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ESTIMATING TWO INDIRECT LOGGING COSTS CAUSED BY ACCELERATED EROSION

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ABSTRACT

In forest areas where high soil erosion potential exists, a comparative yarding cost estimate, including the indirect costs determined by methods proposed here, shows that the total cost of using "advanced" logging methods **may be less** than that of "traditional" systems.

INTRODUCTION

The harvesting of timber in environmentally sensitive areas of the Pacific Northwest has been opposed in recent years by many individuals interested in protecting our forest environment. These conservationists hold a popular concept that timber harvest causes severe damage to soils, stream water quality, reforestation, and wildlife habitat. These fears are not irrational because severe watershed damage has occurred, but a disregard for good forest environment management is not a general practice in the forest industry. Basically, it is not the temporary elimination of trees in a timber harvest operation that precipitates watershed damage. Severe environmental damage to watersheds is usually the result of improper techniques used in the removal of the harvest trees.

Dyrness (1967, 1972), Wooldridge (1960), Ruth (1967), and Klock (1975) have shown that the forest industry presently has proven methods of removing the felled trees from the forest with a minimum of impact on the soil and vegetation resource. In environmentally sensitive areas in Northwest forest lands, proper logging procedures may require the use of an "advanced" logging system such as skyline or helicopter (Klock 1975). Generally the system involves the aerial movement of the felled tree to a landing deck. Since more energy is expended in the aerial movement of logs, the direct yarding cost can be expected to be higher than with "traditional" logging systems (tractor and jammers). However, the expenditure of additional energy for yarding may be offset by less energy requirements for road construction, road maintenance, and log transportation.

Esthetics alone does not justify the increased cost of advanced logging systems. An approach to determining the operating cost differential would be to estimate the potential forest environment damage that might occur on an identifiable timber sale for each available system of removing the fallen trees. The monetary value of these potential damages could be charged to each logging system as an indirect cost assessment on the volume of timber removed. However, this method should not be used to justify destroying nonrenewable natural resources because monetary value estimates may be attached to them.

Indirect costs of timber removal are dffficult to determine and are therefore rarely estimated.[1/] This paper will not attempt to identify all indirect logging costs, nor will it show a complete economic analysis of those that are identified. Because the most apparent indirect costs are those associated with erosion, these are ones I will discuss.

Once eroded soil material has been transported off forest slopes and enters a stream system, the effects can be measured in terms of:

(1) loss of site productivity (both trees and understory vegetation),

(2) sedimentation,

(3) water quality (domestic, esthetic, and irrigational),

(4) fisheries habitat loss, and

(5) increased need for erosion seeding and control.

By developing unit cost figures for these effects, it may be possible to show that soil loss by erosion can be a long-term, indirect cost. If the erosion costs can be determined, they should be added to the direct operational costs when systems of log removal for a particular forest site are evaluated.

1/ Don Boyer. Letter to the record: watershed protection and management damage to watershed values. May 13, 1971. USDA Forest Service, Region 6, Portland, Oreg.

BACKGROUND

Hypothetical indirect cost estimates from soil loss could be developed for most forest areas. To be useful, the degree of potential erosion which may be generated by each proposed logging system must be estimated. This is not an easy task, and more extensive research is needed to predict the erosion potential in many areas.

In the postfire salvage logging operation described by Klock (1975), the impact on soils and vegetation by five logging systems was evaluated. Both "traditional" and "advanced" systems of tree removal were reported for three watersheds in the Entiat River basin of north-central Washington. This area is characterized by steep and rugged relief where mean slope is about 50 percent and can be categorized as an environmentally sensitive area. The base rock in the study area is Mesozoic granodiorite deeply weathered where exposed. Soils are formed from weathered granodiorite colluvium covered by volcanic ash and pumice. Nearly all forest floor litter within the study area had been destroyed by fire; thus the soil surface was in a more sensitive condition for disturbance by logging. After these soils were disturbed by logging they became highly susceptible to erosion during the high snowmelt period and the high intensity rainstorm described in Klock (1975). Habitat types affected by the vast 1970 wildfire ranged from the *Pinus ponderosa/Purshia/Agropyron* at the lower elevation to *Pseudotsuga menziesii/Calamagrostis rubescens* at higher elevations (Tiedemann and Klock 1973). Snowbrush ceanothus (*Ceanothus velutinus* Dougl.) was predominate in the understory cover.

Volume yields are relatively unknown for the study area, but it appears the undisturbed forest under present management levels could produce in one rotation of approximately 120 years, 6,000 board feet per acre (35 m^3/ha) on the steep upper slopes and up to 15,000 board feet per acre (90 m^3/ha) on the more fertile valley lands. An average volume would be about 8,600 board feet per acre (50 m^3/ha).

A replicated greenhouse biomass productivity test (bioassay) of the soils from the slopes of the experimental area reflects the high concentration of available plant nutrients in the immediate soil surface (fig. 1).[2/] Removal of

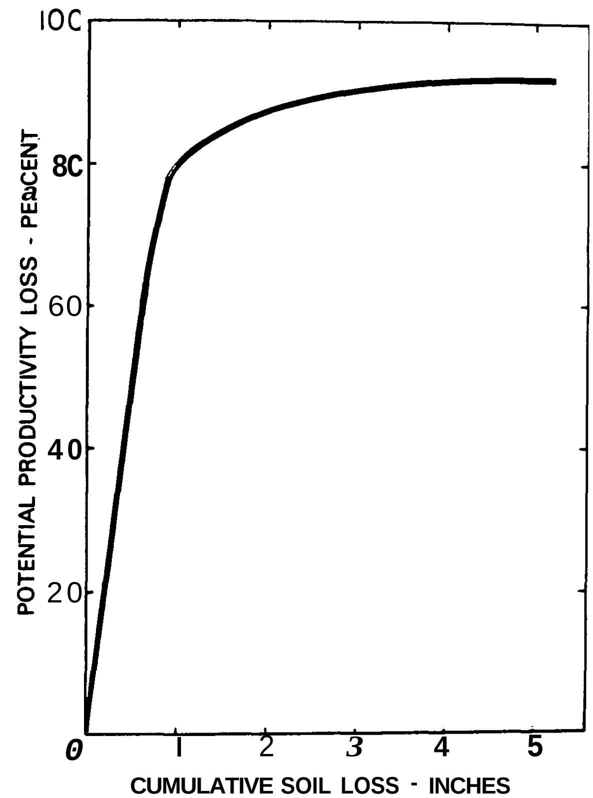

Figure 1.--Potential productivity loss as a function of cumulative surface soil loss.

2/ G. O. Klock. Unpublished data on file, Pacific Northwest Forest and Range Experiment Station, Wenatchee, Wash.

1.2 inches (3 cm) of topsoil from the effective zone of rooting in the soil profile (1 foot) without consideration for future natural nutrient replacement resulted in an 80.5-percent reduction in the short-term biomass yield. Thus, figure 1 shows that potential forest biomass productivity could be reduced strikingly by increased erosion of topsoil within the experimental area.

METHODS OF ESTIMATING INDIRECT COST

Enough information was available from the study area to test the proposed approach to estimating indirect logging costs caused by accelerated erosion. Indirect costs are identified as onsite and downstream damages.

Onsite Damages

An estimation of the rate of natural nutrient accumulation is one possible approach to determining onsite damages due to biomass productivity loss from an increment of soil displacement by erosion. Plant nutrients of particular interest would be nitrogen, phosphorus, and sulfur. In the study area ecosystem it appears that symbiotic nitrogen fixation and precipitation would not be expected to exceed 5 pounds of nitrogen per acre (5.6 kg/ha) annually (Zavitkovski and Newton 1968, Tiedemann and Helvey 1973). Thus, to return the nitrogen level to a preerosion level by natural processes after serious surface soil loss by erosion may take many years. For example, to accumulate through symbiotic fixation and precipitation enough nitrogen in the surface 1 inch (2.5 cm) to raise the total nitrogen level by 0.1 percent may take several hundred years. The replenishment by natural processes of phosphorus and sulfur lost by erosion could also be expected to require a long period of time. It is obvious that a significant loss of soil nutrients by serious surface erosion, particularly from a soil profile where the major nutrient supply is very close to the surface (fig. 1), could have a major influence in reducing future timber production. It may be possible to calculate differences in productivity and relate this to income at the time of the next rotation harvest. However, with current discount rates of 7 to 10 percent, income differences due to different levels of productivity would be negligible at present prices for a rotation of 120 years. Thus, this approach to determining onsite damage has merit but does not appear feasible under present biologic and economic constraints.

Relevant differences in damage to onsite productivity due to various logging methods need to be evaluated in terms of present values. Another approach to determining differential onsite damage cost might be evaluating the cost of chemical replacements for the lost plant nutrients. Use of logging systems that cause more extensive soil erosion should have a higher indirect cost due to probable reduction in future biomass productivity than systems with a low erosion potential. Indirect cost of probable productivity damage due to soil nitrogen loss can be determined by equation 1.

$$\text{Productivity damage assessment} = \frac{\text{area} \times \text{erosion depth} \times \%\ \text{total soil N} \times A \times B}{\text{timber volume assessed}} \qquad (1)$$

A is the fertilizer conversion rate (100 pounds of nitrogen per 100 pounds of fertilizer) and B is the cost of fertilizer plus application (dollars per pound per unit area). The use of ammonium phosphate sulfate for cost calculation purposes should fulfill both the plant phosphorus and sulfur as well as nitrogen requirements and would have a conversion rate of 6.5.

A representative soil total nitrogen level distribution as a function of depth within the soil profile for the study area is shown in figure 2. Using these soil nitrogen levels, along with the total nutrient application costs shown in figure 3 (Perkins and others 1971), the dollar assessment per 1,000 board feet for incremental soil loss can be calculated by equation 1 and is shown in figure 4. Thus, 1 inch of soil loss by erosion could result in a productivity damage assessment at present prices of about $13 per 1,000 board feet harvested in

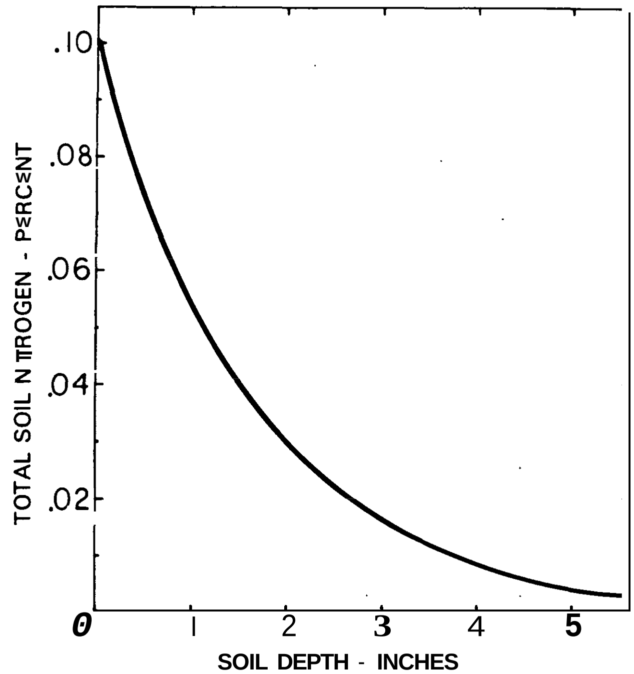

Figure 2.--Representative depth distribution of total soil nitrogen for the study area.

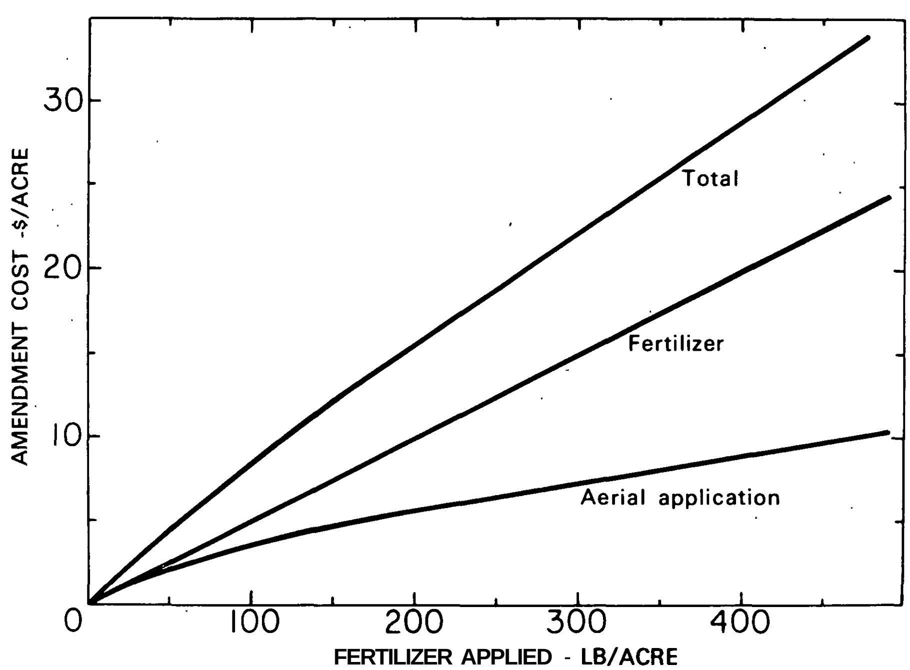

Figure 3.--Amendment application cost for the study area. Fertilizer costs were calculated at $100 per ton and aerial application costs were obtained from a helicopter fertilization program described by Perkins and others (1971).

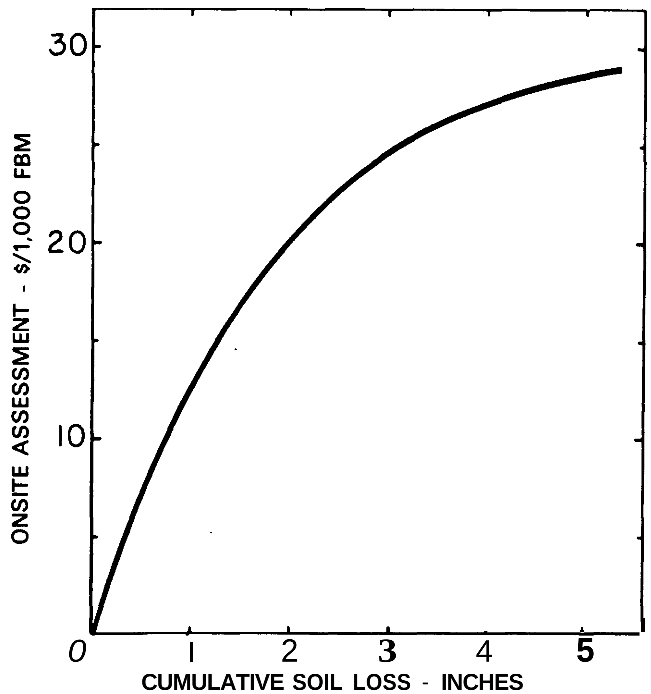

Figure 4.--Indirect logging assessments for possible onsite damage due to cumulative soil loss by accelerated soil erosion after fire.

the study area. This assessment could be larger on a more fertile soil. I believe this cost assessment is very conservative, particularly with respect to the rapidly advancing value of our forest soil resource as well as increasing energy cost for chemical amendments. Although I have used chemical amendments to calculate productivity damage values, their field use in this manner as an alternative for good forest soil management is not recommended.

Downstream Damages

Cost estimates of downstream damages due to erosion from logged areas, such as sedimentation and deterioration of water quality and fisheries habitat, are difficult to determine. These costs must be considered on an individual study basis because the use of water and value of the fisheries yary widely from area to area. Upper values of streambeds for salmon spawning have been estimated to range from $10,000 per acre ($24,700/ha) on Lost Creek, Willamette National Forest, to $3.2 million per acre ($7.9 million/ha) at the Fraser River, British Columbia, Canada.[3/] Numbers of salmon spawning in the Entiat River below the study area watersheds appear to be similar to or slightly below those reported for Lost Creek. Deterioration in watek quality and damaged salmon spawning beds by soil erosion from the study area are evident in the Entiat River. However, other erosion losses from fire-affected watersheds outside the study area make estimates of damages to fisheries by each system of logging impossible.

The only downstream damages for which cost estimates as a function of soil loss appear to be readily available for assessing against timber harvest in the study area are those due to reservoir sedimentation.

Sediment removal costs are available from reservoir sediment removal projects.

3/ R. W. Phillips. Fishery resource considerations on western forest lands. Forest-Fisheries Habitat Seminar, Feb. 17, 1970, Reedsport, Oreg.

Cost of sediment removal will range from $0.25 per cubic yard ($0.33/m^3$) for dredging to as much as $18.30 ($24.00/m^3$) or more where specific placement of sediment is involved. Since sediment removal costs are not available for the hydroelectric storage reservoirs below the study area, I will assume an approximate average cost of $4 per cubic yard ($5.25/m^3$) for sediment removal. This average cost may be quite conservative, particularly in areas where the current energy crisis increases the necessity and value of water in reservoir storage.

Equation 2 provides the incremental sedimentation cost.

$$\text{Sedimentation assessment} = \frac{\text{area} \times \text{erosion depth} \times \text{removal cost}}{\text{timber volume assessed}} \qquad (2)$$

Equation 2 shows that an average 1 surface inch of soil loss will create a sedimentation assessment of $62.53 per 1,000 board feet of saw logs, based on a sediment removal cost.of *$4* per cubic yard in the study area.

I have attempted to estimate only costs of erosion due to yarding. Fredriksen (1970) has shown that timber harvest roads in western Oregon can cause an increase in stream load sediment in the first year of up to 12.5 tons per acre. In another study (Klock 1975), I found the combination of cable skidding and tractor yarding resulted in 12 percent more spur roads than did the combination of helicopter and tractor yarding. This increase in roads certainly demonstrates the potentially higher reservoir sedimentation cost of traditional yarding, compared with advanced logging systems.

TOTAL INDIRECT COST

By combining the onsite and downstream damages in terms of costs as a function of soil loss by erosion, I developed a first approximation of the total indirect cost assessment that could be made against the timber harvested within the.study area in 1972 (fig. 5).

No exact average depth of soil loss can be measured for the various timber harvest techniques used in the study area. I used a rough estimate of soil loss (Klock 1975) to develop a first approximation of total indirect costs with equations 1 and 2 for comparison of ,possibly more realistic long-term cost of timber harvest by the various techniques in the study area. The results are shown in table 1.

In table 1 the harvested timber has been assessed some of the indirect costs created by soil erosion in the study area. In this case, several

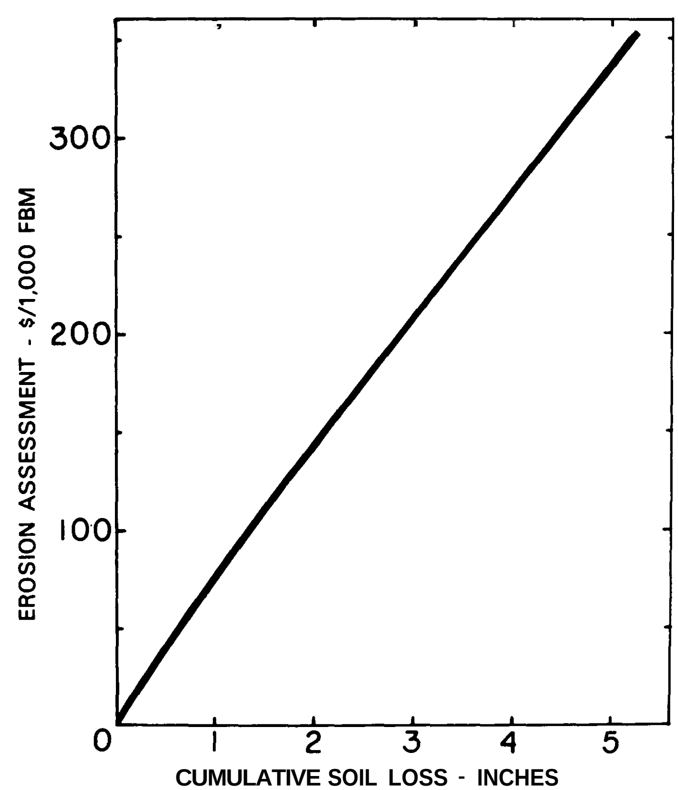

Figure 5.--Total indirect logging assessments for onsite and downstream damages due to cumulative soil loss by accelerated erosion after fire.

Table 1--*Some cost estimates of tree removal per 1,000 board feet of merchantable lumber for several yarding systems used in the fire-affected study area*

System	Erosion	Direct cost[1/]	Indirect assessment		Total "cost"
			Productivity	Sedimentation	
	Inches	*Dollars*			
Tractor, slopes 0-30%	0.20	34.85	3.30	12.50	50.65
Tractor, slopes 30-50%	.80	34.85	10.60	50.00	95.45
Tractor (over snow), slopes 0-40%	.08	38.60	1.50	5.00	45.10
Cable skidding	1.50	35.00	17.00	93.80	145.80
Skyline (Wyssen)	.04	52.73	.80	2.52	56.05
Helicopter	.04	74.98	.80	2.52	78.30

1/ Cost figures are for timber delivered at the mill for each yarding method used in the study area and were provided by Pack-River Lumber Company, Peshastin, Wash.

traditional systems of harvest (tractor over steep, bare ground and cable skidding) were higher in total cost than the advanced systems (skyline and helicopter). Tractor logging over snow appears to have the lowest total unit cost and is considered an environmentally acceptable method of yarding in the study area.

It should again be pointed out that these yarding cost contrasts were developed where (1) the environmentally sensitive study area was in a fire salvage sale, (2) the study area was severely stressed by unpredictable climatic events, (3) once a particle of eroded soil enters a stream system it will be impounded in a reservoir, (4) several assumptions and estimates were used in the models, and (5) other indirect costs such as deterioration of water quality and fish habitat and the detrimental effect of sediment from the road system were not included. These cost comparisons must be considered as first approximations.

Some of the indirect logging cost estimates in table 1 also include erosion damages as the result of fire by itself. Therefore the suggested analyses method used here does cause a relatively small error (up to $2-$3 per 1,000 board feet). This overestimate of the indirect cost caused by insufficient information on erosion levels as a result of fire alone appears most noticeable for advanced loggfng methods used on steep slopes. Linear programing, as well as other useful tools of economic analysis, was not considered in this approach to estimating indirect cost. However, table 1 basically showed that it may have been more reasonable on a long-term cost basis to harvest with an advanced logging system instead of the cable skidding and tractor systems in some parts of the study area. This observation is reached without determining any cost to deterioration in esthetic values which may also be important in this example.

SUMMARY

Hypothetical erosion assessment models have been developed for determining some of the onsite and downstream damage possible by logging. By using the soil erosion potential for several yarding systems to determine the erosion assessments, total relative logging costs for each system may be evaluated. This evaluation method may show that environmentally acceptable advanced systems of of yarding could cost less than traditional yarding systems at some locations. An example of the possible cost advantage of using an advanced system is given for a fire salvage study area described in Klock (1975).

When these suggested hypothetical models are used as tools for making environmentally acceptable land management decisions, the cost advantage of using advanced tree removal techniques may be more evident in many areas of our western forests.

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