can be used several times.

Care should be exercised when using logs or other native materials, hardwood beams, or planks to construct a bridge because they have not been evaluated by engineers to determine their structural strength. It is not possible to accurately estimate their load ratings. Rot, decay, knots, and grain can greatly affect their strength properties. Some of these factors become more important the longer a bridge is in use, especially if the species does not have a high decay resistance.

Engineered timber bridges have been constructed using treated panels of either stress-laminated or glue-laminated (glulam) materials. Stress-laminated bridge panels consist of lumber placed edgewise and held together with high-strength steel rods which are stressed in tension, up to 100,000 pounds/square inch (PSI). The bridge is generally re-stressed at least twice during the first 1 to 2 months after being placed in service. Glue-laminated bridge panels consist of dimension lumber glued together on the wide face. The resulting stress-laminated or glulam panels are then placed side by side across a stream. An advantage of both of these engineered panel products is that they have known strength characteristics.

Through its National Timber Bridge Initiative, the US Forest Service has established a World Wide Web homepage (http://gypsy.fsl.wvnet.edu/frm/timber_bridge/wit.html) on the Internet that describes the program and provides an on-line order form to obtain free publications. The US Forest Service has also published an excellent reference on timber bridge design, construction, inspection, and maintenance (Ritter 1992).

Steel bridges

Steel bridges include hinged portable bridges, modular bridges, and rail cars that are converted for use at temporary crossings. Where permitted, two or more bridge spans or bridge panels (multi-spans) may be connected across a pier to span wide crossings. Hinged bridges fold-up for transport. Modular steel bridges are designed as a series of individual panels that interlock, forming a bridge of variable length and width. Rail cars tend to be very heavy and require reinforcement before they are safe to use as a bridge. In some areas, used rail cars may be available through your local railroad company. In other areas, used rail cars may be purchased from third-party vendors who purchase old rail cars from railroads. Contact your local railroad company or rail car repair facility to obtain a used rail car or to find out how to obtain one. It may be possible to locally fabricate a steel bridge to cross a span shorter than about 50-feet using I-beams.

Concrete bridges

Precast, prestressed concrete panels can be locally fabricated. Although the initial cost of this bridge may be low, they are usually heavy and require larger equipment to install and remove. Be sure that the panels are engineered to handle the anticipated loads.

Rubber mat bridge (dam bridge)

A dam bridge can be constructed from strips of rubber conveyer belting joined side by side (Arnold 1994, Looney 1981). Looney (1981) tested a dam bridge that was constructed from half-inch thick strips of used rubber conveyor belting laid side by side that were cemented and bolted together. Support cables hold the sides upright so that the mat floats on the water to form a "U" shaped, trough-like structure, through which skidders can pass. When a load enters the bridge, the mat is pressed down to the stream bottom by the vehicle's weight, momentarily damming the stream. After the load has passed, the bridge floats to the water's surface, allowing the stream to flow again unobstructed. This action allows the vehicle to be supported by the stream bottom while the rubber mat protects the bottom from rutting and abrasion. The mat must be anchored to a nearby tree or other nearby structure. Skidders equipped with tire chains may have trouble climbing out of a dam bridge. Looney (1981) recommends placing a layer of rock along each shoreline from the water's edge to the end of the bridge.

Pipe fascine (bundled pipe)

Within the context of this paper, a fascine is a series of parallel pipes used to fill a drainage to allow water to flow and vehicles to cross. A pipe fascine crossing is constructed using polyvinyl chloride (PVC) pipes that are cabled together to form mats of varying length. The fascine is then layered in the stream channel, parallel to the stream, so that it adjusts to the shape of the channel. Streams with a U-shaped channel are most appropriate for this option. Covering the pipe or utilizing an ultraviolet-resistant type of pipe may extend life expectancy. Placement of a geotextile fabric under the crossing is recommended to ensure separation from the stream bottom and to facilitate the removal. Typically, a tractive surface such as deck span safety grating, tire mats, wood pallets, or wood mats should be laid over the top mat to reduce impact to the pipe, to keep the pipes in place, and to provide a good running surface.

WETLAND CROSSING OPTIONS

Temporary wetland crossing options include corduroy, wood waste, wood pallets, wood mats, geotextile with metal grating, geomatrices/cellular confinement system, a bridge deck or lumber placed over a geotextile or used paper machine felt, tire mats, tire chips, pipe fascine, chunkwood, low ground pressure equipment, and pole rails. Some of these options are best suited to be used in conjunction with hauling activities and not for use during skidding. As with stream crossings, there are several ways to accomplish each of the various options. A brief description of each option is presented below.

Corduroy

Corduroy is made of brush, small logs cut from low-value and noncommercial trees on-site, or mill slabs laid parallel or perpendicular to the direction of travel. The effect of corduroy is to spread the load over the whole length of the log or slab, effectively increasing the load-bearing area. Brush corduroy will provide less reinforcement than small logs or mill slabs. Temporary corduroy normally is not covered with fill.

Wood waste

Sawmill residue, such as bark, sawdust, and planer shavings can be used. Maintenance will be needed to repair any rutting and low-frequency washboarding.

Wood pallets

Wood pallets for use in wetland crossings are a sturdy multiple-layered variation of a wood pallet specially designed for use as a traffic surface. They are generally made from hardwood planks which are nailed together. They are specially designed so that they can interconnect, are reversible, so that individual pallets can be easily replaced, and so that nail points won't surface.

Wood mats

Wood mats are single-layer platforms where the individual wooden pieces are made of larger, closely spaced hardwood (usually oak) sawn material. In some cases, the individual pieces which comprise the wood mat may be cabled together. During installation, it is important to tuck the ends of all wire loops under the mats to avoid their being caught by a vehicle.

Geotextile with metal grating

Machine weight can be distributed over a broader area by placing a commercially available deck span metal safety grating on top of the geotextile, perpendicular to the direction of travel. By connecting the pieces of metal grating together, the amount of cold pressing (slow deformation or bowing of the sheet metal) will be reduced. While cold pressing does not harm the grating, it does necessitate flipping the grating over occasionally.

Geomatrices/cellular confinement system

A cellular confinement system (see footnote 4), with a geotextile below it, can provide support for wetland crossings.

Bridge deck or lumber placed over a geotextile or used paper machine felt

The decking of a timber bridge could be used to cross a small wetland area. Bridge panel options that do not have an associated superstructure, such as glue-laminated and stress-laminated bridges, may be most appropriate. Also, a temporary decking could be constructed by laying down parallel runners on each side where the truck tires would pass and then nailing down hardwood lumber to serve as the running surface.

Tire mats

A mat or panel of tires can be created by interconnecting tire sidewalls with corrosion resistant fasteners. Mats of varying length and width can be developed. Some designs incorporate the tire tread into the product. No running surface is needed over the mat. Anchoring may be needed to prevent lateral movement during use, especially in areas with a grade over about 5 percent.

Tire chips

Tire chips are produced by shredding car and truck tires until they pass a two-inch screen. The resulting chips can be spread across the crossing area. In addition to providing flotation, traction, and permeability, they also can serve to insulate the underlying soil and to reduce the capillary rise of subsurface water in the spring. Some jurisdictions may prohibit use of tire chips where they come in contact with water.

Pipe fascine (bundled pipe)

As noted in the temporary stream crossing options section, a pipe fascine crossing is constructed using PVC pipes that are cabled together to form mats of varying length. While the length of the mats is generally short for stream crossings, longer lengths can be built for wetland crossings. In effect, a corduroy crossing is established. Ramps up to and down from the crossing are needed as well as a running surface. The US Forest Service is currently testing this option and hopes to be able to summarize their results in late-1996. Covering the pipe or utilizing an ultraviolet-resistant type of pipe may extend life expectancy. Placement of a geotextile fabric under the crossing can facilitate separation of the pipe and soil. No published studies have evaluated the use of pipe fascine for wetland crossings during winter months in an environment where temperatures are consistently below freezing.

Chunkwood

Chunkwood roads can be constructed from low-value and noncommercial trees using a chunkwood chipper that produces fist-sized chunks. Unfortunately, there are very few chunkwood machines available around the world.

Low ground pressure equipment

By reducing ground pressure, equipment flotation is enhanced, traction is usually improved, and road maintenance requirements such as grading can be reduced. Low ground pressure equipment can reduce rut depth and compaction. Ground pressures of less than 5 or 6 PSI are often considered high flotation. Ground pressures lower than 4 PSI may be needed to operate on wetland soils without difficulty.

For skidding equipment, options to achieve low ground pressure include reduced loads, use of high flotation tires, dual tires, tracks, bogeys, small equipment, or forwarders. High flotation tires are wider than conventional equipment, usually wider than 34 inches. Dual tires consist of two adjacent conventional width tires. Track machines distribute the machine's weight over steel tracks. It is possible to add wrap-around tracks to existing, individual, conventional width rubber tires. A bogey system connects tires on adjacent axles with a track. While building smaller loads for skidders is also an option, they frequently experience poor productivity and high production costs under those scenarios. Forwarders are better able to maintain acceptable productivity and costs under situations where a reduced load is needed.

Clambunk skidders and tree-length forwarders can move large loads while exerting a low ground pressure. Cable yarding systems, which can either partially or fully lift logs off the ground, are another option.

Central tire inflation (CTI) technology is a low ground pressure option for hauling. It allows a driver to automatically and uniformly vary the inflation pressure of a truck's tires while the vehicle is moving. With a CTI system, the pressure on radial tires can be lowered to yield a tire with a larger footprint area. That larger footprint translates into better flotation, enhanced traction, and reduced rutting in wet areas.

Pole rails

When attempting to support skidding or forwarding machinery equipped with high flotation or dual tires, one or more straight hardwood poles produced from on-site trees can be laid in the direction of travel below each wheel. The poles can either be with or without limbs. If the poles are not delimbed, more flotation will be provided at the top of the tree where the diameter is smallest. The diameter of the pole should not exceed around 10 inches so that it will penetrate the wet area to a sufficient depth such that the tires come in contact with the soil. Two or more poles may need to be laid parallel to each other below each wheel if only small diameter material is available or if sufficient flotation is not provided. For a longer crossing, two or more poles may be needed lengthwise. The larger end of the stem should be placed on the softer ground to maximize flotation. After placing the poles, it is important to drive across them a few times without carrying a load to get them properly seated in the soil. Remove the poles when there is no additional need to cross the wet area. This option will not work well if the machinery is equipped with conventional width tires because they are too narrow and are operated at too high a pressure to stay on top of the poles.

ENVIRONMENTAL IMPACTS ASSOCIATED WITH CROSSINGS

Unfortunately, little information exists which focuses specifically on impacts associated with temporary stream or wetland crossings. Most of the literature relates to the use of culverts. Few studies have examined impacts associated with the removal of the temporary crossings or compared the long-term impacts associated with using a ford versus a temporary bridge. Information presented below summarizes some of the studies which have reported impacts resulting from crossings.

Studies of stream crossings

A series of one-day post-harvest assessments of 78 recently completed timber harvesting sites was conducted in Vermont to evaluate Acceptable Management Practice compliance, soil erosion extent, and water quality impacts (Brynn and Clausen 1991). The crossings were accomplished with either a metal or wooden culvert, ford, bridge, or brush. Over 60 percent of the crossings were made by a ford. Stream crossing sedimentation and debris were above background levels on 57 and 55 percent of the sites, respectively.

Brynn and Clausen (1991) recommended that stream crossings over brush or pole fords should not be allowed because the brush was infrequently removed and restoration may result in increased sedimentation. Newton et al. (1990) recommended that fords of permanent streams should not be allowed under unusual circumstances.

Tornatore (1995) evaluated suspended solids and turbidity for haul roads and skid trails associated with different stream crossing options at two locations in Pennsylvania. Installation of all skidder crossings caused significant increases in suspended solids and turbidity. The level of impact to the stream was less severe during the installation of the portable bridge versus culvert installation. Installation impacts were reduced to insignificant levels within 24 hours following bridge installation versus 96 hours following installation of the culvert with a log fill.

Increases in suspended solids occurred downstream from all skidder crossings (Tornatore 1995). Increases below the portable bridge appeared to be a result of debris (leaves, twigs, and bark) falling through gaps in the bridge planking. Despite this, the portable steel bridge still outperformed both culverts. The culvert with shale fill performed better than the culvert with log fill. Suspended solids below the culvert with log fill resulted primarily from increased inorganic sediment which may be related to the stability of the approach area and stream bank. Two skidder passes made within 15 minutes of each other at the unmitigated ford crossing increased sediment solids by 350 times.

Hassler et al. (1990) reported that there were no statistically significant differences between turbidity, pH, and conductivity samples taken above and below a stress-laminated timber bridge crossing. Thompson et al. (1994) reported that culverts contributed more sediment to the stream during installation and removal than the bridge crossings which did not contribute any sediment.

A survey of 70 forest road stream crossings in Pennsylvania was conducted to describe the crossing characteristics and to evaluate the long-term impacts of the crossings on habitat quality, channel stability, vegetation, and channel sediment embeddedness above and below the crossings (Miller 1993). Only crossings two years old or older were evaluated. Culvert (57 percent), bridge (30 percent), and ford (13 percent) crossings were evaluated. Overall, relatively few detectable long-term impacts due to permanent forest road crossings were identified. Only 35 of the 814 comparisons of environmental conditions studied above and below the crossings were found to be significant at an alpha level of .05. Significant differences that did occur suggested that stream bed fine sediment levels were higher, basal area lower, and herbaceous cover higher in the immediate vicinity (less than 33 feet upstream and downstream) of some crossings.

Thompson and Kyker-Snowman (1989) evaluated both short- and long-term impacts at an "unmitigated" stream crossing as well as "mitigated" crossings constructed with a portable bridge, a poled ford with a ductile iron culvert[5], and concrete slabs with hay bales. The unmitigated crossings provided no protection from disturbance of the stream or its banks. No clear effect of season (flow level) or equipment type (rubber-tire cable skidder vs. dual rear axle forwarder) on turbidity levels was documented. The effect of mitigation was dramatic. Unmitigated crossings generally caused large increases in turbidity at 15 and 100 feet downstream of the crossing. No significant differences between before- and after-crossing values were found for pH, specific conductivity, or nitrate levels. Nitrate levels were negligible and in no case did they come near the allowable drinking water limit. For both unmitigated and mitigated crossings, there were no significant differences between turbidity values measured at 1,000; 2,200; 2,640; or 5,280 feet below the crossings from samples taken at upstream locations.

Of the mitigated crossings, Thompson and Kyker-Snowman (1989) reported that the bridge was the most effective and the concrete slabs with hay bales the least effective at reducing crossing impacts. Measurable impacts with a portable bridge extended less than 100 feet downstream. Measurable effects with other mitigations rarely extended as far as 1,000 feet downstream. Although a natural ford was not included as a mitigated crossing in the study, the authors concluded that this option would be an acceptable mitigation from observational evidence of active and inactive harvesting sites

Looney (1981) compared the use of a rubber mat dam bridge to a ford and a culvert crossing. While whole-tree skidding, the rubber mat dam bridge yielded a significant reduction in the amount of suspended solids being carried downstream, as compared to a ford crossing. During 1.33 hours of use at one site (5 one-way crossings with the first, third, and fifth crossings being loaded), the ford crossing resulted in 52,707 grams of sediment as compared to 31,239 grams of sediment for the dam bridge. During two hours of use at a second site (8 one-way crossings, every other one being loaded), the ford crossing resulted in 208,455 grams of sediment as compared to 82,326 grams for the dam bridge. The author also noted that the dam bridge provided considerable flotation to the skidder as compared to the ford crossing. Installation and removal of a culvert crossing resulted in 198,075 grams of sediment being added to the stream.

Mason and Greenfield (1995) provide observational information about potential impacts due to pipe fascine crossings. They indicate that soil may be picked up and later deposited into the stream if the crossing has been stored on the ground prior to installation. Also, small fragments of pipe from cutting and drilling may remain inside the pipes and be deposited in the stream. During removal of a pipe fascine crossing, sediment that had settles on the surface of the geotextile can enter the stream mainly from disturbance when the fabric is dragged out.

Studies of wetland crossings

Mason and Greenfield (1995) compared impacts in an area where pallets were used versus another area without pallets. The soil moisture content within the area that did not have pallets was typically 5 to 10 percent less than the area that contained the pallets. The rutting which occurred at the non-pallet crossing was 6 to 10 inches. At the pallet crossing, settlement was only about 0.5 inches. They reported that the use of wood pallets left no specific areas to hold and channelize water or specific areas of high compaction or rutting.

Goudey and Taylor (1992) and Taylor (1994) examined the toxicity of aspen wood leachate to aquatic organisms. They reported that leaching from aspen wood chips and wood piles was very toxic to aquatic animal life. Aspen wood leachate can be produced in any season when the wood is exposed to water and the

[5]The poled ford consisted of filling the stream with logs or poles which were somewhat longer than the width of the equipment which used the crossing. (This crossing is sometimes known as corduroy.) The poles were laid parallel with the flow of the stream. To improve the streamflow through the ford, two ten-foot long sections of 16-inch wide ductile iron pipe, a high-carbon pipe designed to withstand pressurized gas, were added. It was placed in the poled ford without backfill.

temperature is above freezing. Karsky (1993) mentions that the short-term potential leaching of tannic acid from cedar and some other species must be considered when constructing a chunkwood road close to a stream. No studies have reported leachate in wetland road building using chunkwood.

Wolanek (1995) monitored downslope water quality over a 25-month period following construction of a road segment which used mill-generated bark and wood fiber as primary fill material on the Tongass National Forest in Alaska. Overall, the study reported minimal effects on stream water quality. The parameter most effected was pH, increasing significantly by 0.2 to 1.5 pH units in the naturally acidic streams. Dissolved oxygen in the streams remained unaffected.

Bradley (1995) reported that Central Tire Inflation can reduce sediment runoff from unpaved roads. Sediment runoff was reduced by as much as 84 percent on road sections that were used by CTI-equipped vehicles, as compared to vehicles using 90 PSI tires.

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LITERATURE CITED

Adamson, R. B., and G. Racey. 1989. Low water crossings: An inexpensive alternative for low volume roads in Northern Ontario. Ontario Ministry of Natural Resources, Northwestern Ontario Boreal Forest Management Technical Notes TN-02. 4 p.

Arnold, G. 1994. Portable and low cost bridges. Rotorua: New Zealand: Logging Industry Research Organisation. Report Volume 19, Number 14. 12 p.

Bradley, A. H. 1995. Lower tire pressures lessen sedimentation from roads. Field Note No.: Roads and Bridges-47. Quebec, Canada: Forest Engineering Research Institute of Canada. 2 p.

Brynn, D. J., and J. C. Clausen. 1991. Postharvest assessment of Vermont's Acceptable Management Practices and water quality impacts. Northern Journal of Applied Forestry 8(4):140-144.

Ewing, R. H. 1992. Low-cost culvert transportation systems. Field Note No.: Roads and Bridges-31. Quebec, Canada: Forest Engineering Research Institute of Canada. 2 p.

Goudey, J. S., and B. R. Taylor. 1992. Toxicity of aspen wood leachate to aquatic life. Part I: Laboratory studies. Prepared for Environmental Protection Division, Northern Interior Region, British Columbia Ministry of Environment, Lands and Parks. 49 p. (plus appendices).

Hassler, C. C., M. P. Wolcott, B. Dickson, R. E. Driscole, and W. B. Perry. 1990. A modular timber bridge for stream crossings. In: Managing Forest Operations in a Changing Environment Proceedings, Council on Forest Engineering Annual Meeting, Nags Head, NC.: 190-201.

Haynes, F. D., and K. L. Carey. 1996. Safe loads on ice sheets. U.S. Army Cold Regions Research and Engineering Laboratory, Ice Engineering Number 13. 4 p.

Karsky, D. 1993. Chunkwood roads. Engineering Field Notes 26:39-42. Washington, DC: U.S. Department of Agriculture, Forest Service.

Looney, T. E. 1981. A comparison of the dam bridge with current methods of crossing streams with skidders. Blacksburg, VA: Virginia Polytechnic Institute and State University. 58 p. MS Thesis.

Mason, L. 1990. Portable wetland and stream crossings. Publication 9024 1203. San Dimas, CA: U.S. Department of Agriculture, Forest Service, San Dimas Technology and Development Center. 110 p.

Mason, L. E., and P. H. Greenfield. 1995. Portable crossings for weak soil areas and streams. In: Transportation Research Record 1504; Washington, DC: Transportation Research Board, National Research Council: 118-124.

Miller, R. L., Jr. 1993. The long-term environmental impacts and the costs associated with forest road crossings of wetlands in Pennsylvania. State College, PA: Pennsylvania State University. 133 p. MS Thesis.

Newton, C. M., D. J. Brynn, D. E. Capen, J. C. Clausen, J. R. Donnelly, J. B. Shane, Jr., P. A. Thomas, T. L. Turner, and J. E. Vissering. 1990. Executive summary. In: Impact assessment of timber harvesting activity in Vermont. Burlington, VT: University of Vermont, School of Natural Resources: 1-10.

Ritter, M. A. 1992. Timber bridges: Design, construction, inspection, and maintenance. U.S. Department of Agriculture, Forest Service EM 7700-8.

Stjernberg, E. 1987. Plastic culverts in forest road construction. Technical Note TN-110. Forest Engineering Research Institute of Canada. 8 p.

Taylor, B. R. 1994. Toxicity of aspen wood leachate to aquatic life. Part I: Field study. Prepared for Environmental Protection Division, Northern Interior Region, British Columbia Ministry of Environment, Lands and Parks. 59 p. (plus appendices).

Thompson, J. D., S. E. Taylor, K. H. Yoo, R. W. Brinker, and R. A. Tufts. 1994. Water quality impacts from different forest road stream crossings. In: Proceedings of the winter meeting of the American Society of Agricultural Engineers; 1994 December 13-16; Atlanta, GA: Paper No. 94-7510. 12 p.

Thompson, C. H., and T. D. Kyker-Snowman. 1989. Evaluation of non-point source pollution problems from crossing streams with logging equipment and of-road vehicles in Massachusetts: 1987-1988. Amherst, MA: Department of Forestry and Wildlife Management, University of Massachusetts. 78 p.

Tornatore, T. A. 1995. Short-term impacts of forest road and skid trail system crossings on suspended solids and turbidity. State College, PA: Pennsylvania State University. 160 p. MS Thesis.

Tufts, R., S. Taylor, M. Weatherford, and H. Boatwright. 1994. Stream crossings using man-made fords. In: Proceedings of the winter meeting of the American Society of Agricultural Engineers; 1994 December 13-16; Atlanta, GA; Paper No. 94-7509. 10 p.

Wolanek, M. D. 1995. Wood fiber road construction influences on stream water quality in Southeast Alaska. In: Proceedings of the sixth international conference on low-volume roads; 1995 June 25-26; Minneapolis, MN: Washington, DC: National Academy Press: 1(58-66).

MECHANICAL DELIMBING OF NORTHERN HARDWOODS: RESULTS FROM LABORATORY TESTS[1]

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ABSTRACT: The objective of this study was to determine which machine parameters can be varied to reduce the force required to delimb hardwoods by knife.

Five independent variables were chosen for investigation: blade thickness, blade cutting edge angle, oblique cutting angle, cutting speed, and branch diameter. For all tests the branch angle was held constant. Sugar maple was used for all tests. Sapling bolewood held at a fixed angle was used to simulate branches. A total of 68 tests were conducted.

Analysis of Variance revealed that only blade cutting edge angle, oblique cutting angle, and branch diameter were found to significantly affect average cutting force.

Cutting edge angle was the most important factor influencing the cutting force.Reducing the cutting edge angle can significantly reduce the average cutting force.

Results indicate potential for improvement in the efficiency, productivity, and design of knife type delimbing mechanisms.

Key Words: hardwood delimbing, force reduction, cutting angle, delimbers

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[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

PROPOSED INTERNATIONAL STANDARD DEFINITIONS FOR TIME CONSUMPTION IN THE STUDY OF FOREST WORK[1]

by

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ABSTRACT: There are many different time classification and recording systems being used around the world to evaluate forest work. Differences between these systems create difficulties in comparing and using the information generated. Standard definitions for classifying time consumption in forest work is needed to make information collected in different parts of the world comparable and compatible. A subcommittee of the International Union of Forest Research Organizations' (IUFRO) Working Party S3.04-02 (Work study; payment, labour productivity) has completed a test edition nomenclature for classifying time in forest work. This report outlines the details of the classification system proposed by this subcommittee. Of particular interest in this discussion is the relationship between observed time and standard time. The nomenclature in this document is used to develop unbiased estimates through direct observation. The observed times that result can then be used to develop standard times. This process does not destroy observed information; therefore, this nomenclature is considered compatible with both the observed and standard time systems.

Key Words: time classification, standards, nomenclature, work study, forest operations

INTRODUCTION

Forest machines and methods have become more complex in recent years as technological advances are made in machine systems and as environmentally-friendly approaches are developed. Along with the expectations of high productivity and low cost placed on forest equipment, low site and stand impact is also critical. Proper operational planning is essential to attaining these goals.

Because of the complexity associated with operating in this environment, serious study is required to determine the most efficient, economic, and environmentally-acceptable machine systems and operating methods for a given set of operating conditions. The purpose of forest work study is to provide this knowledge using commonly-accepted, unbiased, and repeatable evaluation methods.

Using standard work study methods is important to the usefulness of the information generated. Information collected using different formats and procedures is often incompatible, making it necessary to duplicate studies. This is time-consuming, costly, and would be unnecessary if standard evaluation methods were developed and applied.

The first step in the process of developing a standard forest work study methodology is to develop a recognized standard forest work study nomenclature. In other words, a common understanding of the terms being used in forest work study must precede development of common evaluation methods.

This is especially true for the method used to classify time consumption because the method used will determine how the collected information can be used. Developing standard definitions for time consumption in forest work is especially challenging to achieve on an international basis because of the many languages and work study methods that exist around the world.

The purpose of this paper is to report on the development of a proposed internationally-recognized nomenclature for classifying time consumption in forest work in the English language. English was chosen because it is the most common second language in the world. The nomenclature was developed by a subcommittee of the International Union of Forest Research Organizations' (IUFRO) Subject Area S3.04-02 (members listed in the Appendix).

From this common understanding of nomenclature, it is hoped that widely-accepted evaluation methods will be developed and used throughout the world. This will serve to increase the value of performance information for forest equipment and methods in countries with similar operating conditions.

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

CLASSIFYING TIME

Work can be classified into individual work elements in many different ways which will ultimately affect the compatibility and usefulness of the observed times. The purpose of a time classification nomenclature is to define commonly-occurring work elements in most types of forest work. Evaluation personnel can then use this classification framework to classify specific work elements in the work they are studying.

Many different systems for classifying observed time have been developed around the world. North American researchers generally use the system outlined by Berard et al. (1968), whereas Scandinavian researchers generally use the system outlined by the NSR (1978). Significant variation exists both between these systems and between the application of these systems by individual researchers.

The Scandinavian system (NSR 1978) provides a good basic framework for time classification in forest work. However, it has a few problems. For example, it includes provisions for including individual delays of less than fifteen minutes into gross effective time. This could result in serious inaccuracy when estimating effective time. This system also allows for a subjective delineation of delay times into either avoidable or unavoidable.

The North American system (Berard et al. 1968) classifies the same work element differently depending on whether it occurs within the scheduled shift or out of the scheduled shift. This system also provides an inadequate rendering of work elements not considered productive to the work task. It is hoped that the inadequacies of these two systems have been corrected in the current proposed time classification system.

THE PROPOSED SYSTEM

The nomenclature proposed by this IUFRO sub-committee for classifying time consumption in forest work is presented in Table 1 and Figure 1. The terms and definitions presented were taken from the following published sources (Berard et al. 1968; BSI 1979; NSR 1978; SAE 1990) or developed by the subcommittee.

Table 1. The proposed time classification system.

Total Time (TT): The total elapsed time of the period under consideration (also calendaric or control time).

Non-Workplace Time (NW): The portion of the total time that is not used for the completion of a specific work task.

- **Unutilized Time (UN):** The portion of the non-workplace time that the worker is away from the job; such as time off, etc.
- **Travel Time (TR):** The portion of the non-workplace time that the worker is traveling to and from the job site before and after the work period; such as travel to the job site, travel away from the job site, etc.

Workplace Time (WP): The portion of the total time that a production system or part of a production system is engaged in a specific work task (also scheduled time).

- **Non-Work Time (NT):** The portion of the workplace time that no work is being accomplished on the work task.
  - **Disturbance Time (DT):** The portion of the non-work time that is considered an interruption in the work with no direct or indirect connection to the completion of the work task; such as gathering information, inclement weather, visitors, injuries, etc.
  - **Work-Related Delay Time (WD):** The portion of the non-work time that can be related back to the organization of the work.
    - **Meal Time (ME):** The portion of the work-related delay time used to refuel the workers or animals in the production system; such as breakfast, lunch, dinner, etc.
    - **Rest and Personal Time (RP):** The portion of the work-related delay time used to sustain the working capacity of workers or animals in the production system; such as breaks, rests, personal needs, etc.
    - **Interference Time (IT):** The portion of the work-related delay time in which no work activity is occurring due to the interference of a necessary operation within the production system; such as waiting for the completion of other tasks upon which this task is dependent, etc.
- **Work Time (WT):** The portion of the workplace time that a production system or part of a production system is directly or indirectly involved in completing a specific work task.
  - **Productive Work Time (PW):** The portion of the work time that is spent

contributing directly to the completion of a specific work task, typically occurring on a cyclic basis (also direct work time).

Main Work Time (MW): The portion of the productive work time used to change the work object with regard to form, position, or state within the definition of the work task; such as felling, delimbing, bucking, skidding, loading, etc.

Complementary Work Time (CW): The portion of the productive work time that does not change the work object with regard to form, position, or state but is needed to complete the work task and is an integral part of the work cycle; such as positioning the machine or worker, clearing the work area, assessing the situation, dragging cable, etc.

Supportive Work Time (SW): The portion of the work time that does not directly add to the completion of the work task, but is performed to support it (also indirect work time).

Preparatory Time (PT): The portion of the supportive work time used to prepare the machines and conditions of the work place at a single work site or landing location.

Relocation Time (RL): The portion of the preparatory time used to transport machines, workers, etc. to a new work site.

Planning Time (PL): The portion of the preparatory time used to develop the operational strategy; such as cruising and planning a harvest area, marking off skid trails and sensitive areas, etc.

Operational Preparatory Time (OP): The portion of the preparatory time used to ready the harvest system to continue operating at a particular site; such as changing operators, moving into the stand, changing the rigging (same landing location) for cable systems, etc.

Change-Over Time (CO): The portion of the preparatory time used to set-up and take-down the production system.

Set-Up Time (SU): The portion of the change-over time used to ready the production system for operating at the new site; such as stationing and stabilizing portable equipment, setting up rigging for cable systems, etc.

Take-Down Time (TD): The portion of the change-over time used to ready the production system for moving to a new site; such as mobilizing portable equipment, taking down the rigging for cable systems, etc.

Service Time (ST): The portion of the supportive work time used to sustain the working capacity of machines in the production system.

Repair Time (RT): The portion of the service time used to repair damaged components, occurring as principally non-cyclic interruptions; such as repairing; waiting for repair parts, mechanics, or facilities; transporting for repair; etc.

Maintenance Time (MT): The portion of the service time used to compensate for the successive degradation of tools and machinery occurring as principally cyclic interruptions; such as maintaining; waiting for parts, mechanics, or facilities; transporting for maintenance; warming up equipment, checking equipment function, etc.

Refuel Time (RF): The portion of the service time used to refuel the machine; such as transporting to refuel, refueling, etc.

Ancillary Work Time (AW): The portion of the supportive work time used to perform ancillary work functions that allow the work to continue in the production system; such as assisting another machine or worker, blading skid trails, laying boughs in wet spots, etc.

DISCUSSION

Observing and recording time consumption in forest work using the classification system outlined in Table 1 and Figure 1 is considered the "observed time" system. Of particular interest is the relationship between this system and the "standard time" system used regularly in Germany and the United Kingdom. The standard time system is a work measurement system used to determine the average time it should take for a qualified worker to perform a defined amount of work when performing at an expected level of performance (BSI 1979).

One purpose of the standard time system is to allow for direct comparison of performance by "correcting" for differences in working conditions and workpiece variables. This is accomplished by rating the performance of the worker (performance rating) relative to an expected or standard rate of working and providing allowances for rest and meals.

A strong case exists against using performance rating to "correct" observed data due to the subjective nature of this method (Bjorheden 1992, Samset 1988). However, this practice need not be debated when developing nomenclature for observed times. Developing standard times from observed data is an analysis procedure applied to observed data. Applying a performance rating correction and assuming rest and other times does not destroy the observed data. Therefore, as long as all the information needed to develop standard times (such as operator performance rating) is collected during observation, these basic observations can be statistically analyzed or used to develop standard times.

The question whether or not to collect performance rating during observation of the work need not be addressed when debating this nomenclature. This is a question that should be addressed during the next step of this initiative to develop standard forest work study methods (which should consist of developing specific internationally-accepted procedures for collecting, analyzing, and reporting forest work study results). A standard forest work study system is considered critical to the international compatibility and usefulness of forest work study information.

CONCLUSIONS

This report proposes an internationally-accepted nomenclature for time classification in forest work in the english language (Appendix 1). It is hoped that IUFRO members will either use this nomenclature in technical reports or communicate to this subcommittee why they cannot. It is envisioned that internationally-accepted practices for collecting, analyzing, and reporting results of forest work studies will be the next logical development in this initiative. Anyone interested in working in this area is encouraged to discuss this interest with the leader of IUFRO S3.04-02, Rolf Bjorheden. The development and use of internationally-accepted nomenclature and work study practices is critical to the compatibility and ultimate usefulness of forest work study information.

REFERENCES

Berard, Jean A., D.H.W. Dibble, C.D. Horncastle. 1968. Standard definitions for machine availability and utilization. Pulp and Paper Magazine of Canada 69(1):94,96.

Bjorheden, Rolf. 1992. Introductory remarks concerning an international time study nomenclature. Unpublished paper presented at the IUFRO WP S3.04.02 symposium "Work Study - Measurement and Terminology," 10-12 June 1992, Gottingen, Germany.

British Standards Institute (BSI). 1979. BS 3138: Glossary of terms used in work study and organization and methods. 32 p.

NSR. 1978. Forestry work study nomenclature. The Nordic Forest Study Council. 130p.

Samset, Ivar. 1988. Some observations on time and performance studies of forest operations. In "Developments on Work Studies in Forestry," 22-24 June 1988, Thessaloniki, Greece; IUFRO WP S3.04.02, p. 171-197.

Society of Automotive Engineers (SAE). 1990. SAE J817a: Engineering design serviceability guidelines - construction and industrial machinery. In 1990 SAE Handbook, 400 Commonwealth Drive, Warrendale, PA USA; p. 40.422-40.428.

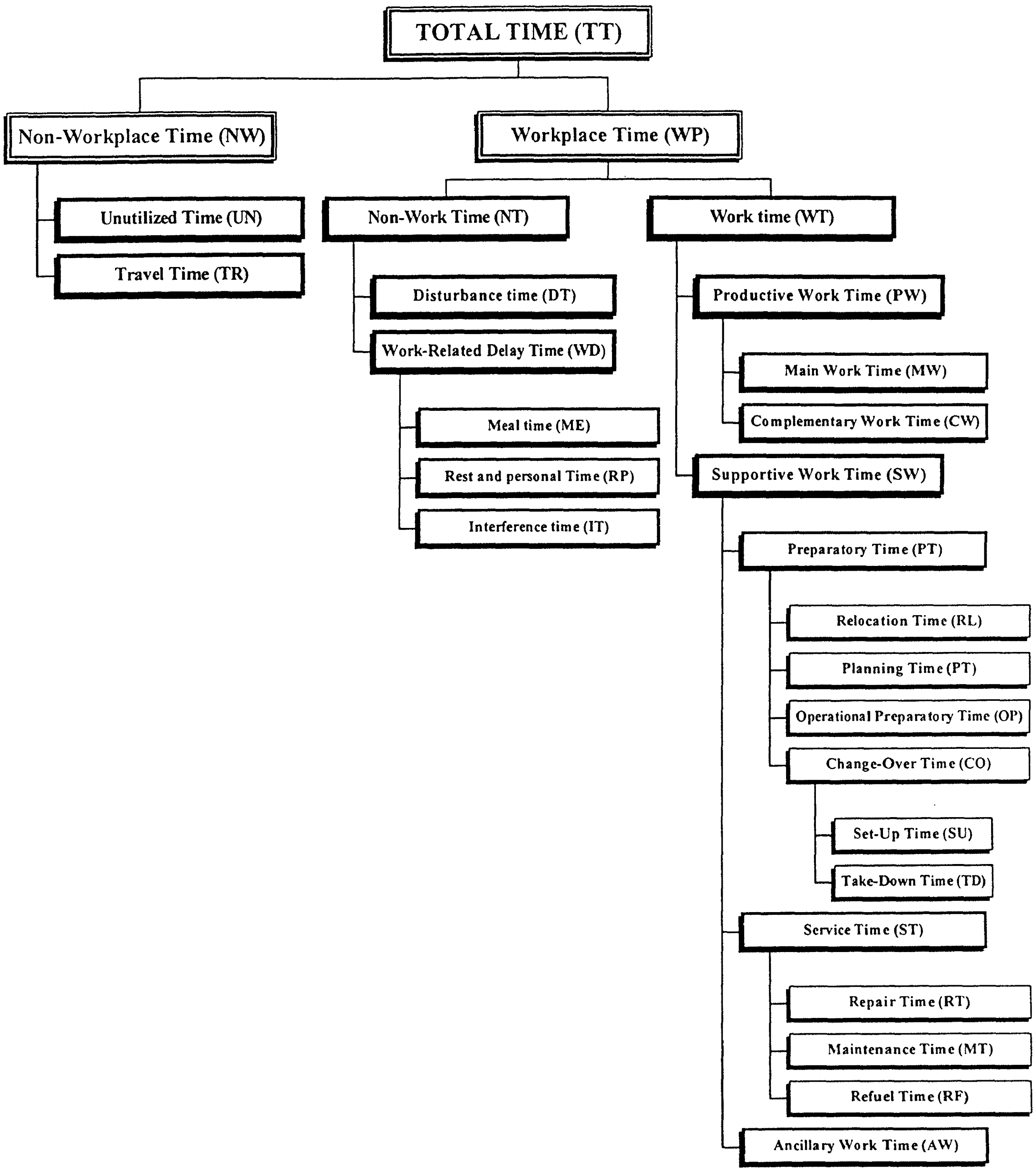

Figure 1. Time concept's structure.

RAPID STABILIZATION OF THAWING SOILS: A DEMONSTRATION PROJECT[1]

by

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ABSTRACT: The US Army Cold Regions Research and Engineering Laboratory (CRREL) conducted a field demonstration project in which a variety of expedient surfaces were constructed and trafficked to test stabilization techniques for thawing soils. The project was conducted at Fort McCoy, Wisconsin, during the 1995 spring thaw. Cooperating partners included the Wisconsin National Guard, the US Army Engineer School, the USDA Forest Service (USFS), Terramat, and Uni-Mat International, Inc. As part of the overall project, the stabilizing techniques were evaluated for expediency, ease of construction, performance during trafficking, and vehicle mobility enhancement. The test and evaluation program generated recommendations for construction of expedient roads under thawing conditions to be incorporated into military engineering decision aids and simulations. The information is also applicable for non-military purposes such as timber- and pipeline-access in the logging, oil and gas industries. This paper provides a general description of the techniques tested and installation methods used as well as some difficulties associated with each. It also briefly describes the tests performed and types of data gathered. Greater detail and results are provided in Kestler et al. (in prep).

Key Words: expedient surfaces, stabilization, thaw weakening, wetland crossings

INTRODUCTION / BACKGROUND

Thawing soils can reduce vehicle mobility on unsuraced roads or trails and severely restrict off-road travel. In addition, trafficking may cause damage by rutting, tearing of surface vegetation, and subsequent erosion. In frost-susceptible soils, freezing temperatures draw soil moisture upward, forming ice lenses. Later, as surface temperatures rise, water from melting ice is trapped in the thawing layer by the impermeable frozen layers below. Additional moisture from snowmelt or precipitation can worsen conditions, as can low nightly temperatures that continue to draw soil moisture toward the surface. These conditions were evident as "muddy roads" during the deployment of US forces in Bosnia, where rapid stabilization of thawing soils was critical for the safe and timely movement of troops.

Vehicle mobility can be enhanced and environmental damage prevented by appropriate stabilization of thawing ground. Phase I, an initial review of rapid stabilization techniques, is provided in Kestler et al. (1994). The objective of the field demonstration, Phase II, was to evaluate the construction and performance of the most promising methods of stabilization suitable for military use on thawing ground. The test program was conducted during March 1995 at Fort McCoy, Wisconsin. The date was selected based on the available historical weather data indicating this as the typical time of spring thaw. Although the test and evaluation program was performed with military vehicles, the techniques are suitable for many civilian applications, such as for construction, mining, oil and forestry, where the ability to travel on thawing ground is desirable.

Stabilization techniques were tested on each of three trails—a thawing wooded trail, a 16 to 18% sloped trail, and a pentagonal-shaped loop trail (to test cornering). The techniques were chosen for field evaluation based on their applicability to military use, expediency, and mechanical interaction with thawing ground to distribute loads and provide both vehicle flotation and traction. The USDA Forest Service has been testing and evaluating many of these techniques as portable crossings for unstable soil, primarily for wheeled vehicles, for the past several years (Mason 1990). Mechanical stabilization techniques evaluated at Fort McCoy include chunkwood, tire chips, wood mats, tire mats, fascines, tree slash, and geosynthetics. Materials were used both separately and in combination with each other. Most test sections were 30 m (100 ft) in length. Trail preparation prior to placing the materials was minimal. Details including labor and equipment needs, time, and amount of material for construction of each surface were carefully observed and noted. Prior to construction, the terrain and soil were characterized. After construction,

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surfacing materials were subjected to 50 passes each of a wheeled military vehicle (Heavy Expanded Mobility Tactical truck [HEMTT]) and a tracked tank (M60A3) (Figure 1). During trafficking, vehicle and test surface performance were monitored for test surface damage through rutting and lateral expansion, material interference with vehicles, vehicle traction and handling problems, and ride quality (Kestler et al. in prep) (Shoop and Stark 1996).

This field program was made possible through collaborative efforts of several government organizations and private industry. The USDA Forest Service (USFS) worked closely with us based on their interests in environmentally-friendly forest operations. They assisted in the production of chunkwood, developed by the USFS as an alternative road-building material, and in fabrication of both wood pallets and PVC fascine mats. The US Army Engineer School helped plan and execute the test and evaluation program to assess various techniques for military use. The WI National Guard 229th Engineers CSE Co. constructed the trails and performed the trafficking and evaluation as part of their annual training exercise. Two private companies (Terramat and Uni-Mat International) donated their time and materials to evaluate their products for military use. Finally, the tests were conducted at Fort McCoy, WI, specifically for testing chunkwood roads for long-term trail improvement and for resource management by thinning trees in selected areas to enhance an endangered species habitat.

STABILIZATION MATERIALS AND CONSTRUCTION

Gravel

Gravel, typically used for Fort McCoy's gravel roads, was obtained from an on-base stockpile. The material was loaded into dump trucks, delivered to the test sites, and spread with a D7 bulldozer. It had a density of approximately 1920 kg/m^3 (120 pcf), compacted easily with construction traffic, and provided a good traffic surface.

Chunkwood

Woodchunker machines were initially developed to improve the utilization of unmerchantable timber (Figure 2a). Two experimental prototype chunkers were built by the USFS, one at the North Central Experiment Station in Houghton, Michigan, and the other at the Missoula Technology and Development Center (MTDC) in Montana. Whole trees are "chunked" and individual chunkwood particles range in size from that of a conventional wood chip to the diameter of the parent tree. Initial uses of chunkwood included biomass fuel and a material for manufacturing flakeboard. However, since 1987, the USFS has used chunkwood in the construction of several low volume forest roads (Arola et al. 1991). Two major objectives in roadbuilding are to minimize the water accumulation on the surface, and to elevate the roadway to maximize subbase drainage. While this can be done with conventional borrow material, chunkwood provides a viable alternative when suitable gravel is unavailable within a reasonable haul distance. Additionally, high permeability makes chunkwood a good replacement for gravel in wet areas.

The USFS has shown that a few inches of aggregate surfacing atop a chunkwood base course improves performance considerably. However, for expediency, no cover was placed on the chunkwood at Fort McCoy (Figure 2b), and it was evaluated as a wear surface. In most instances, chunkwood was mixed with sand (three parts chunkwood to one part sand) to increase the grain size range and improve interlocking. Thickness of the chunkwood test sections ranged from 20 to 40 cm (8 to 16 in.). In addition to the chunkwood test sections, chunkwood served as the mainstay of the trail improvement program, replacing gravel wherever additional fill was required.

Because Fort McCoy had planned to construct additional chunkwood roads on base after completion of the stabilization demonstration project, and because of the uncertainty of continuous operation of the USFS' prototype woodchunker throughout the demonstration project, chunking operations commenced a few weeks prior to the start of the demonstration project. This provided a sizable stockpile for the start of the demonstration project.

The material was loaded into dump trucks, delivered to the site, and spread with a D7 bulldozer. Construction vehicle traffic provided adequate compaction and a smooth wear surface.

The use of chunkwood was ideal for the Fort McCoy site. Thinning was desired to enhance the habitat for an endangered species, and the timber used for chunking was mostly unmerchantable.

Tire chips

Tire chips are produced by shredding old tires into pieces passing a 5-cm (2 in.) sieve. Like chunkwood,

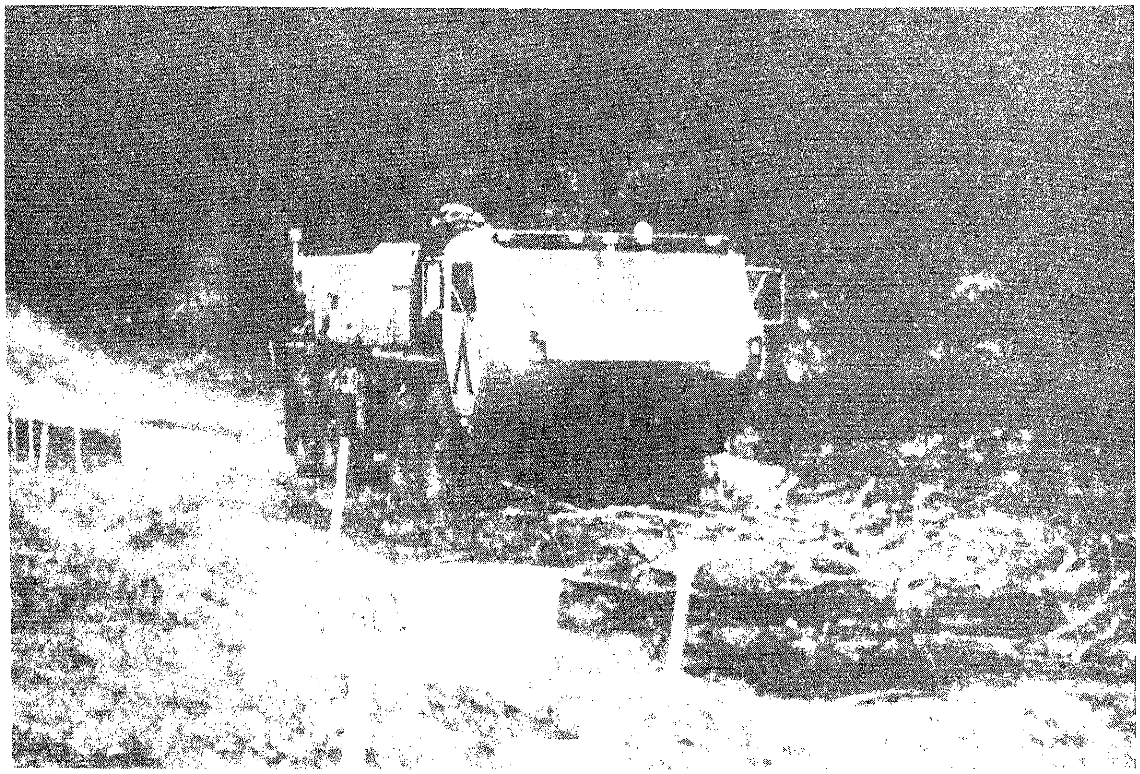


Figure 1a. Trafficking vehicle -- HEMTT on a sloped trail.

Figure 1b. Trafficking vehicle -- tank on a sloped trail.

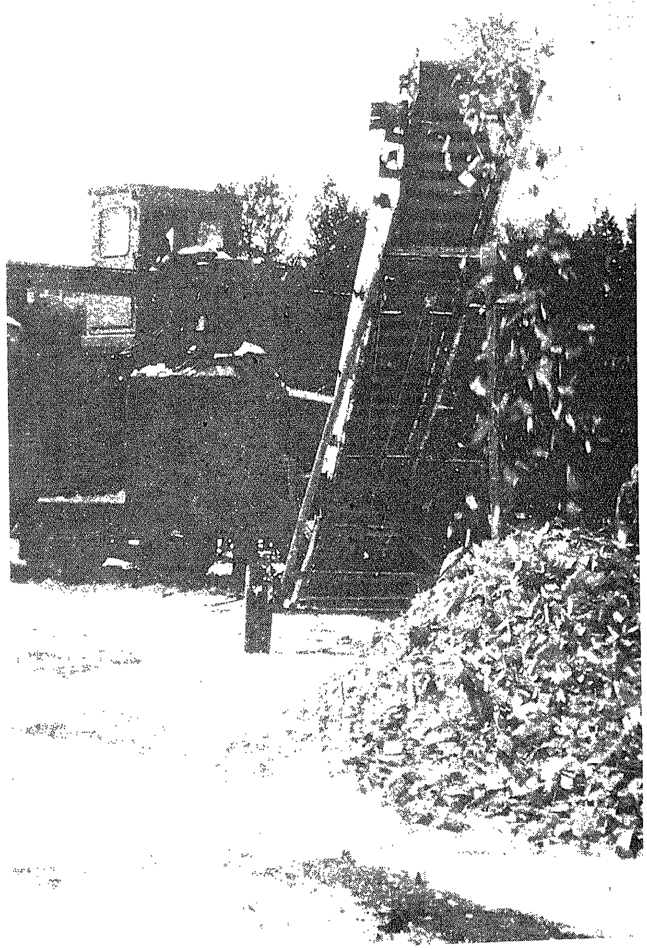


Figure 2a. USDA Forest Service woodchunker.

Figure 2b. Chunkwood road -- wooded trail.

tire chips can replace granular fill material and are very permeable. In recent years, tire chips have been used in road bases because of their high permeability, good insulating properties (to reduce detrimental effects of frost action) and to efficiently recycle old tires (Humphrey and Eaton 1993). Commercially available tire chips can be obtained throughout the US. The chips used in this project were purchased in Wisconsin. The tire chip test sections were approximately 30 cm (12 in.) thick (Figure 3). Traffic was applied directly on the tire chip surface.

Tire chips were loaded into dump trucks, delivered to the site, and spread with a D7 bulldozer. Like chunkwood, the tire chips were lightweight (640 kg/m^3 [40 pcf]). However, in contrast to chunkwood, the tire chips did not appear to compact significantly. The surface remained springy even after several passes of a D7 dozer.

Although the tire chips were ordered to be cut with fresh blades, metal pieces protruded from many chips, and the bead steel caused flat tires on a jeep and grader.

Geosynthetics (Figure 4)

Before the main test program, several types of geosynthetics were tested and ranked according to resistance to damage from M60 tank trafficking. Products that sustained the least amount of damage in the pretests (double-sided geonet and polyrock) were used to stabilize test sections without any cover. The ST1000 geotextile was used with less than 10 cm (4 in.) of gravel cover on the wooded trail and with 30 cm (12 in.) of gravel cover on the pentagonal loop trail test section.

It was also used beneath sections of tire chips, chunkwood, and slash on the wooded trail. The LGT 300 was used to wrap chunkwood, making a "pillow" to successfully repair the wooded trail when a section had slumped into an adjacent ponded area during tank trafficking. Table 1 lists geosynthetic specifications.

Figure 3. Tire chips -- wooded trail.

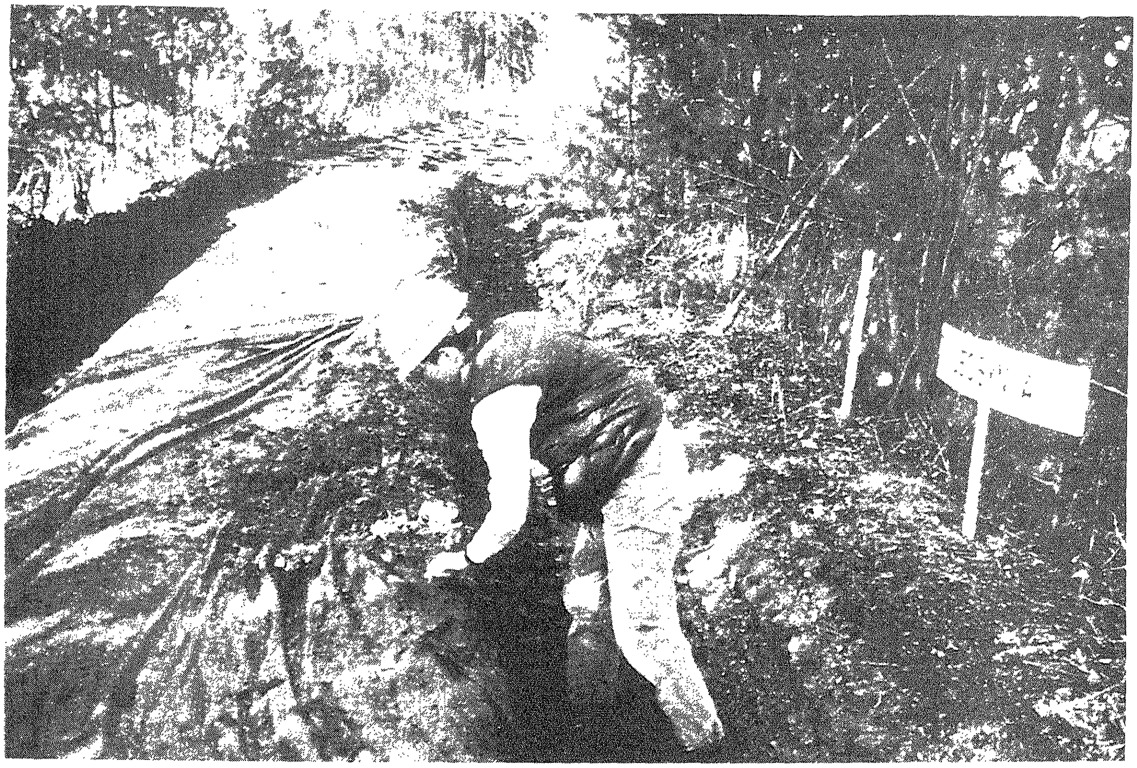


Figure 4. Geosynthetics -- wooded trail.

Table 1: Geosynthetics used at Fort McCoy for rapid stabilization of thawing soils.

Product/construction/mass per unit area (g/m^2)	AOS (mm)	Typical uses	WW tensile strength kN/m (lb./in.)	Puncture kN (lb.)	Burst kPA (psi)
ST1000/NW PP/540	0.15/#100	R, P, S	24.5 (140)/same in both	0.71 (160)	3795 (550)
LGT 300/W PP (slit film)/200	0.60/#30	S/S	31.5 (180)	0.80 (115)	4139 (600)
PR1 NW (PP with PET reinforcement) a HIGH STRENGTH material	to be obtained	R	not yet available	not yet available	not yet available
Double-sided geonet (NW PP geotextile on geonet core) 2000	not applicable	D	not available		

NW=nonwoven, W=woven, PP=polypropylene, PET=polyester, P=protection, R=reinforcement, S=separation, S/S=separation and stabilization, D=drainage

Tree slash

One of the simplest, most natural, and, excluding labor, economic methods of stabilization is to incorporate slash and tree limbs into a debris mat. This method is often used for construction on peat (Phukan 1982), and is typically used as a lightweight fill/base with a soil wear surface for timber access roads in the Tongass National Forest in Alaska (Burnette 1993). The slash used for the Fort McCoy demonstration project consisted of trees branches laid at angles to the direction of travel. The best method of placing the slash was to use the trunks to fill in ruts and hollows and to lay branches no bigger than 8 cm (3 in.) in diameter in a herringbone pattern at 45° angles to the direction of travel (Figure 5). More slash was added during trafficking to replenish the existing surface. Although not demonstrated at Fort McCoy, slash can also be used in combination with other mechanical stabilization methods in instances when large quantities of fill material are not available within a reasonable haul distance.

Tire mats

Terra Mat, a commercial product specifically designed for the purpose of assisting logging trucks across sections of unstable soil, consists of tire sidewalls lashed together to form portable road mats (Figure 6). The product is successfully used by logging, construction, oil, gas, and pipeline industries. When used for timber access roads across wet and thawing soils, the mats provide added benefits of 1) reducing mud tracked onto paved roads, 2) minimizing compaction of the forest floor, and 3) utilizing scrap truck tires.

The tire mats are manufactured in a variety of sizes and weights. Terra Mat Corp. provided its heavy duty model TMC 410-12 mat for use with tracked vehicles. Each mat is 3 m (10 ft) long x 1.5 m (5 ft) wide and weighs approximately 9800 kN (2200 lb.). Mats consist of a layer of interconnected tire treads with a top layer of tire sidewalls and end lifting chains.

Mats were placed along the wheeltracks. Placement methods were tested and modified throughout the demonstration. On the sloped trail, the first six mats were moved to the test section using an all-terrain forklift. However, the forklift could not be used to place the mats because of poor brakes and the steep grade, so a bucket loader was used for placement. The next placement technique involved pulling and placing two mats at a time with the HEMTT and winch. Finally, tire mats were delivered to the pentagonal loop trail on a lowboy, and were off-loaded and roughly positioned with a bucket loader. A D7 dozer was used to move the mats into their final positions.

Small wood pallets

Wood pallets were fabricated on site by the 229th Engineers (Figure 7a). These were constructed primarily of soft wood, and could be placed manually with a seven- to nine-person crew or by using a forklift.

Large wood mats

Shown in Figure 7b is a pre-assembled commercial woodmat on loan from Uni-Mat International. The Uni-Mats, made of oak, were substantially larger (2.44 x 4.27 m [8 x 14 ft]) and heavier (approximately 6300 kN [1400 lb.]) than the pallets. They were placed using loaders or the HEMTT crane.

Figure 5. Slash - pentagonal loop trail.

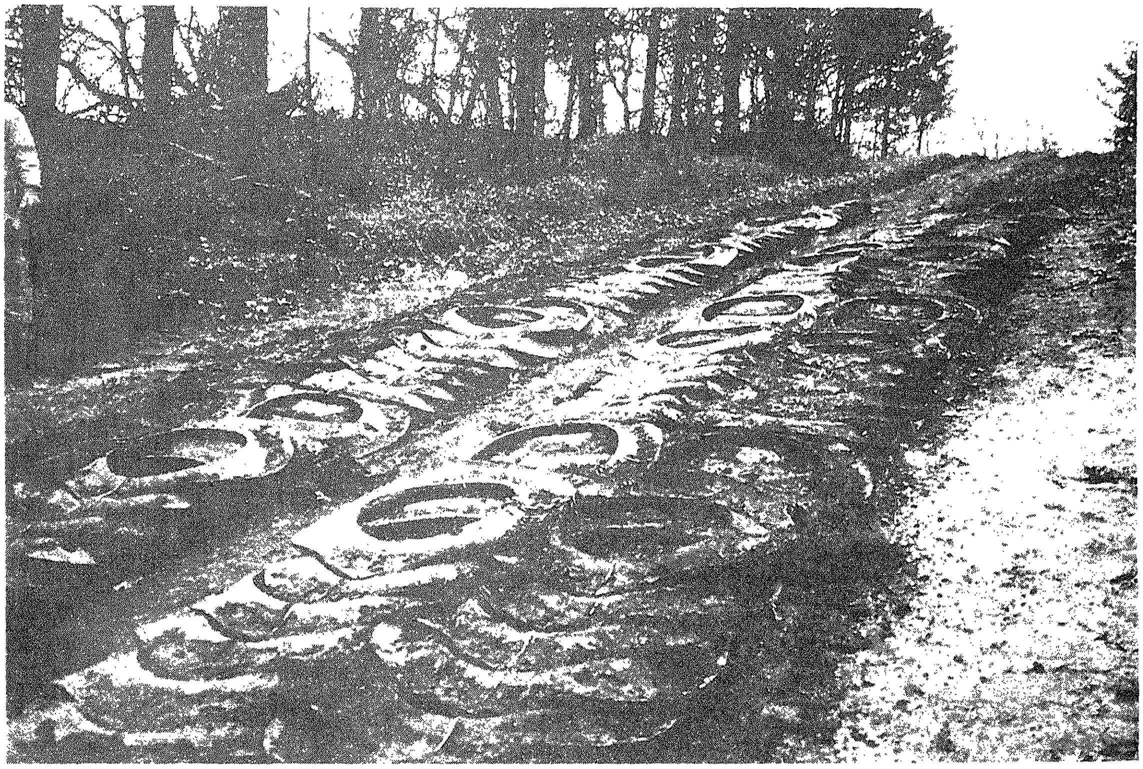


Figure 6. Tire mats -- sloped trail.

Figure 7a. Wood pallet -- wooded trail.

Figure 7b. Uni-mat™ wood mat -- wooded trail.

PVC fascine

A fascine (Figure 8) was built from schedule 80 PVC pipes by linking the pipes together with 1.6-cm-diameter (5/8 in.) steel cable. However, schedule 40 PVC pipes and 0.95-cm-diameter (3/8 in.) cable are adequate. To conserve material, pipes were not continuous across the entire width of the trail. The fascine was constructed on site, and was used to fill low-lying areas while still maintaining drainage though the pipes. It was covered with tire mats in an area where it filled a small stream, and with geotextile and chunkwood where the trail turned a corner adjacent to a swamp.

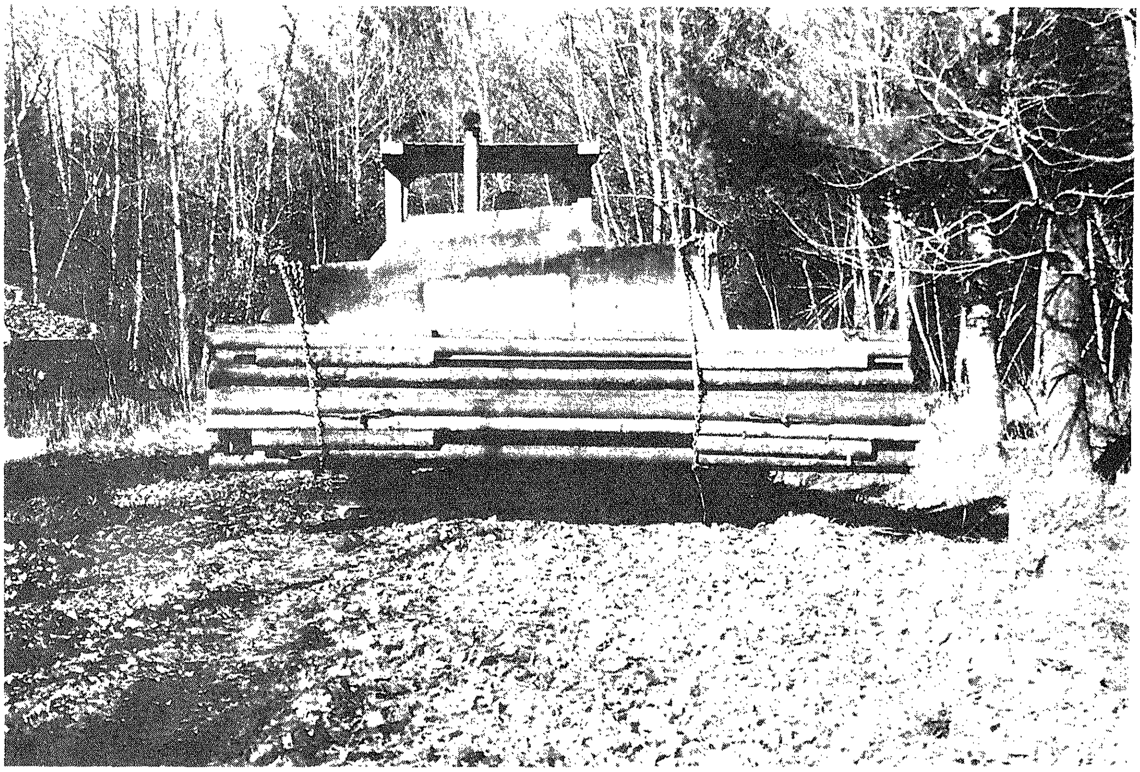
Control

Each test area had one or more control sections of bare ground with no stabilization treatment.

SITE CHARACTERIZATION

The subgrade soil and surface features of test sites were characterized prior to construction. Native material consisted primarily of a silty sand. For the wooded trail, where construction and testing spanned several days, additional soil moisture and thaw depth were measured on an interim basis to document changing conditions in the soil. Table 2 summarizes soil tests conducted and terrain properties measured.

Statistical analyses were conducted on site characterization and performance data to both quantify site variability and investigate the influence of site variability on test section performance (Kestler 1996). Variability analysis results statistically demonstrated that performance of stabilizing materials, as measured by rut depth on the stabilizing surface, could be compared between adjacent sections; however, test sections separated by over approximately 300 ft could not be as "directly" compared because they were constructed on virtually different subgrades.



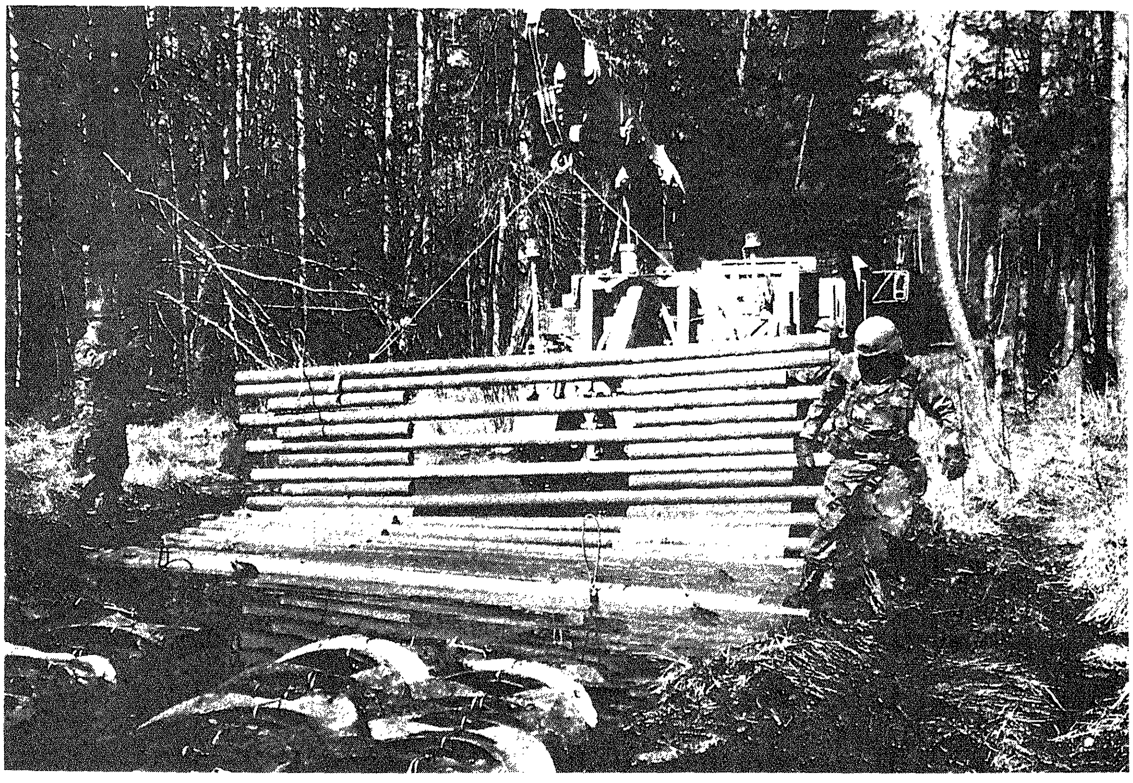


Figure 8. PVC fascine -- wooded trail.

Table 2. Site characterization activities.

Activity or Test Device	To Determine or Measure:
Clegg Impact Tester (CIT)	California Bearing Ration (CBR)--(Hardness)
Dynamic Cone Penetrometer (DCP)	CBR
Static Cone	Stiffness - Cone Index
Laboratory CBR Test	CBR
Vitel Radio Frequency Moisture Sensors	Volumetric Moisture Contents
Gravimetric Moisture samples	Gravimetric Moisture Contents
Nuclear Moisture Density Gauge - Densimeter	Density and Gravimetric Moisture
Thaw Depth Probe and Soil Temperature	Depth to Resistance & Corresponding Temperature
Drive Cylinders	Density
Preconstruction Rut Depth Measurements	Rut Depths
Surface Elevation Survey	Centerline Survey
Bagged Samples for Laboratory Testing	CBR, Resilient Modulus, Gradation, etc.
General Site Characterization Evaluations	General Characterization of Site (e.g., % surface water, drainage, vegetation, etc.)

SUMMARY OF OVERALL PERFORMANCE OF TEST SECTIONS

Gravel

Placing "conventional" gravel is unquestionably one of the most common and expedient techniques. Dump trucks, loaders, and dozers are standard equipment. One problem, of course, is availability of material. It is possible that aggregate sources are simply unavailable. It is also possible that borrow sources may still be frozen, or inaccessible. Finally, the bearing capacity of the subgrade may be inadequate to support the weight of an aggregate roadway embankment.

Chunkwood

Chunkwood proved to be an excellent substitute for gravel for the Fort McCoy demonstration project. Not only was it successfully used in test sections as planned, but it also served as the mainstay for the entire project. When access roads to test sites became impassable, chunkwood was used to reconstruct and allow passage. Because its density is less than half that of conventional aggregate fill, it can be supported by very weak subgrades (such as muskeg and thawing soils) that might not be capable of supporting an aggregate layer of required thickness. A gravel wear surface can be added for use as a permanent road. The chunkwood base reduces frost penetration into the subgrade, therefore reducing detrimental effects of frost action in areas of seasonal freezing. Additionally, in a forested environment, it can complement any forest management program by utilizing unmerchantable timber. However, chunkwood's success relies on the development of a commercial chunker. Availability of trees is also critical for chunkwood road building.

Tire chips

As was the case for conventional roads and chunkwood, construction requires no special equipment or training. Tire chips can be supported by weak subgrades not capable of supporting a gravel embankment. The quantity of gravel that can be hauled at any one time is restricted by weight. In contrast, because tire chips are lightweight, they can be hauled in loaded trucks pulling loaded trailers. As with chunkwood, a gravel wear surface can easily be added if the chips are to be used for the base of a permanent road. The tire chips provide an excellent insulating layer to reduce detrimental effects of frost action in areas of seasonal freezing. Another advantage of tire chips is utilization of a waste product. However, it is imperative that no steel bead or foreign steel pieces be contained in the tire chips if they are to be used as a trafficking surface for small rubber-tired vehicles (or foot travel). Other issues including environmental concerns (when placed below the seasonal high water table) and "flammability" need to be addressed.

Geosynthetics

All geosynthetics were placed quickly and with minimal labor. They are lightweight and easy to handle compared to other stabilizing surfaces. Cover is necessary wherever severe trafficking will occur. As is the case with all materials other than slash, chunkwood, and gravel (which *may* be native to the site), geosynthetics must be delivered to the site. Geosynthetics and other techniques complement each other when used in combination.

Tree slash

Tree slash is inexpensive, and placement requires no special equipment or training. Its availability is slightly broader than that of chunkwood simply because scrub brush, old corn husks, or any vegetative material may be used. A disadvantage is that placement is labor intensive and, for certain military purposes, may expose construction personnel to potential enemy fire for a longer period than for placement of other materials. Like tire chips, it is not a desirable surface for small rubber-tired vehicle passage or foot traffic; walking is extremely difficult. Tree slash can also puncture and damage hydraulic hoses on the underside of equipment.

Small wood pallets

Constructing these on site requires time and labor. However, ease of placement (for the effectiveness of performance) is a plus. Lumber is typically available almost anywhere. Mats were broken during trafficking. However, they continued to perform very well (stabilizing a weak thawing soil to adequately support trafficking). Mats can be re-used if constructed with a strong hardwood.

Large wood mats

Although tank cornering was not tested on Uni-Mats during this demonstration project, its success for horizontal turns has been documented. Uni-Mats seem to be the only surface tested that can withstand the trauma of tank tracks undergoing cornering. Uni-Mats performed very well on relatively level terrain, but were slippery on slopes. They are not designed for bridging large ruts, consequently blading the trail surface may be necessary prior to mat placement. Because Uni-mats are constructed of oak, they can be re-used.

PVC fascine

No special equipment was required, and the fascine mats could be constructed on site. If not adequately supported at a site with flowing water, they can be pushed into the subgrade material causing the pipes to become blocked with sediment (as occurred at Fort McCoy). However, they can still perform well as a supporting mat even though water may not readily pass through the pipes.

Techniques used in combination

Each of the above techniques serves some portion of the design function, and combinations of methods often proved to be more effective than any individual method.

ACKNOWLEDGMENTS

The authors thank all who contributed toward the success of the 1995 Expedient Surfacing Stabilization Techniques demonstration at Fort McCoy, Wisconsin. This demonstration project was the culmination of a 2-1/2-year rapid stabilization study conducted largely in conjunction with, and as the US Army's continuation of, the USDA Forest Service's Study on portable crossings for unstable soil. We particularly thank Lola Hislop whose extensive work in portable crossings provided a solid foundation for CRREL's Rapid Stabilization project to build upon and extend to tank trafficking. We thank Jim Kerkman and Candy Thornton (Fort McCoy), LT Paul Liethen and the 229th Engineer CSE Co. of Wisconsin National Guard, Rosa Affleck, Dave L'Heureux and MAJ Randy Hill (CRREL), SFC Don Purinton (US Army Engineer School), Bob Radcliffe, Joe Sturos, and Jim Mattson (Forestry Products Lab, North Central Experiment Station, USDA Forest Service), Bill Foster (Osceola National Forest, USDA Forest Service), Gary Schulze (Chippewa National Forest), Rodger Arola and John Bowman (USDA Forest Service retirees), Steve Webster (Waterways Experiment Station), Jerry Goldberg (Terra Mat Corp.), and Joe Pouyer (Uni-Mat International, Inc.) for their many contributions to the cooperative demonstration project. We also thank CRREL's editing staff and technical reviewers.

LITERATURE CITED

Arola, R.; Hodek, R.J.; Bowman, J.K.; Schulze, G.B. 1991. Forest Roads Built with Chunkwood, Chunkwood: Production, Characterization and Utilization, North Central Experiment Station, USDA Forest Service General Technical Report NC-145, St. Paul, MN, June.

Burnette, Bruce. 1993. Personal Communication. Tongass National Forest, Alaska.

Humphrey, D.N.; Eaton, R.A. 1993. Tire chips as subgrade insulation - a field trial. Symposium on recycling and effective reuse of discarded materials and by-products for consideration of highway facilities. Denver, CO.

Kestler, Maureen A. 1996. Assessing the significance of subgrade variability on test section performance. In: Proceedings of the ASCE Specialty Conference on Uncertainty in the Geologic Environment, Madison, WI, August.

Kestler, Maureen A.; Henry, Karen S.; Shoop, Sally A. 1994. Rapid stabilization of thawing soils. In : Proceedings of the 17th Annual Meeting, Council on Forest Engineering. Applied Ecology in Action. Corvallis, OR, August.

Kestler, Maureen A.; Shoop, Sally A.; Henry, Karen S., Stark, Jeffrey A.; Affleck, Rosa T. (in prep). Rapid stabilization of thawing soils for enhanced vehicle mobility: A field demonstration project, US Army Cold Regions Research and Engineering Laboratory Report, Hanover, NH.

Mason, Lola. 1990. Portable wetland area and stream crossings. USDA Forest Service.

Phukan, Arvind. 1982. Design methods for muskeg area roads. State of Alaska Department of Transportation and Public Facilities.

Shoop, Sally A.; Stark, Jeffrey A. 1996. Stabilizing thawing soils for Improved vehicle mobility, T96011 (video). US Army Cold Regions Research and Engineering Laboratory Report, Hanover, NH.

DESIGNING REGENERATION SYSTEMS FOR SUSTAINABLE MANAGEMENT TO FLAKE STATES FORESTED WETLANDS[1]

by

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ABSTRACT: Mounding site preparation has been used extensively in Canada and Scandinavia for the regeneration of difficult sites. Mounding is coming into use in the Lake States for plantation establishment on recently cleared wetlands. However, our knowledge of it's effects on wetland processes and functions is incomplete.

This research was undertaken to determine the effects of mounding on several key wetland processes, including soil carbon storage and recovery, decomposition, microclimate, and hydrology. Ultimately, our evaluation of wetland responses to mounding will support resource management prescriptions and policies that sustain productivity, species diversity, habitat, and water quality while accommodating the utilization of wetland resources.

Key Words: wetland processes, soil carbon storage and recovery, mounding, regeneration systems

[1]Presented at the joint meeting of the Council on Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

STREAM CROSSINGS[1]

by

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Oral presentation only, abstract not available.

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

FOREST INDUSTRY SAFETY AND TRAINING ALLIANCE, INC.[1]

by

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ABSTRACT: The Forest Industry Safety and Training Alliance (FISTA) is a non-profit organization that originated in 1991 to address the occupational injuries and deaths in the logging industry. FISTA is comprised of a 15 member Board of Directors, 3 Field Trainers, a full time Office Manager, and an Executive Director. FISTA conducts a majority of its training in Wisconsin. FISTA training is free of charge to Wisconsin loggers; a reasonable fee is charged for other groups. Training is not classroom oriented but is brought to the job site and consists of outdoor demonstrations. In November of 1991, FISTA went into operation with seed money from the Occupational and Safety Health Administration (OSHA), the U. S. Forest Service, and private donations.

Key Words: safety, chain saw, logging

OPERATION

Goal

To assist in the prevention of occupational injuries and deaths in the logging industry through training that emphasizes safety and proper technique.

FISTA serves the logging industry through hands-on, on-site training sessions conducted by Logging Safety Trainers. FISTA currently employs three full-time trainers, an office manager, and an Executive Director. Each trainer is designated to train in a specific area and to conduct training on a request basis.

The initial in-woods training session lasts about four to six hours. Follow-up sessions are also conducted at the logger's request. Training groups may range from as large as one hundred to as small as two. A typical training session will cover the following:

Training program outline

1. Initial meeting
   a. Trainer will meet with the crew supervisor to address their specific training needs

2. Training will address hazards observed as that individual entered the job site
   a. Address how the job is laid out for efficiency and safety

3. Introduction about FISTA
   a. Purpose of the organization and services available
   b. Run-down of the day's agenda

4. Occupational and Safety Health Administration (OSHA) discussion
   a. Regulations and requirements and how they pertain to the logging industry
   b. Employer's responsibility

5. Proper body mechanics

6. Personal protective equipment (PPE)
   a. What is required and available
   b. PPE's importance and function
   c. First-aid kit

7. Tools necessary to aid in safely felling trees
   a. Introduction to wedges
   b. Felling levers (when appropriate)
   c. Files, gauges, etc. to properly maintain saws

8. Saws
   a. Safety features
   b. Reactive forces
   c. Reduced down time maintenance
      (1) Cutter--how it works, its importance
      (2) Proper sharpening
      (3) Carburetor adjustment
      (4) How to maintain the saw, bar, and chain

9. Tree felling (demonstration)
   a. Information before felling begins (plan)
      (1) Hazards
      (2) Escape route
      (3) Proper notch
      (4) Hinge and back cut
   b. Executing the plan

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

10. Limbing, buck and topping (demonstration)
    a. Technique for releasing limbs and spring poles under pressure

11. Question and answer period

12. Material distributed
    a. Certificates of Participation distributed
    b. Three-ring informational binder given to contractor/supervisor (contains OSHA information, Training Guide, Company Safety Policy, etc.)

GENERAL SERVICES

FISTA also conducts a four-day advanced logger training program that qualifies participants to participate in Soren Eriksson's "Game of Logging" competitions on a regional and national level. This advanced program focuses on safety, accuracy, efficiency, and productivity.

Another way that FISTA reaches the industry is through a monthly newsletter - FISTA UPDATE. This newsletter covers a variety of topics such as first-aid, general safety, accident prevention, and anything relative to FISTA's accomplishments and goals.

One of FISTA's services is to provide quality safety and training videos for a reasonable cost. A list of these videos can be obtained by calling FISTA's main office.

FISTA has an 800 number which can be utilized to set-up training programs as well as to answer frequently asked questions. That number is listed below.

APPLICATION

FISTA is having an impact. Logger awareness is rising and accidents are declining. Some Workers' Compensation providers offer incentives to loggers who receive FISTA training and demonstrate clean safety records. FISTA has earned national recognition as a model for other safety programs.

Anyone interested in FISTA training, the FISTA UPDATE newsletter, or FISTA's training videos, can call the main office at 1-800-551-2656 or fax us at 715-282-4975.

EASTERN CANADA REGIONAL REPORT[1]

by

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ABSTRACT: Buoyed by high product prices, the demand for softwood fiber remains strong as both sawmills and pulp mills operated at high capacity levels throughout 1995 and in early 1996. Competition for fiber became evident in several regions. The shortwood harvesting method (also called cut-to-length) is gaining in popularity for reasons of fiber quality, reduced impact on the environment and greater operational flexibility. The responsibility for implementing sustainable forest management on Crown land is being transferred to the industry, with careful monitoring by the provincial agencies through renewed forest management and supply agreements.

Key Words: eastern Canada, harvesting, silviculture, transportation, legislation

INTRODUCTION

Forestry has a long history in eastern Canada, where some of the oldest pulp and paper mills in North America were established at the turn of the century to take advantage of the plentiful, high-quality fiber of northern boreal softwood stands. This region spans the variable terrain of northern Manitoba, the rough Lake Superior topography of northwestern Ontario, the flat clay belt area of northeastern Ontario and northwestern Quebec, the mixedwood and rich tolerant hardwood stands of southern Ontario and southern Quebec, the rugged relief and harsh weather of central and eastern Quebec, the densely forested landscape of New Brunswick, the New England look of Nova Scotia fields and private woodlots, and the adverse ground and weather conditions of Newfoundland.

INDUSTRY STATUS

Currently, about 70 million m^3 of timber are harvested annually in eastern Canada, of which 85 percent is softwood fiber destined mainly for sawmilling and pulp and paper products, and 15 percent is hardwood fiber used mainly for lumber, composite board (e.g., oriented strandboard (OSB), medium density fiberboard (MDF), a variety of value-added solid wood products, and, increasingly, as pulp furnish. Several new MDF and OSB mills using aspen and birch as raw material started operating in Ontario and Quebec during 1995.

Buoyed by high product prices, the demand for softwood fiber remains strong and sawmills and pulp mills both operated at high capacity levels throughout 1995 and in early 1996. Competition for fiber became evident in several regions. Corporate takeovers were common throughout 1995, as several pulp and paper companies acquired sawmills and their associated fiber supply.

In March 1996, the Canadian government decided to charge an export tax on a portion of the softwood lumber destined for the U.S. in an attempt to solve the trade dispute between both countries on this issue.

HARVESTING SYSTEMS

Figure 1 illustrates the current and forecast future distribution of harvesting systems in eastern Canada (adapted from Gingras and Ryans 1992).

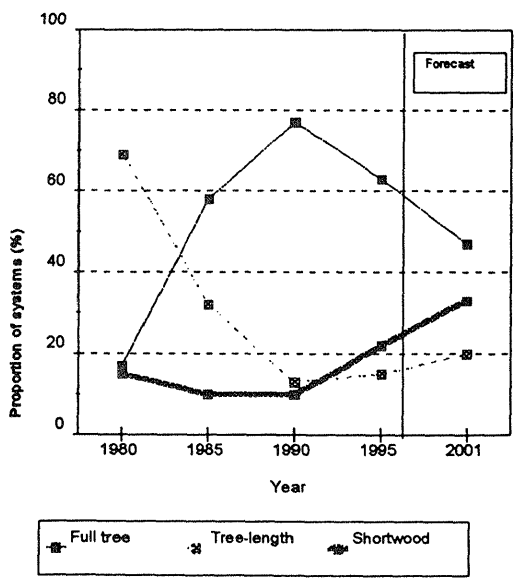

Figure 1. Current and forecast distribution of harvesting systems in eastern Canada (1980-2001).

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

Full-tree to roadside harvesting systems have been declining in popularity since the late 1980s and are expected to represent less than 50 percent of the wood harvested in the region by the turn of the century. These systems typically involve felling using tracked knuckleboom-type feller-bunchers equipped with sawheads, followed by skidding with grapple skidders on good ground, with clambunk skidders over long distances, and with cable skidders on rough or very wet ground. Felling heads with greater abilities to tilt sideways are becoming popular with contractors.

The shortwood method (also called cut-to-length harvesting) is gaining in popularity for reasons of fiber quality, reduced impact on the environment and greater operational flexibility. This system typically uses single-grip harvesters and forwarders and should account for more than one-third of the harvest by the year 2000. Increasingly, domestic cut-to-length equipment is becoming available and is being utilized by operations because it is a cost-effective alternative to Nordic machines. Often, harvesting heads are mounted on tracked excavator-type carriers or converted feller-bunchers. Six-wheel and eight-wheel forwarders are favored by contractors because of their bigger payloads.

About 15 percent of the harvest is conducted using the tree-length system, in which trees are felled and delimbed at the stump, but brought in full-length to roadside. This method is usually conducted with manual felling and cable skidding and is often encountered in private land forestry, small-scale operations and selection logging of tolerant hardwood species. Some development efforts are currently underway to develop a viable mechanized tree-length harvesting method for boreal stands.

FOREST MANAGEMENT

While harvest levels are currently at about 87 percent of the annual allowable cut (AAC) in softwood and 35 percent of the AAC in hardwoods, several provinces are re-examining their AAC levels in light of (for example) new areas taken out of commercial production and more restrictive regulations on cutover size and buffers. At the same time, provincial governments, who have been the traditional stewards of the forest, are facing severe budgetary restrictions. Because of this, the responsibility for implementing sustainable forest management on Crown land is being transferred to the industry, with monitoring by the provincial agencies through renewed forest management and supply agreements.

Faced with increasingly complex resource-management analysis, planning and monitoring, several companies are now using Geographic Information Systems/Global Position Systems (GIS/GPS) technology to assist in their mapping and inventory management activities. Developed in co-operation with the Forest Engineering Research Institute of Canada (FERIC), GPS-based navigation systems for forestry machines have just now reached the point of commercial availability. These systems allow operators to travel within the boundaries of a cut block without having to flag the boundaries ahead of time.

Many companies are looking at commercial thinning to provide additional fiber in the short- term and to improve the growing stock for future harvests. This interest in partial cuts is also spurred by the needs to find lower-cost and better stand renewal techniques and to maintain ecosystem biodiversity, as well as by public pressure to limit the use of clearcuts. Operational commercial thinning is now conducted in most eastern provinces, albeit on a limited scale at this time. A recent FERIC survey revealed that 25 percent of FERIC's member companies are actively involved in commercial thinning, and an additional 34 percent are expected to become involved over the next 5 years.

Some development efforts have also been directed at finding a mechanized system for selection harvesting of large tolerant hardwoods in uneven-aged stands in the southern part of the region. Modified work techniques for feller-bunchers and the use of feller-directors are being studied by FERIC.

In some provinces, such as Quebec, herbicides will no longer be allowed on Crown land within a few years. This means that mechanical plantation- cleaning methods must be developed and expanded rapidly. Alternatives such as the use of extra-large seedlings, mulch mats and tractor-mounted cleaning heads are being explored.

The summer of 1995 was extremely dry in most parts of eastern Canada and several large fires occurred. As a result, a major salvage operation was conducted in Quebec and Ontario. In New Brunswick, salvage efforts were directed mainly at recovering about 2 million m^3 of timber that had been flattened during a late-fall 1994 windstorm.

REGULATORY ENVIRONMENT

The Canadian Standards Association, in co-operation with the Canadian Pulp and Paper Association, is spearheading the development of a sustainable forest management standard, which has also been submitted to the International Organization for Standardization (ISO) as a potential procedure upon which an ISO 14000-series certification could be based. Several test audits have already been done with forest companies and official certification applications are expected to start in 1996.

From a transportation perspective, the various ministries of Transport have started a zero-tolerance policy on overweight vehicles. In Quebec, the industry agreed to pay truckers only up to the maximum allowable weight in efforts to curb overweight payloads on highway hauls. As a result, interest in on-board weigh scales has increased rapidly, with several commercial products now available.

CONCLUSIONS

Forest operations in eastern Canada are going through significant changes in response to the influence of several driving factors, including a high demand for fiber, a more restrictive regulatory context, technological changes in harvesting machinery, the onset of certification, new information technologies and evolving workforce demands.

REFERENCES

Gingras, J.-F.; Ryans, M. 1992. Future Woodlands Equipment Needs in Eastern Canada: 1992-2001. For. Eng. Res. Inst. Can. (FERIC), Pointe-Claire, Que. Tech. Note TN-193. 8 p.

THE WESTERN GREAT LAKES REGION: ISSUES AND TRENDS IN TIMBER HARVESTING AND FOREST MANAGEMENT[1]

by

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ABSTRACT: The states and provinces of the Western Great Lakes Region share many similar problems, but have adopted a wide variety of approaches to the issues they face. Fiber demand and timber harvest levels have increased dramatically over the last five years. Reduced availability of stumpage on federal lands, and to a lesser degree on state lands in the US, and more restrictive license terms on Crown lands in Ontario have all effected the competition for stumpage. The dramatic growth in the volume of timber harvested has created a great deal of public concern over the long-term sustainability and impacts of these increases. Adjusting to the call for increased stakeholder participation in planning efforts on public lands is a significant feature throughout the region. Greater competition and higher prices for stumpage, increased regulation, increased operating costs, and greater public scrutiny have all moved loggers and some timber companies toward light-on-the-land harvest systems. Region-wide collaboration is evolving as a means of speeding up the transfer of information and extending limited financial resources.

Key Words: sustainable forestry, timber availability, stakeholder involvement, regulation, logger education, mechanization

INTRODUCTION

The words most frequently heard in the Western Great Lakes Region (Minnesota, Wisconsin, Michigan, Ontario), and probably throughout Canada and the United States, are "sustainable forestry". Unfortunately there is little public discussion of what "sustainable forestry" means, or what the desired future forest conditions might be. Tied to these words are a number of important issues and trends which fall into three broad categories:

1. timber availability and markets;
2. ecosystem-based management, regulation, and public involvement; and
3. increased mechanization.

Several issues are common throughout the region.

Industry: global competition, increased regulation, reduced timber availability from and more restrictive timber sale contracts on public lands, steep increases in the cost of stumpage, shortage of skilled workers, increased wages and insurance costs, endangered species, old-growth set asides, excessive political influence impacting forest planning, and changes are coming too fast.

Government: shrinking budgets, more confrontations with clientele, more complicated procedures, constantly changing organizational structures, and increased political pressures.

Private land owners: happy about increased stumpage values, but increasingly worried about erosion of private property rights.

Environmental groups: Sierra Club voted for cessation of all timber harvest on federal lands; distrust of industry, government, and voluntary programs such as Best Management Practices (BMPs); want greater input into forest management planning, forest land conversion to plantation forestry or to non-forest uses, loss of biodiversity, protection of riparian areas and wetlands; and change is too slow.

Differing cultural and social environments across the region have resulted in a number of different approaches to these issues and the resulting direction of trends surrounding "sustainable forestry". However, each approach is aimed at the same objective;

> to ensure the enhancement of both timber and non-timber values through the ethical application of effective, affordable land stewardship practices.

The following is a summary of the diversity of approaches to these issues and trends. The results were obtained through an informal survey of public agencies, forest industries, loggers, and environmental organizations from throughout the Western Great Lakes Region.

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

TIMBER AVAILABILITY AND MARKETS

Though the paper and lumber markets are currently soft, fiber demand and timber harvest levels have increased dramatically throughout the Western Great Lakes Region over the last five years. Reduced availability of stumpage on federal lands, and to a lesser degree on state lands in the US, and more restrictive license terms on Crown lands in Ontario have all effected the competition for stumpage. Further reductions in the availability of timber from public lands is a distinct possibility, creating significant uncertainty for industry.

Publicly-owned forest lands (provincial, federal, state, and county) have been the primary source of stumpage in most of the Western Great Lakes Region. The increased competition for the limited volume of public timber has resulted in substantial increases in stumpage prices, and stimulated a dramatic shift to purchasing stumpage from Non-Industrial Private Forest (NIPF) lands in many areas. Species that had been unmerchantable in the past are now in demand as well.

Wisconsin

Wisconsin has historically had the most intensive forest industry base in the region, but has little capacity for new primary industrial expansion. In fact, two pulp mills will likely have to close in the near future and another is changing its species mix due in part to increased competition for wood. A few mills have also expanded their procurement areas to southern Wisconsin and southeastern Minnesota. A mill in Green Bay has switched entirely to recycled fiber for feed-stock.

Ontario and Michigan

Ontario and Michigan have the greatest capacity for continued forest industry growth. Until recently, Ontario had very limited markets for aspen. Expanding markets for Oriented Strand Board (OSB) has stimulated the construction of several OSB plants in Canada, including Ontario. Canadian industries are also implementing wood product certification based on ISO 14001 to better position themselves in world markets.

At least one new pulp mill is under construction in Michigan, and the state could support additional growth. The Michigan Department of Natural Resources (DNR) would like to increase the volume offered for sale from state lands by approximately 30 percent to accomplish their management goals. The increased harvest would come primarily from selective harvesting of northern hardwoods. The Michigan DNR recently received bonding authority to raise funds to hire more staff and to contract with consultants to set-up these additional timber sales.

Minnesota

Minnesota has had significant new and expanded mill capacity due to the abundant volumes of aspen and birch available. Since 1990, mill expansions have pushed Minnesota harvest levels up by over 700,000 cords, to 4.2 million (1995) (Figure 1).

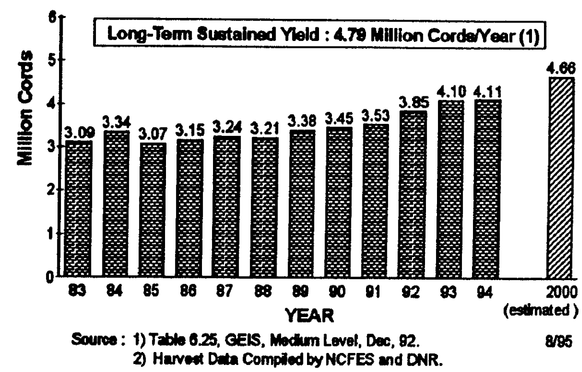

Figure 1. Actual and projected timber harvest in Minnesota - from MN timberland, all ownerships, all species.

Stumpage prices have more than doubled over that same time-span (Figures 2 and 3). Additional permitted mill expansions are likely to increase harvest levels to nearly 4.7 million cords by the year 2000.

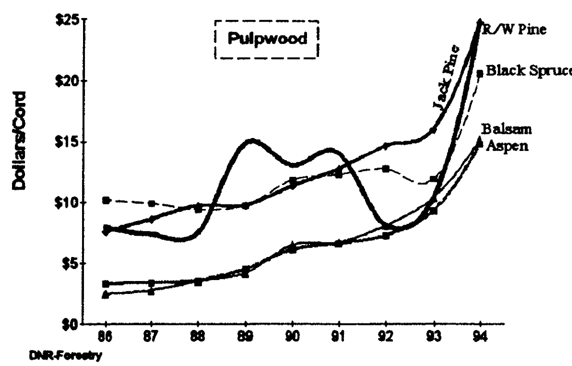

Figure 2. Average prices received for pulpwood stumpage sold by public land agencies in Minnesota: 1986-1994.

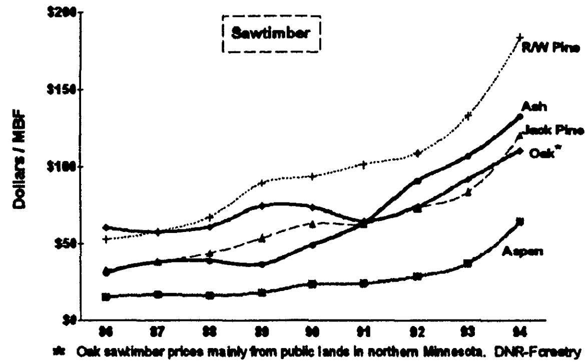

Figure 3. Average prices received for sawtimber stumpage sold by public land agencies in Minnesota: 1986-194

Public agencies, which control approximately 55 percent of the timberlands in Minnesota (Figure 4) are nearing, or have reached their allowable harvest levels. Some additional timber volume (200,000 cords/year) is being made available from state-owned lands as the result of industry-supported legislation to fund several new forester and technician positions. These positions will allow the state to prepare selective harvest timber sales and sales of previously unmerchantable species.

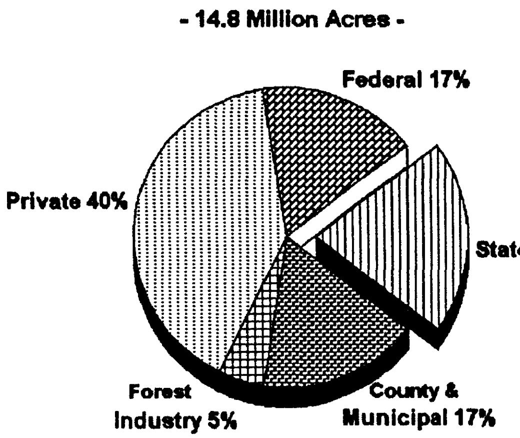

Figure 4. Minnesota timberland by ownership.

Because public agencies in Minnesota are approaching the limits of their allowable harvests, harvest pressure has increased on NIPF lands. The shift has been dramatic (Figure 5). For the first time the harvest from NIPF lands exceeds that from public lands.

Industry within Minnesota is adjusting to the competition for virgin wood by incorporating recycled fiber and additional species into their manufacturing process. Lake Superior Paper, recently acquired by Consolidated Paper, operates a deinking plant for recycled office paper which supplies fiber to many paper mills. Unfortunately, competition for recycled paper is more intense than for virgin fiber.

Northwood Panelboard has installed a new high speed drier to accommodate the different drying requirements of aspen and birch. Other OSB plants are utilizing maple, birch, and pine. The Potlatch paper mill expansion in Cloquet is based on incorporating maple, birch, and basswood.

Short-rotation woody crops (SRWC), hybrid varieties of cottonwood, will provide additional fiber in the near future. Champion International is currently purchasing 30,000 acres of farmland in central Minnesota to plant SRWC varieties. Efforts are underway to encourage farmers in the Minnesota River valley to convert flood plain fields to trees, including hybrid cottonwood. Boise Cascade is testing several new hybrid varieties, and will likely develop leases with landowners to grow them on a commercial scale. A SRWC landowner coop is also being formed. Within the next five years Minnesota may have 100,000 acres of SRWC growing on a ten- to twelve-year rotation.

Mills that produce shavings for poultry bedding and hardboard are having difficulty competing for wood. Urban wood waste may be an option for some of these companies.

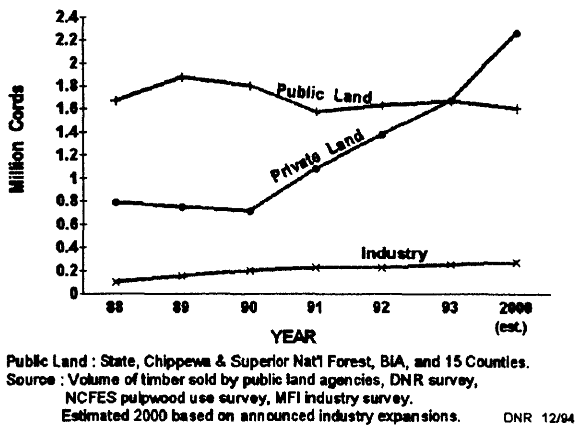

Figure 5. Volume of timber sold by ownership - Minnesota (excludes fuelwood).

ECOSYSTEM-BASED MANAGEMENT, REGULATION, AND PUBLIC INVOLVEMENT

The dramatic growth in the volume of timber harvested in the Western Great Lakes Region has created a great deal of public concern over the long-term sustainability and impacts of these increases. The universal questions are:

1. Are the expanded harvest levels sustainable?

2. Will the harvest levels safely maintain biodiversity and functional ecosystems at the landscape-level?

3. Who will pay the cost of new guidelines and regulations?

Each state and province has responded in their own way to the resulting pressure for increased public participation in forest management. One early response was the formation of the Lake States Forestry Alliance, involving a variety of stakeholders from Minnesota, Wisconsin, and Michigan. The alliance members work collaboratively to identify issues of mutual concern and share resources to address them. An example of this cooperation is the assistance provided by the Minnesota DNR to both Michigan and Wisconsin in development of their BMP programs.

More commonly, public hearings are held, agreements are negotiated, or legislation is passed to address public concerns. Ontario has done all three.

Ontario

1. The Ontario Environmental Assessment Board (EA Board) held hearings on the Class Timber Environmental Assessment for Timber Management on Crown Lands from 1988 through 1992. The hearings generated 70,000 pages of testimony from over 500 individuals, with more than 2,300 supporting exhibits. The EA Board's ruling in April 1994 approved timber management planning under the Environmental Assessment Act, subject to the implementation of 115 terms and conditions. The EA Board gave primary consideration in its ruling to the public's right to be a partner in the decision-making process for managing public lands (Kaiser 1996).

2. In 1993, Ontario appointed a provincial facilitator to negotiate a more effective financial working relationship between industry and the government. The resulting revised Forest Management Agreements created trust funds, funded by industry payment of forest renewal charges as part of a revised stumpage pricing system. The trust funds ensure the availability of funds for reforestation of harvested or severely damaged areas despite shrinking provincial budgets. The new stumpage pricing system also attempts to more accurately reflect changing market conditions, which was a primary concern to industry (Kaiser 1996).

3. In 1994, Ontario passed the Crown Forest Sustainability Act. The purpose of the Act is to ensure the sustainability of Crown forests so that they can "meet the social, economic, and environmental needs of present and future generations" (Kaiser 1996). The Act gives the government significantly more power and enforcement authority. This has created greater uncertainty and concern among some industry people (Kaiser 1996).

Michigan

An issue unique to Michigan is concern over the impacts on forest management of the more than 5,000 oil wells (and associated pipelines) that were been drilled in northern Michigan in the last six years.

Industry has formed a Forest Resource Alliance (FRA) to facilitate implementation of the American Forest and Paper Association's (AF&PA) Sustainable Forestry Initiative (SFI). They funded an enhanced logger training and education program that will be coordinated through the Michigan State University Extension Service. Logger participation is voluntary, but some individual companies are providing incentives. For example, Weyerhauser is paying a $.50/ton bonus to loggers that have participated in approved training programs.

There is commitment within the companies as well. Consolidated Paper has hired two people for SFI work within the company, including monitoring of BMPs.

Two years ago the Michigan DNR began to promote the application and monitoring of BMPs to protect water quality on all forest lands. Lack of extensive stakeholder involvement in the development of the BMPs has been a factor in the continuing controversy between the DNR, industry, and the public, and particularly between governmental agencies.

Wisconsin

Wisconsin recently amended their state forest statutes to provide greater opportunity for public participation in the management of state-owned forest lands. The amendment also requires forest plans to incorporate the concepts of sustainable forestry and biodiversity.

Increased public participation was a significant feature of Wisconsin's recently completed, lengthy, multi-stakeholder process to develop expanded water quality BMPs. The new guidebook was published in early 1995 and distributed statewide to loggers and foresters through a series of workshops.

Broad stakeholder participation was a feature of the first round of BMP auditing which was completed during 1995. Compliance was very good (87 percent). The audit teams were made up of people from the full-range of stakeholders. Feedback has been very positive from all participants.

Forest industry is building on the BMP and logger safety programs to meet their commitments to the AF&PA SFI. Forest Industry Safety and Training Alliance (FISTA), the logger safety program, is leading the new combined logger training and education effort. Training will include safety, BMPs, and business management.

Up-to-date forest inventory data is an urgent need cited by all stakeholders in the state. Wisconsin's statewide forest inventory is nearly twenty years old. While new inventory data will be available soon, a system to update the data annually is very desirable to improve planning and management decisions.

Minnesota

Perhaps the most dramatic response to the increased desire for broad stakeholder involvement in forest management has been Minnesota's Generic Environmental Impact Statement on Timber Harvest and Forest Management (GEIS). Minnesota's Environmental Quality Board commissioned the GEIS in 1989 at the request of a group of private citizens to study the potential environmental, social, and economic impacts of increased timber harvesting on all ownerships throughout the state. It was also to recommend mitigating practices to minimize the anticipated negative impacts.

The GEIS was released in 1994 and has resulted in the passage of the Minnesota Sustainable Forest Resources Act (SFRA). The SFRA established a multi-stakeholder Forest Resource Council (FRC) to advise the Governor, legislature, and public forestry agencies on forest management policy. A companion organization, named the Partnership, was also created though not required by the SFRA. The Partnership is made up of loggers, forest industries, public forest land agencies, and private landowners. Membership is not limited. The Partnership's purpose is to facilitate implementation of the guidelines and policies developed by or as a result of recommendations from the FRC.

To assist the FRC in carrying out its responsibilities, funding was legislatively provided to hire an executive director and limited support staff. Beyond advising the Governor, legislature, and public land management agencies, the FRC is required to;

1. establish a forest research advisory committee, with limited funding to initiate studies on critical issues,
2. appoint four broadly based committees to develop additional voluntary forest management guidelines,
3. initiate statewide landscape level forest planning,
4. design and implement monitoring procedures to evaluate the application and effectiveness of the guidelines, and
5. to facilitate the efforts of professional organizations to establish voluntary certification/continuing education programs for loggers and foresters.

The research committee is now functional. The four guideline committees, which will address riparian management zones, site-specific wildlife concerns, soil productivity, and cultural and historic resources, have all been formed and have initiated work. The work of these groups will be integrated with the state's existing BMPs for water quality, wetlands, and visual quality. Development of monitoring systems will follow shortly thereafter.

The Minnesota DNR has also created an Ecosystem Classification System (ECS) position in anticipation of the FRC landscape-level planning efforts. In addition, efforts are well underway to implement an annual forest inventory system to permit management plans to respond more quickly to changes. If the system being developed works well, it will likely be adapted nationwide.

Loggers have anticipated FRC efforts as well by organizing the Minnesota Logger Education Program (MLEP). The larger forest industries have provided the start up funding and have set targets ranging from 80 to 100 percent for participation of their suppliers. Also, the Minnesota Society of American Foresters (SAF) is developing a state-level forester certification program that builds on the national SAF program.

Addressing environmental issues and public concerns is also occurring cooperatively across the Western Great Lakes Region. A meeting of logger education leaders from Minnesota, Wisconsin, and Michigan took place in mid-May, 1996 to explore ways of sharing resources and addressing issues. The Minnesota DNR has made staff available to Michigan and Wisconsin to assist with the development of their BMP programs. A Region-wide advisory committee, involving individuals from public agencies, industry, loggers, and environmental groups has been established by the University of Minnesota and the Minnesota DNR. They identified and summarized options for temporary water and wetland crossing, compiled known information concerning the potential environmental impacts, and are conducting demonstrations of selected alternatives.

INCREASED MECHANIZATION

Greater competition and higher prices for stumpage, increased regulation, increased operating costs, and greater public scrutiny have all moved loggers and some timber companies toward light-on-the-land harvest systems. Everyone is talking about cut-to-length systems. Scandinavian models have led the way. Now several similar, but more rugged, lower-cost systems are being manufactured in the region.

High flotation tires and replacement of skidders with forwarders have both been recent changes in Minnesota. In the woods chip production is increasing with the development of chain flail processors. Cable yarding, portable water and, wetland crossing structures, and modifications of existing machinery are all being evaluated through research and demonstration projects.

Boise Cascade and the University of Minnesota, Natural Resource Research Institute are studying the practicality of noncommercial thinnings of ten-year-old aspen. Blandin Paper is experimenting with commercial thinning of thirty-year-old aspen. Wood ash, sewage sludge, and other materials are being evaluated for fertilizing forest stands.

Forest management and forest industries in the Western Great Lakes Region are among the leaders in the world. The logging and industrial technologies are adapting rapidly to new societal and market demands.

LITERATURE CITED

Kaiser, Martin. 1996. Ontario's new reality: The timber E.A. and the Crown Forest Act. Canadian Forest Industries; March issue: 33, 34, 36, and 39.

INLAND WEST REGIONAL REPORT[1]

by

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ABSTRACT: The current status of forest industry conditions, timber availability, logging systems mix, forest health, forest engineering schools, and logger certification programs is briefly described for the inland western United States.

Key Words: logging, timber, forest, harvesting, forest industry, forest engineering

INTRODUCTION

The "Inland West" referred to in this paper refers to the intermountain states of Montana, Idaho, Utah, Wyoming, Colorado, New Mexico, Arizona, and Nevada, and a great plains state, South Dakota. The current status of issues and trends pertinent to forest industry, forest land management, and forest engineering is included.

ECONOMIC

Mill closures and consolidations of primary manufactures of boards and dimension lumber continue to occur in the Inland West. Decreased volumes of federal timber being offered for sale continue to adversely affect dependent mills. Forest Service volume under contract dropped 50 percent from 1991 to 1994 in the intermountain states (Powell et al. 1994). There is an increasing dependence on non-federal land ownerships for stumpage.

Prices

Stumpage prices increased as volume under contract decreased with highs reached early in 1994. Lumber prices sharply declined during 1994. Significant volumes of non-industrial private timber was offered for sale by land owners who wanted to take advantage of good prices and who were anxious over increasing federal and state forestland regulation.

Prices were also depressed by large quantities of lumber imported to the United States from Canada. Lumber mill profits were further squeezed in 1995, by a significant drop in paper chip prices, which began in the 3rd quarter of 1995 (Wood Resources International Ltd. 1996).

White wood lumber prices may have bottomed out late in 1995 at about 70 percent of the 1994 price level, with some upward movement beginning in March, 1996.

United States/Canada Trade Pact

An agreement between the U.S. and Canada will cap exports of Canadian softwood lumber to the U.S. from the provinces of British Columbia, Alberta, Ontario, and Quebec at 14.7 billion board feet. This is about 1.5 billion board feet less than was exported by the four provinces in 1995. Exports in excess of that total will be subject to an escalating export tax. (Random Lengths, April 5, 1996). The agreement may improve prices for U.S. producers.

Timber availability

Timber availability on federal lands has declined. Net growth after removals is positive (Powell et al. 1994). Sixty percent of the timberland in the intermountain states is managed by the U. S. Forest Service (Table 1). Major factors affecting timber availability on federal lands currently include: timber sale appeals and litigation, the Endangered Species Act, and Congressional funding levels for timber and road construction. The current Congress is placing renewed emphasis on commodity production from federal lands.

Table 1. Timberland* area (thousands of acres) in the intermountain states by ownership group (Powell et al., 1994).

Ownership group	thousands of acres
National Forest	35,459
Other Public	5,789
Forest Industry	2,894
Non-industrial Private	14,959

*Timberland is defined as forestland capable of producing more than 20 cubic feet per acre per year and not withdrawn from timber production.

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

Which states have most of the wood? Idaho and Montana (all ownerships) account for 56 percent of the softwood and hardwood growing stock in the Inland West (Table 2).

Table 2. Net volume (million cubic feet) of softwood and hardwood growing stock on timberland (all ownerships) in the intermountain states and South Dakota, 1992 (Powell et al. 1994).

State	Millions of cubic feet
Arizona	7,028
Colorado	19,448*
Idaho	33,001
Montana	28,195
Nevada	456
New Mexico	6,768
Utah	4,794*
Wyoming	6,892*
South Dakota	1,796

*Not updated since 1987.

In 1991, Idaho and Montana, accounted for 76 percent of removals from all ownerships in the intermountain states (Powell et al. 1994).

Timber harvest projections

Harvest levels in Idaho (all ownerships) are expected to decline 14.6 percent in the 1997-2000 time period from the 1991-1993 base period (Hamanishi et al. 1996). Harvest levels in Montana (all ownerships) are projected to decline 2 percent in the 1996-2000 time period from the 1991-1995 period (Flowers et al, 1987). Recent comparisons of actual harvest to projected harvest in Montana have indicated that aggregate projections for the 1991-1994 period were close; however, there was a greater shift from Forest Service to private ownerships than projected (Schuster et al. 1996).

ENVIRONMENTAL ISSUES

Forest Health

Current forest conditions in much of the inland west are favorable for high intensity stand replacement fires and large-scale forest pest outbreaks. Fire exclusion efforts, which began over 100 years ago, have altered forest conditions (Thomas 1994).

For example, where there has been a lack of short-interval low-intensity ground fires in historically open ponderosa pine forests, we now have densely stocked stands including mixed species. The additional trees compete for moisture on dry sites, and provide ladder fuels for high intensity crown fires, which can be very difficult to control.

The 1994 fires on the Boise National Forest in Idaho burned 168,000 acres of ponderosa pine and other forest types.

The 1994 fires on the Payette National Forest in Idaho burned 300,000 acres of mostly lodgepole pine and alpine fir forest types. Lodgepole pine stands become susceptible to mountain pine beetle epidemics with age. If not managed, vast areas of heavy fuel loading and large stand replacement fires can result.

Emergency Salvage Timber Sale Program

The Emergency SalvageTimber Sale Program (Section 2001, PL104-19) was signed July 27, 1995 to expedite salvage sales on federal land. Non-appealable NEPA decisions are permitted under the act. Approximately 4 billion board feet of salvage timber is available for salvage nation-wide under provisions of the law. As of March 27, 1996, the salvage program was on schedule and meeting goals. Compliance with all applicable laws is being met.

Timber salvage operations on the Boise and Payette National Forests from the 1994 fires are continuing into 1996 with much of the volume being helicopter yarded.

Environmental regulation

The Endangered Species Act has impacted the forest industry to differing degrees in the Inland West. Concern over chinook salmon and grizzly bear habitat has impacted Montana and Idaho. Concern over the Mexican spotted owl and goshawk has greatly impacted Arizona and New Mexico.

EDUCATION/TRAINING

Forest engineering curriculum

There are currently no SAF accredited forest engineering degree programs offered by universities in the inland west. The University of Idaho does offer a timber harvesting option with the forest products bachelor of science degree.

Logger accreditation

Montana is currently the only state in the inland west that has a program for logger accreditation. The program is administered by the Montana Loggers Association. This program includes practically all of the elements recommended by the American Forest and Paper Association's Sustainable Forestry Initiative for the logger training. The accreditation covers five areas including water quality, silviculture and ecology, safety, first aid, and business management.

The water quality, silviculture, and ecology modules incorporate curriculum developed under the Logger Education for Advanced Professionalism (LEAP) programs by the University of Idaho. In Montana, the LEAP modules are taught by University of Montana Cooperative Extension.

LOGGING SYSTEMS

A variety of ground-based, skyline, and helicopter logging systems are used in the Inland West. Familiar logging systems include the following:

A. HORSE

B. CONVENTIONAL TRACTOR (line skidders and tractors - motor manual felling, delimbing, and bucking)

C MECHANIZED WHOLE TREE (mechanized felling and bunching of whole trees by a feller-buncher; then grapple skidded to the landing for further processing (Kellogg et al. 1993).

D. MECHANIZED TREE LENGTH (mechanized felling, delimbing, and topping at the stump by a mechanical harvester (not feller-buncher); then tree-length skidded to the landing)

E. MECHANIZED CUT-TO-LENGTH/ FORWARDER (mechanized felling, delimbing, and bucking at the stump by a mechanical harvester; logs then forwarded to the landing by a log forwarder (not skidded)

F. MECHANIZED CUT-TO-LENGTH/ SKIDDER (mechanized felling, delimbing, and bucking at the stump by a mechanical harvester head; logs then skidded to the landing by a grapple skidder or tractor)

G. SHOVEL (tracked log loader walked into the cutting unit to swing logs to a skid road or to a truck landing)

H. OFF-ROAD JAMMER (tracked log loader or feller equipped to throw tongs from skid roads or truck roads. May work in conjunction with a grapple skidder or tractor)

I. JAMMER (lightweight ground lead yarder using tongs and usually mounted on a truck with a spar and boom (Mifflin and Lysons 1979))

J. HIGHLEAD (ground lead cable system. The mainline is rove through a fairlead mounted on a tower, spar, or boom for lift. The mainline and butt rigging with chokers are hauled back into the cutting unit by a haulback line.)

K. SKYLINE (slack-pulling or non-slack pulling carriage rides on a live, standing, or running skyline)

L. HELICOPTER

M. OTHER

The mix of logging systems varies greatly from state to state (Table 3).

The logging systems mix on other ownerships may be different.

Table 3. Logging system mix by state expressed as percent of commercial volume harvested in 1995 from U.S. Forest Service lands.

SYSTEM	State							
	MT	ID	UT	WY	CO	SD	NM	AZ
A	<1	1	-	-	<1	-	-	-
B	18	28	80	37	45	25	84	65
C	47	4	-	7	30	67	16	35
D	7	1	-	-	20	-	-	-
E	2	<1	-	-	-	5	-	-
F	<1	<1	-	-	4	-	-	-
G	<1	-	-	-	<1	-	-	-
H	-	<1	-	-	-	-	-	-
I	<1	1	-	-	-	-	-	-
J	<1	3	-	-	-	-	-	-
K	23	26	-	-	-	3	-	-
L	3	36	20	-	-	-	-	-
M	<1	-	-	60 *	-	-	-	-

*Whole tree skidding with motor manual felling followed by mechanical processing at the landing.

LITERATURE CITED

Flowers, P.J., et al. 1987. Montana's timber supply: An inquiry into possible futures. USDA For. Serv. Int. For. & Range Exp. Stn. Resource Bull. INT-40. 22p.

Hamanishi, Craig M.; Wagner, F.G.; O'Laughlin, J.; Gorman, T.M. 1996. Idaho's timber harvest projections by ownership to 2000: an issue-based survey of resource managers. West. J. Appl.For.10(3): 109-113.

Kellog, L.D., P. Bettinger, and D. Studier, D. 1992. Terminology of ground based mechanized logging in the pacific northwest. Forest Research Laboratory, Oregon State University, Corvallis. Research Contribution 1. 12p.

Mifflin, Ronald F.; Lysons, H.H. 1979. Glossary of forest engineering terms. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station. 23p.

Powell,Douglas; Faulkner, J.L.; Darr, D.; Zhu, Z.; MacCleary, D. 1993. Forest Resources of the United States, 1992. Gen. Tech. Rpt. RM-234. Ft Collins, CO: U.S.Dept. Ag. For.Ser., Rocky Mountain Forest and Range Experiment Station. 132 p. + map. (Revised, 1994).

Random Lengths, April 5, 1996. The weekly report on north american forest products markets. 450 Country Club Road #240, Eugene, OR 97401.. 12p.

Schuster, Ervin; Keegan, C.E.; Jackson, D.H. 1996. Assessing Montana's Timber Situation: an assessment. West. J. Appl.For.11(2): 54-58.

Thomas, Jack W. 1995. Forest health: what is it, what we are doing about it. Paper presented at the 60th North American Wildlife and Natural Resources Conference, Minneapolis, MN, March 27, 1995.

Wood Resources International Ltd., 1996. Wood fiber northwest market report, March, 1996. 14(1): 21p. P.O. Box 1891, Bothell, WA 98041.

COFE REGIONAL REPORT - WESTERN CANADA[1]

by

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ABSTRACT: The majority of forest land in Western Canada (British Columbia, Alberta and Saskatchewan) is publicly owned. The provincial governments set the policies under which the forests are managed, and allocate timber to private forest companies through various types of temporary tenure agreements. The policies set by the governments often reflect the public's perception of how forest companies manage their tenures.

Besides environmental issues, forest companies in Western Canada are working to improve wood quality and upgrade their mill output to higher-value products. The industry is also exploring ways to recover non-traditional fibre from, for example, sort yard debris and overmature stands. However, the current down turn in the pulp market will likely have a dampening affect on these activities.

While the US is still the major export market for the forest industry in Western Canada, many companies are looking at expanding their sales, especially of higher-value products, into the Asian and European markets.

Key Words: Forest Practices Code, ForestCare, British Columbia, Alberta, partial cutting.

BRITISH COLUMBIA

In 1995, the government of British Columbia implemented the British Columbia Forest Practices Code, which governs all aspect of forest operations on public land in the province. The Code establishes strict standards for protection of forest productivity, streams and water quality, visual aspects, wildlife habitat, and biodiversity along with heavy financial penalties (up to $1,000,000) and imprisonment for code violations. The sentences can be levied on both forest companies and individuals.

To meet the Code, the forest companies must provide the Ministry of Forests with several layers of detailed plans before a permit to conduct a forest operation of any kind is issued. As a result, planning costs have increased dramatically since the Code was implemented, as has the time between permit application and the time of approval. Any changes or amendments to the original plan must be approved by the Ministry, a process that could take as long as the approval of the original plan. Therefore companies are reluctant to make changes to the approved plans.

The implementation of the Code has also meant changes for the Ministry of Forests; it has increased its staff. Government foresters have also had to learn the new guidelines and how to implement them, a process contributing to the delay in approving permit applications.

Clear cutting is still the most common harvesting practice in British Columbia, but the average size of cutblocks is decreasing. Partial cutting is also becoming more common both on the Coast and in the Interior, primarily to achieve visual quality objectives, protect water quality, or preserve slope stability. Different harvesting systems, ground-based, cable and aerial, are being tried to achieve the desired objective at a reasonable cost. For example, the Forest Engineering Research Institute of Canada (FERIC) in cooperation with member companies, tested a cable system in partial cutting in a Coastal old-growth stand on very steep terrain. The operation proved very successful, primarily because of the amount of planning that involved fallers, yarding crew, foresters and engineers that preceded the operation. Other forest companies are testing long-line systems yarding up to 1000 m to reduce the amount of roads required.

On Coastal British Columbia, harvesting of naturally regenerated second-growth stands is increasing as areas with old-growth forests are being protected. The change to second-growth stands provides the opportunity to mechanize harvesting operations. Feller-bunchers, harvesters and excavator-forwarders are becoming more common in ground-based operations for both clear-cutting and partial cutting.

In the Interior of British Columbia, full-tree to roadside harvesting operations are most common, but cut-to-length systems are increasing in numbers. At MacKenzie in Northern British Columbia, TimberWest recently converted a significant part of its operation to cut-to-length to provide its sawmill with just-in-time delivery of logs, and to reduce hauling costs. Several other companies have also expressed interest in cut-to-

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length harvesting, but will more likely convert only a portion of their harvesting operations to cut-to-length systems.

ALBERTA

Alberta's situation is quite different from that of British Columbia. During the last 10 years, there has been a tremendous expansion of the forest industry with new pulp mills and board mills being built. As a result, all conifer and about 85% of the deciduous timber supply have now been allocated.

In Alberta, the forest industry established its own forest practices code, ForestCare. The Alberta Code is also different from the British Columbia Code in that the former is more 'goal oriented', and relies on industry auditing and enforcement. The Alberta government has also significantly reduced its forestry staff.

Most harvesting operations in Alberta are mechanized ground-based systems employing feller-bunchers, grapple skidders, and roadside delimbers or processors. However, a number of companies harvest a portion of their wood with cut-to-length systems, or use in-wood chippers to supplement their woodroom capacity. At-the-stump processing is also being tried in pine stands by moving conventional roadside delimbers into the stump-area. Grapple skidders are then extracting the tree-length stems to roadside for subsequent loading and hauling.

The expansion of the forest industry in Alberta provided the opportunity for many companies to begin their new operations using the latest harvesting and transportation technology. As an example, Alberta-Pacific Ltd. requires all of its trucking contractors to have Central Tire Inflation (CTI) systems on their log trucks. The company also uses Global Positioning Systems (GPS) technology to monitor the log haul and to supply its hauling contractors with information on truck performance.

SASKATCHEWAN

Saskatchewan is developing a new strategy of forest management focusing on sustainable management. While there has been some expansion of pulp and board mills in this province, there is still room for further expansion as not all of the Province's timber supply has been allocated.

COFE REGIONAL REPORT: EUROPE[1]

by

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Oral presentation only, abstract not available.

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A MIXED-INTEGER PROGRAMMING MODEL FOR TACTICAL FOREST OPERATIONS PLANNING[1]

by

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ABSTRACT: A Windows-based, mixed-integer programming model for the development of integrated forest operations plans was created at the University of New Brunswick. This model allocates harvesting systems to available cut blocks, plans multi-mill wood deliveries and wood purchases, while integrating road (tertiary, access, secondary), stumpage, and silviculture costs into the plan. Equipment (trucks, harvesting machines) purchase decisions can be included in the model. This model was tested in the UNB 1995-96 senior undergraduate forest operations planning case study. This paper summarizes the model's ability to develop a multi-year operating plan in an industrial-strength case study. The structure of the formulated matrix is explained, detailing the decision variables and constraints of the model. The case study is then described and illustrated with some results from the optimal solution. Finally, the model's potential for use as a planning tool in other contexts is discussed.

Key Words: forest operations, mathematical programming, mixed-integer programming, forest planning, timber harvesting

INTRODUCTION

Planning of forest harvesting operations is a complex enterprise that involves the allocation of resources across a wide diversity of forest blocks over a period of up to several years. Forest operation planners are typically required to satisfy the wood requirements of several mills, using particular harvest systems operating on a large number of possible cut blocks. Usually they are also responsible for the planning of road construction and the transportation of wood products to the mills. This is all done in a context of mounting environmental constraints and high operating costs. To help planners meet this challenge, researchers over the last 20 years have developed increasingly sophisticated computer-based planning models. The most common approach adopted in these models has been to implement a mathematical programming methodology to determine the theoretical 'optimum' plan based upon the objectives and constraints that are specified in a series of linear equations. TOPM (Tactical Operations Planning Model), the latest such model developed at the University of New Brunswick, represents a significant advancement in this field. This paper details the formulations used in TOPM, describes its use in a case study, and evaluates its potential for use in operational planning.

PRIOR ADVANCES IN OPERATIONAL PLANNING

Walker and Preiss (1988) developed a Mixed Integer Programming (MIP) model which produced an integrated harvesting and wood delivery plan for E.B. Eddy in Northern Ontario. The parameters of this plan included 228 harvest blocks, 4 products, 5 mills, and 2 harvest systems over a 5-year period. Walker and Preiss (1988) designated the block-harvest decisions to be binary variables, so that if a block was harvested it had to be completely harvested. Wightman (1990) developed a model that determined a minimum cost wood transport plan from harvest blocks to a multi-mill destination set. LOGPLAN II (Newnham 1991) allowed for multiple operating seasons to be defined within multiple operating years. LOGPLAN II minimized the total cost of a harvesting operation while including associated regeneration costs. Zundel (1993) developed a 5-year optimization model, TO-PLAN, that minimized the combined costs of harvesting, transportation, tertiary road construction, and silvicultural requirements. Zundel used TO-PLAN in a case study for Kruger Inc. to develop a 5-year operating plan. Davis (1987) developed a multi-year operational planning model, which he used to develop a 5-year plan for Great Northern Paper in Maine. This model used integer programming to minimize risk of wood fiber loss.

These models have demonstrated that mathematical programming can be used successfully in the development of forest operating plans. Walker and Preiss (1988), Wightman (1990), and Zundel (1993) all found that their optimization models produced solutions that were 4-7 percent better than heuristically produced plans. However, the

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effectiveness and use of these models have generally been limited to one or two situations. There are probably many reaons for this. Inertia in adopting new "high-tech" methods for developing operating plans, and a lack of reliable field data to input into the models certainly accounts for some of this restraint. However, the structure and limited 'user-friendliness' of the models themselves have also contributed to their limited applicability. Most of the above models were designed for one specific situation. For example, the model by Walker and Preiss (1988) was designed to develop a cost-minimized 5-year plan for the specific blocks, mills and products in question. TO-PLAN was designed to handle only one mill destination. Since the parameters and constraints of each forest operation situation varies, it is difficult to make a model 'hard-wired' for one specific situation fit readily into another situation.

TOPM OVERVIEW

TOPM was designed with these advances and limitations in mind. The objective behind the development of TOPM was a forest operations planning model flexible and comprehensive enough so that it could be used in a wide range of multi-year and multi-season forest operations planning situations. TOPM was intended to handle the following kinds of decisions:

1. What harvesting systems should be used in which blocks in which seasons of which years, given that different systems have different costs, production capabilities, block access abilities, silviculture and road requirements.

2. What primary products should be transported by which transportation systems to which mills or buyers.

3 What equipment should be purchased or contracted in which years.

4. Where should tertiary, access and main roads be built, and in which years should they be built.

5. What silvicultural activities should be undertaken in which years and in which blocks.

6. What primary wood products should be purchased by the mills throughout all seasons and years.

TOPM uses mixed-integer programming to formulate and produce the optimum operating plan. In the matrix, block availability for harvesting can be constrained by access roads or other infrastructure (e.g., bridges). As well, minimum and maximum harvest cut sizes can be specified. TOPM will produce either a plan with a minimized total discounted cost or a plan with a maximized Net Present Value - subject to all constraints.

TOPM partitions different plans into scenarios. An unlimited number of planning scenarios can be entered into TOPM. New scenarios can be copied automatically from existing scenarios, so that the user can quickly develop several versions of an operating plan. Each scenario can have different dimension sizes associated with it (e.g., one scenario can have a 3-season operating year with 15 products and 2 mills, wheras the next scenario can have a single season operating year with 1 product and 5 mills). Once the user has configured the planning situation as desired, the matrix and all its coefficients are developed automatically by TOPM.

TOPM MATRIX STRUCTURE

Objective function

The objective function in TOPM is either,

minimize: z = BLOCKCOSTS + TRANSCOSTS + PURCHASECOSTS + EQUIPMENTCOSTS + ROADCOSTS

or

maximize: z = WOODVALUE - BLOCKCOSTS - TRANSCOSTS - PURCHASECOSTS - EQUIPMENTCOSTS - ROADCOSTS

where:

The PURCHASECOSTS, EQUIPMENTCOSTS, ROADCOSTS and WOODVALUE terms are all optional.

$$BLOCKCOSTS = \sum_{b}^{B}\sum_{h}^{H}\sum_{y}^{Y}\sum_{n}^{N} BC_{bhyn} * HA_{bhyn}$$

$$TRANSCOSTS = \sum_{b}^{B}\sum_{y}^{Y}\sum_{n}^{N}\sum_{t}^{T}\sum_{m}^{M}\sum_{s}^{S}\sum_{p}^{P} TC_{byntmsp} * TV_{byntmsp}$$

$$PURCHASECOSTS = \sum_{m}^{M}\sum_{y}^{Y}\sum_{n}^{N}\sum_{s}^{S}\sum_{p}^{P} PP_{mynsp} * PV_{mynsp}$$

$$EQUIPMENTCOSTS = \sum_{y}^{Y}\sum_{e}^{E} EC_{ye} * NE_{ye}$$

$$ROADCOSTS = \sum_{r}^{R} RC_{r} * BR_{r}$$

$$WOODVALUE = \sum_{m}^{M}\sum_{y}^{Y}\sum_{n}^{N}\sum_{s}^{S}\sum_{p}^{P} UWV_{mynsp} * DV_{mynsp}$$

and

b - denotes a harvest block out of a total of B blocks
h - denotes a harvest system out of a total of H systems
n - denotes an operating season out of a total of N seasons in a year
y - denotes an operating year out of a total of Y years
t - denotes a truck-type out of a total of T truck-types
s - denotes a species out of a total of S species
p - denotes a species-product out of a total of P products for a species
m - denotes a mill out of a total of M mills
e - denotes an equipment type (harvest machine or truck-type) out of a total of E types of equipment
r - denotes an access or secondary road out of a total of R roads

$\mathbf{BC}_{bhyn}$ = block cost coefficient in \$/hectare for system - h, in block - b, year - y and season - n.
$\mathbf{HA}_{bhyn}$ = decision variable in ha for system - h, in block - b, year - y and season - n. This is a semi-continuous variable.
$\mathbf{TC}_{byntmsp}$ = transport cost coefficient in \$/m^3 for truck - t, in block - b, year - y, season - n, transporting species - s, product - p to mill - m.
$\mathbf{TV}_{byntmsp}$ = decision variable in m^3 for truck - t, in block - b, year - y, season - n, transporting species - s, product - p to mill - m. It is an unbounded, continuous decision variable.
$\mathbf{PP}_{mynsp}$ = purchasewood cost coefficient in \$/m^3 at mill - m, in year - y, season - n, for species - s, product - p.
$\mathbf{PV}_{mynsp}$ = purchasewood decision variable in m^3 at mill - m, in year - y, season - n, for species - s, product - p. This variable is bounded in the matrix to remain between the minimum required and maximum allowed purchase levels.
$\mathbf{EC}_{ye}$ = discounted purchase cost in \$ of equipment (harvesting machine or truck) - e in year - y
$\mathbf{NE}_{ye}$ = decision variable of number of equipment - e to purchase in year - y. This is a general integer variable (NE=0,1,2,3..)
$\mathbf{RC}_{r}$ = road cost in \$ to build road - r
$\mathbf{BR}_{r}$ = binary decision variable (0,1) to build road - r or not.
$\mathbf{UWV}_{mynsp}$ = unit wood value in \$/m^3 at mill - m, in year - y, season - n, for species - s, product - p. This coefficient is currently equal to PP_{mynsp}.
$\mathbf{DV}_{mynsp}$ = total delivered volume in m^3 at mill - m, in year - y, season - n, for species - s, product - p. This is equal to the amount of wood purchased (PP_{mynsp}) and all wood transported to the mill ($\Sigma_b\Sigma_t$ $TV_{btynmsp}$)

Constraints

The constraints can be grouped into different categories, some of which are optional.

Harvest cut size

TOPM optionally defines the decision variables HA_{bhyn} in the objective function to be semi-continous variables. Semi-continuous variables differ from continous variables in that they have a discrete jump in their allowed values.

$$HA = 0, \quad \text{or} \quad HA >= c, \qquad c > 0$$

Thus, HA **cannot** take on a value in the range: $0 < HA < c$, where c is specified by the user. This feature is included to account for the overhead that occurs in harvesting when starting a new cut. At the very least the harvesting machinery must be moved to the block. Thus, the cost of the first m^3 cut in a new block is not equal to the cost coefficient of the continuous variable. To deal rigorously with this extra start-up cost, binary variables would need to be included in the objective function similarly to what has been done with access and secondary roads (see below). However, the prohibitively large number of binary variables involved would make the model difficult, if not impossible, to solve. In addition, the magnitude of this overhead cost does not usually warrant such a rigorous treatment. As a compromise, this option puts discrete bounds on the allowable harvest cut sizes, so that if a harvest cut is made (i.e., HA > 0), the cut must be greater than a required minimum size (i.e., HA >= *c*). This will constrain TOPM from producing a solution with unrealistically small cut sizes. The fixed cost of the harvest start-up is thus assumed to be absorbed as part of the larger variable cost. The semi-continuous variables do increase the computational effort required to solve the problem, but not to the extent that would occur if binary variables were used for every HA decision variable.

An upper bound can also be specified so that the HA variables must remain less than a maximum allowable cut size.

Harvest block area

This is a required set of constraints to ensure that the total area of a block cut over the course of the plan is less than or equal to the area of the block (so the block area cannot be cut more than once).

$$\sum_{b}^{B} \left(\sum_{h}^{H}\sum_{y}^{Y}\sum_{n}^{N} 1 * HA_{hynb} \leq BAREA_{b} \right)$$

where:

$\mathbf{BAREA}_b$ = the area of block b in ha.

TOPM also allows the user to constrain the total harvested area to a minimum percentage of the total area of all blocks. This ensures that a minimum percentage of land area will be harvested over the course of the plan.

Harvest volume transfer

This large set of constraints is required to convert the area harvested in each block into product volumes available for transport.

$$\sum_{b}^{B}\sum_{y}^{Y}\sum_{n}^{N}\sum_{s}^{S}\sum_{p}^{P}\left(\sum_{h}^{H}\left(SP_{bynsph} * HA_{bhyn}\right) - \sum_{t}^{T}\sum_{m}^{M} TV_{byntmsp} >= 0\right)$$

where:

$\mathbf{SP}_{bynsph}$ = species-product volume per ha (m^3/ha). This is calculated in TOPM by assuming a uniform distribution of the species-product mix across the block. The product volume in the block is divided by the block area to get a product m^3/ha coefficient.

These equations can either be specified as equalities (i.e., =0) or as inequalities (i.e., > 0). The first case forces transport of all cut wood, whereas using inequalities allows cut wood to be left at the block.

Mill constraints

These constraints are written in one of two ways. The first routine assumes that in each season there is a rigid maximum and minimum demand that must be met for all products at all mills. The equations for this approach are:

$$\sum_{m}^{M}\sum_{y}^{Y}\sum_{n}^{N}\sum_{s}^{S}\sum_{p}^{P}\left(MMIN_{mynsp} \leq \sum_{t}^{T}\sum_{b}^{B} TV_{byntmsp} + PV_{mynsp} \leq MMAX_{mynsp}\right)$$

where:

$\mathbf{MMIN}_{mynsp}$ = minimum mill inventory for mill - m, in year - y, season - n, for species - s, product -p.
$\mathbf{MMAX}_{mynsp}$ = maximum mill inventory for mill - m, in year - y, season - n, for species - s, product -p.

These constraints ensure a minimum and maximum wood intake level for each product at all mills for every season. In addition, TOPM also has the option to constrain total wood intake. Setting a large minimum and maximum range for each product, and including these total wood volume constraints will allow TOPM to choose the optimum product combination for each mill. The set of constraints for total wood volumes are:

$$\sum_{m}^{M}\sum_{y}^{Y}\sum_{n}^{N}\left(TMIN_{myn} \leq \sum_{t}^{T}\sum_{b}^{B}\sum_{s}^{S}\sum_{p}^{P} TV_{byntmsp} + \sum_{s}^{S}\sum_{p}^{P} PV_{mynsp} \leq TMAX_{myn}\right)$$

where:

TMIN$_{myn}$ = total (all products) minimum mill inventory for mill - m, in year - y, season - n
TMAX$_{myn}$ = total (all products) maximum mill inventory for mill - m, in year - y, season - n

These constraints specify that the sum of the product volumes must remain between a minimum and maximum range for all seasons. It should be noted that use is made of Right Hand Side ranging in the matrix to model both the maximum and the minimum limit in one equation. If this were not the case, two equations would need to be written - one for the maximum and the other for the minimum constraint.

The second approach explicitly incorporates mill consumption of wood. Mills are assumed to have a consumption level in each season and maximum and minimum allowable inventory levels. Wood not consumed by the mill (and thus in inventory) at the end of one season is available the subsequent season for consumption, along with the delivered wood of that season. Thus mills can be modelled to build and deplete inventory levels for times when wood delivery is expensive or impossible. This approach is modelled by:

$$\sum_{m}^{M}\sum_{y}^{Y}\sum_{n}^{N}\sum_{s}^{S}\sum_{p}^{P}\left(MMIN_{mynsp} \leq \sum_{1}^{y}\sum_{1}^{n}\left(DV_{mynsp} - CV_{mynsp}\right) \leq MMAX_{mynsp}\right)$$

where:

CV$_{mynsp}$ = mill consumption in m3
DV$_{mynsp}$ = delivered volume, which is the sum of purchased wood (PV) and transported wood (TV)

In each season, the CV and DV terms are summed for all previous seasons and years. Thus, these constraints force the difference of the cumulative delivered volume and cumulative consumed volume to remain between the minimum and maximum limits. Including the total wood constraint option would add the following equations to the matrix:

$$\sum_{m}^{M}\sum_{y}^{Y}\sum_{n}^{N}\left(TMIN_{myn} \leq \sum_{s}^{S}\sum_{p}^{P}\sum_{1}^{y}\sum_{1}^{n}\left(DV_{mynsp} - CV_{mynsp}\right) \leq TMAX_{myn}\right)$$

It should be noted that if the wood purchase option is not used, the PV terms are not included as part of the DV variables.

Equipment constraints

This set of constraints is optional, and if activated, can also be put to use in one of two ways. The first approach sets seasonal constraints on the availability of the equipment (harvest machines and trucks). Based on the number of available machines or trucks, number of operating days per season, number of scheduled hours per operating day, and the utilization of each machine or truck, the available productive machine hours (PMH) for each piece of equipment in every season is calculated (i.e., PMH = operating days/season * scheduled machine hours/day [SMH/day] * PMH/SMH * number of machines). This is considered the maximum amount of time that an equipment type is available for productive work in any season and thus becomes the right hand side in this set of constraints:

$$\sum_{y}^{Y}\sum_{n}^{N}\sum_{h_m}^{H_M}\left(\sum_{b}^{B}\left(HA_{bynh} * HH_{bynhm}\right) \leq HMAX_{ynhm}\right)$$

for harvest machines, and for trucks:

$$\sum_{y}^{Y}\sum_{n}^{N}\sum_{t}^{T}\left(\sum_{b}^{B}\sum_{m}^{M}\sum_{s}^{S}\sum_{p}^{P}\left(TH_{byntmsp} * TV_{byntmsp}\right) \leq TMAX_{ynt}\right)$$

where:

h_m = harvest machine m in harvest system h
H_M= total number of harvest machines in all harvest systems
HH$_{bynhm}$ = PMH/ha required for machine - m, in harvest system - h, block - b, year - y, season - n. This is calculated from the machine productivity equation (m^3/pmh) and block volume (m^3/ha)
HMAX$_{ynhm}$= Maximum number of available machine hours (PMH) for machine - m, of system - h, in year - y, season - n.
TH$_{byntmsp}$ = coefficient for truck time for hauling wood (PMH/m^3). This is a function of truck speeds, road distances and load size.
TMAX$_{ynt}$= maximum number of available truck hours (PMH) for truck - t, in year - y, season - n.

Minimum required hours of use, **HMIN** and **TMIN**, for each season can also be specified. These force TOPM to work these machines to at least these minimum levels in each season.

The other way of constraining equipment availability is to include equipment life and the purchase of new equipment into the decision-making process. Not only is equipment constrained by seasonal capacity, but also by economic life.

$$\sum_{e}^{E}\sum_{y}^{Y}\sum_{n}^{N}\left(\sum_{-elife}^{y} NE_{ey} * ECAP_{en} - EPMH_{eyn} > 0\right)$$

$$\sum_{e}^{E}\sum_{y}^{Y}\left(\sum_{1}^{y} NE_{ey} * ELIFE_{e} - \sum_{1}^{y}\sum_{n}^{N} EPMH_{eyn} > 0\right)_{w}$$

where:

ECAP$_{en}$ = seasonal capacity (PMH) per piece of equipment - e, in season - n. This is the product of operating days/season * scheduled hours/day * utilization rate.
EPMH$_{eyn}$ = PMH used by equipment type - e, in year - y, season - n. This is calculated by transfer rows which sum the PMH for that equipment by season and year.
ELIFE$_{e}$ = economic life in PMH of equipment - e.
NE$_{ey}$ = General integer decision variable (i.e. 0,1,2,3...) to determine how many pieces of equipment type - e, to purchase in year - y.
ELIFE = expected economic life in years based on scheduled hours and utilization.

The first set of constraints ensures that an equipment's seasonal level of use (total PMH) cannot exceed the total seasonal capacity of the equipment. The seasonal capacity is the product of the total number of pieces of equipment in service (those purchased in current and previous years) multiplied by the seasonal capacity per piece of equipment. Total seasonal capacity can be increased by the purchase of new equipment. The second set of constraints ensures that the cumulative level of use of the equipment does not exceed total acquired economic life.

It should be noted that these different equipment constraints affect the way that cost coefficients are calculated. If the first method is employed (equipment purchase is not considered), the depreciation rate ($/PMH) for each machine is included as part of the cost coefficient in both harvesting and transportation. The second method (equipment purchase is considered) does not include the depreciation in these cost coefficients. This cost is captured in the purchase cost.

Access and secondary road constraints

TOPM distinguishes between three different types of roads. A harvest or tertiary road is one where the length of the road to be built is proportional to the area of the block that is to be cut. Since this cost is proportional to the amount of wood cut, this road cost is bundled in as part of the block operating cost coefficient.

The other road types in TOPM are those where the entire road must be built (and hence the entire road cost incurred) before any harvest operations can commence. Typically, this occurs when a road provides access to a block, or to several blocks. In this situation, the assumption of proportionality between length of road built and area of a block cut is untenable, and this situation is better modelled as a binary (0,1) decision. Either the road is not built (the variable takes on the value 0), or the entire road is built (the variable takes on the value 1). If the road is not built, no harvesting can occur in that block. In TOPM, roads which provide this kind of access to one block are called block access roads, whereas roads which provide this type of access to more than one block are considered secondary or primary roads. TOPM has a special window in its interface to allow blocks to be picked and 'attached' to the secondary road in question. The access and secondary roads are included in the matrix in the following manner:

$$\sum_{r}^{R}\left(\sum_{b}^{b}\sum_{h}^{H}\sum_{y}^{Y}\sum_{n}^{N} HA_{bhyn} - M * BR_{r} \leq 0\right)$$

where:

BR$_{r}$ = binary decision variable (0,1) to build road r or not.
M = any large number (greater than the total area of the blocks in question)

For secondary/primary roads, the HA_{bhyn} variables include those from several blocks, whereas for block access roads they only include those from the one block in question. In this formulation, if variable BR is 0 (i.e., no road built), all the HA variables must also remain 0 (i.e., no harvesting activities) to avoid violating the inequality (i.e., so the left hand side remains zero or below). In order to allow any of the HA variables to take on a non-zero value (i.e., do some harvesting), the BR variable must equal 1 (i.e., build the road). The coefficient 'M' is simply a number that is large enough to ensure that the left hand side of the equation remains negative even if all the HA variables take on positive values, thus satisfying the inequality. The value of M is currently set at 99,999.

User specified constraints

Through its interface, TOPM allows the user to constrain the generation of decision variables. This keeps TOPM from generating variables that are nonsensical. For example, suppose that there are four different harvest systems being considered in a plan. However, two of the systems will only work in softwood blocks. Thus, decision variables for these two systems in hardwood blocks are meaningless - they will not work in such blocks. TOPM will allow the user to quickly locate all blocks of a certain trait (in this case it is softwood/hardwood type) and will allow the user to set these two systems to be 'unavailable' for this group of blocks. When TOPM generates the matrix, no decision variables will be generated for these two systems in the hardwood blocks. The effect is to constrain the model without adding more constraint rows (which increases model size and required computational effort) by decreasing the number of variables which decreases model size. TOPM allows the user to constrain all block-system, block-season, block-year, block-mill and truck-product combinations.

MODEL SIZE RESTRICTIONS

TOPM will produce all coefficients and generate the matrix as an ASCII file in Mathematical Programming System (MPS) format. TOPM allows up to 125,000 blocks, and has a maximum of 50 for all other dimensions (e.g., number of species, mills, systems, years etc.). MIPIII[2] is the MIP solver that is currently being used to solve the matrix produced by TOPM. MIPIII allows a maximum of 32K constraints. The number of variables is limited only by the RAM of the computer. Thus large and complex planning scenarios can be solved by TOPM.

OBJECTIVE FUNCTION COEFFICIENTS

Block operating costs

The decision variables (HA_{bhyn}) are semi-continuous and are in units of hectares. This set of decision variables represent all the harvest system-block alternatives over the course of the plan. The coefficients of the HA variables are therefore in units of \$/hectare. These are composite coefficients, composed of the following components:

1. Harvest cost is the base component, and is the product of system cost per m^3 and block volume per ha (i.e. \$/m^3 * m^3/ha). Since TOPM allows for multi-year planning, the block volume can optionally be grown each year according to a user-specified formula. Thus, the m^3/ha term can 'grow' or 'die' as desired. This is useful in situations where volume change is significant, as in high growth rate zones, in regions undergoing excessive dieback as in a spruce budworm outbreak, or with longer planning time frames. The harvest system cost is the sum of the \$/m^3 costs of all machines that are in the system. The \$/m^3 cost for each machine is calculated either as the multiple of the rental rate and a productivity equation (\$/pmh * pmh/m^3), or is calculated directly from a cost equation. Cost equations are useful in situations where harvesting is contracted out at a negotiated rate. The cost and productivity equations are completely user-definable and accept block parameters (e.g., m^3/tree, slope, m^3/ha etc.) as input variables. As well, constants can be used in place of the equations. TOPM calculates machine rental rates from input cost data or allows the user to specify a rental rate.
2. Stumpage or royalty costs. This is an optional component where the stumpage costs are inputted as \$/m^3 for each type of wood product. Based on the species-product composition of each block, and the m^3/ha value for each year of the plan, TOPM calculates a weighted average stumpage cost

[2] MIPIII is a commercial product from Ketron Management Science, a division of Bionetics Inc.

in \$/ha. This is then added to the harvest cost to give a combined \$/ha coefficient.

3. Silviculture costs. This is also an optional component. Blocks in TOPM can be grouped into forest classes or strata, based on user-defined silvicultural criteria. Harvest systems can also be grouped into classes based on silvicultural criteria. A silvicultural transition matrix (forest strata * harvest system classes) can then be developed. Each element of this matrix contains the the expected silvicultural activities for that particular forest class and harvest system class to bring the harvested block back to a 'free-to-grow' state. The sum of the discounted costs of these activities is thus the expected present cost of silviculture in \$/ha.

4. Tertiary road costs. A tertiary or harvest road is defined in TOPM as a road system in a block where the total length of the road to be built is proportional to the area of the block cut. TOPM uses an inputted default road cost (\$/km) multiplied by a block specific road spacing ratio (km/ha) to obtain a tertiary road component in \$/ha which can optionally be added to the block cost coefficient. The road spacing ratio is calculated by the optimum road spacing formula. Alternatively the user can input a road spacing ratio to override the optimum value.

These components are summed to produce a combined block operating cost coefficient in \$/ha (i.e., cost of wood at roadside before loading or transport). This coefficient is then discounted to produce a present value block operating cost.

Transport costs

The transport decision variables are in units of m^3. This set of decision variables represent all the product-block-mill transport alternatives over the course of the plan. The cost coefficients are in units of \$/m^3. These coefficients are the product of truck rental rate and trip time and loadsize (\$/PMH * PMH/block-mill trip * block-mill trip/m^3). The trip time between all mills and blocks is calculated by using average empty and loaded travel speeds multiplied by distances for the different road classes. TOPM allows the user to vary load size by product and season, to account for possible weight restrictions and varying species densities.

Purchase costs

The purchase decision variables are in units of m^3. This optional set of decision variables represent the purchase alternatives from outside sources for all the mills over the course of the plan. These variables can have upper and lower bounds set, representing minimum purchase obligations and maximum purchase supply levels. The coefficients are in units of \$/m^3, representing the delivered wood cost.

Equipment costs

These variables are general integer variables (0,1,2,3...) and represent the quantity of each equipment (harvest machine or truck) to buy in each year. The coefficient is the discounted purchase price for that piece of equipment.

Road costs

This is a binary (0,1) set of decision variables. The coefficients for these road decisions represent the total cost to build each complete road, and are thus in units of \$. For block access roads the total cost is simply the product of the standard tertiary road cost rate (\$/km) and the required length (km). For a secondary or primary road, the user inputs a unit road cost (\$/km) as well as the required length (km) to arrive at a total cost for the road.

Wood value

These variables represent the amount of wood arriving at the mills through the course of the plan. If the objective is set to minimize costs these variables are not generated, and all the above cost coefficients are given positive values. The model will then find the least expensive way to get the required wood to the mills. If the objective is to maximize profits, these wood value variables are generated to track the amount of wood arriving at the mills. The coefficients for these variables are in units of \$/m^3 and represent the discounted value to the organization of having a m^3 of wood on-hand at the mill. Currently this coefficient is equal to the purchase price of the wood (see purchase costs above) to approximate the market value of wood. When the model maximizes profit, it sets all cost coefficients to negative values and finds the combination of activities that results in the greatest discounted wood value less total discounted costs.

THE CASE STUDY

At the Univeristy of New Brunswick, the graduating class of the faculty of forestry, as part of the core curriculum, is required to develop an integrated forest management and forest operations plan. In the context of a fictitious company, a woodlands division (which includes the whole class) is assembled to develop and present these plans to the board of directors (a team of professors) by year-end. Though the company is fictitious, the mills correspond to actual mills of the surrounding area, and all forest resource and map data is obtained from the New Brunswick Department of Natural Resources and Energy.

For the 1995-1996 year, the forest operations plan was developed, for the first time, by using TOPM. The dimensions of this operations plan included 650 harvest blocks, 5 harvest systems, 7 species groups, 2 product classes, 4 mills, and several woodlot marketing boards. Normally, in New Brunswick, such plans are developed for a 5-year period, but due to blocking problems inherited from the 1994-1995 case study, the planning horizon was reduced to 3 years.

The operations managers chose to divide the years into 3 operating seasons - summer, winter and spring break-up, to reflect the differing operating conditions throughout the year. The wood from the marketing boards was treated as purchase wood options, with the maximum supply from the marketing boards being the upper bounds of the decision variables, and the contractual obligations to the marketing boards being the lower bounds. Minimum harvest cut sizes were set at 6 hectares. Of the five harvest systems, two were constrained to be available only in softwood blocks, one was available only in hardwood blocks, one was available in both hardwood and softwood blocks, while the fifth system (a thinning system) was available only in blocks which were designated for thinning. All harvesting and trucking activities were specified as being unavailable in the spring break-up season. Thus, mills could only rely on purchased wood and millyard inventories to satisfy their demands during this season. Certain blocks, identified from a geographic information system (GIS) as being swampy, were designated as being available only in the winter season. The objective was set to maximize net present value, while the block operating coefficients included harvest cost, stumpage, tertiary road construction, and silviculture costs. Finally, access and secondary roads were defined for all blocks that were not currently accessed.

These constraints were incrementally added over a two month period. Students would generate optimal solutions and scan them for unrealistic outputs. Constraints were then added to ensure validity of the scenario. Each iteration of the plan produced a matrix size averaging 20,000 rows and 40,000 to 50,000 variables. A pentium 133 MHz DELL computer with 32 MB RAM was used to run TOPM and the MIP solver. Each solution took approximately 5 to 6 hours to generate.

RESULTS

The following tables have been taken from the TOPM report files for this case study. These reports are generated automatically when TOPM reads the optimum solution. The actual report files are extremely large as they report on all the non-zero decision variables. Other reports from TOPM show Right-Hand Side slack, shadow prices, reduced costs, and post-optimal ranging[3] results. If the solution is infeasible, TOPM will detect the infeasibility and report on what is causing it.

Table 1. Harvesting schedule for the case study.

YR	SSN	SYSTEM	BLOCK	HA	COST
1	WI	S/HRWD-FT1	3941-05	17.00	9469
2	SU	S/HRWD-FT1	3941-05	6.00	3042
2	SU	S/HRWD-FT1	3941-06	6.00	5574
3	SU	S/HRWD-FT1	3941-06	100.00	84600

Table 2. Transport schedule for the case study.

YR	SSN	BLOCK	TRUC	MILL	SPECIES	PROD	M3
1	WI	4947-10	MACK	SOUTH	PINE	LOGS	100
1	WI	4947-10	MACK	SOUTH	HEM/TAM	LOGS	1036
1	WI	4947-10	MACK	SOUTH	CEDAR	SHIN	750
3	SU	4948-01	MACK	ANNE	MIXDHR	PULP	748

[3] This is a procedure to determine values beyond the current iteration of the LP solution. This provides information useful in sensitivity analysis.

Table 3. Mill purchase and delivery schedule for the case study.

MILL	YR	SSN	SPECI	PROD	BUY	CO. OP	CONSUM
JUNIPER	3	WI	SPF	LOGS	9877	151073	92750
JUNIPER	3	SP	SPF	LOGS	0	0	66250
ASHLEY	1	SU	SPF	LOGS	1472	44728	38500
ASHLEY	1	WI	SPF	LOGS	1144	33506	22458

Table 4. Road construction schedule for the case study.

BLOCK	ROADTYPE	YEAR	KM	COST
4950-03	HARVEST	3	0.37	2150
4951-01	HARVEST	3	0.09	529
3940-05	ACCESS	1	0.25	1757
3941-05	ACCESS	1	0.50	3515

Table 5. Silviculture schedule for the case study.

YEAR	BLOCK	HA	ACTIVITY	COST
2	3940-05	8.00	SITE QUAL	13
3	3940-05	8.00	PLANT QUAL	17
6	3940-05	8.00	5YR ASSESS	8
15	3940-07	95.48	PCT	11338

Table 6. Equipment acquisition schedule for the case study.

YEAR	SYSTEM	MACHINE	NO.	COST
1	SFWD-FT#1	HOODSLA	1	263840
2	SFWD-FT#1	HOODSLA	2	360909
3	SFWD-FT#1	HOODSLA	3	474994
3	S/HRWD-FT1	TJ380GS	2	299961

The costs in the tables are discounted. TOPM also reports future value cost reports. From these reports other more specific reports (such as averages by year, season or mill etc.) can be developed. In addition, solutions from TOPM can be exported to a GIS so that the spatial dimension of the operating plan can be studied. This would allow managers, for example, to see year-by-year and season-by-season where the harvesting, trucking, road building and silvicuture operations are scheduled to occur.

CONCLUSION

TOPM has good potential to be an effective forest operations research and planning tool. This is true for several reasons. Its matrix structure is very flexible, with many options. All major activities and cost sources including harvesting, silviculture, stumpage, road construction, transportation, and wood purchases can be included in the objective function to produce a truly integrated plan. TOPM includes wood purchase decisions and incorporates millyard inventory levels when the plan is formulated. Thus, integration has been extended beyond the traditional forest activities (harvesting, trucking, road construction and silviculture) to include wood purchases and mill consumption levels. The use of integer variables for equipment purchase decisions, secondary and block access road construction decisions, and harvest cut size restrictions allow for a closer approximation to real-life situations than can be done using standard linear programming. TOPM can produce and solve extremely large planning problems. The Windows-based graphical user interface (GUI) is a powerful interface to enter, analyze and validate the large amounts of input data. The flexible structure of TOPM allows it to handle problems of varying sizes, thus making it quite versatile. In fact, TOPM was used to solve four other different operational planning problems at the same time it was used to work on this case study.

One aspect of the ability to handle multiple scenarios, each with different dimension sizes, that may prove extremely useful is when re-planning is required. Once a plan has been developed and implementation of the plan has progressed to some degree, re-planning based on the current 'as-is' status of the implementation could be quickly done. A new scenario could be copied from the existing plan. Blocks already harvested could be removed from the block list, the number of operating days in the season could be reduced accordingly, future mill demand adjusted to current estimates, and any other required modifications could be entered. The new revised plan, based on the current status of the implementation would then be produced. In fact rolling plans could conceivably be developed at periodic intervals, so adjustments to changing operating and market conditions could be regularly incorporated.

The ability of TOPM to handle problems with basically unlimited dimension sizes allows the users to adjust each particular problem so that limits of the LP solver are not exceeded. For example, in this case study, the students initially adopted a four season operating year. Some initial calculations showed that the problem would exceed the 32K row limit of MIPIII. Rather than reduce the number of blocks, or the number of mills, the students decided that the summer and fall season were similar enough to collapse into one season. Other situations may have led to reducing other dimensions of the problem. TOPM can accomodate the situation no matter how the user decides to delineate the problem.

Though TOPM has the potential to be an important tool in the planning process, reliance on it demands that the planners understand what the model is doing, know the assumptions behind it, and develop a trained ability to analyze and interpret the output reports. Indeed, the greatest danger in relying on this kind of model is that inadequate and incompetent screening of the large amounts of input data will allow undetected errors to skew the plan. This risk is increased if users blindly accept non-intuitive solutions. Though mathematical optimization can and does lead to non-intuitive solutions, such solutions can also come about due to faulty input data, and the user must be aware of this. TOPM does check for unusual or invalid input data, but not all cases can be completely anticipated beforehand. This was particularly obvious at the beginning of the case study, when the students studied the 'optimal' outputs and did not recognize that some solutions did not really make sense. However, towards the end of the planning process students were much more adept at detecting and recognizing invalid or inconsistent results. The formal structure of the model allowed students to understand the major causes and effects in their operations (e.g., "if costs are low, check the productivity equations"). This is because TOPM, as a model of the real world, provides an ideal framework in which to understand and study the factors that govern the outcomes in an operational situation.

If the potential that TOPM offers in multi-year planning is to be realized, then further enhancements and development will be needed. Issues such as linkages to GIS and other planning models (longer term harvest scheduling, blocking and operational scheduling and budgeting) will need to be addressed. This, however, is best done based on evaluations and experience gained from applying the model to a wide range of forestry problems. Industrial groups are being contacted to find partners interested in further research and development work on TOPM.

LITERATURE CITED

Davis, C. J. 1987. *Planning Timber Harvest Activities with Geographic Information/Decision Support Systems.* 250 pp. Virginia Polytechnic Institute. Ph.D. Thesis.

Newnham, R.M. 1991. "LOGPLAN II - Model for Planning Logging and Regeneration Activities." For. Canada Info. Report FMR-X-102

Walker, H.D. and S.W. Preiss. 1988. "Operational Planning using Mixed Integer Programming." The Forestry Chronicle. pp. 485-488.

Wightman, R.A. 1990. *An annual harvest distribution model.* 82 pp. University of New Brunswick. M.Sc.F. Thesis.

Zundel, P. 1993. *Planification des Choix et l'affectation de Systemes d'Exploitation Forestiere a Moyen Terme.* Universite de Laval. Ph.D. Thesis.

TIMBER HARVEST PLANNING IN THE PACIFIC NORTHWEST: LESSONS FOR TANZANIAN FOREST PLANTATIONS[1]

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ABSTRACT: Plantation forests in Tanzania, East Africa, are situated on mountainous areas of variable terrain. After successful plantation establishment in the 1950's, harvesting started in the 1970's well in time to meet an increased national timber demand. Current problems facing timber harvesting in the form of a volume surplus and signs of environmental degradation are associated with uncontrolled harvests, mismatch of harvest systems to site needs, and post-harvest practices. Comprehensive harvest planning is the needed solution. Protocols and effectiveness of timber harvest planning in the Pacific Northwest (PNW) provide some valuable lessons. Planning is an expensive undertaking, raising a concern for implementable harvesting plans. The accomplishments of plan objectives, planning tools, harvesting systems options, implementation requirements and monitoring criteria are explored in different settings. A planning procedure intended for the technical, economical, and institutional timber harvesting situations of Tanzania and other similar circumstances is advanced for review and consideration.

Key Words: timber harvest planning, protocol, harvesting systems, environment.

INTRODUCTION

Lack of appropriately planned and mismatched harvesting systems will likely lead to economic, technical and environmental problems. Obvious problems include uncontrolled harvests; waste of resources; site degradation; and adverse impacts on the soils, water and other non-timber forest benefits.

A recently noticed problem is the existence of appreciably large areas and volumes that were declared inaccessible to harvesting due to unproven difficult terrain. Timber harvesting needs to be carried out according to a pre-determined scheme to ensure an overall achievement of expected results. Traditionally, timber harvesting was dictated solely by economic requirements; hence, it was possible to harvest according to simple planning, written or not. The necessity for harvesting depended on the size of area, volume, length of project period, and the magnitude of economic gains at stake. Of late, the requirement for environmental protection and long term economic forecasts have made timber harvest planning a necessity, with increasing complexity brought in by more stringent, and at times conflicting economic, environmental and regulatory constraints.

Harvesting of plantation forests in Tanzania, which are situated on mountainous areas of variable terrain, started in the 1970's in time to absorb an increased national timber demand. Presently there is an estimated surplus of about 800,000 m^3 of plantation wood (Abeli and Ole-Meiludie, 1991); however, some areas have been over-harvested and there are signs of potential environmental degradation. Tanzanian environmental protection policy is still in the making (MTNRE 1994). Currently, plantation forest management objectives are broad statements of management for sustained yield and protection of natural resources. Harvesting is performed under voluntary guidelines interpreted from the Forest Division Standing Orders, which lack the present-day technical, economical and environmental implications. Apart from brief statements of volumes to be harvested and areas involved, no efforts are made to make well documented harvesting plans. Harvesting methods applied are geared to suit available technique rather than seeking techniques which meet appropriate criteria. In general, the plans are too simplistic for practical purposes. The force behind timber harvesting is mostly driven by volume with disregard for harvesting efficiency and environmental conservation.

The effectiveness of a forest harvest planning protocol is determined by the success of its implementation and the achievement of the envisaged objectives. The protocol must be complete and practical by including compatible objectives, efficient planning tools, a set of harvesting options,

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August, 1996.

implementation requirements and monitoring criteria. Overall, the protocol should safeguard decision making with specific relationships to appropriate technology and protection of the environment. Harvesting plans which follow the above protocol tend to be effective. This calls for examination of a harvesting planning protocol to identify critical steps in order to make harvesting plans efficient and implementable. Assessments of planning protocols practiced in the PNW provides some basis for effective planning procedures for Tanzanian timber harvesting situations and other similar circumstances. There are many forms of timber harvest planning to go with the broad institutional and technical spectrum and their associated problems. Proven effective planning procedures as well as failed attempts present a rich base to learn more effective harvesting planning.

TIMBER HARVEST PLANNING

Scope

There are three levels of planning commonly used in timber harvest according to length of planning period and size of project area. The broadest is strategic planning, also known as chance area planning, refers to broad statements of intent for very large areas over long periods (up to 10,000 acres, 20 years). Tactical planning, also known as mid-term planning, refers to planning periods of 3 to 5 years, covering areas of up to 1000 acres.

The lowest level is operational planning which covers small single units or compartments of up to 20 acres in one season, synonymously known as sale planning or sale layout. Each of these planning procedures yield a strategic plan, a tactical plan or a unit plan (Figure 1). This paper concentrates on tactical and operational level of timber harvesting.

Figure 1. Levels of harvest plans

From a broad perspective, timber harvesting activities in Pacific Northwest (PNW) can be presented in a spectrum according to area, ownership and management intensity (Figure 2).

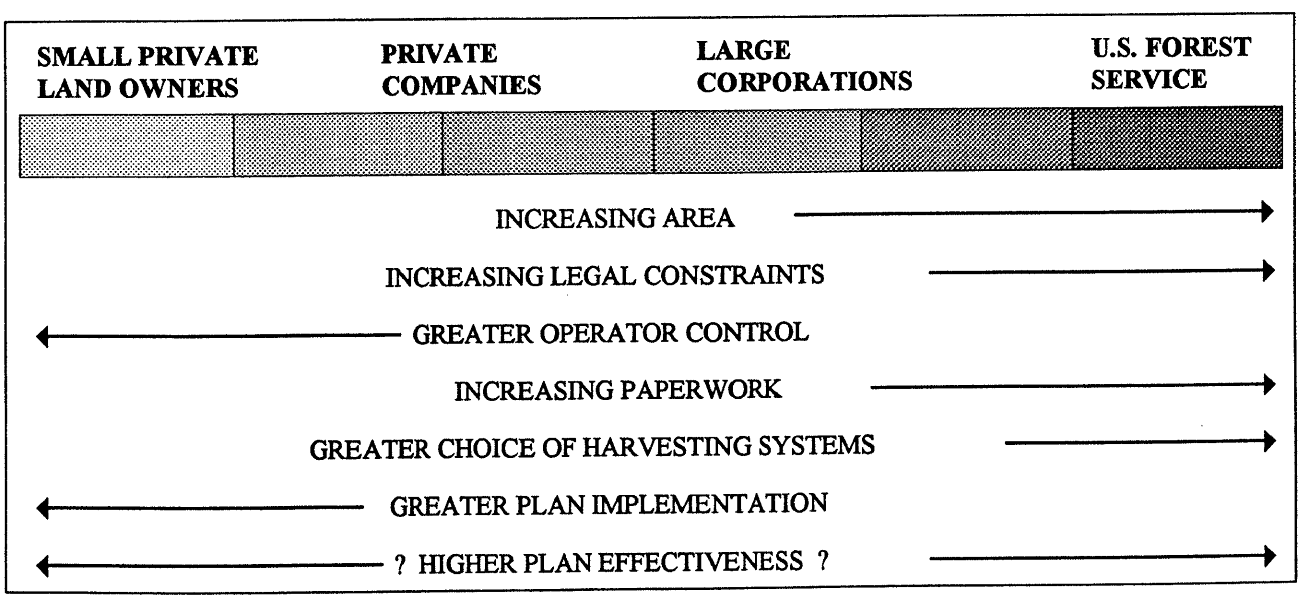

Figure 2. Spectrum of forest management ranks

On one extreme is the small private forest owners of small areas from 5 to 100 acres, while the other extreme is large forests of up to millions of acres owned by big companies, State or National agencies. Harvest planning approach, implementation and effectiveness vary along the spectrum.

Forest harvesting planning protocol

Protocol is defined in this context as a code prescribing strict adherence to correct etiquette or precedence (as in diplomatic exchange or military or the plan of a scientific or medical experiment or treatment) (Webster's New Collegiate Dictionary, 1979). Forest harvesting planning protocol is the sequence of proprieties necessary for a complete timber harvesting plan. A literature survey and observations made on current timber harvest planning in the Pacific Northwest revealed the following sequence of steps as the most common:

1. Objectives
2. Area description
3. Action planning
4. Sale layout
5. Implementation

Most of the small land owners have complete control of all five steps because of the scale of their operations, which is not the case for large land owners and public forests (especially with objectives and implementation steps). The need for environmental protection and consideration of endangered species have greatly modified objectives, introduced a necessity for more information in area description, and increased constraints to action planning. There is a legal need for small forest owners to observe regulatory requirements when making decisions on timber harvesting in the PNW.

In large scale timber harvesting, objectives are outlined according to the strategic plan, in most cases some time and distance away from the material project. The regional office receives volume quotas to fulfill in a given period and binding regulatory requirements under given resource capability. It is in this part of the spectrum where more steps are necessary: To identify environmental values in the area description; to identify feasible harvesting systems and determine their environmental acceptability in action planning. Implementation becomes a problem in most cases because of either an obsolete plan due to a long planning period, or conflicting objectives, such as last minute discovery of an owl nest in an area planned for harvesting. Failure of harvest plans of large scale area, time and objectives has always been laid on the intricacies of resources involved, uncertainty and changing parameters with time. However, the secret behind the success of small scale timber harvesting could be used to make an improvement. Schiess *et al.* 1988 pointed out the inadequacy of planning methods at tactical level to capture the financial gains envisioned through complex strategic planning. It was recommended to shift efforts towards site specific level planning where the realistic information results in effective plans.

Planning tools

Harvest planning tools include those aids used to make a harvesting plan. These include: maps; photos; inventory data sets; devices and programs for data recording, analysis and display; and the expertise to use the tool for decision making. There are various approaches for use of these tools, from a simple "pick and choose approach" to comprehensive planning incorporating many tools in a systematic process.

Information is becoming increasingly easy to obtain and accuracy is increased in the current information revolution. Tedious traditional timber harvesting planning methods which made use of contour maps, aerial photographs and timber cruise data are being replaced by fast and more accurate computer based analytical and display tools from GIS-based to simple tailor-made programs. There are many software programs available to fit the level of planning and amount of detail needed (Table 1).

Pick and choose approach

Those using this approach either use a model as shown in Table 1 or a selection of them to form a heuristic procedure. This is the common practice of many harvest planners; however, there is increased use of more comprehensive computer-based choices because of efficiency and increased availability of computer technology.

Comprehensive planning approach

Large ownerships in the management spectrum practice more comprehensive planning. The regulatory requirements, especially with regard to environment protection and endangered species, make harvest planning nearly impossible for medium to large areas using traditional methods. For example national and state forests plus large companies have their plans completely computerized. There are also consultant companies which provide professional harvest planning. Using a good selection of the available planning tools helps ensure efficient harvest planning.

Table 1: Some Harvest Planning Computer-based Analytical and Display Tools

Software Name	Problem Being Solved	Approach	Hardware/Software Requirements
FOCAS Ver 1.1 & 2.1	Logging equipment cost on cash flows.	Lotus spreadsheet template	IBM compatible; Lotus Compatible: Quattro
FOREST Ver 2.1 & 2.2	Forest roads planning	longitudinal profile, grade line and cross sections.	PC, math coprocessor, color monitor, mouse; printer or plotter optional
FRP.-Harvest 1992	Alternative harvesting plans based on GIS	Harvesting systems costs and estimated timber volume.	Undetermined Compatible: TerraSoft, Pamap
FOROPERA (1989)	Total skidding cost	Interval changes of variables; statistical evaluations	IBM PC XT/AT; dBASE III+; SPSS. Compatible: dBASE III+
HELIPACE Ver 1.3 (1992); Ver 2.0 (1993)	Helicopter logging production rates and costs	Spreadsheet with on-line help	IBM PC, VGA graphics, MS WINDOWS. Compatible: NETWORK II
LOGGERPC Ver 3.2 (1995)	Profile analysis for skyline planning: load path and allowable load	Solution of catenary equations.	386 math coprocessor, mouse, VGA graphics, WINDOWS Compatible: WINDOWS
NETWORK II (1988.)	Network analysis for road and harvesting choices.	Heuristics and dynamic programming	PC with 640 K, MS-DOS Spreadsheets
OFFTRACK Ver 1.0 (1989)	Calculation of wheel paths around curves	Algebraic solution of tractrix equations	IBM 286, math coprocessor, MS-DOS Compatibility: None
PACE Ver 1.0 (1986)	Machine cost, road cost, road spacing optimization	Spreadsheet	PC, MS-DOS Compatibility: None
PLANS Ver 1.12 (1992)	Development of timber harvest plans for large areas	Use of digital terrain model (DTM) and computer-aided design (CAD)	IBM PC, EGA or VGA color graphics, Digitizer Compatibility: Several GIS packages
PLANEX Ver 1.0 (1995)	Layout of harvest units and roads	Use of DTM and GIS together with harvesting system specifica-tions in heuristic algorithm	IBM compatible 386/486, Intel compatible math coprocessor, mouse, VGA and 4MB RAM
ROADENG Ver 2.0 (1995)	Database management analysis and Display: Cable layout and Roads (include 3-D)	Use of manual and digital terrain model (DTM) to support computer-aided design (CAD)	MS-Windows 3.1 or higher, 4MB RAM, Graphics monitor, mouse, Digitizer recommended. Compatibility:
SNAP II Ver 2.03 (1992)	Harvest scheduling, route location, evaluation of cumulative effects	Heuristics and network analysis	386 math coprocessor, Mouse, EGA color, 2MB RAM, MS-DOS Compatibility: ASCII files
STRATIS Ver 3.4; CAD Ver 4.0 (1992)	Digital terrain models; different route-locations interactively (CAD)	Calculation of project data, drawing of plans	IBM PC AT or PS/2 or compatible. Graphics card IBM 8514/A Compatibility: ASCII, DXF, SICAD, REB

Harvesting options

The selection of a logging systems[2] to use in a harvesting operation is one of the critical decisions of a planner. A competent planner should have appreciable knowledge in timber harvesting technology and its application based on scientific and engineering principles. It refers broadly to equipment and techniques, planning and control methodologies, scientific knowledge and engineering principles, education, training and relevant practices (Dykstra 1994).

The approach practiced in the PNW is to match a logging system to fit the situation. In essence the prevailing physical, technical and socio-economic conditions act as screens to all possible logging systems to achieve the most suitable (Figure 3). The best approach to handle harvesting system selection requires in-depth knowledge of performance categories of different harvesting systems (Garland, 1984), as well as clear description of the prevailing conditions of the harvest area. These conditions should first be refined to state specific ranges and standards, which in turn act as screens of acceptability to all possible harvesting systems. For example timber type and size category should be refined to state the species, size class, and other possible subsequent conversion if sawlogs or pulp wood; likewise terrain should be stated in terms of constraining slope class. Category refinement forms an important reference by setting ranges and standards relevant to the planning area as well as ranking dominance of the categories as specified by the planning objectives.

The concern for environmental protection has pushed for preference of cable systems on steep slope timber harvesting. Though cable systems stand out as trade-marks of PNW logging, ground based systems are used as well where slopes and soils permit. Forest practices regulations, developed by state and federal agencies, help foresters and forestry enterprises select practices to be followed in carrying out forest management and utilization operations (Berg *et al.* 1993).

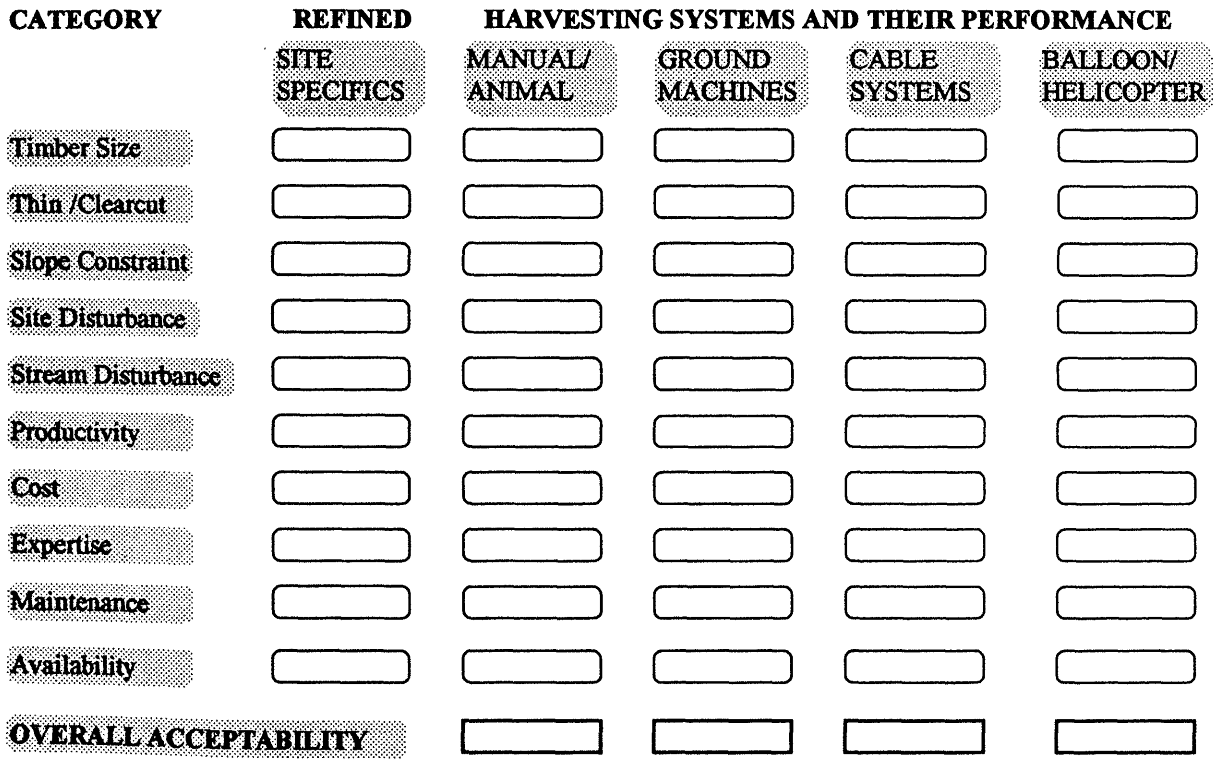

Figure 3. Flowschart demonstrating the decision process involved in matching logging systems to the situtation.

[2] Harvesting system is the larger term describing the technologies to move trees from the stump to a processing facility or mill. Logging systems are primarily characterized by the yarding system used.

Environment protection issues

The impact of environmental protection requirements on timber harvesting practices cannot be over-emphasized. Not even the adoption of the computer can compare to the impact of environmental regulations and court orders affecting timber harvest planning. In North America, a code of forest practice is mandatory in more than a dozen states. The National forest planning in the US today is a convoluted process to meet the intent of the many laws governing natural resources, particularly the National Forest Management Act (NFMA) and the National Environment Policy Act (NEPA) (Cubbage et al. 1993). It is through these regulations that comprehensive harvest planning becomes a necessity.

Comprehensive harvest planning, which emphasizes environment protection, has produced many conflicts of interest between loggers and environmentalists. More often plans were made which could not be implemented due to either appeals against cutting or incompatible to the latest environmental act. The results of the US Forest Service sponsored evaluation of its planning process in 1989 recommended adjustments in the planning process. Observations of the General Accounting Office (GAO) (Hill, 1996) reported that Forest Service spends an average of $13 million per year to develop forest plans which may be obsolete by the time they are complete; and that $250 million, 20% of the National Forest System Budget, are spent per year to conduct project level environmental analyses. There is an appreciable number of forest harvesting issues in American courts today which seem to indicate inconsistent and conflicting laws, making harvesting planning nearly impossible and federal harvest operations in the PNW a rare event.

Monitoring

Monitoring is an integral part of any planning and has a significant role in comprehensive timber harvesting planning. Impacts on the environment from soil disturbance, habitat degradation and adverse effects on hydrologic regimes need to be monitored for immediate rectification or as a feedback to future planning. There are three levels of monitoring: implementation monitoring, where answers are sought as to whether the plan is being implemented or not; effective monitoring, to check whether the goals envisaged are being achieved; and, validation monitoring, to check whether the assumptions and data used in planning were realistic.

Assessment of harvest plans

A plan is said to be successful if it was effective in attaining the goals sought. Evaluation of harvesting plans is a complex undertaking due to the number and diverse issues involved. Wang Lihai (1992) suggested five factors as a criteria for evaluating harvesting operation plans: operation cost, degree of working safety, ratio of forest resources input to timber production output, degree of soil disturbance and damage to vegetation. In a larger sense, a harvest plan can be judged successful if it meets criteria that are technical, economic and institutional in nature. Plans that can be implemented without violating the laws of physics or operational characteristics of harvest systems can be termed technically feasible. Plans that achieve financial objectives are economically feasible. Finally, plans that stay within legal boundaries and produce social goals of employment, efficiency of administration, or other amenities can be seen as institutionally feasible. Comparing one plan or planning process to another can be seen as a matter of various forms of numerical assessments, completeness measures, subjective rankings or comparisons, expert review processes, performance on optimality measures, capacity to incorporate risk and uncertainty, and other comparative schemes to determine better or best .

The best plan could be the one with an overall higher score. Other factors could be added provided they are independent, authoritative in illustrating the action or system under study, qualitatively observable and qualitatively measurable.

LESSONS FOR TANZANIA PLANTATION FORESTS

There is a big contrast in the institutional and economical conditions between the Pacific Northwest and Tanzania, and some differences in the physical conditions with respect to climate. However, much could be learned to improve the harvesting phase of the successfully established plantations. Tanzania plantations fit in the middle part of the management intensity spectrum.

At the tactical and operational planning levels, objective statements should provide measurable realistic and environmental sensitive goals from the broad Forest policy and Forest Division directives. We hope to develop and adopt a planning protocol as practiced in PNW with expectation to its being incorporated in the routine management practices.

At the time of this writing, some developments have been made on a planning protocol. On the background of this PNW context, a harvest planning protocol potential to Tanzania plantation forests is shown below. For presentation purposes, the general statements are selectively illustrated to show what is meant by comprehensive harvest planning protocol.

1. Refine objectives: [Involves compilation of all objectives and goals concerning the harvest area, identification of decision makers and their expectations and, more important, to resolve conflicting goals and objectives so as to have streamlined, acceptable and workable objectives]

2. Describe harvesting area

3. Identify economic values: [Identify the economic values involved with the harvesting operation at the local, regional and national levels, and variation of these values and economic opportunities with time. The consideration should be comprehensive to include economic values directly related to timber, non-timber and human resources involved].

4. Identify environmental values: [High level of consideration of environmental issues pertaining to timber harvesting in the PNW have been recognized. Rationale will be exercised to choose what practices are adaptable and workable on the Tanzanian physical, climatic and social settings].

5. Identify feasible harvesting system

6. Determine environmental acceptability

7. Determine economic performance

8. Formulate and schedule harvest units

9. Implement plan

10. Monitor plan.

We need to be careful in selecting planning tools for Tanzania since some are either too site-specific or require specific infrastructure unavailable in the Tanzanian situation. However, some GIS software and computer programs that operate well in stand-alone computers are good candidates. We need to improve our knowledge of climatic and hydrologic regimes, timber, terrain, soils, wildlife and social concerns as necessary components for selection of harvesting system options and formulation of an environmental assessment protocol. As a doctoral research project, a comprehensive timber harvesting planning protocol, including an environmental assessment procedure, is being developed for an identified area in Northern Tanzania, which has been classified as heretofore "inaccessible" due to its terrain characteristics.

SUMMARY

Timber harvest planning and environmental assessment is urgently needed by Tanzanian softwood plantations to ensure satisfaction of forest demands without environmental degradation. Findings of studies and assessment of timber harvest planning in PNW will be adopted to challenge the formulation of a comprehensive planning and environment assessment procedure for timber harvesting in Tanzania plantations.

LITERATURE CITED

Abeli, W.S.; Ole-Meiludie, R.E.L. 1991. Future harvesting strategies in Tanzania forests. *In:* Proceedings of a Symposium on Forest Harvesting in Southeast Asia; 1991 June 17-20, Singapore. Forest Engineering Inc., and Oregon State University, Corvallis, Oregon: 123-130.

Berg, Scott; Gustafson, E; Halvorsen, K; Miley, E. 1993. State forest practices throughout the United States: A Review of Forest Laws, Practices Acts and Best Management Practices. Report. American Forest & Paper Association and Wisconsin Paper Council. 74 p.

Cubbage, Frederick W.; O'Laughling, J; Bullock III, C.S. 1993. Forest resource policy. New York, NY: John Wiley and Sons Inc.: 342-347.

Dykstra, D.P. 1994. FAO model code of forest harvesting practice. FO:Misc/94/6 Working Paper: Food and Agriculture Organization of the United Nations. Rome. 104 p.

Garland, J.J. 1984. Timber harvesting options. Extension Woodland Notebook, Circular No. 858. Oregon State University Extension Service. Corvallis: Oregon State University. 2 p.

Hill, B.T. 1996. Forest Service: Issues relating to its decision-making process. Testimony before the Subcommittee on Forest and Public Land Management, Committee on Energy and Natural Resources, United State Senate. January 25, 1996. General Accounting Office, GAO/T-RCED-96-66. 15 p.

Lihai, W. 1992. Methods for comprehensively evaluating forest harvesting operation plans. In: Proceedings of the International Seminar On Forest Operations Under Mountainous Conditions. 1994 July 24-27; Harbin, P.R. of China. Department of Forest Engineering, Oregon State University: 301-323.

MTNRE (Ministry of Tourism, Natural Resources and Environment), 1994. National Environment Action Plan: First Step. MTNRE, Dar-es-Salaam, Tanzania. 60 p.

Schiess, P.; Cullen, J.; Brown, S. 1988. Long-term timber sales planning. In: Proceedings of the International skyline symposium. 1988 Dec 12-14; Portland: Department of Forest Engineering, Oregon State University: 82-86.

--- 1979. Webster s new collegiate dictionary. Springfield, MA: G&C Merrian Publishing Co.: 2532 p.

MAXIMIZING FINANCIAL YIELDS WHILE MEETING LANDOWNER OBJECTIVES AND ECOSYSTEM GOALS[1]

by

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ABSTRACT: Managers, planners, loggers, and landowners are being challenged to consider all aspects of the forested ecosystem when proposing harvesting treatments. Of particular interest to all is how specific management activities affect the suitability of wildlife habitat. With the use of an integrated expert system called FOREX, landowners can evaluate personal management objectives while meeting ecosystem or landscape-level goals. Results from this research suggest that there are at least six economically feasible alternatives for this set of landowner and ecosystem objectives. Most of these options also will enhance habitat suitability for selected wildlife species. Thus, landowners can select the alternative that maximizes financial yields while meeting ecosystem goals.

Key Words: thinnings, expert systems, economics, wildlife, harvesting

INTRODUCTION

The hardwood region in the Northeast and Appalachian region is a world-class, wood-growing area, and world demand for hardwood products from this resource continues to grow. This demand is not only for wood products but also for suitable habitat for game and nongame wildlife, visual and aesthetic quality, clean water, recreation, and social values. A major challenge to owners of forested land is meeting both financial and personal objectives while achieving goals at the ecosystem or landscape level.

The production of wood products is a natural process in forested ecosystems, which undergo a series of seral states that lead to a climax state over time (Odum 1969; Hunter 1990). For example, many ecosystems left undisturbed undergo a series of states because system changes are constant over time. The vegetation at each state in the process suits different creatures and different people at different times. A forest stand may be in the pole timber class for 40 to 50 years as part of its 100- to 200-year rotation age. In this state, trees of the same species kill each other in competition for light, nutrients, and water (Odum 1969). During this phase, many different species of wildlife occupy and use the site (DeGraaf et al. 1992), and also kill each other in a natural struggle for survival (Dasmann 1964; Odum 1969; Black 1994). In this 40- to 50-year period, many plants and trees as well as wildlife can be harvested without stopping the process. As the forest moves through various seral states, wildlife comes and goes: a thicket-like stand that is a good area for hunting ruffed grouse at age 30 will have few grouse by age 50.

At some point in this natural process, forests become larger with fewer trees. These larger woods seem to be the ones that many people want to protect and/or keep constant. But man cannot force nature to stand still. In fact, the same process of timber production and ecosystem management can be aided by us. For example, researchers have demonstrated that thinning stands can produce trees that are more valuable and faster growing than many unmanaged stands.

A second major challenge to owners is bringing together the volumes of research information on wildlife habitat, stand management, logging technology, economic and market factors, and the impact of time when deciding how to manage their forest land. This challenge is complicated in that the vegetation and various organisms that make up a forest ecosystem survive and reproduce on a site because they have adapted to their physical environment and are able to coexist with one another. When humans disturb this balance by removing vegetation from the site or changing its species composition, certain species of wildlife may no longer find the site suitable as habitat. Land managers can avoid much of this potential disruption to wildlife by maintaining the natural/original species composition of the site/stand. This may best be achieved by the use of natural regeneration following disturbance/regeneration versus regenerating the site with artificial methods that favor one species of vegetation over another (Hunter 1990).

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

This challenge is further complicated by a lack of decisionmaking tools for integrated analysis. In the absence of decisionmaking software/tools that allow for integration across disciplines, land owners usually are constrained to manage their land on the basis of personal experience. Often, the result is the continued implementation of a handful of silviculture practices that may not meet all of a landowner's personal and ecosystem objectives.

We have developed an expert system called FOREX that allows for integrated decisionmaking in the management of hardwoods forests (LeDoux et al. 1995). FOREX considers the potential growth and yield, products, and development of a stand over time, economic and market factors, and impacts on wildlife habitat. This system can be applied to all forest types in the Northeast, and currently considers impacts on wildlife habitat for New England forest types. As wildlife data on other forest types and regions become available, they will be incorporated into the FOREX database. In this article we apply FOREX to a hypothetical situation that a landowner might encounter.

Description of FOREX

FOREX uses data from simulation runs from MANAGE (LeDoux 1986; LeDoux et al. 1995). The user can obtain information on present net worth (PNW), optimal thinning entry timing, optimal stand rotation age, diameter at breast height, volume by grade and value of the trees harvested, and, based on the cable yarder used, average slope yarding distance, truck class, road class, log-bucking methods, and number of thinnings desired. FOREX also provides information on the effect of harvesting treatments on wildlife habitat. The user can obtain information on the PNW, DBH, and volume required for a specific set of management objectives, and perform a sensitivity analysis which eliminates the need to sort through numerous simulations.

Landowner objectives

In our example, the landowner holds 544 hectares of forested land in the northern red oak forest cover type. The species mix includes red oak, red maple, hickories, black oak, scarlet oak, and chestnut oak. The average site index of the stand is about 80. The stand is 30 years old and contains 823 trees per hectare that are more than 12.7 centimeters DBH. The average stand DBH is 16.18 centimeters. The land is located on moderate to steep slopes and requires cable logging for harvests.

The landowner desires periodic positive cash flows from thinnings and does not want to clearcut the stand until final harvest. The specific objective is to have a stand on the site until final harvest for wildlife habitat, aesthetics, and for the property to serve as a temporary travel corridor for wildlife and vegetation until recently regenerated surrounding forests grow back. The landowner also desires suitable habitat for a variety of wildlife species, particularly white-tailed deer, turkey, gray squirrel, red fox, ruffed grouse, and timber rattlesnake, and plans to leave as much woody debris as possible on the site following harvests. Tops, limbs, and unmerchantable parts of trees would be retained for use by wildlife and to return organic matter/nutrients to the site for future crops.

FOREX runs/options

After our landowner's property attributes and objectives were incorporated into FOREX, the program returned results for six economically feasible options that will meet the desired conditions (Table 1). Options available to the landowner ranged from one thinning and final harvest to two thinnings and final harvest. Initial commercial thinning entries occur at ages 40 (Option 3) and 50 (Options 1, 2, 4, 5, 6) with optimal rotations ranging from 90 to 110 years. Options 1, 2, and 3, are for average slope yarding distances of 60.96 meters. Options 4, 5, 6 are for average yarding distances of 121.92 meters. Option 1 calls for one 30-percent thinning at age 50 with an optimal rotation length of 100 years, providing 406.12 m^3 of merchantable wood/hectare with a cumulative PNW of $1022.99/hectare. Option 3 calls for the initial 50-percent thinning at age 40 with an optimal rotation age of 90 years, producing 369.74 m^3 of wood products/hectare with a cumulative PNW of $1326.93/hectare. A heavier thinning allows the first entry to be scheduled 10 years earlier than Option 1.

Options 2 and 5 call for thinnings at ages 50 and 60 with optimal rotation ages of 110 years. Options 2 and 5 are identical except that Option 2 is for 60.96 meters yarding distances and Option 5 is for 121.92 meter distances. The difference in yarding distance reduces the cumulative PNW by 8.20percent with Option 2 versus Option 5. Option 2 represents an increase in cumulative PNW of 6.04percent over Option 1, yet provides a longer rotation period (110 years versus 100) and about 22.75 m^3 more merchantable wood products/hectare.

Table 1. FOREX results by option.

	Option 1		Option 2			Option 3	
Attribute	T30[a]	FH[b]	T30	T30	FH	T50[c]	FH
Yarding distance (meters)	60.96	60.96	60.96	60.96	60.96	60.96	60.96
Buck type	1	1	1	1	1	1	1
Road class	2	2	2	2	2	2	2
Truck class	2	2	2	2	2	2	2
Age (years)	50	100	50	60	110	40	90
Trees (no.)	227	393	227	151	274	393	324
DBH (centimeters)	21.79	36.75	21.79	25.88	40.69	18.72	37.26
Volume (m^3)	61.15	344.97	61.15	60.24	307.48	74.16	295.58
G1 (m^3)	0	38.98	0	0	53.69	0	40.95
G2 (m^3)	0	0	0	0	4.62	0	0
G3 (m^3)	0	1.74	0	0.47	3.58	0	1.99
G4 (m^3)[d]	61.15	241.85	61.15	58.56	157.62	74.16	182.11
PNW (dollars)	51.89	971.10	51.89	64.25	968.63	24.71	1302.22
Cash flow (dollars)	93.90	7689.75	93.90	155.67	10306.54	32.12	7672.46

	Option 4		Option 5			Option 6	
Attribute	T30	FH	T30	T30	FH	T50	FH
Yarding distance (meters)	121.92	121.92	121.92	121.92	121.92	121.92	121.92
Buck type	1	1	1	1	1	1	1
Road class	2	2	2	2	2	2	2
Truck class	2	2	2	2	2	2	2
Age (years)	50	100	50	60	110	50	110
Trees (no.)	227	393	227	151	274	378	292
DBH (centimeters)	21.79	36.75	21.79	25.88	40.69	21.79	40.87
Volume (m^3)	61.15	344.97	61.15	60.24	307.48	102.21	295.02
G1 (m^3)	0	38.98	0	0	53.69	0	56.47
G2 (m^3)	0	0	0	0	4.62	0	0.45
G3 (m^3)	0	1.74	0	0.47	3.60	0	8.57
G4 (m^3)	61.15	241.85	61.15	58.56	157.62	102.21	159.79
PNW (dollars)	17.30	924.15	17.30	39.54	938.98	29.65	938.98
Cash flow (dollars)	32.12	7316.63	32.12	96.37	9992.72	54.36	9992.72

[a]T30 = 30 percent thinning.
[b]FH = final harvest.
[c]T50 = 50 percent thinning.
[d]G4 = pulpwood.

Integrating wildlife habitat objectives

Forest wildlife populations and their habitats are products of the land and how it is managed for wood fiber (DeGraaf et al. 1991, DeGraaf et al. 1992) or in unmanaged stands from events that occur naturally. DeGraaf et al. (1992) developed species/habitat matrices that forest managers, planners, silviculturists, loggers, and wildlife biologists can use to increase potential numbers of bird, amphibian, and mammal species in New England forest types. Information is provided for species occurrence and utilization by forested habitat and forest type by life history activities and seasons. These species/habitat matrices, which are tied to the seral states present in the development of a given forest type, have been incorporated into the FOREX database.

With the FOREX program, actual stand attributes such as DBH, volume per hectare, number of trees per hectare, and species mix are matched with DeGraaf et al. (1992) guidelines for the wildlife species chosen. In our example, each of the six options provides a forested area for a long period that will be in balance with stated wildlife goals, yet provide wood products from periodic thinnings (Table 2). Reported needs for the selected wildlife species are listed in Table 3.

Table 2 lists habitat suitability by species and option for final harvest before and after conditions. The scheduled thinnings do not alter habitat suitability because the residual stand conditions remain much the same as the initial stand with respect to the site attributes used in the guidelines (DeGraaf et al. 1992).

The proposed management options show that for the red fox, the final stand is used for breeding habitat, breeding-season feeding, winter habitat, and winter feedings (Table 2)

Final harvest changes the suitability for the red fox from habitat that is used to one that is preferred. Final harvest conditions affect the gray squirrel, wild turkey, and timber rattlesnake the most. For example, the gray squirrel preferred the final stand for all activities and

Table 2. FOREX habitat/utilization results by option for selected species.

Turkey		Gray squirrel		Red fox		Ruffed grouse		White-tailed deer		Timber rattlesnake	
UP	PREF	UP	PREF	UP	PREF	UP	PREF	UP	PREF	UP	PREF
					OPTION 1						
Before		**Before**		**Before**		**Before**		**Before**		**Before**	
BH	U	BH	P	BH	U			BH	U	BH	U
BSF	U	BSF	P	BSF	U			BSF	U	WH	U
WH	P	WH	P	WH	U	WH	U				
WF	P	WF	P	WF	U	WF	U				
After		**After**		**After**		**After**		**After**		**After**	
BH	U	NS	NS	BH	P	BH	U	BSF	U	NS	NS
BSF	U			BSF	P	BSF	U	WF	U		
				WH	P						
				WF	P						
					OPTION 2						
Before		**Before**		**Before**		**Before**		**Before**		**Before**	
BH	U	BH	P	BH	U			BH	U	BH	U
BSF	U	BSF	P	BSF	U			BSF	U	WH	U
WH	P	WH	P	WH	U	WH	U				
WF	P	WF	P	WF	U	WF	U				
After		**After**		**After**		**After**		**After**		**After**	
BH	U	NS	NS	BH	P	BH	U	BSF	U	NS	NS
BSF	U			BSF	P	BSF	U	WF	U		
				WH	P						
				WF	P						
					OPTION 3						
Before		**Before**		**Before**		**Before**		**Before**		**Before**	
BH	U	BH	P	BH	U			BH	U	BH	U
BSF	U	BSF	P	BSF	U			BSF	U	WH	U
WH	P	WH	P	WH	U	WH	U				
WF	P	WF	P	WF	U	WF	U				
After		**After**		**After**		**After**		**After**		**After**	
BH	U	NS	NS	BH	P	BH	U	BSF	U	NS	NS
BSF	U			BSF	P	BSF	U	WF	U		
				WH	P						
				WF	P						

Table 2. FOREX habitat/utilization results by option for selected species (continued).

Turkey		Gray squirrel		Red fox		Ruffed grouse		White-tailed deer		Timber rattlesnake	
UP	PREF	UP	PREF	UP	PREF	UP	PREF	UP	PREF	UP	PREF
					OPTION 4						
Before		**Before**		**Before**		**Before**		**Before**		**Before**	
BH	U	BH	P	BH	U			BH	U	BH	U
BSF	U	BSF	P	BSF	U			BSF	U	WH	U
WH	P	WH	P	WH	U	WH	U				
WF	P	WF	P	WF	U	WF	U				
After		**After**		**After**		**After**		**After**		**After**	
BH	U	NS	NS	BH	P	BH	U	BSF	U	NS	NS
BSF	U			BSF	P	BSF	U	WF	U		
				WH	P						
				WF	P						
					OPTION 5						
Before		**Before**		**Before**		**Before**		**Before**		**Before**	
BH	U	BH	P	BH	U						
BH	U	BH	U								
BSF	U	BSF	P	BSF	U			BSF	U	WH	U
WH	P	WH	P	WH	U	WH	U				
WF	P	WF	P	WF	U	WF	U				
After		**After**		**After**		**After**		**After**		**After**	
BH	U	NS	NS	BH	P	BH	U	BSF	U	NS	NS
BSF	U			BSF	P	BSF	U	WF	U		
				WH	P						
				WF	P						
					OPTION 6						
Before		**Before**		**Before**		**Before**		**Before**		**Before**	
BH	U	BH	P	BH	U			BH	U	BH	U
BSF	U	BSF	P	BSF	U			BSF	U	WH	U
WH	P	WH	P	WH	U	WH	U				
WF	P	WF	P	WF	U	WF	U				
After		**After**		**After**		**After**		**After**		**After**	
BH	U	NS	NS	BH	P	BH	U	BSF	U	NS	NS
BSF	U			BSF	P	BSF	U	WF	U		
				WH	P						
				WF	P						

UP = usage pattern.
PREF = preference.
BH = breeding habitat.
BSF = breeding-season feeding.
WH = winter habitat.
WF = winter feeding.
U = utilized.
P = preferred.
NS = not suitable for this species.

Table 3. Habitat needs for white-tailed deer, turkey, gray squirrel, red fox, ruffed grouse, and timber rattlesnake (DeGraaf et al. 1992).

Species	Habitat Needs[a]
White-tailed deer	31 to > 70% canopy, deciduous seedlings, saplings, shrub layer in .61-3.05 meter zone, ericaceous shrub layer in .61-3.05 meter zone, > 75% coverage in 0-.61 meter zone for ground vegetation, coniferous overstory, mast and fruit.
Turkey	16-70% canopy, ericaceous shrub layer in .61-3.05 meter zone, > 75% coverage in 0-.61 meter zone for ground vegetation, deciduous overstory inclusion, seeps, mast and fruit.
Gray squirrel	> 70% canopy, live, broken top or large limb > 45.72 centimeters DBH, and live, hollow > 60.96 centimeter DBH trees, deciduous overstory, mast and fruit.
Red fox	< 15% canopy, mixed deciduous, coniferous vegetation in .61-3.05 meter zone in the shrub layer, ericaceous shrub layer in .61-3.05 meter zone, loose soils, mast and fruit.
Ruffed grouse	16-70% canopy, > 75% coverage in 0-.61 meter zone for ground vegetation, dead and down material in duff/ground layer, deciduous and coniferous overstory, mast and fruit.
Timber rattlesnake	forest litter and moss in the duff/ground layer, rock ledges, and forested hillsides.

[a]breeding season, breeding-season feeding, winter use, and winter feeding needs combined.

would find the site unsuitable for any activity following final harvest. The wild turkey preferred the final stand for winter habitat and winter feedings. Final harvest changes the site so that the turkey no longer would use this site for winter habitat and winter feeding. Before the final harvest, the rattlesnake used the site for breeding and winter habitat. Now it would find the site unsuitable.

The most important finding from Table 2 is that each option affects the wildlife species chosen similarly. Although not considered here, many species of wildlife have adapted to humans. Foxes, opossums, raccoons, and a variety of birds have learned to coexist with humans, for example, by living in drains and/or using bird feeders.

CONCLUSION

The use of expert systems such as FOREX to study the impact of landowners and ecosystem objectives on wildlife, economic cash flows, wood flows, and optimal rotation lengths will not solve all the problems facing managers, but they can help them understand the tradeoffs required for a specific set of objectives. For example, the landowner could treat the entire 544 hectares with Option 3 or use Option 3 on 123.55 hectares and a mix of the other options on other portions of the land to achieve additional objectives.

Ecosystems are constantly changing and while future conditions cannot be predicted with certainty, each ecosystem offers many options for uses, values, products, and services. With tools such as FOREX, landowners can maximize financial yields by growing quality wood products while still meeting wildlife and ecosystem goals. If several economically feasible alternatives exist for meeting a set of objectives, landowners would be prudent to select the ones that also maximize their financial returns.

LITERATURE CITED

Black, H. C., tech. ed. 1994. Animal damage management handbook. Gen. Tech. Rep. PNW-GTR-332. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 236 p.

Dasmann, R. F. 1964. Wildlife biology. New York: John Wiley and Sons. 231 p.

DeGraaf, R. M.; Scott, V. E.; Hamre, R. H.; Ernst, L.; Anderson, S. H. 1991. Forest and rangeland birds of the United States-natural history and habitat use. Agric. Handb. 688. Washington, DC: U.S. Department of Agriculture. 625 p.

DeGraaf, R. M.; Yamasaki, M.; Leak, W. B.; Lanier, J. W. 1992. New England wildlife: management of forested habitats. Gen. Tech. Rep. NE-144. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 271 p.

Hunter, M. L., Jr. 1990. Wildlife, forests, and forestry-principles of managing forests for biological diversity. Englewood Cliffs, NJ: Prentice-Hall. 370 p.

LeDoux, C. B. 1986. MANAGE: A computer program to estimate costs and benefits associated with eastern hardwood management. Gen. Tech. Rep. NE-112. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 7 p.

LeDoux, C. B.; Gopalakrishnan, B.; Lankalapalli, K. 1995. FOREX--An expert system for managing even-aged upland oak forests on steep terrain. In: Gottschalk, K. W.; Fosbroke, S. L. C., eds. Proceedings, 10th central hardwood forest conference; 1995 March 5-7; Morgantown, WV. Gen. Tech. Rep. NE-197. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 474-480.

Odum, E. P. 1969. Fundamentals of ecology, 2nd ed. Philadelphia, PA: W. B. Saunders Co. 546 p.

AN INTERACTIVE SIMULATION OF PARTIAL CUTTING OPERATIONS OF FELLER-BUNCHERS[1]

by

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ABSTRACT: Partial cutting is increasingly prescribed on forest lands to satisfy the demands of the public. It is nearly always more expensive to perform and can potentially have greater negative environmental impacts due to the more frequent entries into the forest. An interactive simulation program was developed in this study to model harvesting machines and evaluate their activities in partial cutting operations. The simulation is performed by moving the machine image within a stand map on the computer screen. The residual stand and machine running path are recorded simultaneously for later analysis. The physical and economic feasibility of partial cutting can be evaluated with this technique.

Key Words: interactive simulation, partial cutting

INTRODUCTION

Computer simulation is used extensively in analysis of forest harvesting systems. Due to the wide variety of logging systems used and the variation among the types of forest stands harvested, simulation often offers the only way to examine certain logging situations. In general, simulation involves building a model of a system to assess how it reacts to changes in its operating environment.

Computer simulation of feller-buncher operation has been reported by several authors (Goulet et al., 1979, 1980a, 1980b), as well as a model which simulates complete harvest or thinning systems from cutting through loading (Stuart, 1981). Garbini (1984) used animation to illustrate material movement and machine activities in continuous simulation of a log merchandiser. The program was developed to increase piece production rates of log merchandisers in the face of the smaller tree sizes currently being harvested. In another decision simulator application, graphical animation and numerical data were used to make log bucking decisions (Lembersky and Chi, 1984). That simulator is an interactive program that allows individual operators to compare their own attempts at log bucking with actual computed optimal solutions. This application was reported to have saved millions of dollars for a major forest products company by improving the use of their raw material furnish.

Fridley et al. (1985) reported the use of interactive simulation for studying the design of swing-to-tree feller-bunchers used for thinning. The program (Fridley et al, 1982) used graphical animation as a type of output for verification and evaluation purposes. It was used to identify the effect of various design parameters on feller-buncher performance during thinning.

Greene and Lanford (1984, 1986) developed an interactive simulation program for modeling feller-bunchers. The program was used to identify the importance of stand and operating variables during thinning of southern pine plantations. Working with this simulation, Greene et al. (1987) concluded that variability between simulation operators exists but does not appear to affect the usefulness of interactive simulation.

A three-dimensional, color, interactive, real-time, computer graphics simulation of a feller-buncher was developed by Block and Fridley (1990). The simulation operator views what would be seen looking through the windshield of a feller-buncher in operation on the screen of the computer. The software allows the programmer to vary physical parameters of the feller-buncher that will affect its performance in the forest. This simulation was developed on a Silicon Graphics Iris 3020 Workstation. The software runs under the UNIX operating system and programs written in the C programming language access the graphics features of the system. A ground-based harvesting system simulation model has also been developed to estimate stump-to-truck production rates and multiproduct yields for conventional ground-based timber harvesting systems in Appalachian hardwood stands (Baumgras et al., 1993). This program is to evaluate a model numerically over a time period of interest, and data are gathered to estimate the desired true characteristics of the model. A method of estimating damage was developed in conjunction with an interactive machine simulation program that can model harvesting performance in a variety of silvicultural operations

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

(Bragg et al., 1994). The damage estimation worked well in an empirical comparison, but further testing with data from other harvesting systems and stands could improve the model's usefulness.

One logging situation which has been difficult to accurately simulate with numerical simulation is the movement of a feller-buncher in partial cuts. The machine must avoid the remaining trees in the stand while effectively moving between the trees to be cut. Many logging simulators do not adequately model these machine movements. Studies using interactive simulation to study feller-bunchers have found it to be a useful method of studying mechanical felling in partial cuts.

The utility of interactive computer simulation has been demonstrated. However, many of these reports are now based on the data that is 10 years old. They also simulated the system that should be different from the systems used today to some extent. Furthermore, today's computer simulation environment and languages can also improve the forest harvesting simulation tasks.

OBJECTIVES

This paper reports on (1) some examples of adapting previous techniques for interactive graphical simulation of feller-buncher operations to handle a variety of partial cuts in mature stands with drive-to-tree feller-bunchers; (2) obtaining stand map data for representative forest stands considered for the partial cuts evaluated; (3) modeling drive-to-tree feller-bunchers performing felling duties in the partial cuts considered; and (4) analyzing and estimating the physical possibility and economic feasibility of such operations.

SYSTEM STRUCTURE

The system uses IBM compatible, Pentium-based personal computers. The simulation program is written with Visual Basic, an event-driven programming language that runs under the Microsoft Windows environment.

Stand map data involve locating each tree within a plot using a coordinate system and recording its species, DBH, total height, volume, and whether or not it is to be harvested. This map information forms the basis for the simulation effort. Plot size is variable, but should be larger than 0.08-ha (0.20-acre) and less than 0.4-ha (1.0-acre).

The program uses five visual forms and a code module with Run, Analysis, View, Output, and Exit submodules. The Run module contains the main part of the simulation system. Within the Run module, the system asks the user to input a stand file name, machine running path name, and plot size. The stand map and machine image are then displayed in the main simulation window. In this window, each solid blue circle represents a tree of a given diameter. Two smaller windows display machine activities, action commands, and the messages for the user.

A simulation is performed by moving the machine image in the stand map on the computer screen using a mouse. While the machine image is approaching the tree to be cut, the location of the machine is recorded into the machine running path file. The left mouse button invokes the action commands and loads the image machine at the very beginning of the simulation. The right button is used to move the image machine. To begin the simulation, the user moves the image machine toward the first tree to be cut.

Each time a location point is recorded, the machine summary window is replaced by the machine action menu. Actions for the feller-buncher include its common work elements including move to tree, cut tree, move to dump, and dump. These four actions plus an Exit command are displayed in a window. The operator selects the appropriate machine action by using the mouse to point and click within the command window. Each time a point location of the machine is recorded and an action is selected, the machine summary is updated and displayed in the machine summary window. When a tree is cut, a solid black circle is drawn to signify the stump and the machine can then move forward from this point. Later, if the operator attempts to cut another tree at this point, the program will indicate "tree not found". The machine image can be rotated 360^0 and is able to detect obstacles such as the remaining trees. When the machine collides with a tree, the program gives sound and text warnings. The machine must then move in the opposite direction or cut the now "damaged" tree.

The above procedure is repeated until the felling head is full. The capacity of the felling head can be changed to model different machines. The system reminds the user when the maximum number of trees is held by the felling head. The user then uses the 'MoveToDump' command to move the machine image to the location of the bunch to be built and drops the trees. The machine summary window is cleared, showing an empty head on the machine, and the dropped trees are drawn to scale on the screen in the direction the machine image was facing when they were dropped.

When ending the simulation run, the system saves two files. One file contains the coordinates of the machine running path in chronological order with associated actions and the diameter breast height (DBH) of each tree cut. The second contains the coordinates and dimensions of the trees in the residual stand. These two files along with the file containing the original stand map data are used in subsequent statistical analyses.

The Analysis module compares the original stand to the residual stand and displays each in the format of stand and stock tables. Since thinnings alter the diameter distribution of stands, diameter distribution histograms are provided in auxiliary windows along with the stand and stock tables.

Any previous simulation can be viewed again using the View module. The stand map, histograms of DBH distributions, stand and stock tables, and the machine path file can be reproduced either on screen or on paper.

IMPLEMENTATION

To illustrate the use of this program, three harvesting prescriptions were evaluated on a southern pine plantation (Table 1). These prescriptions include a light thinning (LT) with a target residual stand of 865 trees per ha, a heavy thinning (HT) with a target residual stand of 620 trees per ha, and for comparison purposes a clearcut. The area harvested during the simulation contained 0.16-ha (0.4-acre) and measured 40 m (132 ft) square.

Table 1. Stand and stock table for example stand before thinning.

DBH (cm)	Trees per Ha	Total Height (m)	Basal Area (m^2/ha)	Volume (m^3/ha)
10.0	173	12	1.4	6.3
12.5	99	13	1.3	6.9
15.0	222	14	4.1	25.8
17.5	420	14	10.4	71.2
20.0	346	15	11.2	79.4
22.5	148	15	6.1	43.5
25.0	49	15	2.5	18.3
Total	1457		37.0	251.4

Trees to be cut were marked according to their DBH. The feller-buncher was first located at one end of the plot and then moved parallel to the rows of trees which were 5-7 m wide. Marked trees on either side of the machine were removed. When the machine reached the end of the row, it turned around and cut another tree in the nearest swath, continuing until the plot was finished.

Two general types of summaries are provided: (1) stand summaries and (2) machine summaries. The stand summary compares the original stand to the residual stand and computes the trees, basal area, and volume removed per acre in the thinning. This is provided in the stand and stock table format commonly used by foresters to report stand information and in a histogram (Figure 1). This summary can be used to determine the quality of the thinning performed from a silvicultural standpoint or as input for economic decisions. The difference in the stand before and after thinning provides information on removals by diameter class--an important input for estimating logging cost.

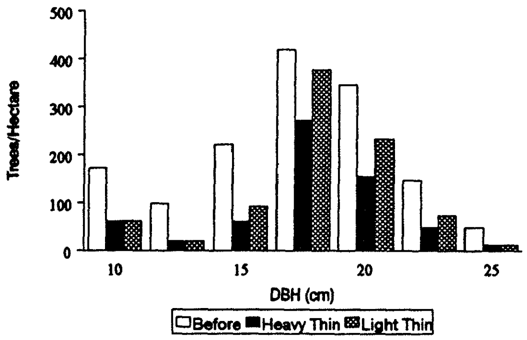

Figure 1. DBH distributions for the example stand before thinning and after a heavy and light thinning.

Machine summaries are provided in three parts: (1) an elemental time summary, (2) a summary by cut and dump cycles, and (3) a production summary. The elemental time summary reports information as if a time study of the machine had been performed. Feller-buncher cycles correspond to the machine actions available while running the simulation program. In analyzing the output of the run, cut and dump times are estimated using production equations developed from previous time studies of the machine. Times of travel to tree and travel to dump were computed by dividing the distance traveled by the average speed of the machine. Elemental time figures are provided since they are an accepted method of describing machine performance (Table 2).

The summary by cut and dump cycles provides the most useful information from the simulation run (Table 3). Information in this summary can indicate the effect of the stand on machine productivity and the ability of the operator to use the machine to its full potential. One useful measure of stand effects on machine movement is provided by the "moves to tree needed" value. In maneuvering the machine model through a dense stand, more actions of "move to tree" are needed to accurately represent the machine path than would be the case in a sparsely stocked stand. A good indication of the ability of the operator to utilize the potential of the machine is provided by the "number of trees per dump" or "basal area per dump" measure. This reports the number of trees and the basal area held by the felling head when the trees are dropped into the bunch. Feller-buncher production is often greatest when this measure is maximized. Another measure of feller-buncher efficiency in this type of simulation is the total distance traveled. A method is more efficient than another if it cuts the same trees, but in doing so travels a shorter total distance. As our example illustrates, production is reduced as harvest intensity decreases (Table 3).

Table 2. Summary of elemental times (minutes) for three harvesting prescriptions examined with interactive simulation in a 0.16-ha (0.4-acre) planted stand. The three prescriptions were a clearcut (CC), a heavy thinning (HT), and a light thinning LT).

	CC			HT			LT		
Element	#	Mean	SDev	#	Mean	SDev	#	Mean	SDev
Move to tree	265	0.04	0.01	183	0.05	0.01	162	0.05	0.01
Cut	221	0.14	0.02	134	0.14	0.02	95	0.15	0.02
Move to dump	80	0.01	0.01	52	0.01	0.01	36	0.01	0.01
Dump	80	0.32	0.05	52	0.29	0.05	36	0.28	0.04

Table 3. Machine summary by cut and dump cycles for the harvesting prescriptions clearcut (CC), heavy thinning (HT), and light thinning (LT).

Item	CC	HT	LT
Cut			
moves to tree needed per tree cut	1.20	1.37	1.71
distance between cut trees (m)	2.12	2.65	3.16
elapsed time between cuts (min.)	0.05	0.06	0.09
Dump			
moves to tree per dump	3.31	3.52	4.50
move to dump per dump	1.74	1.83	1.89
trees per dump	2.76	2.58	2.64
basal area per dump (m^2)	0.07	0.06	0.06
volume per dump (m^3)	0.45	0.41	0.39
distance between dumps (m)	8.5	9.8	10.8
time between dumps (min.)	0.52	0.51	0.56
Total distance traveled (m)	678	509	390

The final machine summary provides the typical production figures used in comparing machines (Table 4). These measures include trees per minute and volume per productive machine hour. These values represent a relative measure of unconstrained machine performance. As such, they are not to be taken as an accurate measure of actual field performance. However, comparison of these measures for different operating circumstances provides an indication of the relative performance of the machine.

Table 4. Machine production summary.

Prescription	Trees/Minute	m^3/PMH
CC (Clearcutting)	3.32	32.63
HT (Heavy thinning)	3.20	30.49
LT (Light thinning)	3.16	27.99

FUTURE WORK

Interactive simulation is a viable method for examining the operation and working patterns of machines in forest stands. The method can be used on relatively inexpensive computer equipment with simple graphics capability without sacrificing excessive detail. Such a method offers potential for studying and improving the work methods of operators and machines in a variety of harvest prescriptions. Since the program requires user decisions as input, the results obtained through the simulation are more easily accepted. The user immediately sees the effects of his decisions while running the program.

A new stand generator module will be added to the system. This will allow the user to ask that a stand be generated with a given set of characteristics instead of providing a stand map file. The stand generator will generate either planted or natural stands.

Machines other than feller-bunchers will also be added to the program, including machines to extract the wood in addition to felling and processing equipment. Once these features are added, harvesting prescriptions such as group selection, shelterwood, and clearcutting (as a base case for comparisons) will be compared to evaluate differences in production or possible stand effects (percent of area traversed, trees damaged, etc.).

LITERATURE CITED

Baumgras, J. E., Curt C. Hassler, and Chris B. LeDoux. 1993. Estimating and validating harvesting system production through computer simulation. Forest Products Journal 43(11/12): 65-71.

Block, W. A. and J. L. Fridley. 1990. Simulation of forest harvesting using computer animation. Transactions of the ASAE 33(3): 967-974.

Bragg, W. C., W. D. Ostrofsky, and B. F. Hoffman, Jr. 1994. Residual tree damage estimates from partial cutting simulation. Forest Products Journal 44(7/8): 19-22.

Fridley, J.L., J.L. Garbini, and J.E. Jorgensen. 1982. Interactive simulation of forest thinning system concepts. ASAE Paper No. 82-1603. St. Joseph, MI.

Fridley, J. L, J. L. Garbini, J. E. Jorgensen, and P. A. Peters. 1985. An interactive simulation for studying the design of feller-bunchers for forest thinning. Transactions of the ASAE 28(3): 680-686.

Goulet, D. V., R. H. Iff, and D. L. Sirois. 1979. Tree-to-mill forest harvesting simulation models: Where are we? Forest Products Journal 29(10): 50-55.

Goulet, D. V., R. H. Iff, and D. L. Sirois. 1980. Five forest harvesting simulation models - Part I: Modeling characteristics. Forest Products Journal 30(7): 17-20.

Goulet, D. V., R. H. Iff, and D. L. Sirois. 1980. Five forest harvesting simulation models - Part II: Paths, pitfalls, and other considerations. Forest Products Journal 30(8): 18-22.

Greene, W. D. and B. L. Lanford. 1984. Geometric simulation of feller-bunchers in southern pine plantation thinning. ASAE Paper No. 84-1612. St. Joseph, MI.

Greene, W. D. and B. L. Lanford. 1986. An interactive simulation program to model feller-bunchers. Alabama Agricultural Experiment Station, Bulletin No. 576.

Greene, W. D., J. L. Fridley, and B. L. Lanford. 1987. Operator variability in interactive simulations of feller-bunchers. Transactions of the ASAE 30(4): 918-922.

Lembersky, M. R. and U. H. Chi. 1984. "Decision simulators" speed implementation and improve operations. Interfaces 14(4): 1-15.

Stuart, W. B. 1981. Harvesting Analysis Technique: a computer simulation system for timber harvesting. Forest Products Journal 31(11): 45-53.

DEVELOPMENT OF FOREST ENGINEERING AND ITS LITERATURE[1,2]

by

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ABSTRACT: The development of the academic and professional field of Forest Engineering since the late 1800s is examined in terms of the key events and the published literature that is most significant to the field. Although forest engineering appeared as early as 1884 at the Royal Indian Engineering College at Cooper's Hill in the United Kingdom and in 1902 at Cornell University in the United States, the modern field of Forest Engineering developed primarily out of the efforts of the Pacific Logging Congress in the early 20th century along with several Universities located on the North American West Coast.

Key Words: forest engineering, history, literature, development of, logging engineering

FIRST ACADEMIC PROGRAMS

The Royal Indian Engineering College at Cooper's Hill (Great Britain) was among the first colleges to blend engineering with forestry when in 1884 it established a school of forestry.[3] Headed by William Schlich, the school taught its students technical material in preparation for employment in the Colony of India. Forestry program graduates would aid in the harvesting of India's forests. *Schlich's Manual of Forestry* became the definitive English language forestry textbook of that era.[4] The volume on forest utilization written by Karl Gayer, Professor of Forestry at the University of Munich, was the recognized standard on forest utilization in Germany. Within this volume the section on wood transportation describes road, rail, cable, and water-based transportation systems. There are good structural illustrations but no numerical analysis is offered. The academic program at Cooper's Hill was moved to Oxford in 1905, marking a transition in becoming what we now view as modern forestry instead of an area of applied engineering.

The first American Forest Engineering degree was awarded at Cornell University in 1902, where Bernard E. Fernow, a German educated forest engineer, led a short-lived program (1896-1903). Only seventeen students graduated with this degree, which Fernow described as follows: "This degree, it is believed, expresses more adequately... the fact that not a science but an art of technical character has been studied as a profession; it is a title indicating practical rather than literary attainments and describes the work for which the student has prepared, namely, the application of technical scientific knowledge to a business and in a productive industry."[5] Fernow clearly identified the engineering aspects of forestry; a profession whose mission reached beyond the logging operation to address such issues as regeneration and protection of the soil and water resource.[6]

In the southeastern United States, the Biltmore Forest School operated from 1898 to 1913 under the direction of another German forestry school graduate, Carl A. Schenck. The Biltmore School did not have a forest engineering curriculum but did emphasize the practical aspects of forestry, including substantial attention given to logging.[7] Schenck's

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[1] Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

[2] Reprinted from J. L. Fridley, J. A. Miles, and F. E. Greulich, "Development Forest Engineering and Its Literature," in *The Literature of Agricultural Engineering,* ed. Carl W. Hall and Wallace C. Olsen, Copyright 1992 by Cornell University. Used by permission of the publisher, Cornell University Press.

[3] B. E. Fernow, *A Brief History of Forestry* (Toronto: University Press, 1913), p. 377-78.

[4] William Schlich, *Schlich's Manual of Forestry,* 2d ed. (London: Bradbury, Agnew & Co., Ltd., 1908 [Vol. V, "Forest Utilization," English translation by W. R. Fisher of *Die Forstbenutzung* by Karl Gayer]).

[5] R. S. Hosmer, *Forestry at Cornell* (Ithaca, N Y Dec. 1950).

[6] B. E. Fernow, "The Forester, an Engineer," *Journal of the Western Society of Engineers 6* (5) (1901: 402-420.

[7] J. O Hearne. "How Shall We Teach Logging Engineer 5th Annual Session, Pacific Logging Congress, 1913.

text, *Logging and Lumbering or Forest Utilization; A Textbook for Forest Schools,* was apparently published in 1912, although the book does not in fact give a publication date.[8] Part I dealt with logging operations while Part 11 discussed the manufacture of wood products. Part I consists of three chapters and is an excellent descriptive treatment of logging engineering practice during that era. The first chapter covers camps, duration of employment, enumeration, and animals, the discussion is non-technical and is a generally thorough introduction to the topic. The second chapter describes the tools used (including discussion on setting and filing saw teeth), tree felling and bucking. Chapter 3, transportation, is quite detailed and covers land transportation (without vehicles), water transportation, vehicles, roads, loading, cable logging, and choosing between transportation systems. The section on roads includes equations for grade, curve layout, cuts and fills, etc., along with prediction equations for the rolling resistance of wheels.

An early textbook by Ralph Clement Bryant, a forest engineering graduate of the program at Cornell, is similar in topical content to Schenck's book.[9] Bryant does not present any engineering analysis of harvesting activity but, somewhat unique for that period, he does give an extensive bibliography. Bryant's text was the first widely distributed textbook on logging in North America. This text was followed with a thoroughly revised second edition in 1923.

THE EMERGENCE OF LOGGING ENGINEERING

The need for engineering skills in North American logging and forest management continued to grow during the first decade of this century, especially in the west. The U.S. Forest Service responded to this need for engineers when, in 1905, F. G. Plummer was transferred from the Geological Survey to the Forest Service. Plummer was the first engineer in what was to become, in 1907, the U.S. National Forest System. By 1910, activity on the National Forest had produced 320 miles of road, 2,225 miles of trail, 1,888 miles of telephone lines, 464 cabins and barns, and fifty-one corrals.[10] Industry was similarly responding. Turn-of-the-century loggers in the Pacific Northwest well understood the value of a capable engineer.

Western loggers were contending with steep rugged terrain, big trees, and logging technology that was based on cable systems and railroads. They needed persons who could survey railroad lines and property boundaries as well as oversee road layout and construction. Many civil and mechanical engineers had the necessary educational background, but two problems prevented these engineers from being employed by the logging firms. First, young mechanical and civil engineering graduates were not compatible with the loggers. The Pacific Northwest was extremely rural, logging enterprises operated out of camps, and the climate was, true to the northwest's reputation, conducive to wet socks and webbed feet for those who undertook an engineering career in the outdoors. Formally educated engineers were finding preferable employment in more urban settings at more attractive salaries. Further, the logging business did not know what to do with engineers. It was not appropriate to turn an engineer into an overpaid logger; yet with no existing career track for engineers in the business, there did not exist means for an engineer to become sufficiently familiar with the operations of the business.

The second problem impeding the employment of engineers in the logging industry was the poor performance of engineers who had been hired by the industry. When civil and mechanical engineers were employed by the logging industry the results were frequently disastrous. E. T. Clark describes a case where a logging outfit engaged a civil engineering firm to locate some boundary lines. The surveyors, not understanding the nature of logging, located the section corners but, to the loggers' dismay (and too late discovery), did not blaze the boundary lines for the fallers. Clark also told of a logging company that hired a "gang of civil engineers" to survey a few miles of rail line. The construction crew discovered the newly surveyed line would have required excavation at a cost not justifiable by the timber to be extracted. The company then called in their own timber cruiser (Note: probably a college educated

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[8] C. A. Schenck *Logging and Lumbering or Forest Utilization A Textbook for Forest Schools* (Darmstadt, Germany: L. C. Wittich, 1912).

[9] Ralph C. Bryant, *Logging The Principles and General Methods of Operation in the United States* (New York: John Wiley & Sons, Inc., 1913).

[10] United States Forest Service, *History of Engineering in the Forest Service 1905-1969* (Washington D.C.: USFS Engineering Staff, 1972).

forester) to "spot in a road that could be built without bankrupting the company."[11]

In August of 1908, George Cornwall, editor of a trade magazine called *The Timberman,* and Edward English, an influential logging firm owner from Mt. Vernon, Washington, visited in the Dillar Hotel in Seattle. At that meeting Mr. Cornwall proposed his ideas for a meeting of what was to become the Pacific Logging Congress. The congress would be a "friendly powwow of other loggers for an exchange of ideas (pertaining to logging)." It is evident that Cornwall understood the nature of the men operating logging operations and the importance of their perceptions, thus he allowed that "the idea of this congress was therefore a mutual and simultaneous inspiration." [12]

Cornwall subsequently met with Dean Frank G. Miller and Professor Hugo Winkenwerder of the University of Washington to discuss the upcoming Pacific Logging Congress to be held on the campus of the University of Washington in Seattle. Miller and Winkenwerder had recognized the growing need for engineering talents in the logging camps and were interested in establishing a program in logging engineering. But, they too recognized that the success of their endeavor would depend on acceptance by the loggers, and that the easiest way to attain acceptance was to allow the idea to come from the loggers themselves. George Cornwall, for his part, needed little convincing and took it upon himself to become a champion for the effort to establish a "new" profession. So, the profession and academic field of "logging engineering" became an important component of the Congress' mission.

The first Pacific Logging Congress (PLC) was held July 19-21, 1909, in the Hoo-Hoo House at the Alaska Yukon Pacific Exposition in Seattle. At that first PLC, George Cornwall stated:

> Logging is an engineering science and as such it must be considered in the future to a greater extent than it has in the past. The country is doing bigger things in every department of human activity, and the logging business is no exception to the rule. It takes close application and a high grade of engineering skill to be able to lay out the proper location of roads, which will intersect and draw to one common point the greatest amount of timber in any one tract. The grasp of this one problem is the deciding factor in determining the ability of the engineer, which often can be realized only after the tract is well opened up. There is a growing field on the Pacific Coast for young men with a knowledge of engineering, both civil and mechanical, who will devote their time to a study of the Pacific Coast logging requirements, with a view of being able to present in an intelligent and practical manner a working plan for opening up and logging a tract of timber, This is practically an unoccupied field, and one of the underlying motives which dominated the congress.[13]

Although Cornwall may well have been the one to coin the term logging engineering, Frank Lamb is one of the earliest to use the term in publication. In a paper presented to the first PLC, Lamb of Lamb Timber Company in Hoquium, Washington, discussed some of the subjects that compose logging engineering and suggested: "I hope that I have briefly outlined a few of the subjects comprised under the general term logging engineering, and while it would not make us more valuable men or more successful in our business, yet I think that if we practical men were to call ourselves logging engineers instead of simply loggers or boss loggers it might give us greater pride in our profession. I use the term profession advisedly, because I think the act of drawing logs out of the woods to the markets of the world is fully as elevating, fully as useful an occupation as is the drawing of useless teeth out of another man's head, and if one is a profession, so should the other be."[14]

The following year, 1910, a short course in logging engineering was taught at the University of Washington by Professor W. T. Andrews.[15] One year later Elias T. Clark was hired to take charge of

[11] E. T. Clark, "Logging Engineering Should Be Recognized by Institutions of Learning," 4th Annual Session *Pacific Logging Congress,* 1912 10.

[12] G. M. Cornwall, "Development of the Logging Industry of the Pacific Coast States," 1st Annual Session, Pacific Logging Congress 77, *The Timberman* 10 (1909): 32.

[13] Ibid.

[14] F. Lamb, "Logging Engineering Requires Skill and Experience for Success," 1st Annual Session, Pacific Logging Congress, *The Timberman 10* (1909): 32.

[15] W. T. Andrews, "Introduction to the Practical Teaching of Logging Engineering and Lumber Manufacture at the University of Washington," *Forest Club Annual* (University of Washington) 4 (3) (1925):34-37.

the forest engineering program at the University of Washington.[16] A major strength of that program was in the extensive use of a capstone field exercise that is still the trademark of the program today.[17]

Oregon State University (then Oregon State Agricultural College) established a department of logging engineering in 1913. A well-respected logger from industry, J. P. Van Orsdel was hired as the program's first professor of logging engineering and the first logging engineer graduated from this program in 1915.[18] The new curriculum was outlined to the PLC as follows:

> In the student's freshman year he is taught, aside from (citizenship, executive training, military training) trigonometry, analysis, general forestry, elementary mensuration, plane surveying, general chemistry, and wood work. In the second year, engineering physics, blacksmithing, tool making and tempering, machine shop, practice, mechanical drawing, topographic surveying, railroad surveying and dendrology and mensuration. In the third year this is followed up by advanced mensuration, forest appraisals and reports, log scaling, logging railroads, logging machine design, elements of steam engineering and steam laboratory, mechanism, lumber rates and tariffs. The senior year is devoted entirely to specialized work and the following ground is covered: topographic logging plans, logging devices and equipment, logging methods, timber technology and testing, and lumber manufacture.[19]

By 1920 logging engineering programs had been established at the University of California (Berkeley), Oregon State University, the University of Washington, the University of Idaho, and the University of British Columbia. These early curricula, like the one described by Van Orsdel, stressed traditional forestry, logging planning and setting layout, surveying (land and railroad), topographic maps, and steam engines. However, by 1920, the very nature of logging engineering was beginning to change.

RE-EMERGENCE OF FOREST ENGINEERING

Two forces were acting to change the fundamental nature of the problem addressed by logging engineering. First, technology was changing. Advances in the internal combustion engine and manufacturing processes during World War I were enabling the development of tractors and motor trucks suitable for logging. The result was a change in logging methods that reduced dependence on railroads. Second, concern for the forest resource was building and with that concern came increased interest in regeneration and selective logging.

In 1919 the Oregon Engineers Registration Law was passed and logging engineering was included as one of the branches.[20] The passing of legislation that provided for professional licensing of logging engineers was an acknowledgment of the importance of engineering to the protection of forest resources.

The primary emphasis of the early logging engineering programs was however directed at the problem of economic development of a timber resource located on difficult terrain. The requisite system of railroads and cable yarders represented a substantial capital investment. Poor harvest design, resulting in high logging costs, were of constant concern. The preparation of boundary and topographic maps, the development of a rail and cable transport system and the actual railroad survey, design and location called for the skills of an engineer. That forestry knowledge was also required in equal measure was not as clear. Indeed it was not until the early 1920s when public concern about sustained forest yield became a political issue that forestry skills were accorded significant recognition in the conduct of harvesting operations. In 1922 George Cornwall, writing for the industry, observed: "From now forward the growing of timber will become a recognized and essential part in logging. A good fundamental knowledge of forestry will be helpful, in fact necessary, in conducting logging operations in the future; where the question of how best to remove the present crop with a view of

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16 Clark, "Logging Engineering . . ."

17 J. L. Fridley and P. Schiess. "A Successful Senior Forest Engineering Capstone Design Course" (1989 *[ASAE Paper* no. 89-5510]).

18 W. A. Davies "Western Logging Engineering Schools—Oregon State College" 42nd Annual Session, Pacific Logging Congress, *Loggers Handbook* 11 (1951): 87-89.

19 J P. van Orsdel, "Presentation of Logging Engineering Curriculum at the Oregon State Agricultural College " 8th Annual Session, Pacific Logging Congress 1916.

20 Davies, "Western Logging Engineering Schools."

providing for a continuous future supply will be regarded as a test of efficiency."[21]

In 1924 the director of the newly formed Pacific Northwest Forest Experiment Station of the U.S. Forest Service, Thorton T. Munger, called logging without forest replacement "industrial suicide."[22] It was during this period that the term forest engineer first appeared in the Pacific Northwest. As noted by Cornwall the same paper, it was felt that the name of "logging engineer" should be widened to "forest engineer" to reflect adequately the scope of these new responsibilities. As previously noted the term "forest engineer" had already been introduced by Fernow whose earlier definition of the scope of the forest engineer's activity is consistent with the ideas advocated by Cornwall and Munger.[23]

The confluence of advancing technology and increasing concern about the forest resource had then forced a reconsideration of the role of the logging engineer. If logging (forest) engineers should once again enjoy a high profile in corporate operations, it was thought that it would be because of the broader issues of forest resources management and the ability of forest engineers to address those issues with a uniquely appropriate set of skills. But during the economic depression of the 1930s and the Second World War, the interest of the forest industry focused on short-term economic efficiency. Logging time and cost studies were increasingly applied, and the forest engineer began to use many of the techniques popularized by industrial engineers. Interest in and development of the broader role of the forest engineer in forest resource management seemed to have waned.

The Civilian Conservation Corps (CCC) program initiated in the early 1930s supplied over 250,000 young men to do conservation work. Hundreds of engineers were employed to design and supervise the construction of roads, trails, bridges, etc. While we usually do not think of these CCC related activities as forest engineering per se, this activity provided much of the infrastructure which has been essential to efficient forest transportation, and was a catalyst in stimulating the U.S. Forest Service to publish their own *Engineering Field Tables* in 1935.[24] This handbook concentrated on practical surveying, earthwork, road drainage and surfaces, and concrete and timber construction.

The 1940s brought many advances to steep terrain harvesting technology, which had been the impetus for logging engineering in the Pacific Northwest. The appearance of track mounted steel towers, wide use of rubber and track mounted cable loaders and the wide acceptance of the power chain saw in felling and bucking operations were some of the more significant advances. Along with the improvements in technology came greater interest in forestry as a component of logging engineering. During the 1940s the logging engineering curricula began to show changes reflecting this new emphasis. The program of Oregon State University was renamed to forest engineering,[25] and the program at the University of British Columbia was changed to add more English, technical forestry and forest products in place of the applied engineering courses.[26]

In Washington State, a tax law designed to encourage forestry on private land was passed in 1941.[27] The first forest practices act for the State was passed in 1945 and was directed at achievement and maintenance of adequate regeneration on cut-over land.[28] Further significant forest practices legislation would not be seen again until early in the 1970s. In 1949 logging engineering was granted recognition as a distinct branch of engineering, for purposes of professional licensing, by the Washington State Legislature.[29]

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21 G. M. Cornwall, "The Profession of Logging Engineering," *Forest Club Quarterly* (University of Washington) 10 (1922): 17-19.

22 T. T. Munger, "Objectives of the New Federal Forest Experiment Station," 15th Annual Session, Pacific Logging Congress, 1924. p. 6-7.

23 Fernow, "The Forester, an Engineer."

24 United Sallies Forest Service, *Engineering Field Tables* (Washington, D.C.: U.S. Government Printing Office, 1935).

25 Davies, "Western Logging Engineering Schools".

26 L. Besley, "Western Logging School—University of British Columbia," 42nd Annual Session, Pacific Logging Congress, *Loggers Handbook* 11 (1951): 79-84.

27 D. H. Basinger, "The Status of Forest Taxation in the State of Washington," *Forest Club* Quarterly (University of Washington) 15 (2) (1941): 17-20.

28 L. T. Webster, "Washington's Forest Practices Act," *Forest Club Quarterly* (University of Washington) 19 (1-3) (1945 46): 5-7.

29 G. D. Markworth, "Western Logging Engineering Schools—University of Washington," 42nd Annual Session, Pacific Logging Congress, *Loggers Handbook*, 11 (1951): 85-87.

PROFESSIONAL SOCIETY ACTIVITIES

The previously mentioned Pacific Logging Congress was, until about 1930, an organization that functioned much like today's technical societies. The annual meetings consisted of presented papers, formal discussion, field trips and a business meeting. The presented papers were very often of high caliber and some of them remain landmark papers in forest engineering research. The fundamental nature of the PLC began to change during the thirties. This change manifests itself as the presentations change from the technical to the business side of logging.

The Canadian Institute of Forestry was founded in 1908 as the Canadian Society of Forest Engineers with the participation of Fernow. The current name, adopted in 1950, more accurately reflects the members' preponderant professional interest in forestry rather than engineering. This professional society continues to publish the *Forestry Chronicle* which contains only occasional articles of minor engineering content.

The Society of American Foresters (SAF) is yet another professional forestry association. Lacking a traditional interest in the engineering aspects of forestry it provides only limited support to forest engineering activities. In spite of this limitation it has historically been widely subscribed to as a professional organization by American forest engineers. Its publications such as *Forest Science* and the regional applied forestry journals *(Western, Southern, and Northern Journals of Applied Forestry)* provide an important outlet for forest engineering articles.

The Forest Products Research Society is an organization of researchers with a common interest of solid wood products. Through such publications as the *Forest Products Journal* and the *Timber Harvesting and Merchandising Newsletter* the FPRS has been active in the publication of forest engineering research.

In the later 1960s and early seventies, protection of the public resources adversely affected by forest harvesting operations became a front page political issue. The increased public awareness sparked interest in forest engineering among other disciplines. The American Society of Agricultural Engineers (ASAE) held two forest engineering conferences in 1968 and 1969. The interest of the ASAE serves to illustrate that (1) the public concern for the forest resources was sparking interests of professionals outside of forestry and (2) the broader scope of forest engineers (outlined by Fernow in 1901 and further discussed by Cornwall and others during the 1920s) was becoming recognized. B. Y. Richardson wrote, in the Foreword to the proceedings of the first ASAE sponsored forest engineering conference, "Good engineering is also required in site preparation, regeneration, cultural and protective functions. These needs take the form of design, development and testing of machines for precise planting, seeding, fertilizer application, nursery operations as well as insect, disease and fire control." [30]

The second ASAE sponsored forest engineering conference, held in 1969, is significant because it was the first conference held since the early Pacific Logging Conferences that was directed at teaching and curricula in forest engineering. (The PLC had, as previously mentioned, evolved so as to place dominant emphasis on the business and occupation of logging as opposed to the profession and discipline of forest engineering.) S. J. Coughran noted in the opening remarks of the conference that "it was quite evident that the subject matter to be explored in this conference is extremely controversial."[31] The controversy he refers to was one of determining whether forest engineers are or should be foresters or engineers. George Cornwall's notion of a distinct profession of forest engineering had perhaps become forgotten.

In 1981, ASAE sponsored a third forest engineering conference, the Forest Regeneration Symposium. This conference was held in Raleigh, North Carolina, and published a proceedings under the same title.[32] This conference identifies Forest Engineering as a profession which serves all the aspects of forestry, where most previous works concentrated on the removal of timber and the associated transportation systems.

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30 B. Y. Richardson. "Foreword " *Proceedings of the Forest Engineering Conference,* American Society of Agricultural Engineers, Michigan State University, East Lansing, Sept. 25-27 1968.

31 S. J. Coughran "Opening Remarks." *Proceedings of the Forest Engineering Conference on Education,* American Society of Agricultural Engineers, Chicago, Dec. 8-9 1969.

32 American Society of Agricultural Engineers, *Forest Regeneration,* Proceedings of a Symposium on Engineering Systems for Forest Regeneration, Mar. 2-6, Raleigh, N.C. (St Joseph Mich.: American Society of Agricultural Engineers, 1981 [ASAE Publication no. 10-81]).

The ASAE's technical journal, *Transactions of the ASAE*, has served as an important outlet for the more engineering oriented research papers since the 1968 and 1969 conferences.

By the end of the 1970s, most of the western states had toughened and enlarged the scope of their forest practice legislation. Companies engaged in the harvest of a very valuable timber resource were operating on difficult terrain under restrictive forest practice acts. Forest engineers were again in high demand. The forest engineering programs in the Northwest were strong and numerous and others had materialized throughout the country. Some of the newer programs had affiliation with Agricultural Engineering Departments. In 1979 a forest engineering conference, independent of any existing organization, was held in Corvallis, Oregon. This conference marked the formation of the Council on Forest Engineering (COFE), a proximate professional organization for persons interested in forest engineering. At that first meeting of COFE it was decided that no affiliation should be sought with either the ASAE or the Society of American Foresters. The "controversy" of the 1969 meeting was still a concern. By the beginning of the eighties, however, even the forest engineering profession was impacted by the industry-wide recession. Academic concerns were replaced by institutional concerns as employment opportunities and student enrollment declined.

DEVELOPMENT OF THE CURRENT LITERATURE

The previously mentioned early texts by Schlich, Schenck and Bryant were followed by J. P. Stewart's 1927 *Manual of Forest Engineering and Extraction.*[33] At the time, Stewart was a lecturer in Forest Engineering at the University of Edinburgh. His examples draw from extensive experience in North America, Africa and India where he had served as an advisor to various forest managers. His manual provides practical solutions to a variety of forest engineering problems ranging from protection from wild animals and malaria to a variety of logging and transportation schemes. Surveying, sleds, petrol and steam tractors, wire rope operations, slides and flumes, road, railways, trestles, water transport, permanent buildings and timber conversion and seasoning are included. Published with his manual are twenty-four pages of advertisements for goods commonly needed in a logging camp.

Some of the books by Brown were written as forest engineering texts. These books are generally descriptive of logging practices and contain little engineering analysis.[34] One point of significance in the 1936 volume is the inclusion of silvicultural considerations within the chapters on logging methods. Only a loose tie is made between forestry and engineering.

In 1942 Professor Donald Matthews published his book *Cost Control in the Logging Industry.*[35] This text reflects the concern for economic efficiency prevalent during the 1930s. Among the topics covered are the economic location of roads and landings, economic service standards for roads and the selection of logging equipment by economic criteria. Despite the voluminous research that has been inspired at least in part by this book, it remains the only English language text written specifically on the topic of forest engineering economics. A major weakness of this poorly referenced text is its lack of a bibliography.

In 1947, the American Pulpwood Association initiated the *Technical Release* series oriented toward solving problems and presenting innovative ideas for loggers. Each monthly mailing to the Association membership contained several "Releases," each devoted to a single topic. In many cases these were written by the logger who actually developed the problem solution. Approximately 100 of these articles are published each year. While they normally are not written or reviewed by professional engineers, many do address the art and occasionally the science of forest engineering. These articles, although not of the technical quality exhibited in the early PLC papers, probably served to fill some of the void created as the PLC departed from its strong

33 J. P. Steward, *Manual of Forest Engineering and Extraction* (London: Chapman and Hall, 1927).

34 (a) Nelson C. Brown, *Logging—Principles and Practices in the United States and Canada* (New York: John Wiley, 1934). (b) Nelson C. Brown, *Logging—Transportation: The Principles and Methods of Log Transportation in the United States and Canada* (New York: John Wiley, 1936). (c) Nelson C. Brown, *Logging: The Principles and Methods of Harvesting Timber in the United States and Canada* (New York: John Wiley, 1949).

35 D. M. Matthews, *Cost Control in the Logging Industry* (New York McGraw-Hill, 1942).

technical beginnings and became more of a social and trade organization.

A second contribution from the University of Edinburgh appeared in 1951 in the form of *Forest Engineering Roads and Bridges*.[36] James L. Harrison had been Forest Officer in India and following his retirement from foreign service he lectured on forest engineering and utilization at Edinburgh. This text discusses road reconnaissance and location, drainage structures, quarrying, retaining walls and river crossings. Harrison points out the essential need for a transportation network regardless of the particular logging system to be used. This textbook is one of the first to offer rigorous engineering analysis directed at bridge and retaining wall structures typical of forestry operations. This book represents an engineering version of the type of text written by Schenck or Bryant.

With the exception of the text by Harrison, the previously mentioned books dealt with forest engineering topics in a descriptive fashion, lacking engineering analysis and synthesis. Filling this void are a number of manuals and handbooks.

Logging and forest road construction appeared as chapter topics in the *Forest Handbook for British Columbia* in 1953.[37] The original *Handbook* was primarily written by students at the University of British Columbia, under the direction of John (Jack) Walters. Walters was later to become internationally recognized for his work in developing a mechanical tree planter and serving as one of the first chairmen of the Forest Machine Committee of the American Society of Agricultural Engineers. It is interesting that this handbook had two sections devoted to engineering topics. The first, simply titled "Engineering," dealt with planning issues such as surveying and setting layout. The second section was titled "Logging Safely," and consisted of seven pages of direct quotations from the new British Columbia Safety code, implemented by the Workman's Compensation Board on September 1, 1950. This handbook is currently in its fourth edition.

In 1955 the Society of American Foresters published its first handbook, the *Forestry Handbook*.[38] A committee led by A. M. Koroleff of the Pulp and Paper Research Institute of Canada prepared the chapter on logging. The chapters on road engineering and surveying were prepared by a committee chaired by Anthony P. Dean of the U.S. Forest Service. A total of 167 pages of this handbook are dedicated to forest engineering, which is indicative of the need for published materials at the time. Although not explicitly an engineering handbook the *Forestry Handbook is* a common reference book in the libraries of most forest engineers.

A *Forester's Engineering Handbook* was written by Eric R. Huggard, a lecturer in forest engineering at the University College of North Wales, in *1958*.[39] It covered the familiar topics of surveying, road and bridge design and construction, use of explosives, and timber extraction. The United Nations through the Food and Agriculture Organization (FAO) has also published a variety of manuals starting with one that gives a good blend of practical application and theory, *Tractors for Logging*.[40] In 1958, the United Nations Economic Commission for Europe (ECE) and the Food and Agriculture Organization of the United Nations formed a joint FAO/ECE Committee on Forest Working Techniques and Training of Forest Workers. An International Training Course on Mechanized Forest Operations was held in Sweden in 1959, and a lengthy publication of this work was published by the U.N. in 1960.[41] Topics included equipment analysis, work-study, transportation systems, road standards, detailed descriptions of logging systems, and even human physiological requirements related to woods operations. Many of the topics, including some of the same diagrams, still appear in the current research literature. Several additional manuals of interest have been published by FAO.[42]

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36 J. L. Hamson, *Forest Engineering Roads and Bridges* (Edinburgh: Oliver and Boyd, 1951).

37 J. Walters, *Forest Handbook for British Columbia.* 1st ed. (Vancouver: University of British Columbia, 1953).

38 American Society of Foresters, *Forestry Handbook.* ed. by R. D. Forbes (New York: Ronald Press, 1955).

39 E. R. Huggard, *Foresters' Engineering Handbook* (Bangor: University College North Wales, 1958).

40 United Nations, *Tractors for Logging* (Rome: FAO, 1956 *[FAO Forestry Development* Paper no. 1]).

41 United Nations, *ECE/FAO Joint Committee of Forest Working Techniques and Training of Forest Workers* (Geneva. 1960).

42 (a) United Nations, Logging *and Log Transport in Tropical High Forest* (Rome: FAO. 1974 *[FAO Forestry Development Paper n* o 18]). (b) United Nations, *Harvesting Man-Made Forests in Developing Countries* (Rome: FAO, 1976). (c) United Nations, *Planning Forest Roads and Harvesting Systems* (Rome: FAO, 1977

A short time later, J. Kenneth Pearce of the University of Washington published the first of several versions of the *Forest Engineering Handbook.*[43] Pearce is a registered civil engineer but his handbook is written for practitioners who may not have had formal engineering training. It also filled an important gap in the literature because it was specifically written for use in western North America where European literature had not gained wide acceptance.

During this same period in Canada, Lussier published a textbook dealing with the application of management science techniques to forest engineering problems. This book has stimulated numerous research papers and remains an excellent source of material for both teaching and research.[44]

Another publication which has been reprinted in several versions and has served as source material for several texts is the *Skyline Tension and Definition Handbook,* by Hilton Lysons and Charles Mann.[45] The authors presented tables and graphical techniques to aid in the design of skyline yarder settings. Presented in 1967, these techniques became the standard yarder setting design guide until they were replaced by computer techniques in the early 1980s.[46]

Several descriptive manuals of logging operations were published by the U.S. Forest Service during the 1970s. Norman Sears was responsible for initiating a continuing series of publications known as *Engineering Field Notes.* [47] While this series is intended as a U.S. Forest Service internal communication network to provide guidance on engineering methods, information exchange, continuing training and awareness of new developments and technical literature, the *Notes* [48] are widely distributed and commonly used by the forest engineering community.

It was not until 1972 when J. Kenneth Pearce and George Stenzel published *Logging and Pulpwood Production* that a textbook was written in the United States as a replacement for the texts of the 1910-40 era.[49] This text addresses the same familiar topics as earlier published handbooks, but with much more attention to referenced research and some attempts to expose basic principles as well as problem solutions. By contrast, Steve Conway's books, *Timber Cutting Practices* [50] and *Logging Practices* [51] contain detailed descriptions of logging practices, but are of limited scholastic value due to scant reference to research papers and the absence of any discussion of fundamental engineering principles.

In 1974, the Woodlands Research Division of the Pulp and Paper Research Institute of Canada and the Logging Development Program of the Canadian Forestry Service were merged to form the Forest Engineering Research Institute of Canada (FERIC). With a 1990 budget in excess of seven million dollars and a Canadian staff of 84 people, this cooperative government-industry alliance is the largest and most prolific source of forest engineering literature. Major activity areas are harvesting, secondary transportation, silvicultural operations and woodlot technology. They have staff support in the areas of design engineering, instrumentation and computers, and library functions. Their *Log Bridge Construction Handbook is* indicative of their orientation toward the forestry construction practitioner rather than the design engineer.[52] Although it lacks much needed engineering analysis this manual is an excellent handbook for field design of log stringer bridges.

[FAO For Paper no 21]). (d) United Nations, *Assessment of Logging Costs from Forest Inventories in the Tropics* (Rome: 1978 *[FAO Forestry Papers no* 10]).

43 J. K. Pearce, *Forest Engineering Handbook* (Department of the Interior, Oregon State Office, 1961).

44 L. J. Lussier, *Planning and Control of Logging Operations* (Quebec, Canada: Forest Research Foundation, Universite Laval, 1961).

45 42. 43. H. Lysons and C. Mann, *Skyline Tension and Deflection Handbook* (Washington D.C.: U.S. Government Printing Office, 1967 [U.S. Forest Service PNW 39]).

46 V. W. Binkley and J. Sessions, *Chain and Board Handbook for Skyline Tension and Deflection* (USDA FS PNW Region, 1979 [GPO 799-549]).

47 (a) Fred C. Simmons, *Handbook for Western Timber Harvesting* (Broomall, Pa: USDA FS NE Area Slate & Private Forestry, 1979). (b) Keith L. McGonagill, *Logging Systems Guide* (1978 [USDA FS Alaska Region, Div. of Timber Management, Series no. R10-21]). (c) Donald D. Studier and Virgil W. Binkley, *Cable Logging Systems* (Corvallis, Oregon.: O.S.U. Book Stores, Inc., 1975).

48 United States Forest Service, Engineering Field Notes (Washington. D.C.: U.S. Departmental of Agriculture, 1909 +).

49 J. K. Pearce and G. Stenzel. *Logging and Pulpwood Production* (New York: Ronald Press, 1972).

50 S. Conway, *Timber Culling Practices* (San Francisco: Miller Freeman Publishers, 1968).

51 S. Conway, *Logging Practices* (San Francisco: Miller Freeman Publishers, 1976).

52 Michael M. Nagy, J. T. Trebett, C. V. Wellburn, and L. F. Gower, *Log Bridge Construction Handbook* 1980. (Vancouver, British Colombia, 1980 [*Engineering Research Institute Of Canada Handbook* no. 3]).

The following two manuals are characteristic of the vast quantity of published material from a variety of sources. The manual *Trucks and Trailers and Their Application to Logging Operations* by McNally represents a good blend of analytical and descriptive material.[53] The *Manual for Roads and Transportation,* most recently revised by David Holmes in 1978 and brought out in two volumes, is an excellent textbook for students.[54] It employs a good blend of numerical analysis with the practical and descriptive. These two manuals and many others of similar high quality have been published but are not widely distributed.

A number of forest engineering texts and references have been generated by European authors during the 1980s. Ivar Samset from the Norwegian Forest Research Institute produced a very complete cable logging text written in Norwegian. Fortunately, *Winch and Cable Systems* was translated into English in 1985.[55]

In 1981, the Skogsarbeten organization in Sweden produced three volumes on forest machinery systems. Unfortunately, the *Terrangmaskinen* series 32 was only available in Swedish until 1989, when the first volume was translated into English.[56] The excellent diagrams used in these books provide a valuable resource even if the reader does not understand the written text.

Tree Harvesting Techniques was written by K. A. F. Staaf from the Swedish University of Agriculture at Uppsala and N. A. Wiksten.[57] This text appears to rely heavily on earlier Swedish works and is clearly a descendent of the FAO/ECE work listed above. The two volumes on *Operational Efficiency in Forestry* edited by U. Sunburg from the Swedish University of Agricultural Sciences at Farpenberg and C. R. Silversides from the Canadian Forestry Service also seem to have grown from the FAO/ECE roots.[58] This is the first book to seriously address such things as ergonomics of forest operations, problem analysis, energy analysis and the interaction between the stand, the prescription and the machine. Measurements and logging systems are confined to four pages.

Another step in the development of the forest engineering literature occurred in late 1989, when *The Journal of Forest Engineering* began to be published under the sponsorship of the Forest Engineering Department at the University of New Brunswick. Representatives of twelve countries sit on the editorial board, so it is clear that an international scope is intended.

CHALLENGES FOR THE FUTURE

The development of the forest engineering discipline and its literature has been influenced by Western society's deep concern for the world's forests and by a pragmatic need for wood-based products. It is reasonably clear from the literature however that the discipline has spent the last eighty to 100 years responding to the change in technology and the shifting emphasis on environmental concerns, as opposed to building a foundation from which tomorrow's new technology and solutions will arise. The result is a discipline with a body of literature that has never developed a cohesive framework of information that can serve to increase the awareness of a novice or enhance the analytical and design capabilities of advanced students. A perusal of the forest engineering literature would lead one to conclude that forest engineering design, the area of synthesizing new solutions, is not dependent upon analysis but rather upon an orally transmitted collection of field procedures.

The forest engineering profession now faces a serious challenge. Scholars must address the need for a literature that will serve to fully describe and define forest engineering. This new literature must not be merely descriptive nor a handbook presentation of known solutions of limited analytical value. This new literature must present a synthesis

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[53] J. A. McNally, *Trucks and Trailers and Their Application to Logging Operations* (Fredericton, New Brunswick: University of New Brunswick, Department of Forest Engineering. 1975).

[54] David C. Holmes, *Manual for Roads and Transportation,* Rev. ed. (Burnaby, British Columbia: British Columbia Institute of Technology, 1978).

[55] I. Samset, *Winch and Cable Systems* (Translated from Norwegian) (Dordrecht Martinus Nijhoff/Dr. W. Junk Publishers, 1985).

[56] (a) C-E. Malmberg, *Terrangmaskinen* (Slockholm, Sweden: Skogsarbeten, 1981). (b) C-E. Malmberg, *The Off-Road Vehicle.* (Translation of *Terrangmaskinen,* vol. 3) (Montreal: Joint Textbook Committee of the Paper Industry, 1989).

[57] K. A. G. Slaaf and N. A. Wiksten, *Tree Harvesting Techniques* (Dordrecht: Martinus Nijhoff/Dr. W. Junk Publishers, 1984).

[58] U. Sunburg and C. R. Silversides, eds., *Operational Efficiency in Forestry* (Dordrecht: Martinus Nijhoff/Dr. W. Junk Publishers, 1988).

of the dispersedly published engineering analysis that has been directed at forestry problems.

Practitioners are also facing serious challenges that call for innovative solutions not to be found in the handbooks. Low elevation second-growth stands in the Pacific Northwest are being harvested and are the focus of intensive management activity. These stands, as compared to the old-growth stands of former years, have more homogeneous timber located on gentler terrain. Road location and logging are not as challenging in this regard. The use of computers has greatly reduced office engineering time, thus a given quantity of design activity can be accomplished with fewer engineer hours. Easier conditions for roading and harvesting have reduced the obvious financial benefit associated with careful planning and engineering design.

If planning and conducting the roading and harvesting operation have been made easier by the terrain and technology, in at least two aspects it has become, and will become, much more difficult. First, the large and highly valuable logs of the old-growth forest have been replaced with small diameter lower value logs. This change in log size and value has made log handling critical to the profitability of a logging enterprise. The homogeneous nature of the timber resource better lends itself to mechanized harvesting and handling operations than did the old-growth timber. Successful mechanized logging operations are highly engineered systems. Second, increased recognition and legislation for the protection of the public resources of air, water, fish and wildlife have placed major constraints on timber harvesting and other forest management activities. The resources belonging to society at large cannot be dismissed as illegitimate or ephemeral concerns. It is here that the forest engineer can make a substantial contribution to the forestry industry and to society. The engineering design of forest roads, harvest systems, or other forest management operations is the key to the integration of the many constraints currently placed on forest management and utilization. To the extent that engineering skills and accountability can contribute to the identification and implementation of environmentally acceptable, ecologically desirable, and financially attractive management and harvesting activities, forest engineers must be involved.

The future of the profession depends on practicing forest engineers and educational institutions cooperating to redefine the areas of technology or bodies of knowledge that constitute forest engineering. The continued development of forest engineering should address the technology and problems of today and anticipate those of tomorrow. It is also the time to examine the profession in a new way, not engineering with some forestry, not foresters with some engineering, not even a hybrid engineer-forester, but as a distinct profession and academic discipline.

THE GENESIS OF COFE: A POPULIST RESPONSE TO A PROFESSIONAL NEED[1]

by

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ABSTRACT: The Council On Forest Engineering (COFE) began at a small conference at Oregon State University in 1978 and grew into the principal professional organization for forest engineers in North America. It is a history of excellent technical communication, professional networking, and many contributions to forestry.

Key Words: forest engineering, professional society

The 1970's may well be described as the "Golden Age" of forest engineering. There was rapid development of timber harvesting and road construction technology. New forest engineering curricula and departments were being started in universities in Canada and the United States. There was a great deal of creative innovation in equipment development within the forest industry and by equipment manufacturers in North America and Europe, especially Scandinavia. Timber was actually being harvested on federal lands in the United States. In the West, much of this timber was being harvested with skylines, helicopters and balloons.

The forest engineering profession was likewise growing. Universities were beginning to graduate larger numbers of students from forest engineering programs. In federal agencies, at least in the United States, administrators were scrambling to fill specialist positions in forest engineering to assist in the layout of advanced harvesting systems. It seemed that no district could do without at least one complex skyline sale and one helicopter sale.

The problem was that there were not enough trained forest engineers to go around. Agencies took the initiative, simply designating people as "forest engineers" even though they had no technical expertise in any engineering discipline.

A related problem was that many of the advanced harvesting systems being employed required special attention to transportation. Road systems and harvesting systems had to be planned together to be effective. This necessitated a lot of communication between the civil engineers responsible for road design and construction and the "forest engineers" designated to layout harvest units. Often, there was neither a common vocabulary for communication nor an appreciation of the design requirements that dictated road location or harvest unit configuration.

At the universities, forest engineering curricula were expanding to meet the new demands of industry and agencies. Forest engineering faculty were in high demand; there were almost no Ph.Ds available with both engineering expertise and the field experience necessary to translate theory to practice. There was a great need for the faculties from the several university forest engineering programs to share information, lesson plans and experiences and to standardize, at least regionally, the structure and content of forest engineering curricula.

During this decade, universities were also beginning to establish programs in forest engineering or timber harvesting extension. Like their colleagues responsible for resident instruction, forest engineering extension specialists found themselves swamped with demand for programs but with few materials to support county extension staff. And like others in the forest engineering profession, there was no good forum for them to share information or discuss opportunities for cooperation.

Two professional societies, the Society of American Foresters (SAF) and the American Society of Agricultural Engineers (ASAE), both had (and still have) working groups or sections on forest engineering. However, these groups met only at the national conventions of the parent organization and then only for a few hours. Unless forest engineers had some interest in the full convention program, it was difficult to justify the time and expense of travel to the convention for a two-hour section meeting.

It was in this environment of expanding demand for forest engineers, expanding need for technological development, and a critical need for professional communication that the Council on Forest Engineering (COFE) was born.

Like many auspicious developments, COFE was triggered by a very inauspicious incident. In the autumn of 1977, the Society of American Foresters

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquett, MI, July 29-August 1, 1996.

held its annual convention in Albuquerque, New Mexico. Conor Boyd, then program manager for forest engineering research at Weyerhaeuser, and I were invited to give technical papers summarizing recent forest engineering developments in industry and universities at the SAF Forest Engineering Working Group meeting. Three people attended that meeting--the Working Group chair, Conor and me. In disgust, Conor and I adjourned to a good restaurant for beer and Mexican food.

Conor and I agreed that something must be done to provide a forum for forest engineers in industry, government and universities to come together annually to share information and to develop stronger professional networks. Neither of us knew what type of organization would meet those needs best, but decided to start by bringing together a cross-section of forest engineers from industry, government and universities in the United States and Canada to see what was possible. I agreed to help organize such a meeting and to host it at Oregon State University. Conor agreed to co-sponsor the meeting and to help with organization and finances.

Upon returning to Oregon State, I described the proposal to the Forest Engineering Department faculty and they enthusiastically embraced the idea. We organized a program with general sessions on overviews of forest engineering research, teaching and extension. We also had concurrent "break-out" sessions on these topics for attendees to work in small groups and discuss trends and needs. We planned some field trips to exhibit some of the advanced harvesting systems being used in Oregon. We also planned a wrap-up session that would focus on establishing some kind of organization to facilitate continued professional development opportunities for forest engineers. Finally, we put together an invitation list of those most actively involved in forest engineering. It was a relatively small group, no more than 30, to insure manageable dialog.

Once the invitations were sent, the word quickly spread among forest engineers. We decided to take all comers and the attendance grew to 60.

The four day conference (August 8-11, 1978) exceeded our expectations. The discussions during the meetings, breaks and field trips reflected an enthusiasm that clearly justified our prediction of a need for communication that was not being met by either SAF or ASAE. People began talking almost immediately about "how do we keep this momentum going", "where will we meet next year" or "shouldn't we have a more formal process to get us together regularly."

The closing session was critical. The goal was to determine if there was sufficient interest in forming some kind of organization for forest engineers and, if so, how such an organization would function and be structured. Everyone quickly agreed that an organization was necessary, but that we needed to start with something informal and allow very open participation.

This led to a discussion about by-laws and Ross Silversides, our senior statesman, agreed to help craft the first draft. We decided to meet in different locations each year, with the host organization providing the logistical support (on a break-even basis), calling for papers and organizing the meetings and field trips. We decided not to have a formal dues structure initially, but to reconsider that need as the organization grew. We agreed on a name.

Having resolved these general issues, the final question tested the commitment of the attendees to actually beginning the Council on Forest Engineering. As closing session chair, I asked "Who will host and organize the next meeting in 1979"? After a long period of silence, Tom Walbridge volunteered to host the 1979 meeting at Virginia Polytechnic Institute and State University in Blacksburg, Virginia. And, as they say, "the rest is history". At the end of the meeting at VPI, three organizations volunteered as hosts and COFE was off at full speed.

Looking back at the origins of COFE, it seems to me that several key factors contributed to the establishment and immediate success of the organization. First, there was a clear and immediate need for such an organization. Timing, as they say, is everything and clearly the time was right; no other organization came close to providing the opportunities for professional interchange and growth that COFE affords its participants.

Second, and clearly most important, a group of highly motivated, committed people came together to make something happen. These were people used to taking responsibility and assuming leadership roles. Finding people to host meetings, chair committees, and give presentations has never been a problem.

Third, there was a wealth of knowledge and experience to be shared. One of the most important aspects of COFE has been, right from the start, that forest engineers from industry, government and universities participated equally in the meetings. This was not just a forum for forest engineers working in research to give scientific papers. Forest engineers working in the field came forward to share their knowledge, experiences and frustrations in ways that provided the basis for great discussions about needs for new information or educational programs.

Finally, the traditional culture of forest engineering is one of getting things done. Or as one of my favorite forest engineers is fond of saying "lead, follow or get the hell out of the way!" We didn't get bogged down in a lot of formality or bureaucracy. The by-laws that Ross Silversides and his committee crafted are a marvel of simplicity. We spent as much time in the field as in meetings. We kept costs low so lots of people could participate. In short, we "just did it."

It is clear that the idea behind COFE was a good one. After almost 20 years, the organization not only still exists but it has grown and prospered in those two decades. Many of those who attended that first meeting in 1978 are still providing leadership to our profession and are still actively participating in COFE. Membership is around 400; about 80 percent of the members are from the United States, 15 percent from Canada and 5 percent from countries overseas. There are active regional COFE organizations in the northeastern and southern United States. From a very modest beginning, COFE has emerged as an organization that now represents the core of the forest engineering profession. And that is a legacy to be proud of!

INTEGRATED FOREST MANAGEMENT SYSTEM (IFMS) DESIGNS FOR NORTH AMERICAN FOREST PRODUCT COMPANIES[1]

by

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ABSTRACT: The principles of hierarchical forest management planning and integrated forest management system (IFMS) design have been applied to the problems faced by a forestry organization responsible for tropical forest plantation management in Thailand. Although integrated forest management is at least as important an issue for the managers of the extensive natural forests of the northern United States and Canada, the nature of the problem environment is significantly different. In order to address the decision-making needs of those who are responsible for the long, medium and short-term forest management of integrated forest product companies in this region, design modifications will be required and additional tools and techniques may have to be incorporated. This paper proposes an integrated decision-making process for such companies and presents an IFMS design which is primarily based upon available technologies.

Key Words: integrated forest management, hierarchical production planning, decision support systems

INTRODUCTION

"Traditional forestry research ... is not keeping pace with the growing complexity and problems to be faced now and in the future" (Buckman, 1990).

"Because of the complexity of forestry systems, fore-seeing the likely consequences of a particular decision is not an easy task" (Buongiorno and Gilless, 1986).

"Resource management issues are becoming increasingly complex" (Kiil, 1989).

"The management of forest and agricultural lands and their associated resources is becoming more complex" (Lund, 1991).

Although the repetition of an opinion does not necessarily make it true, there is considerable evidence that forest managers truly are faced with an increasingly complex decision environment. In the case of large, integrated forest products companies, the decisions are usually made by management teams. These teams are charged with developing and implementing a "system" of strategic, tactical and operational plans that have multiple objectives, require varying levels of detail, are the responsibility of several levels of management and span a range of time horizons and spatial resolutions. Where it is recognized that all of these plans must be linked in a rational and explicit manner, the entire system could be referred to as an "integrated" forest management plan.

All integrated forest management plans are likely to include strategic, tactical and operational elements, but the specific decision environments in which they are formulated should dictate the design of the overall system of plans and its elements. Although there are implications for companies in other regions, this paper will primarily refer to the situation that confronts forest products companies operating on public lands in eastern Canada.

DECISION ENVIRONMENT

Most large, integrated forest products companies that operate in eastern Canada have acquired rights to extract the timber from specific crown forests for a period of time in exchange for fees and the responsibility to manage those forests. The forests are usually extensive (often several hundred thousand hectares) and complex (containing tens or hundreds of thousands of stands composed of varying species mixes and age classes). Although forest resources are a provincial jurisdiction and forest management agreements vary by province, in general the agreements require that the forests be managed sustainably for timber and non-timber values (including the protection of water quality, wildlife and environmentally sensitive areas). In most cases, there is the understanding (implicit or explicit) that, if the forests are properly managed, the management agreement will be extended after every review period. For example, the management agreement may be for a 25 year duration, with a review every five years. If, after the first review period, it is found that a company has undertaken proper forest management, the agreement will be extended by five years, bringing the total duration back up to 25 years. On the other hand, a failing grade in the review will mean that the agreement will not be extended and so will only have 20 years to run.

[1] Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996

Although it might seem that this would only be a minor inconvenience for a company (after all, there would still be twenty years left in the agreement), the implications are actually quite serious. Such companies carry these agreements as major assets on their balance sheets. The failure to renew an agreement would, in fact, represent a significant reduction in the value of their assets. Furthermore, it is quite likely that a flagrant failure to manage these forests might be used by a government as a reason to cancel the entire agreement.

At the same time, a company must manage all of its resources to make a profit and obtain an adequate return on investment for its shareholders. Therefore a company's woodlands division must also demonstrate that it can satisfy the requirements of the company's wood processing plants at a reasonable cost, make a profit on products supplied to external markets and obtain an adequate return on its own capital investments. In the longer term (perhaps twenty-five years) it must show that it can meet its forecasted mills' requirements from its forests (and wood purchases) and indicate what long-term investments (such as major roads) will be required. Looking at shorter time frames, woodlands managers must produce multi-year operating and capital investment plans that satisfy more certain mill requirements and maximize profits and returns. Finally, woodlands must produce very detailed annual operating schedules and budgets.

Although it would appear obvious that the two main purposes for planning (to satisfy management agreement requirements and to maximize returns for shareholders) should be equally important to industrial forest managers, at least one study has suggested that this is not the case. Based upon a survey of major Canadian forest products companies, MacDonald (1991) surmised that their planning processes seemed primarily designed to satisfy the requirements of forest management agreements. He also found that, although managers recognized the need to link planning processes over all time frames and organizational levels, such integrated planning was generally not being done. When queried about this, respondents seemed to indicate that institutional barriers and managerial inertia were the major reasons.

MacDonald's report is not the only one that suggests that modern forest product companies everywhere suffer from the lack of well-developed integrated analysis and planning capabilities. For example, Kent et al (1988) reported that the "link between operational feasibility and forest plans is tenuous" and concluded that the "necessary linkages between different levels of planning must be developed".

GENERAL PLANNING PROCESS

If we were to envisage a truly integrated forest management planning process for the above-mentioned situation that encompasses both government requirements and company needs, it might include the following procedures:

1) The development of a long term (one or more rotations) forest-wide plan for sustainable wood supply (and the sustainability of other resources). Since these forests are ordinarily quite extensive and structurally complex, this harvest schedule must normally be aspatial and some degree of aggregation is required.

2) The development of a medium to long-term (twenty to thirty year) plan that addresses issues relating to a) an implementable timber supply that coincides with the life of major investments (such as processing plants and road networks) and b) landscape, watershed and wildlife management concerns. In this case, some level of spatial referencing and disaggregation is required. Since natural forests are composed of stands of various sizes and shapes that do not always coincide with operational requirements, there must be a method of blocking that puts together stands (or parts of stands) into decision units and schedules these with the timber supply and landscape management objectives in mind.

3) The development of a multi-year (five to ten year) plan to supply specific markets with specific products from specific blocks in order to achieve profit (or cost) objectives. Important decisions to be made at this level include those concerning system acquisition, allocation and scheduling, as well as detailed access road network development.

4) Finally, a detailed annual operating plan and budget must be produced for road construction, harvesting, stand establishment and hauling operations (as well as support functions). This includes an operating schedule which ensures that the plan is implementable and that periodic (weekly or monthly) mill delivery targets can be met.

Each planning level has distinct sets of major and minor decisions that must be made with respect to problem modelling and solution evaluation. At the same time, relationships between decision sets must be established. The following is a description of the major modelling decisions that must be made at each planning level:

Long-term, forest-wide planning - Planners must decide on the objectives of the strategic plan, the explicit constraints that must be applied, the constitution of the "operable" forest, the data types and structures that will be employed (especially as they relate to forest stratification and the modelling of forest dynamics), the interventions that may be employed, and the operability and action time frames that are most appropriate for their situation.

Block creation and scheduling - At this level, planners must choose the specific landscape management, operability and market constraints to be followed, the outputs to be tracked and the stand aggregation and timing rules to be employed. Since the creation and scheduling of blocks may reduce the achievement of strategic objectives, they must also decide on the degree of incongruity between plans at these two levels that can be accepted without requiring that the entire planning process be started again.

Tactical/operational planning - Since most landscape management objectives and constraints should have been addressed at the block creation and scheduling level, the tactical/operational plan can focus on issues concerning profitability, return on investment and the fulfillment of foreseeable market demands. As such, planners must choose the objectives, constraints and operating variables that would form the basis of an optimum multi-year operating plan. The decision to maximize profits rather than minimize costs, for instance, will change the structure of the modelling process and the outputs that will be tracked and constrained. In choosing the possible operating systems that should be modelled, planners must decide whether the additional benefit of adding more alternatives is worth the extra data gathering effort and increased model size.

Annual operational scheduling and budgeting - At this final, major planning level, decisions regarding the degree of scheduling and budgeting detail and measures of plan acceptability must be decided. Are monthly (as opposed to weekly) delivery schedules adequate? What outputs of the plan will be used to decide that a budget is unacceptable or that the risk of "unimplementability" is too high?

Given the amount and complexity of data manipulation and analysis that is required in order to make appropriate integrated forest management planning decisions, managers could benefit from the availability of models and decision support tools, especially if the tools were themselves well integrated. This might suggest that it would be beneficial to develop the integrated plan by using one large model. However, it is difficult to see how this could be accomplished within a single model since:

- the decision makers and the objectives at each level may differ significantly;
- each level of planning differs in terms of time scales, types of decisions and kinds of information upon which to base decisions;
- the data used at each level differs in terms of detail, accuracy, and degree of aggregation and spatial referencing.

Support for the idea that a series of distinct (but linked) models are preferable in such a situation is found in hierarchical production planning literature.

HIERARCHICAL PLANNING

Integrated forest management planning can be described as a hierarchical production planning problem since all decision-making levels are involved and the goals of the process are related to the production of goods, services and values (eg. timber, wildlife habitat, recreational opportunities). According to Hax and Candea (1984), a hierarchical approach is necessary to integrate the strategic, tactical and operational components of a complex production system since it "recognizes the distinct characteristics of the type of management participation, the scope of the decision, the level of aggregation of the required information, and the time framework in which the decision is to be made". In their opinion, attempting "to deal with all these decisions simultaneously, via a single monolithic system or model" would be "a serious mistake" since it would not meet the needs of each management level and would prevent interactions between the levels.

Although there is some evidence that single models can be used to integrate some parts of the forest management planning process (Nitaya, 1996), it would be wrong to try to address the entire problem in this way. When describing the general nature of the decision support tools that would be needed to address the hierarchical production problem, Hax and Candea suggest that an integrated approach is necessary to avoid suboptimization, but that the problem must be decomposed and these decomposed subproblems must be addressed at the appropriate organizational level before an overall solution can be found. As Vollman et al. (1984) state, hierarchical production planning is based upon the premise that product aggregations should be matched to decision-making levels.

Hierarchical planning proponents also suggest that an iterative approach is necessary: once the overall problem is decomposed, the subproblems can be solved, but these solutions must be linked and constrained by one another (Bitran and Hax, 1977). In the words of Hax and Candea, "decisions made at higher levels provide constraints for lower level decision-making: in turn, detailed decisions provide the feedback to evaluate the quality of aggregate decision-making". It should not be forgotten, as well, that many of these linkages must be made between different sets of decision-makers at the same level of the planning hierarchy. An example of this in forest management planning might be where operational planners and wildlife managers must work together to ensure that blocking patterns are both operationally feasible and biologically acceptable.

Given that each of the subproblems has its own set of goals and constraints, and that the solution of one subproblem will constrain others, it is necessary to be able to conduct trade-off analyses between solution sets. In a large, integrated forest management plan, it is not enough to simply pass down constraints to lower levels of planning: it is also necessary to study the effects of each plan on the others in the hierarchy and, where necessary, make decisions concerning the achievement of each plan's goals relative to the achievement of others. A good example of trade-off analysis between planning levels is provided by Nitaya (1996), who studied the relationships between long-term harvest scheduling and short-term wood procurement.

The purpose of this paper is to propose a design for a decision support system (or system of systems), based upon hierarchical planning principles, that could be used to enhance integrated forest management processes.

PREVIOUS DESIGNS

There have been previous endeavours aimed at producing IFMS designs for the Canadian decision environment. MacDonald, in his 1991 report, described several systems that were at various stages of development at that time and that purported to be integrated forest management systems. Although the descriptions of the projects were not extensive (or entirely correct), his report does provide an overview of the approaches being taken. One of these projects, described in a IUFRO paper by Jamnick and Robak (1992) forms the basis of the design that will be presented here. However, before proposing an IFMS design that could be used by Canadian forest products companies, I will first briefly describe an integrated management system developed for an organization in Thailand.

The Integrated Plantation Management System (IPMS) for the Forest Industry Organization of Thailand (FIO) has been previously described more fully in Robak (1992) and Robak (1995). What I would like to focus on here is the management environment in which it works, and to show how a distinctly different decision environment has resulted in significant design differences.

FIO is a state corporation responsible for the management of 133 forest plantations located throughout Thailand. Teak (Tectona grandis) is the primary species grown in the Northern Division plantations, while Eucalyptus (Eucalyptus camaldulensis, primarily for pulp) and Para (Hevea brasiliensis, for latex and timber production) are predominant in plantations in the Northeast and Southern regions respectively.

Each forest plantation is administered by a separate management structure and both the plantation and the organization that work on it are referred to as a "Plantation Unit". Each Plantation Unit usually consists of twenty to thirty blocks of approximately 160 hectares of forest plantation. Each of these blocks usually represents a single species planted in a particular year on a contiguous piece of land. Management personnel know these blocks very well and, although there is some movement of the management personnel between plantation units, the management structure is generally quite stable. For this reason, and because all plantations are mapped (manually) and there is no real need for GIS technology.

Plantations units are administered by one of the three regional divisions of FIO. Many of the operational policies are set at that level, and the divisions monitor operating budgets and results very closely. However, the operational planning is primarily undertaken at the Plantation Unit level.

Strategic planning, on the other hand, is principally carried out at the corporate level, with some input from the divisions. The strategic forest management planning is essentially concerned with harvest scheduling and plantation investment.

An interesting characteristic of FIO's decision environment is that there does not appear to be a great need, at this time, for tactical-level forest planning. Given the relatively small number of blocks (fewer than four thousand), harvest scheduling can be block specific: no stratification is required. As well, since the plantations are only now beginning to produce a small amount of timber, the optimum allocation of this supply is not considered an important problem. Therefore, once the strategic forest development plan has been completed, it can be fed directly into the operational planning process where the managers are able to check the validity of the strategic plan and provide feedback directly to the corporate planning office.

At this time, most major decisions regarding plantation management are either made at the Plantation Unit level (with respect to short-term planning and day-to-day management), or at the corporate level (strategic planning, policy development and investment analysis). Regional-level decisions are either not complex enough to warrant the use of more elegant software, or can be handled by the strategic level software since it is possible to use it to undertake regional level strategic planning.

It is unlikely that this process will be considered acceptable once the plantations begin producing more products and it becomes necessary to efficiently allocate products to the markets on a regional basis. In fact, it is quite likely that the divisions will insist upon some intermediate level intervention as soon as they realize that the new strategic/operational planning process has usurped much of their own traditional decision-making authority. At such a time, it is likely that tactical-level tools will be required for multi-year resource allocation and investment planning.

In any case, the current decision environment has resulted in an integrated system that focuses on decision processes related to long-term planning and operational planning (along with some medium-term planning related to capital budgeting). As described in Robak (1995), besides the forest inventory system (FIS), the major models required are PIPM (a harvest scheduler), OP-PLAN (for operational planning and budgeting) and CTS (for operations monitoring). GIS technology is unnecessary since most spatially-oriented decision-making is currently undertaken at the Plantation Unit level where hand-drawn maps and managers' knowledge of the land is considered adequate.

Although the IPMS is quite adequate for FIO's current needs, it is apparent that the design of their system would be inadequate for the Canadian decision environment. The main deficiencies of the IPMS in this regard are that:

1) There are no strategic/tactical level tools which would facilitate the creation of blocks and their scheduling over some intermediate time period. In other words, the IPMS ignores the need for spatial disaggregation that must be undertaken when working with extensive natural forests, and the spatial constraints that modern landscape management requires.

2) There are no tactical/operational level tools which would be needed for multi-year operations planning. The operations managers of an integrated forest products company in Canada might be required to design operations that entail several harvesting systems producing many products from many blocks in order to satisfy the requirements of several mills and external markets. At the same time, these operations must satisfy the constraints and objectives set by the strategic and tactical level plans. This is a complex decision process that impacts directly on the profitability of an organization and the viability of the strategic and tactical plans.

If we look at Jamnick and Robak's (1992) paper, it must be recognized that the multi-year planning needs of Canadian forest products companies are not well addressed by the IFMS design presented there. Although OP-PLAN can be used in a multi-year mode, it is cumbersome when confronted with a large number of blocks and complex mill requirements. The following design takes that flaw into account, as well as addresses some other issues that were not well addressed in the 1992 design.

PROPOSED DESIGN

Building and expanding on that previous design, the following are the primary elements of an IFMS that should address the primary forest management planning needs of companies that must work the Canadian decision environment (Figure 1):

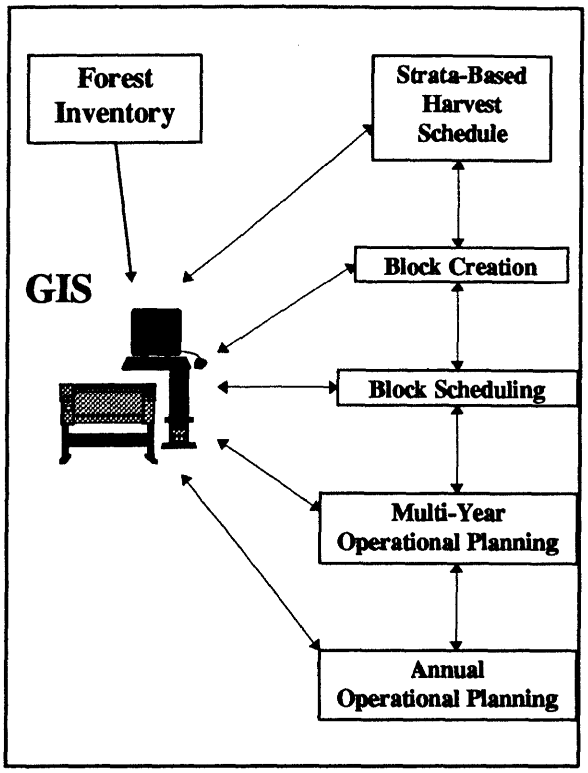

Figure 1: Overview of the Integrated Forest Management Planning System

1) Strategic Planning - The strategic plan should describe the timing and nature of all actions (interventions) that must be undertaken on specific forest types in order to achieve the strategic objective(s) of the organization, while respecting constraints set by the government or the company's own policies. Besides ensuring the sustainability of timber resources, the "harvest scheduling" process should be able to address other values and concerns, primarily those related to long-term ecosystem management, economic objectives and community stability. In other words, the long-term planning process should be able to plan for and document the environmental, economic and social sustainability called for by the "green certification" programs that are currently being established by various national and international bodies. As such, the tools that are used for strategic planning should be able to identify trade-offs among objectives in a multi-objective decision environment. Multiple criteria decision making (MCDM) optimization techniques should probably be employed in order to generate feasible, non-inferior alternatives that would be used to analyze trade-offs between objectives at the strategic level or between objectives at the strategic level and lower levels of planning (see Nitaya, 1996, for an application of this technique and reference to other literature on this subject).

   As well, although the models used may be primarily aspatial, they should be able to handle some spatial referencing. In other words, although the strategic level may primarily focus on aggregated and aspatial information, it may also require that some parameters (related to wildlife habitat or community-level employment stability, for example) may need to be constrained.

   Furthermore, it should be possible to easily restratify the forest and develop (or modify) various yield curves "on the fly" in order to facilitate sensitivity and trade-off analyses. Such restratification may be based upon spatial or aspatial economic, biological or social parameters. For example, some stands that might theoretically provide habitat may not be large enough or may be too close or too far from important landform features such as inhabited areas or water-ways. In other situations, revenue and cost curves may be derived from current cost information (implying linkages to operational monitoring systems) or lower levels of planning (implying that these curves will be developed after one iteration of the planning process) and the result may be that some stands will be removed from the analysis for economic reasons.

2) Block creation is the process of aggregating stands into units that can be considered to have similar or compatible characteristics with respect to operational and silvicultural criteria. As well, of course, the aggregation process should ensure (as much as is possible) that all stands in a block should be eligible for the same interventions in the same time periods (as prescribed in the strategic plan). However, the process should allow for some discretion regarding how much flexibility will be allowed in the block creation rules and the results of the process should be able to be easily compared to the results of the strategic plan. If the strategic plan is very stringently followed, the blocks that are created may make it difficult to or

impossible to develop an acceptable operational level plan. On the other hand, two much flexibility in the rules will result in too great a deviation from the strategic plan, thereby resulting in a decrease in the achievement of the strategic objective(s) or the decoupling of the strategic plan from lower levels (tactical and operational) of planning.

Two stand creation tools that have been developed are described in Baskent and Jordan (1991) and Walters (1991). Although the approaches and usage contexts of each of these tools differs somewhat, their goals are similar: to produce blocks from stands in order to tie the strategic and operational planning levels together. Neither of these tools is completely satisfactory, however. The ability to include operational and landscape management constraints could be strengthened. As well, to my knowledge, neither of these tools is able to incorporate partial stands in blocks without direct human intervention (an onerous task, given the huge number of stands that must be considered). Blocks that follow stand boundaries exactly may not be operationally feasible or may be unacceptable for landscape management reasons (such as those related to wildlife habitat or visual impact maintenance). The ability to modify stand boundaries (automatically or through facilitated human intervention) would be an important improvement to the IFMS design described in Jamnick and Robak (1992).

3) The scheduling of blocks ensures that landscape management, operational and market demand issues are spatially addressed in the medium term, or at the strategic/tactical level of planning. Specific issues that must be dealt with include wildlife habitat requirements (location and size of contiguous habitat, migration corridors), aesthetics, and the location of operations over time (for infrastructure and community stability reasons). At the same time, blocking schedules must be related to the strategic plan to ensure that they adhere to the strategic objectives. Although some of these requirements might be met (initially) at the block creation level, it is quite likely that the large number of blocks that are created and spatial constraints that must be satisfied will require that block scheduling be a separate, though linked process. The block scheduling tool described in Jamnick and Robak (1992) used a Monte-Carlo simulation approach, but the availability of more powerful computers and mixed integer programming solvers may mean that optimization could now be applied to the problem.

4) Once the block scheduling process has been carried out, it is necessary to produce operating plans that use the blocks from the first few years of this schedule. Such operating plans must be implementable, must normally fulfill mill requirements (from short and medium-term market forecasts), and must do so with the objective of maximizing profits for the organization. Multi-year operational planning (or tactical/operational planning) was not properly addressed in the IFMS design described by Jamnick and Robak. At this level of planning, it is necessary to choose:

- what harvesting systems should be used in which blocks in which seasons of which years, given that different systems have different costs, production capabilities, silvicultural and road requirements;
- what products should be produced in which blocks and transported by which transportation systems to which mills or buyers;
- what equipment should be purchased or contracted in which years;
- where should tertiary, secondary and main roads be built in which years;
- what silvicultural activities should be undertaken in which blocks in which years.

Such a multi-year planning tool would obtain the first period blocks from the block scheduler (through the GIS). The GIS should also be used to help to produce road location and block -to-mill distances. Another paper at this conference (Oborn, 1996) describes the Tactical Operational Planning Model which has been designed to produce optimum multi-year operational plans. It should be recognized that the plan that results from the use of TOPM must be fed back to higher levels of planning to ensure that strategic and strategic/tactical objectives are still met (and to validate the assumptions of the higher level plans). Furthermore, the results of the plan should be modeled by the GIS so that managers can visually verify the feasibility of the plan (and adherence to near-term landscape management objectives).

5) Since the optimum multi-year plan includes most of the decisions related to the annual planning, the annual operational planning process can concentrate on very short term scheduling, implementation, and budgeting issues. The OP-PLAN model (Robak, 1989) has many of these capabilities, but it should be improved by:

   - linking it to the multi-year planning tool so that the data does not need to be re-entered;
   - improving its scheduling algorithms so that managers can more quickly develop feasible harvesting and mill delivery schedules;
   - linking it to GIS so that plan implementability can be more easily verified.

The IFMS proposed for the problem environment described is more than a set of tools: it includes the procedures and processes that ensure that the best possible decisions are made. Two related concepts, iteration and trade-off analysis, should be applied to ensure the formulation of well-integrated, robust plans.

An iterative approach is necessary for understanding the complex forest management planning problem (and the inherent relationships among its component plans) and for generating alternative solutions that satisfy objectives and constraints at all levels. This requires that managers undertake sensitivity analyses of the impacts of decisions at one planning level on all the others. Stratification strategies at the strategic planning level, for example, may constrain tactical and operational plans in a way that could not be foreseen at the initial stage. Similarly, basic assumptions used at an upper planning level (regarding costs, for instance), may be found to be false once lower level plans are developed, and this information should be fed back up to be used as the basis of new upper-level planning.

Trade-off analyses, which assume an iterative approach, are used to produce best compromise solutions when multiple, competing goals must be satisfied. Since the performance measures for these conflicting goals are not always compatible, an optimal solution cannot always be found. For example, an organization must have to decide questions like "How much should we give up in terms of sustainable long-term harvest levels in order to increase profits over the short term?".

The application of an iterative approach and trade-off analyses are necessary because the objectives are different at the planning levels, but also because the decision-makers at various planning levels are usually themselves different managers from different levels of organizational hierarchy. Therefore, an iterative approach and trade-off analyses are used to support the negotiations that must be undertaken before an acceptable and implementable integrated plan can be produced.

IFMS SUPPORT

In order to support the above-mentioned models and approaches, it will be necessary to have a well-integrated GIS and forest inventory system incorporated in the IFMS design.

The forest inventory system should include data that describes the forest according to criteria related to the requirements of all planning levels: stand dynamics, habitat suitability, operability, wood product characteristics, other forest values and so on. The inventory database should be a multi-layered system that includes information from photo-interpreted data, permanent sample plots and operational cruises, with information from each level updating and verifying the information at other levels. Permanent sample plot information should be used to regularly validate and improve yield curves. Furthermore, scaling information should be linked to the inventory system in such a way that the data it contains regarding product yields will be automatically (or semi-automatically) updated and improved over time. The structure of the databases should be flexible enough to support restratification of the forest and spatial modelling requirements on an as-needed basis.

The linkages between the GIS and the tools used at the various planning levels will need to be very strong since:

- the GIS would be the repository or "coordinator" of all physical data that is required by those tools;
- the GIS would be used to generate much of the secondary data (distances, overlays, spatial relationships) required by models;
- managers would want to view the results of any plan on a map to verify implementability

and to help them generate new modelling approaches.

Given the complexity of the overall management planning process and the iterative approach that should be used, the ability of managers to verify results and generate new planning approaches before passing plans to the next planning level is an important one. Managers at each planning level would want to visually check the plans that are passed down to them from higher levels and the results of their own planning efforts. This would include such things as the visual analysis of the overall period/strata schema at the strategic level, the blocking patterns for landscape management purposes at the tactical level, and implementability issues at the operational level.

CONCLUSIONS

A design and approach such as the one described should help managers of forest products companies improve their strategic, tactical and operational level planning. Besides enabling managers to understand the forest management problem more completely, it should help them generate alternatives and best compromise solutions to large, multi-objective forest management planning environment. Most of the tools that are required to support this process currently exist, although some adaptations and improvements may need to be made.

Although the proposed IFMS design has not yet been implemented by an actual forest products company, it has been tested in a "realistic" case study in a forest management practicum involving senior forest ecosystem management and forest engineering students at the University of New Brunswick. The course requires that an entire class of students develops an integrated forest management plan for a fictitious forest products company on an actual land base in New Brunswick. The students have used an IFMS similar to the one described above to better understand planning processes and the relationships between decisions made at the various levels of planning.

LITERATURE CITED

Baskent, E.Z. and G.A. Jordan. 1991. "Spatial Wood Supply Modelling," *The Forestry Chronicle*, Vol. 67, No. 6, December, pp. 610-621.

Bitran, G.E. and A.C. Hax. 1977. "On the Design of Hierarchical Production Planning Systems," *Decision Sciences*, Vol. 8, No.1, January, pp. 28-54.

Buckman, R.E. 1990. "Global Forestry Research: Closing of the First Century, Preparing for the Second," IUFRO World Congress Report, Montreal, August, pp. 53-54.

Buongiorno, J. and J.K. Gilless. 1986. Forest Management and Economics. Macmillan Publishing Company, New York, 285 pp.

Hax, A.C. and D. Candea. 1984. *Production and Inventory Management*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 513 pp.

Jamnick, M.S. and E.W. Robak. 1992. "An Integrated Forestry Planning System," Proceedings of S3.04.01 IUFRO Conference, Christchurch, New Zealand, Jan 27-31, 1992, pp. 17-25.

Kent, B., Hof, J. and L. Joyce. 1988. "Experiences with FORPLAN: A Distillation to Two Proceedings from a Research Perspective," Proceedings of the 1988 Symposium on Systems Analysis in Forest Resources, Pacific Grove, California. U.S. Forest Service General Technical Report RM-161.

Kiil, A.D. 1989. "Welcome," Proceedings of the Forest Modelling Symposium, Saskatoon, March, Information Report NOR-X-308, pp. 2-4.

Lund, H.G. 1991. "Integrated Data Collection - A Challenge for the Future," Proceedings of the Symposium on Integrated Forest Management Information Systems, Tsukuba, Japan, October, pp. 1-10.

MacDonald, J. 1991. Review of Proposals for Forest Management Activities in Canada. Unpublished Interim Report for the Forest Engineering Institute of Canada, December, 23 pp.

Nitaya, K. 1996. *Integration of Long-Term Harvest Schedule and Short-Term Wood Procurement Decisions.* Ph.D. Dissertation, University of New Brunswick (In Print)

Oborn, R.M. 1996. "A Mixed-Integer Programming Model for Tactical Forest Operations Planning," To be published in the proceedings of the joint meeting of the Council on Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, Michigan.

Robak, E.W. 1989. "Integrated operational planning: an OP-PLAN update," Proceedings of the IUFRO Subject Group 3.04 Executive Committee Meeting (Vol.II), Wageningen, Netherlands, May, pp. 37-46.

Robak, E.W. 1992. "FIO Plantation Planning System Project Proposal," Proceedings of S3.04.01 IUFRO Conference, Christchurch, New Zealand, Jan 27-31, 1992, pp. 195-206.

Robak, E.W. 1995. "The FIO Plantation Management System Project Proposal," Proceedings of S3.04.01 sessions at the 1995 IUFRO World Congress, Tampere, Finland (In Print).

Vollman, T.E., Berry, W.L. and D.C. Whybark. 1984. *Manufacturing Planning and Control Systems*, Richard d. Irwin, Inc., Homewood, Illinois. 745 pp.

Walters, K.W. 1991. *Spatial and temporal allocation of strata-based timber harvest schedules*. MScF Thesis, Univ. of New Brunswick, Fredericton. 102 pp.

QUALITY-BASED WOOD PROCUREMENT PLANNING AND INDUSTRIAL END-USE OF ABSTRACT WOOD[1]

by

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ABSTRACT: The paper deals with methods and procedures that are used in Finland in wood procurement to steer the raw material to the right industrial process according to its quality. This implies accurate and up-to-date information on the stands to be harvested or the quality characteristic of the raw material to be bought from outside.

Customer-oriented quality-based wood procurement means that the wood is measured, cross-cut into the appropriate lengths in harvesting, transported as soon and as fresh as possible to the mill and used for the process that maximizes the value of raw material.

There are several methods to carry out the pre-measurement of stands and the necessary calculations to find out the quality distributions of timber. These distributions, together with the demand of different dimensions of sawn timber, are used to create a value table that is then used in the shortwood harvester to actually cross-cut the trees into the appropriate lengths for sawing.

In a self-employed forest owner's sawtimber harvesting operations a so called A,B,C quality classification scheme is used. The measurements are carried out at the sawmill with an automatic measurement device.

The quality and freshness have become more and more important for the pulp and paper industry as well. The pulpwood is classified according to the dimensions and freshness and steered then to the most appropriate product line (e.g., mechanical pulp or chemical pulp).

Key Words: wood procurement, quality, cross-cutting, measurement, harvesting, transporation

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INTRODUCTION

Quality is a word that is used more and more frequently when the development needs of industrial products are discussed. It is believed that higher quality products also bring a better quality of life. Forest industry and forest products are not an exception. On the contrary, because vast areas are used for timber and wood fiber production, special attention must be paid to sound environmental practices when harvesting timber crops. Other basic quality factors should not be endangered either. Wood is a versatile material that can be converted into many high quality products if only wood properties, conversion processes, and customer needs are known.

To properly steer the wood procurement process according to these requirements is a challenging task for woodland management. An additional contemporary problem is that customers start to require quality certificates or standards of the forest operations as well. The technical quality requirements will be discussed in more detail within this paper.

MODERN WOOD PROCUREMENT PLANNING

Wood procurement is a logistic process that has the following key elements; material flow, information management, and cash flow management. An extra difficulty in Finnish conditions is that the raw material must be purchased from several hundred thousand private woodland owners. These owners have many times special requirements as far as the environment, quality and timing of operations are concerned. This makes the planning procedure rather difficult. The organization of wood procurement consists of the following activities: material purchase, planning, harvesting and transportation in addition to management and administration. Organizations usually operate on three levels; local work management, regional district management, and at a company woodland management level.

The raw material quality requirement information comes usually from themill or in a more general form from the consumer.

When planning the activities the key element to a successful operation is the right timing of all operaions to minimize the quality loss, interest cost, operational cost and manufacturing cost. The environmental factors must be borne in mind all the time.

CUSTOMER ORIENTED APPROACH

The trend in the modern European forest industry is more and more towards the customer products. There are fewer and fewer such bulk products that may be picked "directly from the shelf". This is true for sawn goods and recently also for wood fiber products.

The sawmill companies plan their sawing production according to the customer orders. Very rarely is sawn timber produced for stock to be sold later. All the products should have a known final end-use before they are produced. This is important especially for non-integrated smaller producers that frequently have problems with byproducts such as pulp chips.

The market pulp sale has stayed level although the pulp production has doubled within the past two decades. Market pulp currently comprises only 7 percent of the 10.5 million tons of pulp produced per year. This means that companies produce special pulps for their own high-grade customer products.

Information needs

It is clear that the above mentioned customer-oriented approach sets strict requirements for the raw material information to be used for various products. The sawmill should know in advance what kind of raw material it gets from a particular stand if it is purchased. The companies apply procedures that have been developed for this purpose at the universities and research institutes.

Similarly, the pulpwood characteristics should be known in addition to the freshness that must be maintained all the time. This information is kept in the files that are monitored by the harvesting and transportation scheduling programs.

PRE-MEASUREMENTS

When gathering information from sawtimber stands, some sort of clever sampling procedure and calculation method needs to be developed for predicting the quality of timber. In Jori Uusitalos' dissertation project, this sort of procedure was developed. The basic aim is to maximize the reliability while minimizing the information needed and the cost involved. Uusitalo uses the logistic regression models with Weibull distributions to reach the goal. This information is then used to develop value tables for harvesting machine operation on a particular stand. A value table combines the on stand characteristic information with the distribution of customer product dimensions to be produced into an operable form when harvesting timber.

The same kind of information can be gathered at the sawmill by using an automatic measurement device and a so-called "A,B, C classification scheme". The cross-cutting optimization is not possible, however, since it is already done according to the more or less permanent cross-cutting rules.

WOOD QUALITY PARAMETERS

Mechanical forest industry

In the Nordic conditions the quality parameters for pine in most cases are diameter breast height DBH, dead branch height, crown height, the early growth rate, tree height, and tapering that predict the quality of sawn timber from a tree. Uusitalo found that the first three parameters are the most significant. From these parameters it is possible to develop a premeasurement scheme that can be used for more accurate prediction of quality. This work is being done at the moment. The other species and mixture of various species will be handled in successive studies.

Chemical forest industry

The thermomechanical pulp process requires fresh wood so that the following paper quality requirements are met.

1) Good strength properties.
2) Good formation, high smoothness, low porosity and high opacity.
3) Low fiber coarseness.
4) High brightness.
5) Sufficient proportion of long fibers to minimize reinforcement.

The wood quality characteristics affecting the above mentioned properties are: basic density, extent of decay, fiber morphology, moisture content, chip size distribution, branch and knot wood, inner and outer bark, sapwood and heart wood, mature and juvenile wood, chemical composition and wood extractives, earlywood and latewood, and impurities such as sand (Tyrväinen 1995).

In wood procurement, the factors that are harmful should be minimized. Such factors are, for instance, the volume of decayed, overaged, and dry wood. Selection of stands having high basic density should be steered to mechanical pulping where the high debarking grade is important.

The procurement process needs to planned and carried out so that the wood does not get in contact with sand or other impurities.

The quality requirements for chemical pulp used for high grade printing and writing papers are also becoming more strict. Low quality knotty, dry softwood pulpwood may yield 20 percent less pulp than high quality wood. Decayed wood is not allowed. It is important to maintain the fiber length distribution in the chip flow also. This means that the mill has to maintain several chip piles containing different quality chips.

The most important factor affecting procurement is the freshness of wood. As shown in Figures 1 and 2, winter harvesting and transportation gives more freedom than summer harvesting when the wood deliveries must be completed within a week for mechanical pulp and within three months for chemical pulp. The industry tries to apply even more tight schedules, especially during the winter time, even though such need from the quality point of view does not exist.

HARVESTING AND TRANSPOR-TATION SCHEDULING

Wood procurement scheduling relies on optimization of activities. The most important part of this is the optimization of transportation. The scheduled cutting and transportation programs must be integrated to consider supplies coming from company lands as well as wood purchased from private forests.

In this system, the location data of the woodlots that has been cut are fed into a computerized database. The optimization program allocates the wood coming from different geographical districts to the appropriate mills, recognizing demands they have to fulfill.

In the next phase, the weekly pick-up program is created for the trucks. Global positioning systems (GPS) are used to find the location of the piles. The pick-up program schedules the arrival of the trucks to the mills. This means that an individual truck gets its transportation program for the week in the beginning of the week.

Stock level and route optimization options are also included in the program packages. The overall goal is to increase vehicle use and minimize the interest cost of tied-up capital in stocks and standing timber.

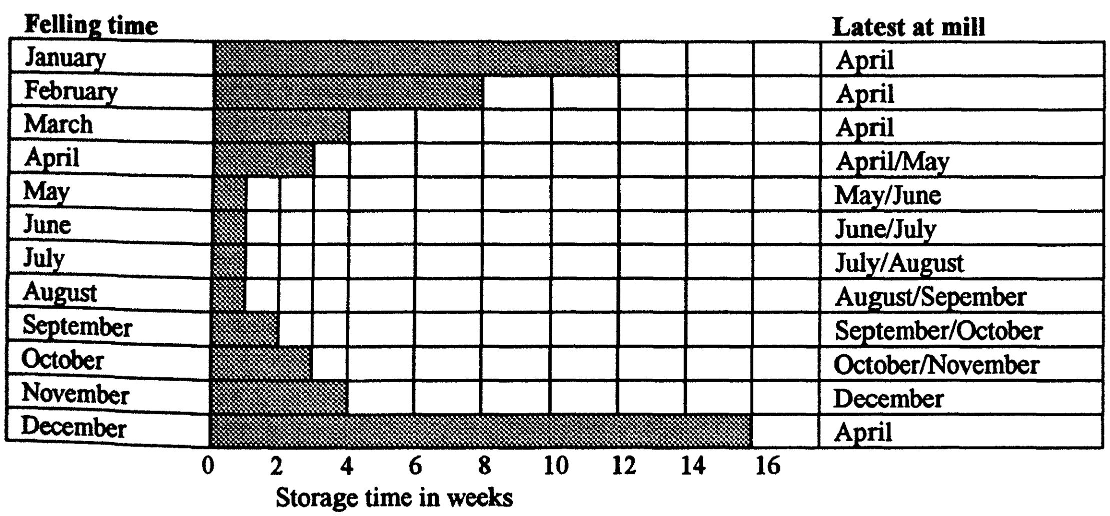

Figure 1. The freshness calendar for mechanical pulpwood in Nordic conditions.

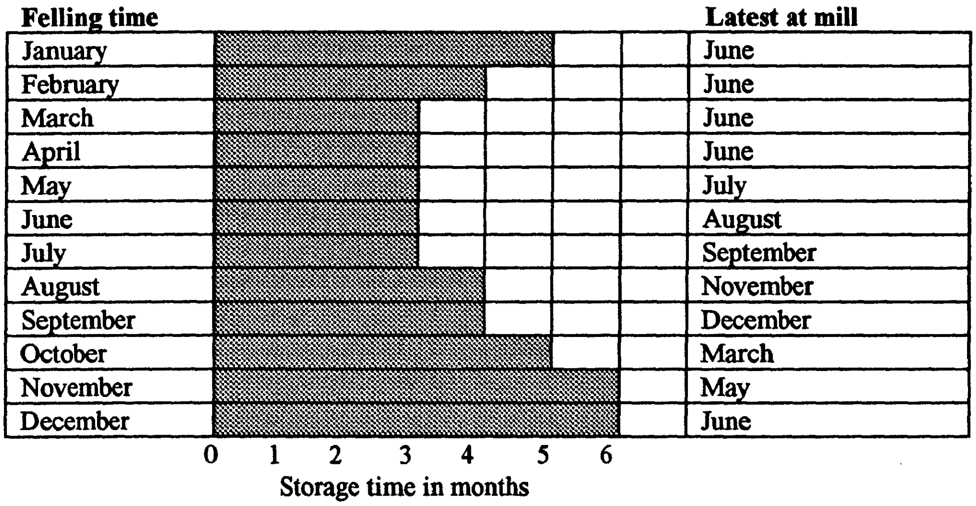

Figure 2. The freshness calendar for chemical pulpwood in Nordic conditions.

DISCUSSION

The quality-based wood procurement concept has been around for few years in big companies. It is gaining ground also in smaller companies, especially within the sawmilling industry. They can cut their operating costs dramatically by applying modern computer technology and the just-in-time principle in planning the operations.

There are, however, difficulties that must be overcome before the operations run smoothly. Probably the most difficult ones are the educational levels and attitudes of the personnel and frequently the quite high initial investment compared to turnover of the enterprise. One additional obstacle of some companies is their limited product palette which makes it difficult to fully attain all of the benefits.

LITERATURE CITED

Anonymous. 1995. Profitable Harvesting. The Finnish Foreign Trade Association. Helsinki.

Anonymous. 1996. Quality handbook of Metsä-Rauma pulp mill (in Finnish). Rauma.

Hakkila, P. 1995. Procurement of Timber for the Finnish Forest Industries. The Finnish Forest Research Institute. Research papers 557. Helsinki.

Rummukainen, A., Alanne, H. and Mikkonen, E. 1995. Wood Procurement in the Pressure of Change - Resource Evaluation Model till Year 2010. Acta Forestalia Fennica 248. Helsinki.

Uusitalo, J. 1995. Pre-harvest Measurement of Pine Stands for Sawing Production Planning. University of Helsinki. Department of Forest Resource Management Publications 9. Helsinki.

Tyrväinen, J. 1995. Wood and Fiber Properties of Norway Spruce and Its Suitability for Thermomechanical Pulping. Acta Forestalia Fennica 249. Helsinki

BUSINESS PROCESS IMPROVEMENT: THE KEY TO SATISFIED CUSTOMERS AND COST REDUCTION[1]

by

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ABSTRACT: Business Process Improvement (BPI) is a concept with great potential in forestry. SkogForsk has experience with BPI-projects in small and large forestry enterprises, covering objectives such as reduced costs, reduced lead time, improved flexibility and more satisfied customers. SkogForsk has developed a method that includes identification of customer demands, mapping of processes, and benchmarking. Forestry is a supplier of raw materials. There are numerous steps between the forest owner and the end-user. A considerable period can elapse between the time the forest owner sells the timber and the time at which the converted product reaches the customer. In the past we focused our attention on operations in the woods. However, by looking at the entire process that creates revenue for the forest owner and value for the customer, we can increase efficiency. Our findings so far indicate that Business Process Improvement can secure lower costs, shorter lead times, faster response to market changes and happier customers.

Key Words: business process reengineering, total quality management, benchmarking

INTRODUCTION

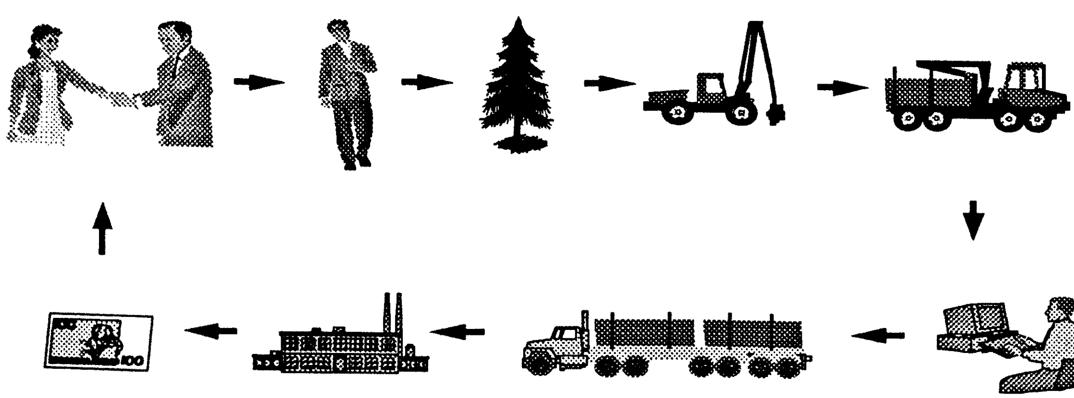
Business Process Improvement is a relatively new concept in the field of business development, has great potential as a management tool in forestry. Based primarily on the ideas put forward by H. James Harrington (Harrington, 1993), SkogForsk has developed a method of which the central elements are identification of customer requirements, mapping of processes, and benchmarking (learning from the best). Several forest enterprises in Sweden are now using the concept.

In part, the methodology is similar to that employed in everyday rationalization work and cost comparisons. The new elements relating to Business Process Improvement include:

- focusing on the customer (determining what is important to the customer),
- a holistic approach (endeavoring to span the entire chain from purchase to delivery), and
- a deeper analysis of those with whom comparisons are being made.

WHAT IS A PROCESS?

Figure 1 shows a number of events, from the purchase of timber from the private forest owner, logging, secondary transport and delivery to the mill,



Fgure 1. Examples of processes in forestry.

[1] Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

activities can be regarded as a process. Another approach is to regard each activity as a subprocess, with the activities together from purchase to final payment comprising a single process.

A process can be defined as a working method designed to produce a product or to provide a service. The process receives input from an internal or external supplier and delivers an output to an internal or external customer. Processes can be classified as main processes and support processes, as defined in Figure 2.

Main process	**The business's production and distribution process. Creates value for the customer and revenue for the business (e.g., logging and transport).**
Support process	**Meeting internal needs and requirements. Supports main processes (e.g., administration, office functions).**

Figure 2. Different types of processes.

What is Business Process Improvement?

The aim of Business Process Improvement is to increase the efficiency of the business by taking a holistic approach to it. We have put a lot of time and effort into improving individual parts of the processes in forestry, but we are perhaps less adept at taking a holistic view, looking at an entire process or the entire chain from purchase to delivery, and analyzing how the different activities contribute to the achievement of an overall satisfactory result. The wood and administration flows cut through several areas of responsibility. Naturally enough, information gets lost along the way and it is easy to lose sight of our overriding goal (of creating value for the customer and revenue for the business), as we find ourselves immersed in the everyday operational objectives. However, by studying the business processes, we can acquire a greater understanding of how the activities function and be better equipped to attain the desired end.

Business Process Improvement is to be found today under a variety of names, including.:

- Business Process Improvement,
- Business Process Reengineering (BPR),
- Process Management.

BPR is perhaps the most widely used of these.

This new management vogue originated in the United States following the 1993 publication of the book, Reengineering the Corporation (Hammer and Champy, 1993). The authors define BPR as a radical reengineering of processes in order to bring about dramatically improved results in an organization. A faithful following of the concept would involve reorganizing the business starting with a clean sheet, in other words, totally ignoring the existing organization. This is clearly an extremely radical approach and too radical in most cases. The five-step method developed by SkogForsk is more closely aligned with Business Process Improvement, which concentrates more on improving the existing organization.

A closer analysis of the business process concept usually reveals that there are several major processes in an organization. One way to gain an overview is to produce a simple business process flow chart, which shows the main processes in the business and how they are linked to each other. An example flow chart is shown in Figure 3.

Private woodlot owner → Purchase ↘
Harvesting → Delivery → Mill
Forest management ↗

Figure 3. A simple business process flow chart. The chart shows the four main processes in a forest management district.

WHICH QUALITY SYSTEMS LEAD TO SUCCESS?

Satisfied customers constitute a key strategic goal in all businesses. In the end, it is the customers who finance the entire enterprise. It is also naturally important to keep costs down, so that the business is competitive and able to survive downturns in the market.

Before we take a closer look at Business Process Improvement, it is worthwhile examining the approaches that can lead to the success of a business internationally. A few years ago, the International Academy for Quality commissioned Ernst and Young to conduct a scientific study of the link between quality and success. Interim findings of this study were presented at a conference in May 1995 (Harrington, 1995). The study took three years to complete and covered 500 companies in Japan (representing Asia), Germany (representing Europe), the United States and Canada. The study material was broken down by profitability, productivity and quality (customer satisfaction). After statistical processing of the results, it was established that the following approaches are effective in all types of business:

- top management is involved,
- cycle time analysis,
- process value analysis, and
- process simplification.

Thus, three of the four approaches are directly concerned with the business processes. In conclusion, therefore, Business Process Improvement should make an important contribution to the task of making the business more competitive.

BUSINESS PROCESS IMPROVEMENT METHODOLOGY

Let's look at the five-step method of Business Process Improvement developed by SkogForsk, which has now been used by several forest enterprises in Sweden (Figure 4).

Step 1. Organize the project

1. Ideally, a corporate vision or strategic plan for the business should first be drawn up, involving all the employees. The purpose of this is to firmly implant the idea of change into the business culture and to create a high level of awareness among all employees of the business's strategic success factors.

2. Select the process to be improved (usually one of the main processes)

3. Sell the project idea to senior management.

4. Set up an interfunctional project group of key individuals from the functions and personnel categories affected.

5. Draw up a project plan.

6. Inform personnel, contractors, etc., likely to be affected by the project.

Step 2. Map the process

1. Map the process. Suppliers, affected personnel and customers should be interviewed.

2. Define and structure customer requirements on the process.

3. Produce a flow chart of the process.

The flow chart should show which activities are included, which function or personnel category is involved in each activity and how the flow proceeds. An example flow chart is shown in Figure 5.

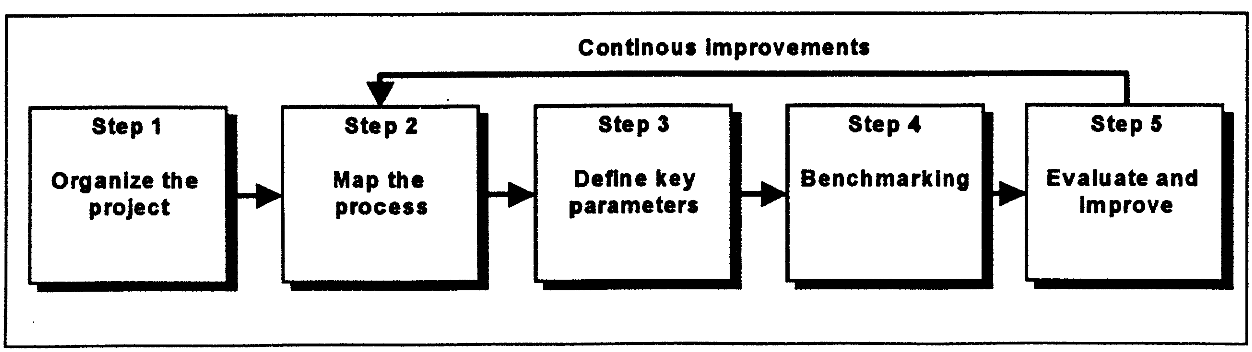


Figure 4. The five-step method of Business Process Improvement.

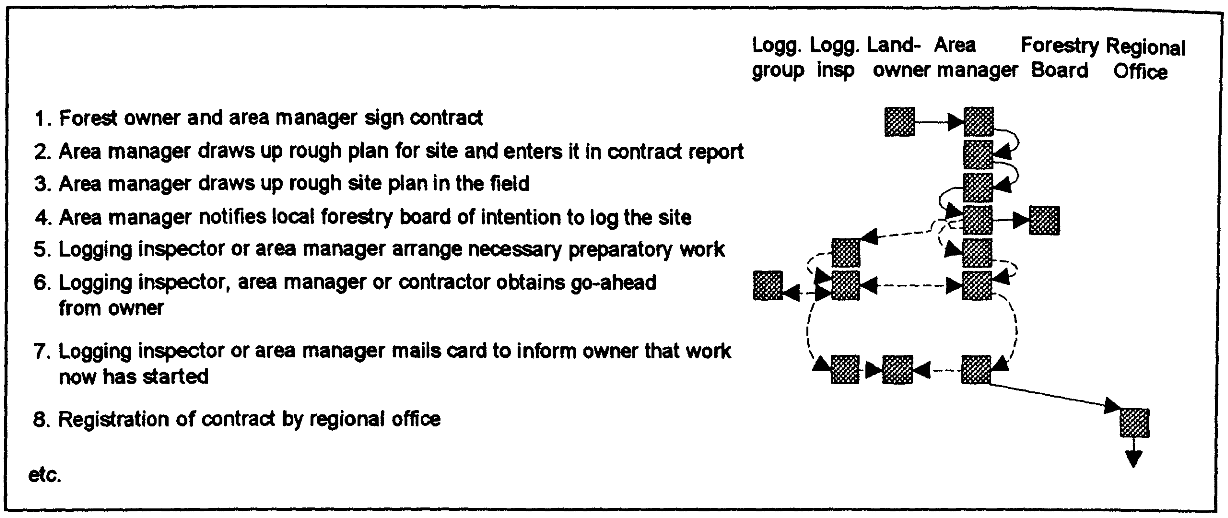


Figure 5. Flow chart example. The course of events goes from signing a contract with the forest owner to the final reporting of logging work (a total of 65 activities in the chain).

Step 3. Define key parameters

1. Focus on key factors in the process (e.g., lead times, value to customer, costs and flexibility).

2. Define key parameters that are easy to measure, monitor and compare.

Typical key parameters that can be used are:
- Lead time between activities.
- Costs and value-adding effects (revenue) from different activities.
- Productivity expressed in terms of production per employee/contractor per year.
- Delivery precision at different levels (possible indicator of how well assortment-category volumes supplied meet customer requirements).
- Number of people fully or partly responsible for each activity (measure of complexity within the organization).

Step 4. Benchmarking

1. Production of key indicators (e.g., by means of existing monitoring routines).
2. Identification of the best districts or the equivalent by use of the key parameters.
3. Comparison of the processes with the best.

4. Analysis and conclusions learning from the best.

5. Benchmarking should be carried out both internally (comparison of districts) and externally (comparison with other companies).

Step 5. Evaluate and improve

Business processes can often be improved through:
- Simplification of the processes. (Run through the processes and remove all unnecessary elements.)

- Decentralization, integration and process orientation. In practice, this often implies moving as much as possible of the operational responsibility out to the machine-based teams, collaborating more closely with suppliers and customers, and streamlining the decision-making process at all levels.

3. Improved coordination, communications and support systems.

4. Training of personnel.

PROJECTS IN PROGRESS AT SWEDISH FOREST ENTERPRISES

Several forest enterprises in Sweden have projects in progress at which the five-step method of business process improvement is being used. A summary of some selected projects is given in the Table 1.

PROJECT RESULTS

We can now present some of the results of the above projects (pilot studies, aimed at identifying potential improvements).

The five-step method of Business Process Improve-ment is of a general nature and can therefore be used in a wide context in forestry. The two examples given below concern a woodlot owner association and a timber hauling company.

The Mälarskog T50 project

The aim of the project was to identify possibilities for halving the lead time between the signing of a logging contract and receipt of the final payment. Shortening the lead time is one way to make for more satisfied association members.

During mapping of the process, from the signing of the contract through to receipt of the final payment, a number of activities were identified that could be discontinued or simplified immediately, together with others requiring further evaluation.

The internal benchmarking involved a comparison of key parameters (lead times for different activities in the chain from contract to final payment) for all ranger districts and forest management districts. The bar chart in Figure 6 shows the lead time from logging to reporting on completion for each Mälarskog forest management districts and for the fastest ranger district in the respective forest management district. The difference between the lead time of a given forest management district, and

Table 1. Sample of ongoing projects at Swedish forest enterprises

Enterprise	**Mälarskog** (a woodlot owner association)	**MoDo Skog**	**Skogsåkarna** (a hauling cooperative)	**Skogssällskapet**
Project name	Mälarskog T50	Logging-organization improvement	Future transport management	Business Process Improvement
Objective	Halving of lead time from signing of contract to final report (satisfied members)	Reduced logging costs	More efficient transport coordination (satisfied customers)	More efficient production organization
Method	Business Process Improvement	Business Process Improvement (using ABC* and advanced benchmarking)	Business Process Improvement (with in-depth customer interviews)	Business Process Improvement
Key parameters	Time	Costs	Delivery precision, optimized transport-ations, lead time	Time, costs
Focus	Time-based management**	Improved cost-effectiveness	Strategic alliances and improved logistics	Time-based management** and improved cost-effectiveness

* ABC or Activity Based Costing is a technique used to apportion joint costs to the respective activity

** Time-Based Management is the management philosophy that a business can achieve greater success if it focuses on cutting the time taken in every activity.

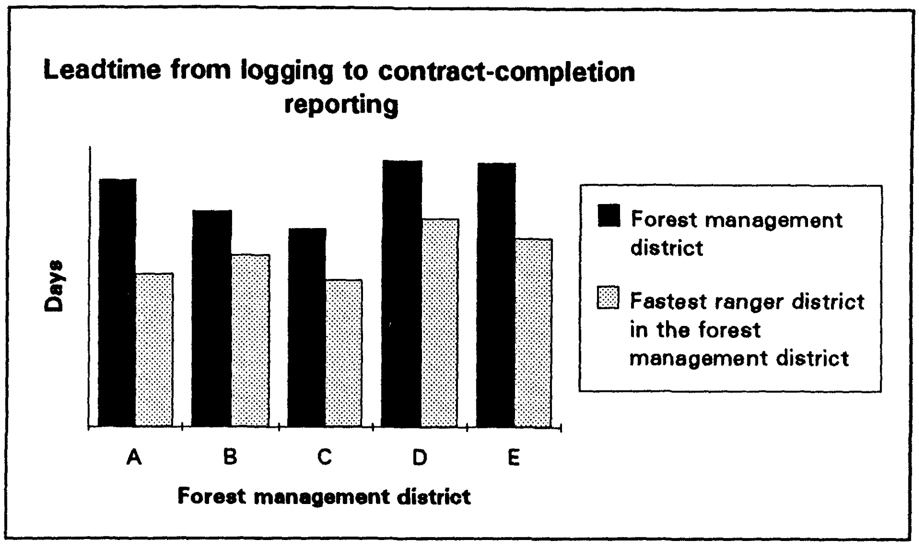


Figure 6. There is relatively wide scope for improvement in forest management district A.

the fastest ranger district within it, can be seen as the potential scope for improvement. Thus, if the methods of the ranger district having the shortest lead time in forest management district A in the chart were employed throughout that forest management district, the overall lead time could be reduced by some 30 percent. The comparisons were followed by interviews with the inspectors in the fastest ranger districts to identify the working methods used and thus learn from the best.

In the external benchmarking, the organization of the ranger districts of three woodlot owner associations were compared. We found that the work of the inspectors involved in purchasing timber and logging in the areas was organized according to one of two models (Figure 7). The first uses specialists: the area manager liaises with the forest owners, while the logging inspector liaises with contractors, etc. The second model uses generalists: the inspector drawing up the contract with the owner of the tract is in charge of all aspects of the contract up to the point at which the completion report is submitted to the owner.

Both models have their pluses and minuses. To make the right choice, an overall assessment must be made of lead times, the benefits to members, and profitability.

The project group published recommendations for future action together with a scenario for the future. The recommended action focuses on the introduction of annual benchmarking to be managed by a special quality controller. The scenario of the future describes the consequences of following strict implementation of Time Based Management. Lead times have been shortened by reducing the number of transfers of information and responsibility between units and organizational levels; by decentralization; and by relating responsibility to the flow. New information systems and IT applications make all the necessary information available for those who need it and render administration more efficient. Although the scenario is confined to the lead-time criterion, there are obviously other factors that influence a business's chances of success.

Preliminary findings from the Skogsåkarna project: future transport management

The Skogsåkarna hauling cooperative operates in four counties in central Sweden. This region offers plenty of scope for route planning and coordinated transport to minimize vehicles travelling empty. The company hauls roundwood and wood chips for several large forest enterprises. Every year it carries 6 to 7 million m^3 (solid wood inside of the bark) of roundwood, and 2 to 3 million m^3 (loose volume) of

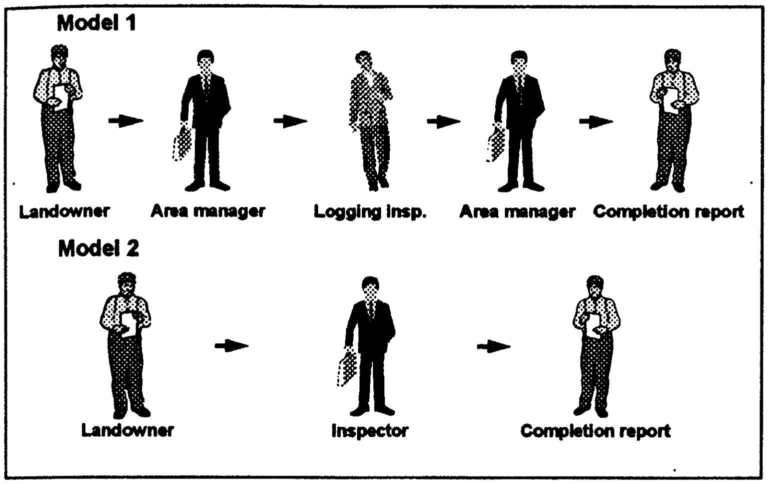


Figure 7. Two models of the organization of the work of inspectors in wood purchasing and logging.

of chips and bioenergy fuel in 15,000 to 20,000 hauling assignments. The transport fleet comprises 160 to 200 roundwood and chip vehicles. By coordinating shipments from multiple customers, and employing route planning, the company can offer an efficient fleet of vehicles with a high level of utilization. High utilization helps to reduce the cost to the customer and to give the haulers greater profit stability.

The "Future Transport Management" project is a pilot study set up to identify the potential for development aimed at improved transport coordination and increased customer satisfaction. All the customer categories are represented in the steering group, in this case, a prerequisite for a successful outcome.

Skogsåkarna can be described as a cooperative that is the result of a strategic alliance between a number of large customers (forest enterprises) on the one hand and a major trucking firm on the other. It was therefore important during the mapping of the processes to identify the hauling requirements of all the parties. To this end, searching interviews were conducted. Samples of he findings are given below.

Customer requirements vis-à-vis Skogsåkarna (The forest enterprises requirements vis-à-vis the hauling cooperative)

An organization with information technologies and communications systems able to ensure:

- High delivery precision and a steady inward flow of raw materials to the mill.
- Low costs.
- Improved route planning and reduction in empty vehicles on the road.
- Improved coordination of all material transport within a given geographical area.
- Improved quality and reliability.
- Services tailored more closely to the needs of the customers.
- High flexibility (e.g., faster rescheduling on closure of reception area at mill).

Skogsåkarna's requirements vis-à-vis the customers (The haulier cooperative requirements vis-à-vis the forest enterprises)

- Reliable shipping plans (to facilitate improved resource planning).
- Improved delivery of timber and chips to roadside.

- All large customers to introduce daily reporting on volumes extracted to roadside.

- Facility to collect from customer via data-communication system details of volume of wood stored at roadside.

- Adoption of a common standard for pinpointing the location of wood for collection, in order to facilitate coordination of loads from different customers.

Hauliers' requirements vis-à-vis Skogsåkarna or vis-à-vis the forest enterprises

- Customer requirements are conflicting (high-precision deliveries, high percentage of route planning, small storage volume and short lead times). Clearer signals needed on how to prioritize the criteria.

- Shorter lead time between identification of shortage of a given assortment at the mill and time at which transport manager informed and able to take action.

- More information on why certain quota systems are introduced by some mills

Interviews with the "best" haulers (Figure 8) revealed the following information, which should prove valuable in the continuing work aimed at improving operations. Those haulers who recorded the highest amount of transportations on optimized routes:

- Are aware of the cost-effectiveness of using planned routes.

- Have access to possible route planning/are situated advantageously.

- Have systems for route planning and collaborate with other hauliers.

- Actively seek out possible routes.

USINESS PROCESS IMPROVEMENT, THE NEW KEY TO SUCCESS IN FORESTRY?

Forestry enterprises are suppliers of raw materials, which means that the chain of activities between the forest and the final customer is a long one. A long period can elapse from the time at which the forest owner sells the standing timber to the time at which the converted timber reaches the end-user. By examining the entire process that creates revenue for the private forest owner and the forest enterprise, and value to the end-user, we can find hidden scope for improvement. Improving the processes can result in lower costs, shorter lead times, faster response to market fluctuations, and more satisifed customers.

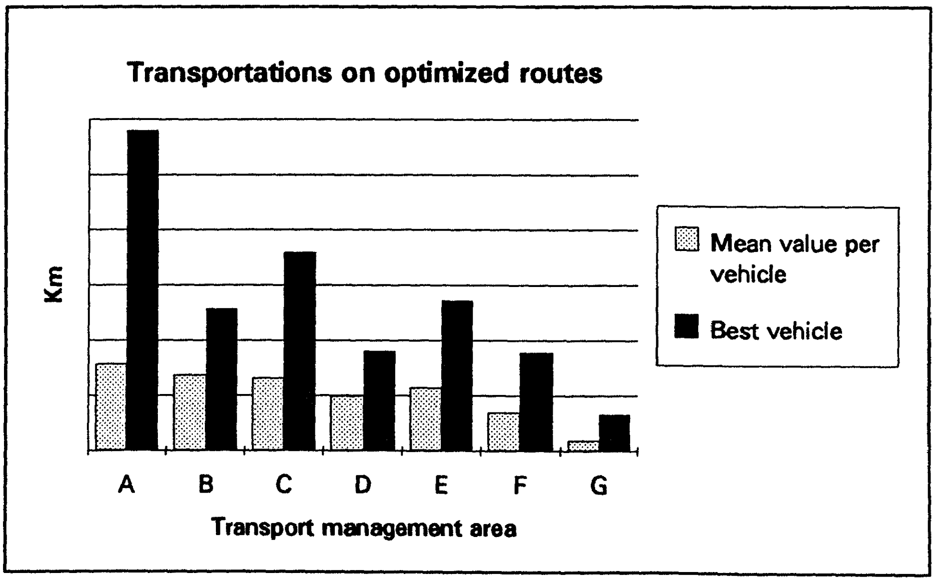


Figure 8. Findings of internal benchmarking by Skogsåkarna

Making internal and external comparisons among companies is nothing new. The new form of benchmarking perhaps differs in that there is real cooperation between the parties being compared. There is an open exchange of information, which means that both parties can benefit from the findings. Intensive efforts go into identifying and analyzing the approach and business processes that lie behind the success of the "best".

In the past, information technology projects often resulted in automation of the processes, thus perpetuating existing methods of working. By starting with process improvement, organizations can secure a higher return on their investments in information technology.

Business Process Improvement and benchmarking, combined with the possibilities opened up by modern information technology systems, will constitute vital elements in the future development of forestry.

LITERATURE CITED

Hammer, Michael; Champy, James. 1993. Reengineering the Corporation. New York: Harper Business. 240 p.

Harrington, H. James. 1991. Business Process Improvement. New York: Mc Graw-Hill. 274 p.

Harrington, H. James. 1995. An International view of what works and what doesn't work. In: Proceedings from ASQC Annual Quality Congress; 1995 May 22-25; Cincinnati, OH. ASQC, American Society for Quality Control: p. 438-447.

DETECTING MANMADE FOREST ACTIVITIES AND NATURAL DISASTERS USING LANDSAT TM SATELLITE DATA - A METHOD PRESENTED FOR CONTROLLING CONTINUOUSLY UPDATED FOREST INFORMATION IN FINLAND[1]

by

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ABSTRACT: Methodology applying multitemporal Landsat TM satellite images was presented for detecting rapid changes in forest canopy. The accuracy of the method varied from 80 to 87 percent expressed in overall percentage of correct classification. With general change classes, more accurate results were obtained compared to accurate labeling of the reason for change. The method was proposed to be used for controlling the quality of continuously updated operational forest data base. It was estimated that the costs of maintaining the accuracy of forest management data would be about one third compared to the old updating method based on repetitive base line inventories.

Key Words: remote sensing, updating, forest inventory

INTRODUCTION

Satellite remote sensing material provides promising information for different monitoring purposes. Often addressed advantages of the imagery from the nature observation satellites, such as Landsat or SPOT programs, are repetitive and cost-economic coverage of large areas. However, the available technology sets remarkable constraints to phenomena that can be observed.

The phenomena addressed have to cover large enough area and should be spectrally and radiometrically separable from its background and possible obliteration factors to became detectable from space. The effect of these limitations, when compared to accuracy of the satellite sensors, can be characterized by applying simple forest monitoring examples. With the available methodology and Landsat TM or SPOT single image acquisitions, only very large changes have been detectable. If the satellite image base line inventories are considered the standwise root mean square error volume estimation for example has varied upwards from 26 percent in boreal forest conditions (Hagner 1990). Considering the mean annual growth in Finland is about 3.8 m^3/ha, mean volume of the growing stock is 91.9 m^3/ha (Metsätilastollinen... 1995) and the typical thinning drain varies from 30 m^3/ha to 60m^3/ha the limitations of present satellite images become obvious. Under these circumstances the growth estimates, for example, are reliable only for large areas (Tomppo 1992) and/or long monitoring intervals such as 20 to 30 years. The random variation in the object covers easily the interesting phenomena or change in analyses. In many applications, such as operational forest monitoring, this has led to use of several succeeding images (i.e., multitemporal image) for improving the separability of interesting objects or changes in forest (Häme 1991, Olsson 1994, Varjo 1996a).

The problems and constraints with multitemporal analyses can be highlighted for example by calibration problems. Let us consider that the task is to control the forest damages or manmade actions for an area like the one state forest district in Finland (20,000 to 100,000 ha) applying multitemporal images. By analyzing multitemporal satellite images with 1- to 2-year intervals, the phenomena that drastically change about one third of the basal area, such as thinning or wind damage, start to become separable (Häme 1991, Olsson 1994, Varjo 1996a). However, somewhat usable accuracy in detection of the changes with this magnitude requires very good training data (Varjo 1996a, 1996b, 1996c). It can not be expected that the training data could be collected for each image pair and interval because of the high cost of field survey. As this is the case, the methods have been developed for calibrating the image pairs or difference images radiometrically comparable, i.e., eliminating the effects of varying observation conditions, for example, between the image acquisitions (Olsson 1994). Promising results have been reported from the application of relative regression calibration and studentization (Olsson 1994). It seems probable that the calibration accuracy achieved makes it possible to concentrate on detection of actual object, change in the forest (Olsson 1994, Varjo 1996b).

The introduction of continuous updating system, provided a good example of actual monitoring needs and a suitable case for developing remote sensing methods. Many organizations such as the Finnish

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Forest and Park Service, which manages all the state owned forest in Finland, have started to apply this updating method (Varjo 1996a). To fulfill today's needs of management planning and decision making, the information about forest resources has to be on-line information if possible (Varjo 1996a). This has led to establishment of forest data bases that are continuously updated by counting for growth once per growing season and by updating the forest treatments immediately after accomplishment. The accuracy of the present growth estimation in the Finnish conditions allows about 20- to 30-year intervals in growth updating without new base line inventories (Siitonen 1983). However, a risk for updating errors has been noticed especially during the transition period. The errors may be caused by undetected changes in stand delineation, human errors in updating and undetected forest damages. As one possible solution, a satellite image based control method for continuous updating was proposed (Varjo 1996a). However, operationalizing of this kind of method requires a lot of research and testing.

Many of the changes that should be detected in relation to controlling continuously-updated forest information, form difficult patterns to be detected by satellite remote sensing. Final cuttings such as clear cuts or regeneration cuts in which the drain in Finnish conditions varies from 150 to 300 m^3/ha have been detectable by several methods, starting from visual interpretation (e.g. Saukkola 1982, Häme 1991). However, many of the other treatments or damages do not change the spectral information observed by satellite sensors as radically and are thus more difficult to detect. For example, only some of the silvicultural treatments have been detectable even with multitemporal approach by comparing the spectral response before and after change applying two separate images. An obvious reason for this is the nature of the changes to be detected. For example, different thinnings affect only about one third of the growing stock and if thinning is done from below, the following spectral change is even smaller than could be estimated based on the drain. In detection of forest changes on young stands unclosed canopy causes increased problems. The spectral response from ground vegetation may obliterate the interesting change in tree canopy. This has been obvious with clearings of young stands and forest change detection on peat land where forest canopy often is unclosed (Varjo 1996c).

In addition to small and sometimes obliterated changes to be detected, the pattern shape formed by forest changes sometimes causes difficulties. The ideal approach with satellite image based change detection would be the use of pixel level approach. If the pixel sizes of Landsat TM (30 30m) or SPOT (20 20m) would allow the detection of change in forest attribute information, it also would make it possible to detect the changes in spatial delimitation of the interesting object, such as cutting or forest damage. However, the spectral variation within the interesting objects, such as cutting area, has been too wide to allow accurate pixel level change detection (Varjo and Folving 1996). These experiments have led to detection of several small-area false changes covering a couple pixels, and it has been impossible to delineate moderate changes, such as silvicultural treatments (Varjo & Folving 1996).

Due to the above mentioned problems larger observation units than pixel has been proposed. Olsson (1994) has presented suitable calibration methods for producing multitemporal material for forest change detection applying a forest stand as an observation unit. The problem with a stand as an observation unit in change detection is nonsymmetric and occasionally multimodal within stand radiometric variation on satellite images (Varjo 1996a, 1996c). This has led to the introduction of methodology in which no distribution assumptions are needed (Varjo 1996a). Good results for the forest change detection have been demonstrated based on classifying changes applying broad change classes such as 'final cuts' and 'silvicultural treatments and damages' with nonparametric Kernel discrimination (Varjo 1996a). In this paper Kernel methodology is tested with more accurate change labeling and 1- to 2-year interval between succeeding images used for forming multitemporal difference image data on mineral soil. The calibrations method proposed by Olsson (1994) is used in data production (Varjo 1996b). The achieved change detection accuracy is evaluated for controlling the quality of continuously updated operational forest data base and the economy of the proposed control is estimated in comparison with the old updating method based on repetitive base line field inventories.

MATERIAL AND METHODS

The study area was located in Hyrynsalmi (referred H) in Eastern Finland (location of the centre Long. 28°30' E, Lat. 64°30'N). The forest on the study area is typical Boreal Forest dominated by coniferous species (*Pinus sylvestris* and *Picea abies*). Only mineral soil stands were included in this study. Two data sets were composed from the study area. For training, the change analysis following categories and numbers of observations were included in the training data: untreated (Unt. 390 obs.), uncommercial thinning

(Unc. Thinn. 13 obs.), hold over removal (HO rem 4 obs.), commercial thinning (C. Thinn. 15 obs.), preparatory cut (Prep. cut 26 obs.), regeneration cut (Reg cut 13 obs.) and clear cut (28 obs). To verify the results of the method proposed, a separate test data was composed. It included 593 mineral soil stands. In addition to training purposes observations in the class 'untreated' in the training data was used for radiometric calibration purposes (Varjo 1996b).

There were three Landsat TM acquisitions available from the Hyrynsalmi test site. The track and row coordinates were 188/15 for all the quadrants and the acquisition dates were: June 21, 1990, October 10, 1992, and July 7, 1993. The images were acquired at the end of the growing season to avoid phenological differences as much as possible. In addition, there were two Landsat TM acquisitions available from the study by Varjo (1996a) in Nurmes (referred N) to be applied for comparison where test and training data are from different geographic locations.

The satellite images were registered together and rectified into the Finnish Uniform Coordinate System. The digital stand map available from the latest base line inventory was combined with satellite data. These forest stands were used as observation units. Because of the possible differences in acquisition conditions and phenologicall stage of the forest the images were brought to a radiometrically comparable level. Bandwise regression models were estimated for each image pair by explaining the standwise intensity mean of the later image by applying the standwise intensity mean an of earlier one. Untreated forest area where changes were caused only by normal growth and above mentioned differences between acquisitions were used. In the calibration, stands with possible forest damages or stands located under cloud or shadow of cloud were excluded from the data applying the principles of robust regression (Rousseeuw and Leroy 1987, Varjo 1996a). The regression models were weighted by the inverse of within stand variance in the earlier image in order to give large and homogenous stands more weight in parameter estimation (Equations 1-4) (Varjo 1996b).

$$\bar{y}^{t}_{ch3}(n) = \beta^n_0 + \beta^n_1 \bar{x}^{t-n}_{ch3} + \beta^n_2 \bar{x}^{t-n}_{ch4} + \varepsilon \qquad (1)$$

$$\bar{y}^{t}_{ch4}(n) = \beta^n_0 + \beta^n_1 \bar{x}^{t-n}_{ch4} + \beta^n_2 \bar{x}^{t-n}_{ch3} + \varepsilon \qquad (2)$$

$$\bar{y}^{t}_{ch6}(n) = \beta^n_0 + \beta^n_1 \bar{x}^{t-n}_{ch6} + \beta^n_2 \bar{x}^{t-n}_{ch4} + \varepsilon \qquad (3)$$

$$\bar{y}^{t}_{ch(i)}(n) = \beta^n_0 + \beta^n_1 \bar{x}^{t-n}_{ch(i)} + \varepsilon \qquad (4)$$

where:

β^n_p = parameters, p ε{0, 1, 2}

$\bar{y}^{t}_{ch(i)}$ = mean intensity of a stand on channel i at the moment t

$\bar{x}^{t-n}_{ch(i)}$ = mean intensity of a stand on channel I ε{1, 2, 5, 7} at the moment t-n

n = interval between image acquisitions n ε{2, 3}

ε = error term.

The estimated regression coefficients were used to bring the intensities detected from an earlier image radiometrically comparable with a later image by applying equations 1-4 for all the image pair interval n. After bringing the detected intensities into the comparable level, the differences of stand means, standard deviations, skewnesses, and upper (75%) and lower (25%) quartiles were calculated between the later and earlier images in each image pair interval. These difference features were not comparable due to the different scaling of the image pairs due to regression (Weisberg 1985, Olsson 1994). Thus they were studentized (in sense of Weisberg 1985) by dividing the difference features by the between stand variance estimate (Olsson 1994). This estimate consisted of two components, the error of the calibration model (Equations 1-4) and the leverage of observation (see Weisberg 1985, Olsson 1994, Varjo 1996c). An exception observation also needed to have larger change than the mean observation to be classified as a change after studentization. The studentization was supposed to make all the image pairs comparable with each other.

For the actual change detection nonparametric Kernel discrimination was applied (Varjo 1996a, 1996c). The method is quite similar with the ordinary Maximum Likelihood classifier except that no distribution assumptions are necessary. The probability for each stand under classification for belonging to untreated class or change classes in training data was estimated. This was obtained by comparing the stand under classification with all the stands in a change class of the training data using the difference features produced. In the analysis, differences of mean were used from every TM channel except channel 1; differences of standard deviations were used from channels 3, 5 and 6; difference of skewness was used from channel 4; differences of lower quartiles were used from channel s 5 and 6; difference of upper quartile was used from channel 7. In addition, basal areas of pine spruce and birch as well as age of the main storey were used as additional explaining variables (Varjo 1996c). In comparison the probability to belong a certain training class was obtained as a mean of comparison with all the observations belonging into this training class (Equation 5) (Varjo 1996c).

$$f_c(x) = \frac{1}{l_c} \sum_{i=1}^{l_c} K_c(x - y_i) \tag{5}$$

Where:

$f_c(x)$ = kernel density estimate for assigning stand x to class c
l_c = number of observation in the training class c
y = an observation in the training class c

$$K_c(z) = \frac{1}{(2\pi)^{\frac{p}{2}} h^p |S|^{\frac{1}{2}}} e^{-\frac{1}{2} z' S^{-1} \frac{z}{h^2}}$$

Where:

p = dimension
h = window parameter for smoothing
S = pooled variance-covariance matrix

Finally the stand under classification was labelled according to the training class with the greatest probability (Equation 6.) (Varjo 1996c).

$$p(c|x) = \frac{f_c(x)}{\sum_{c=1}^{l} f_c(x)} \tag{6}$$

where:

p(c|x) = posterior probability of the stand x to belong class c
l = number of classes in the training data.

The accuracy of proposed change classification was estimated by applying the lower edge of 95 percent confidence level for overall correct classification (Equation 7) (Jensen 1986).

$$s = P - (z\sqrt{\frac{PQ}{n}} + \frac{50}{n}) \tag{7}$$

Where:

s = lower confidence limit
P = correct classification percentage
Q = 100 -P
z = critical value in Students T test
n = sample size

RESULTS

In the training data, the classification proposed resulted in 100 percent correct classification with both intervals applied. When the classification accuracy was analyzed in the test data applying the accurate change classes available the overall percentage of correct classification was 87 percent for two-year interval and 78 percent for three year interval. The lowest accuracy was achieved with the 'commercial thinning' class at 3-year interval and 'uncommercial thinning' class at 2-year interval. The best results were achieved in the classes 'untreated' and 'preparatory cut' (Figures 1 and 2). The 'hold over removals' were detected accurately as well, but the low number of observations did not allow any final decisions concerning the separability of this class to be made.

When the classification from a change class to any of the change classes were considered to be correct the accuracy in different classes were different. The best accuracy was achieved with the drastic change classes such as 'clear cut' class and 'regeneration cut' class. However, the differences between these and the other changes were not large except from the thinning classes in three-year interval (Figures 1 and 2).

The accuracy of detecting natural disasters, such as forest damages serious enough to affect forest management planning, could be estimated only based on the test data. This was because the damage classes were not present in the training data. There were only two partial wind damages on the two-year interval from which another was detected as 'preparatory cut' and another one was misclassified to the class 'untreated'. On the three-year interval there were altogether 10 partial wind damages. Two of them were misclassified into the class 'untreated'. From the rest three were classified into the both classes 'preparatory cut' and 'clear cut' and remaining two into the classes 'commercial thinning' and 'regeneration cut'.

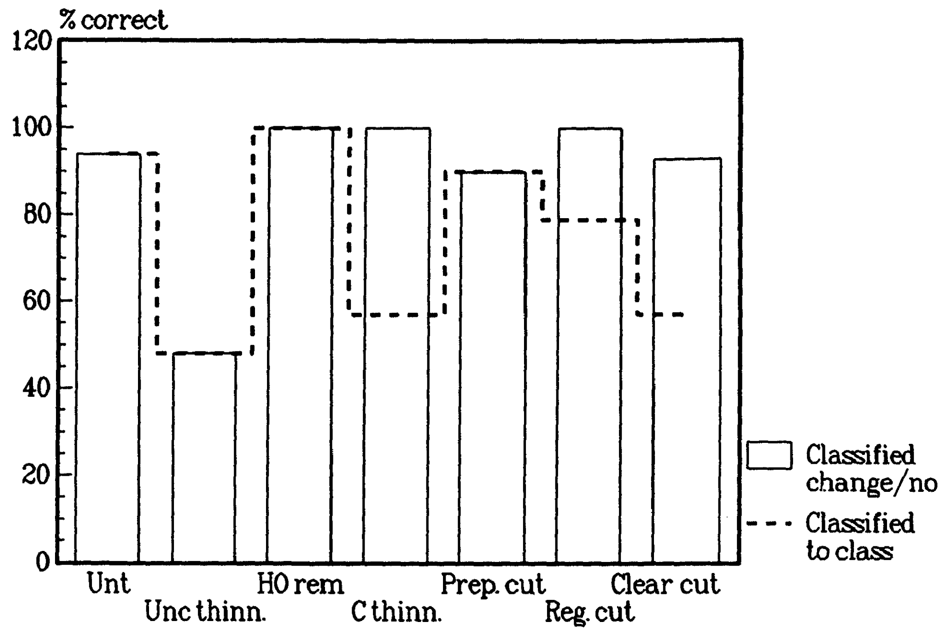

Figure 1. Classification accuracy in different classes on the image pair H92-H90.

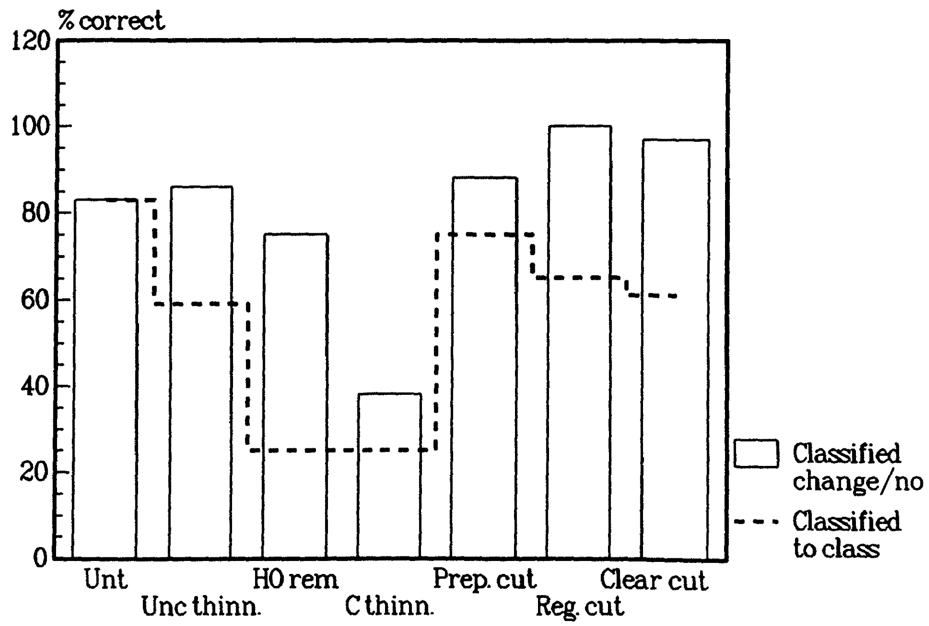

Figure 2. Classification accuracy in different classes on the image pair H93-90.

For evaluating the proposed method for controlling the accuracy of continuously updated forest data base, the overall correct classification percentages were estimated (Figure 3). In this test, only the classification from a certain class to the same class was considered correct. With all the intervals and data combinations used the accuracy was higher in the training data compared to test data. However, the difference was at its most 22 percentage units with the three-year interval. It has to be noted that in the results where the Nurmes data (Varjo 1996a) was classified applying the Hyrynsalmi training data, the only change classes applied were 'clear cut', 'thinning' and 'hold over removal'. These were the only classes present at the Nurmes data.

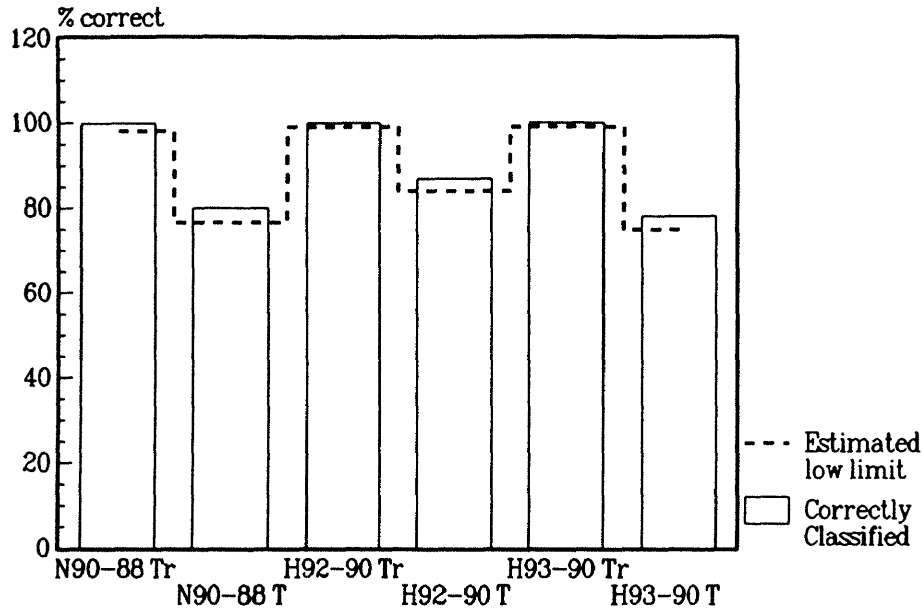

Figure 3. General classification accuracy on different image pairs, Tr = training data and T = test data

The usability of the presented method for controlling quality of the continuously updated forest information was estimated by comparing the detected changes with the treatment register available. On the base of these information sources the district officer responsible for forest management divided detected changes in tree categories (Varjo 1996a):

a) Correctly updated, the treatment register confirms the satellite image change analysis

b) The change class detected in satellite image analyses differs from that recorded in the treatment register but there is no need for further inspection due to the nature of the difference. For example, a detected hold over removal was registered as a clear cut in the treatment list. In this case the future treatments and development of the stand will be similar.

c) Field inspection recommended. The satellite image interpretation differs notably from the treatment register information due to possibly incorrect updating or a possible forest damage.

The division of the changes detected in satellite image analysis is presented in Figure 4.

It was estimated that the sufficient accuracy of a continuously updated forest data base could be maintained by field inspecting only the changes in the category 'c'. This would decrease the need for field work notably compared to the old updating by repetitive field inventories. When the number of the chances to be inspected in field is compared to total amount of stands in the test data, the recommendation for field inspection includes 6.9 percent of all stands in two-year interval. The three-year interval was not included in this analysis because of weaker classification results.

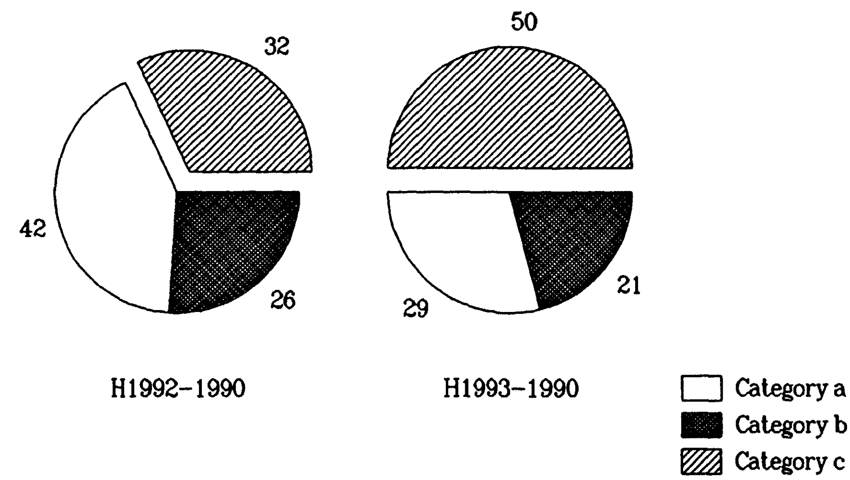

Figure 4. Division of the detected changes according field control recommendations.

Considering the economy of the proposed method it is natural to use the ten-year interval applied for the traditional updating by repetitive field inventories. This means that approximately 35 percent of the stands should be field inspected within a 10-year interval to maintain the accuracy of the continuously updated forest information. The inspection of selected stands will probably be more expensive than the inventory of a stand in the normal standwise base line inventory. However, at least part of the control inspections could be combined with other field work, such as the management and cutting planning and control. Considering these, it could be expected that the costs of the field inspection of the proposed control is directly comparable with the costs of the base line inventory. In this case, the proposed control method would be profitable if the costs of the satellite image analysis would be less than two thirds of the costs of total base line inventory and the accuracy achieved would be acceptable.

DISCUSSION

The application of broad change classes in the analysis seems to improve the results. It was not expected that the moderate changes such as commercial thinnings would have been among the most accurately detected ones in two-year interval when only the labelling to the according accurate classes were considered correct. When classification from a change class to the same or to any other change class was accepted, the drastic changes such as final cuttings were detected most accurately as expected, especially in the three-year interval. This indicates that more errors occur between change classes when classifying drastic changes compared with classifying some of the moderate changes, such as 'thinnings'. This supports the idea of the application of broad change classes such as 'untreated', 'moderate change' and 'drastic change' (Varjo 1996a). With these class levels, the interpolation between different causes of spectral change seem to work well (Varjo 1996a). In addition, the detection of wind damages could be possible when applying broad change classes.

In addition to the improvement gained by the broad change classes in the analysis of a single difference image, it seems possible to use training data from different image pairs and different geographic locations. This is a notable advantage when operational systems are designed. It can be expected that rather large geographical areas could be controlled by applying the same training information that would improve the economy of the proposed control method.

When comparing the costs of satellite image acquisitions needed for the ten- year control period it can be easily detected that the analysis of the required 5 image acquisitions is economic. When using a two-year image interval the material costs would be about FIM 0.4 per hectare (Varjo 1996c). The analyzing costs are difficult to estimate because the analysis phase can be almost completely automated. In any case, the costs can not be greater than the costs of satellite image-based base line inventory, which means maximally FIM 2.0 per hectare (e.g. Tomppo 1992), When this is compared with the cost of base line field inventory (about FIM 50.0 per hectare), the proposed system should make notable savings possible. The critical question will also be the accuracy of the standwise information achieved by the proposed method. However, it has been estimated by Varjo (1996c) that only 1 percent of the stand information would include errors serious enough to affect the management planning, after proposed satellite image based control. Under these conditions the application of the proposed method seems profitable. However, only mineral soils were included in this study and it can be expected that on peat land the results will be worse (Varjo 1996a). This is due to often unclosed canopies. With them satellite image analyses is affected by ground vegetation. In addition the between year spectral variation has noticed to be wider on peat land compared to mineral soils (Häme 1991, Varjo 1996a)

REFERENCES

Hagner, O. 1990. Computer aided forest stand delineation and inventory based on satellite remote sensing. In: Proceedings of the 1990 SNS/IUFRO workshop; 1990; February 26-28; Umeå, Sweden: 94-106.

Häme, T. 1991. Spectral interpretation of changes in forest using satellite scanner images. Seloste: Metsän muutosten spektrinen tulkinta satelliittikeilainkuvien avulla. Acta Forestalia Fennica 222:1-111

Jensen, J.R., 1986. Introductory Digital Image Processing - a Remote Sensing Perspective. Prentice-Hall, Englewood Cliffs, New Jersey. 228 p.

Metsätilastollinen vuosikirja 1995, (Statistical yearbook of forestry). Finnish Forest Research Institute Information Service. Helsinki, Painatuskeskus. 354 p.

Olsson, H. 1994. Monitoring of Local Reflectance Changes in Boreal Forests using Satellite data. Swedish University of Agricultural Sciences, Remote Sensing Laboratory, Umeå, Sweden. Report 7.

Rousseeuw, P. J. and Leroy, A. M. 1987. Robust Regression & Outlier Detection. John Wiley & Sons. New York, Chichester, Brisbane, Toronto, Singapore. 329 p.

Saukkola, P. 1982. Uudistushakkuiden seuranta satelliittikuvista. Valtion teknillinen tutkimuskeskus, Helsinki, Finland. Tutkimuksia 89:1-108.

Siitonen, M. 1983. A long term forestry planning system based on data from the Finnish National Forest Inventory. In: Proceedings of the IUFRO Subject Group 4.02 meeting. 1983 September 5-9, Helsinki, Finland. University of Helsinki, Faculty of Forestry, Research papers 17:195-207.

Tomppo, E, 1992. Multi-Source national forest inventory of Finland. In: Proceedings of Ilvessalo Symposium on National Forest Inventories; 1992 August 17-21; Helsinki, Finland; The Finnish Forest Research Institute Research Papers 444:52-50.

Varjo, J. 1996a. A Nonparametric Method for Controlling Stand Register by satellite data. International Journal of Remote sensing, 17(1):43-67.

Varjo, J. 1996b. Radiometric correction of multitemporal Landsat TM data for detecting rapid changes in mineral soil forest land. Paper accepted to be presented in XVIII International Society of Photogrammetry and Remote Sensing (ISPRS) Congress, Vienna 1996 July 9-19. International Archives of Photogrammetry and Remote Sensing (IAPRS) XXXI. 6 p.

Varjo, J. 1996c. Calibration and change detection method for controlling continuously updated forest information by Landsat TM material. Manuscript for Finnish Doctoral degree in forest management planning.

Varjo, J., and Folving, S. 1996. Regional Monitoring of forest Changes Using Unsupervised Methods; a Case Study From Forest on Mineral Soils. Manuscript submitted into the Scandinavian Journal of Forest Research.

Weisberg, S. 1985. Applied Linear Regression. John Wiley & Sons, New York, Chichester, Brisbane, Toronto. 283 p.

A MODEL OF TIMBER SKIDDING PREDICTING[1]

by

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ABSTRACT: MCE (multi-criterional evaluation method) as means of LSA (Land suitability Analysis) and decision support process has been used to work out the model for a wood skidding prediction. The adequacy level of joint impact of influential factors for individual wood skidding form determines the most suitable skidding method for each model area unit - a grid cell with a resolution of 50 x 50 meters or of 1/4 hectare.

Three main data sources have been used (a digital evaluation model (DEM), a digital network of forest roads, and data from forest inventory). This disposable data has been converted into the required form and at the same time used for providing supplementary information necessary for the correct selection of the wood skidding form. The result of the model has been compared to a map of potential wood skidding means, which was terrain obtained.

Key Words: wood skidding, model, multi-riterional valuation method, computer simulation

INTRODUCTION

Relative smallness of Slovenia (two million hectares, among which more than one half represents forest land) and variety of land form which is determined with the Alps (NW, W), the Pannonia lowland (NE, E), the Dinaric mountains with Karst phenomena and partly Mediterranean area (SW) dictate a rich palette of possible skidding forms. A specific environmental impact, economy, and work organization of skidding form is so evident that today's management requires an optimization process. With the optimization we have to choose a proper skidding form for any forest area included in the production process.

Research work on method development for choosing the best skidding form due to use disposable data to assist in the decision process is a very important task for a researcher in the forest technique area. Modern computer technology helps us provide tools for simulation of different phases in the forest production process. Models are tools which simplify complex reality into simple, more understandable and guidable systems. Models can be to a smaller or greater degree adopted to originals - the objects of modeling, although we do not intend to reach full equals with them (Košir 1995). More important is to capture the most important parts and relationships. A proper simulation of real conditions, therefore, depends not only on variable numbers which control a model, but more on a proper processing of core variables.

The main reason for working out a model of timber skidding prediction was to find out the possibilities of using specific forest databases in selection of appropriate wood skidding form. We want to expand the role of computer technologies from analyses, proceeding and storing data to the quality tool for decision support system.

PROCEDURE

The model includes some original procedures and solutions (the determining of wood skidding direction, eliminating of ridge points, a model elaboration of thematic charts on the basis of forest inventory); yet for the most part it makes use of the instruments offered by standard program packages, primarily the IDRISI GIS program package (Eastman 1993). The latter has a number of modules to help in the processes of bringing decisions.

As a modeling object, the Jezersko Forest Enterprise unit, which has been well processed from the part of forestry regarding information, has been selected. The Jezersko Forest Enterprise unit comprises approximately 5000 hectares of forests. It is situated in the Alpine region, between the Karavanke mountains and the Kamnik-Savinja Alps, with diverse terrain and stand conditions that require a rich selection of appropriate wood skidding forms.

[1]Presented at the joint meeting of the Council On Forest Engineering and International Union of Forest Research Organization Subject Group S3.04-00, Marquette, MI, July 29-August 1, 1996.

DATA SOURCES

Four main data sources have been used for the model of wood skidding forms prediction:

- a digital elevation model (DEM),
- a digital network of forest roads,
- data from forest inventory,
- data of the significance of influential factors or limitations for wood skidding forms.

A digital relief model is a source of data on the relief and terrain slopes. From these data and by means of a model data on the location of ridges or the delimitation of gravitational units can be obtained. We developed an algorithm for recognizing all those points (data) in the Digital Elevation Model (DEM) file that are ridge located.

Ridge points location helped us to determine gravity fields, skidding fields, and haul directions. The model determines haul direction way due to land form (slope and ridges) and location of truck roads. An algorithm that sorts all basic raster cells (1/4 hectare) in two haul directions on the base of upper and lower edge of roads body was made. In the most cases the upper edge corresponds with digging slope and lower edge with dam slope. There are some exceptions in local dikes or cuts, but we avoided some large mistakes by monitoring of a broader area beside the roads.

When determining haul direction, we considered a very rough average for tractor skidding where on a hang with equal slope conditions on the upper 1/3 of the hang we skid wood uphill, and on the lower 2/3 of hang we skid wood downhill. Consequently, we determined the haul direction for every model area unit, and with the help of cost-distance analyses, which modules are a part of IDRISI software.

The data source for microtopography and floor conditions was state forest inventory database, made in 1990 (Mikuliè 1990). The smallest inventory unit in the data base was a division or subsection, which contains forest stands data, sites, volumes, ownership, geological and floor conditions, function of forest etc. The following data have been used as influential factors in the model of timber skidding predicting: stoniness, rockiness, groundwork and soil depth. A spatial representation of those data demands a digitalization of corresponding inventory units to which data refer. It was necessary to constitute a link, an identification key that was in both databases (forest inventory - nongraphic data base and digital base of inventory units borders, which is a graphic database) identical. IDRISI software has some ability to create a raster thematic images with such values that are in forest inventory database. The thematic images are geographically referenced and help us provide a spatial view of data dispersion. Raster thematic was made for every influential factor.

The data on the significance of influential factors or the limitations first of all refer to the properties of the means of work used in individual forms of wood skidding. Working ranges of individual machines have been brought in line with the data from forest work standards; in the limiting of cable crane reach, the former are defined by means of technical characteristics of individual cable cranes.

Auxiliary limitation to those regarding forest technique equipment and skidding forms, we defined constraints that are related to public and other functions of the forest, such as providing biotop conditions for endangered animal and plant species, water source preservation, and others which are spatially determined. For each prior limitation, a special mask file marking the areas that are due to limitation inappropriate for the use of a wood skidding form has been worked out.

WORKING METHOD

Simplicity of a model is an important characteristic of each model and also for its quality. Therefore we decided to use a relatively simple method to determine suitability of a forest area for specific skidding form. The method is called Multi - Criteria Evaluation (MCE) and is also an advantage because IDRISI software has modules that support their use. The method is dedicated to maintain and help in the decision process where it is necessary to choose the optimal disposable solution.

Every disposable solution has to have a suitability file (in our case skidding form suitability files). A very common procedure for arriving at a suitability index is a weighted linear combination where each influential factor is multiplied by a weight and then summed to arrive at a final suitability index. In a module of timber skidding prediction the following influential factors have been taken as input variables:

- terrain slope,
- a distance to a truck road,
- wood skidding direction,

- stoniness,
- rockiness,
- groundwork,
- soil depth.

All influential factors were converted in raster GIS (Geographical Information System) environment where each model area unit - a grid cell represents an area of 50 x 50meters or of 1/4 hectare.

Weight or influence of specific factor is possible to achieve by subjective decision or by the objective way through the use of some comparative methods. A weighted linear combination demands a sum of weight equals one. Ratings are provided on a nine point continuous scale (Table 1). We used a pairwise comparative method. A square reciprocal matrix of pairwise comparisions between the criteria has to be worked out. The comparison concerns the relative importance of two criteria involved in determining suitability for the stated objective (in our case skidding for selection) Table 2).

Weights for influential factors were derived by taking the principal eigenvector of a square reciprocal matrix (Table 3).

The method of multi-criteria evaluation requires standardized values of input data that have to be at the same time uniformly correlated with the suitability for an individual variant choice.

The standardized interval was determined on the scale from 0 to 20, which was the base for linear interpolation of basic values of all the influential factors. Before the interpolation in standardized interval all basic values had to be positively correlated to the suitability for an individual variant choice.

The main point of all the creative work represents the choice and standardization of influential factors. We have to simulate the real conditions and interrelationships with simplification and at the same time be as close to the real conditions as possible.

Table 1. The continuous rating scale.

- -								+ +
1/9	*1/7*	*1/5*	*1/3*	*1*	*3*	*5*	*7*	*9*
Extremely	*Very*	*Strongly*	*Moder-ately*	*Equally*	*Moder-ately*	*Strongly*	*Very*	*Extremely*

Table 2. Pairwise comparision matrix for assessing the comparative importance of influential factors.

INFLUENTIAL FACTOR	Terrain slope	A distance t a truck road	Stoniness	Rockiness	Ground-work	Soil depth
Terrain slope	1					
A distance to a truck road	3	1				
Stoniness	7	5	1			
Rockiness	3	3	1/5	1		
Groundwork	5	7	1/3	3	1	
Soil depth	8	7	3	5	5	1

Table 3. The principal eigenvector of a square reciprocal matrix.

INFLUENTIAL FACTOR	Terrain slope	A distance to a truck road	Stoniness	Rockiness	Groundwork	Soil depth
WEIGHT	0.4077	0.2854	0.0461	0.1520	0.0811	0.0277

Figure 1 shows the inverse linear relation between suitability of some skidding forms and distance to a truck road. At the same time the chart shows the function between basic and standardized values for influential factor distance to a truck road.

The same standardized interval of influential factors and the sum for them, which equals one, caused the suitability to be determined by values on the standardized interval. Values on the standardized interval are positively correlated to suitability for specific skidding form. Suitability files give information, where specific skidding form is more and where less suitable for implementation. To obtain a skidding chart, which is the purpose of the model, we have to make a joint analysis of all suitability files. A very convenient procedure is touse the IDRISImodule. Multi-dimensional choice that produces an output map indicating which of a series of input maps (suitability files) has the higher value of each cell. The result of the choice could be influenced with the set of weights for input files favoring some skidding forms.

Output file of Multi- dimensional choice was at the same time the final result of the model and was represented as the raster thematic image indicating model optimal choice of skidding forms for forest enterprise (Figure 2).

THE ACCURACY OF THE MODEL

Each model has to have a known threshold of accuracy. The model of timber skidding predicting was controlled by the comparison of the model skidding chart to the chart that was made from terrain observation by local foresters. We had a skidding chart for Jezersko Forest Enterprise which was terrain obtained. The computer comparison of model and terrain determined skidding forms finds each possible combination of true and mapped categories (Table 4).

Tabulation along the diagonal represents cases where mapped category matched the true value. All off- diagonal tabulations represent differences and are tabulated as totals in the margins. Careful analysis of difference matrix enables not only difference assessment but also where it occurs and how it might be remedied.

The model is relatively accurate with the most frequent wood skidding forms (tractor downhill and cable crane uphill), while the discrepancy with other wood skidding forms is higher. Due to high frequency of most accurate determined skidding forms, the sum of the difference is relatively small (38 percent).

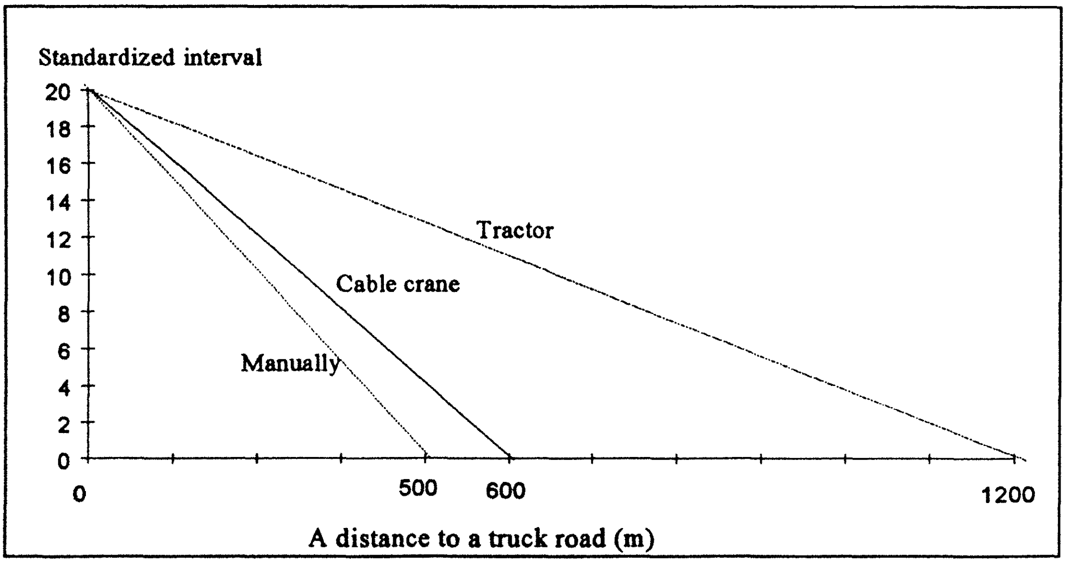

Figure 1. Function between basic and standardized values for influential factor distance to a truck road to constitute a positive correlation with suitability for some skidding forms

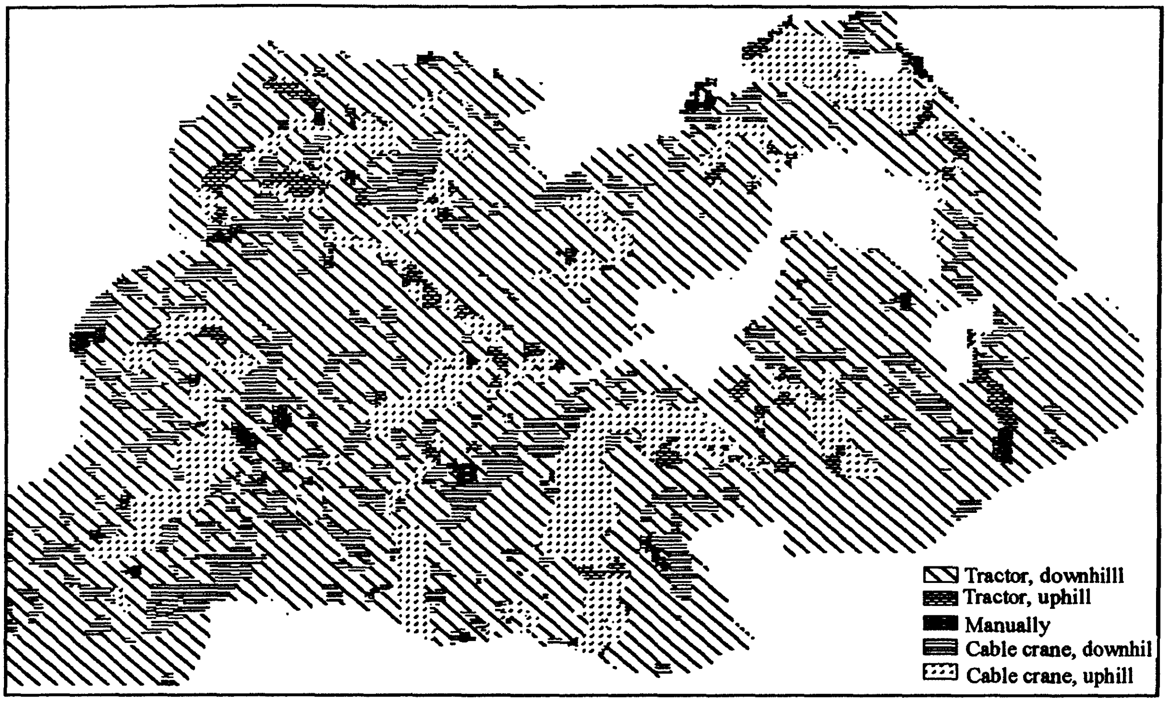

Figure 2. Skidding forms for forest enterprise derived by a model.

Table 4: Difference matrix between model and terrain obtained skidding forms.

TERRAIN SKIDDING CHART

		Tractor downhill	Tractor uphill	Manually	Cable crane downhill	Cable crane uphill	Sum	% difference
		15	2	0	30	0	47	1.0000
M	Tractor, downhill	8,932	138	702	2,497	42	12,311	0.2745
O	Tractor, uphill	27	237	0	10	200	474	0.5000
D	Manually	132	1	37	50	1	221	0.8326
E	Cable crane downhill	1548	6	290	555	3	2,402	0.7689
L	Cable crane uphill	107	939	50	64	1,204	2,364	0.4907
	Sum	10,761	1,323	1,079	3,206	1,450	17,819	
	% difference	0.1700	0.8209	0.9657	0.8269	0.1697		0.3846

DISCUSSION

The model proves it is possible to predict skidding forms due to use of computer technologies. A computer supported procedure of Multi- Criteria Evaluation with use of proper data bases is of great importance in the decision process regarding the planning of wood production and extraction. Mostly it is possible to support forest management in short or middle time periods on the area of forest enterprise unit (2,000 to 10,000 ha). For more accurate evaluation of skidding form on smaller area unit we have to have more precise set of input data (influential factors) that is a wider network of digital elevation model (DEM) from more accurate sources, a better digitalization of line objects (truck roads, tractor haulage tracks, forest section borders) and more accurate information about floor and stand condition.

There are three most important influential factors (terrain slope, a distance to a truck road and rockiness), which have all different data sources and therefore different accuracy.

The distance to a truck road factor is to a great degree, of subjective nature because it is the result of existing forest road network which was planned and constructed due to influence of specific professional, economic, and social conditions.

The model does not concern existing secondary forest communication (tractor haulage tracks, cable crane lines) which would lower the difference between the model and the terrain obtained skidding chart. On the other hand, including the secondary communication would cause a loss of objectivity because planning and construction were also under subjective and time responsible conditions.

Model of timber skidding predicting has a pretty lax procedure which, however, could be complemented with new dimensions being added to it or it could also be made simpler in relation to specific conditions, needs ,and aspirations.

The model was developed as a part of research project named *Adjustment of forest production function to other forest functions* and was the same theme of a master thesis (Krè 1995).

SUMMARY

This paper deals with a model that makes a skidding chart of forest enterprise with use of disposable skidding forms. The criteria are related not only to properties and technical characteristics means of work, but also to forest stands and terrain conditions that have the most important influence on suitability determination. The model is based on the method of Land Suitability Analyses (LSA), called Multi-Criteria Evaluation which determines the most suitable skidding form for each model area unit (raster cell representing area of 50 X 50meters or 1/4 hectare).

The model is computer supported and is a kind of computer simulation. The algorithm of model uses mostly modules of IDRISI software and some originally written procedures. All the input data had to be converted to IDRISI raster or vector environment. The model does not use only forest and terrain data but also data about existing forest road network. Some original procedures provided more complete information and data for suitability of skidding forms determination.

The results of the model could be used as input information for various economic, ecological and other forest management analyses.

LITERATURE CITED

Eastman, J.R., 1993. IDRISI update manual, Worcester, Massachusetts, USA, Clarc University, 209 p.

Košir, B., 1995. Some experiences with the models for operational planning - IUFRO XX World Congress, Division 3 Forest Operations and Technique, P3. 04-00 Small-Scale Forestry, Tampere, 11 p.

Krè, J., 1995. Model napovedovanja oblik spravila lesa. -Magistrsko delo, Biotehniška fakulteta, Ljubljana, 114 p.

Mikuliè, v., 1990. Oblikovanje in korišèenje skupnih zbirk podatkov. Raèunalniška obravnava podatkov za potrebe izdelovanja gozdnogospodarskih naèrtov. -Raziskovalna naloga, IGLG, Ljubljana.

*U.S. GOVERNMENT PRINTING OFFICE: 1996-757-743/40030

U.S. Department of Agriculture, Forest Service.
1996. Blinn, Charles R.; Thompson, Michael A., eds. **Planning and implementing forest operations to achieve sustainable forests: Proceedings of papers presented at the joint meeting of the Council on Forest Engineering and International Union of Forest Research Organizations**. Gen. Tech. Rep. NC-186. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 282 p.

Contains a variety of papers presented at the joint meeting of the Council on Forest Engineering and International Union of Forest Research Organizations Subject Group S3.04 and that support the meeting theme "Planning and Implementing Forest Operations to Achieve Sustainable Forests."

KEY WORDS: Forest engineering, forest operations, forest harvesting, operations planning and control, work study.

Our job at the North Central Forest Experiment Station is discovering and creating new knowledge and technology in the field of natural resources and conveying this information to the people who can use it. As a new generation of forests emerges in our region, managers are confronted with two unique challenges: (1) Dealing with the great diversity in composition, quality, and ownership of the forests, and (2) Reconciling the conflicting demands of the people who use them. Helping the forest manager meet these challenges while protecting the environment is what research at North Central is all about.

NORTH CENTRAL FOREST EXPERIMENT STATION