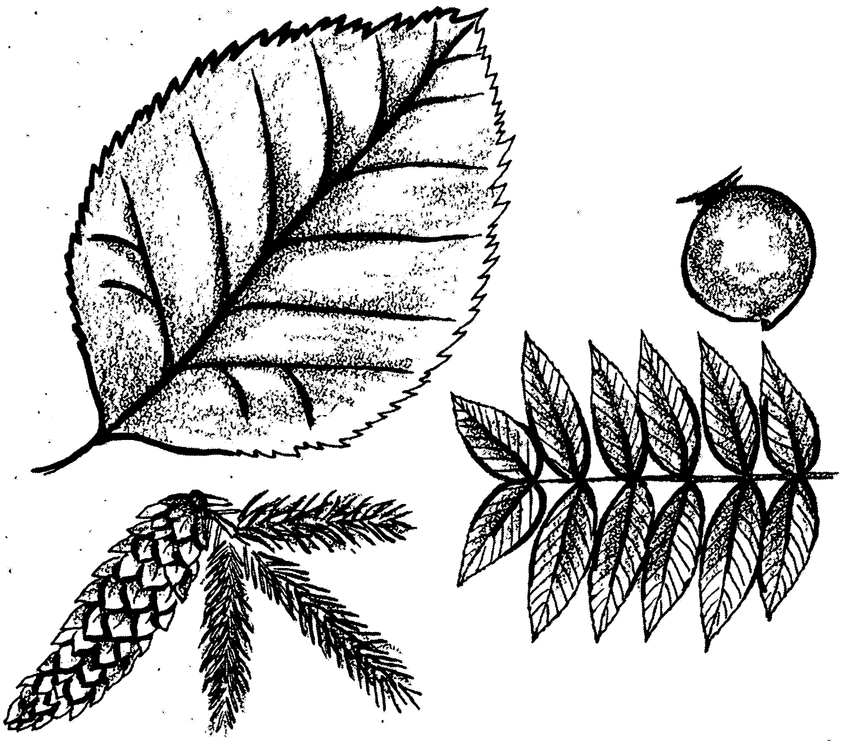
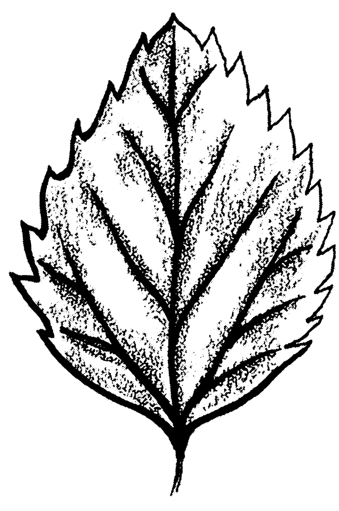
USDA FOREST SERVICE
RESEARCH PAPER NC-40
1970

TREE IMPROVEMENT OPPORTUNITIES in the NORTH CENTRAL STATES as RELATED to ECONOMIC TRENDS,

A Problem Analysis



David H. Dawson
and
John A. Pitcher



NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

CONTENTS

THE AUTHORS are Plant Geneticist at the Institute of Forest Genetics, North Central Forest Experiment Station, Rhinelander, Wisconsin, and Regional Geneticist, Region 9, Milwaukee, Wisconsin.

NORTH CENTRAL FOREST EXPERIMENT STATION
D. B. King, Director

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue
St. Paul, Minnesota 55101

ACKNOWLEDGMENTS

This publication has been prepared with the encouragement and endorsement of the Lake States Forest Tree Improvement Committee. It is the result of much help from many people.

We are particularly grateful to John Macon, Director of Timberlands for Consolidated Papers, Incorporated, who, at the request of the Lake States Tree Improvement Committee, served as the leading collaborator on the publilcation.

The original draft of the manuscript was presented at the Program Review at the Institute of Forest Genetics at Rhinelander, Wisconsin, on April 24, 1969. Many helpful suggestions presented by representatives of the universities, industry, and State and Federal Government in the North-Central Region were considered in preparing the final draft.

Although the authors accept full responsibility for the findings of the survey, and the recommendations presented, they are none-the-less grateful for the help of all the reviewers.

Tree Improvement Opportunities in the North-Central States Related to Economic Trends

David H. Dawson and John A. Pitcher

Abstract

The National need for wood products is expected to increase 80 percent by the year 2000 and there is estimated continued growth in demand after 2000. These products must be grown on a constantly diminishing area due to increased use of land for other purposes.

Tree improvement is one possibility for increasing quantity and quality of forest products in the North-Central Region.

Priorities for tree improvement programs can be determined by analysis of (1) the projected demand for forest products for the year 2000, (2) the nature and availability of planting sites, (3) the forest management alternatives to meet the demands, and (4) the amount of genetic guidelines available.

Based on an analysis of these factors, the major emphasis on regional tree improvement programs should look first toward increased yields of fiber (woodpulp) and second toward better hardwood veneer. There is little indication that the lumber industry will grow significantly.

Until more basic genetic information becomes available, developmental and action programs in tree improvement in the Region should concentrate on the following (listed alphbetically):

Betula alleghaniensis	*Pinus banksiana*
Juglans nigra	*Pinus echinata*
Larix spp.	*Pinus strobus*
Picea glauca	*Pinus resinosa*
Picea mariana	*Populus* spp.

The "North-Central Region"—Minnesota, Wisconsin, Michigan, Iowa, Illinois, Indiana, and Missouri – is about 28 percent forested. This 76-million-acre natural resource contributes substantially to the economic and social well-being of the people within and beyond the Region's boundaries. In 1962, the North-Central Region produced over one billion board feet of saw logs, 96 million board feet of veneer logs, and over 3 million cords of pulpwood. In 1958 timber-based economic activity, including the conversion of imported wood products, added over 4 billion dollars to the Region's gross product (Hair 1963).

Because of the importance of this resource, much attention has been and will be given by public agencies and private industry to maintaining and increasing the quality and quantity of forest products.

The productivity of forest land and the quality of forest products can be increased by various forestry practices, singly or in combination. One of these practices is the use of genetically improved planting stock in reforestation, which suggests the needs and possibilities for applied research, developmental, and action programs in forest tree improvement.

The purposes of this problem analysis are (1) to determine how tree improvement programs can best help satisfy the large increases in demand that will be made on the forests of the North-Central Region, (2) to set general species priorities, (3) to establish a method of analyzing tree-improvement program needs, and (4) to suggest specific improvement programs for priority species.

While certain portions of this problem can be quantified, the scope of this present analysis is confined to the qualitative aspects of the total problem.

From the standpoint of discussion, administration, and analysis, it seems necessary to place precise definitions on "tree improvement" and "forest genetics." In reality the two fields are almost inseparable at this time.

"Forest genetics" is the broad field concerning variation and inheritance in forest trees. Although this analysis is not intended to explore the needs for forest genetics research, it may possibly serve to orient basic forest genetics programs.

"Tree improvement" refers to the application of forest genetics to bring about heritable improvement in trees (Dorman 1962). It involves:

1. Selection of superior trees for growth rate, form, insect, disease resistance, etc.
2. Planning and establishing seed-production areas.
3. Planning and developing clonal and seedling seed orchards.
4. Open and controlled pollinations to determine general and specific combining ability.
5. Mass production of improved species, hybrids, or other variants.
6. Small seed-source studies to determine best sources for local use.

This publication does not contain a review of literature pertinent to forest genetics, tree improvement, or the economic and social aspects of forestry. It refers briefly to the more significant works in these fields as they relate to the possibilities for tree improvement in the North-Central Region.

Although the need for improved trees for aesthetics or special purposes such as air purification, erosion control, shelterbelts, or the production of timber-related crops (e.g., Christmas trees) is recognized, these needs are beyond the scope of this study.

Tree-improvement is by necessity a long-term effort. It is essential, therefore, in program planning to consider the needs and nature of future society and its probable technological development at the time the products of today's projects are available.

Projects being started today are not likely to be producing many tested, improved materials much before the year 2000. The tree breeder must consider not only which *species* will be needed to meet the demands of the 21st century, but also what *specific traits* within the species may become most important. He must consider the amount of suitable land available for planting improved trees and what intensive cultural practices will be used to take advantage of the improved biological efficiency of the tree.

What, specifically, will be the demands of the 21st century? What will be the effects of population pressures on land use? What specific forest products will be in the greatest demand? These questions are difficult to answer. Nonetheless, it is generally agreed that the demand for all timber products, with the possible exception of fuel wood, will increase.

Any plans based on long-term projections and estimates of future situations must be flexible. Forest genetics researchers will continually develop new variants of species, new hybrids, and new introductions. As we learn more of the genetic potential of various genera and species, more alternatives will be available to the tree-improvement forester. Similarly, as changes occur in industrial technology in the wood-using industries, in economic projections, in the development of substitute materials for wood, or in new wood products, the plans for tree-improvement programs may change also. There will, therefore, be the need for periodic reviews of the problems and revision of the programs discussed in this analysis.

Because of the diverse objectives and product requirements of the various agencies and industries interested in tree improvement, it is impossible to set specific, inflexible priorities for species improvement. However, the analysis of problem components and presentation of alternate solutions should help each interested organization or agency more effectively set its own more precise priorities within the "high priority" group presented here.

The Problem

This study addresses itself to a component of a more extensive National problem cited by numerous other investigators (USDA Forest Service 1965; Hair 1967; Landsburg *et al.* 1962) and briefly summarized by Cliff:[1]

> "Demand for timber products in domestic and export markets has been growing steadily, and we foresee very substantial further increases in the years ahead.
>
> "At the present time our expanding markets for timber products are being supplied by young-growth forests, particularly in the East, by liquidation of old-growth stands in the West, and by importation of about 10 percent of our total wood use.
>
> "In the near future, however, our forests – under present levels of management – will be unable to supply prospective increases in timber demands. The supply of timber prospectively available from domestic forests and probable imports begins to fall short of the rising trends in use within the next 15 to 20 years. By the year 2000 the projected supplies will fall considerably short of the Nation's projected demands for timber."

and

> "The most promising opportunities for meeting the large increase in future demands for timber products are to be found in intensification of management of our public and private forests. In all forest regions supplies of timber could be substantially increased by such measures as planting, thinning, stand improvement, increased protection against destructive agents and access road construction."

and

> "–silvicultural measures such as tree improvement and use of fertilizers also show great promise for increasing timber growth and quality."

To decide what species or what specific improvement objective within a species will offer the best opportunity for increasing the growth and quality of forests in the North-Central Region four factors have been seriously considered:

1. *The projected demand for forest products.* – Projections of demands indicate general trends in products usage. Although no projections can be completely accurate, they certainly serve as a better guide to the future demand than do the demands of the present. The major forest products considered are pulpwood, plywood and veneer, and lumber.

2. *The area and condition of the Region's commercial forest land.* – We need to ascertain the quality and quantity of land that will be available to provide optimum planting sites for improved trees. By analyzing timber type data it is possible to estimate acreages of land with alternative possibilities for treatment and thus develop some guidelines that will indicate tree-improvement programs needed to satisfy projected demands.

3. *The consideration of other alternatives to meet the demands for the products.* – Although tree-improvement programs may be used to meet future demands, other alternatives may be more economical, more rapid, or more effective. These alternatives need to be considered in any forest management decisions and in particular where long range investments are contemplated.

4. *The status of genetic knowledge available to breed trees.* – The amount of basic genetics information available for various species or genera is essential in determining if they are to be emphasized in a tree-improvement program. It is not economically or technically feasible to initiate tree improvment without *some* knowledge of heritabilities for specific traits. Developmental and action programs can be much more effective if they are based on proven genetic factors.

In the following sections these four factors are discussed.

Projected Demands for Forest Products

An appraisal of the demand for forest products exclusively on a regional basis is not realistic. No longer can the North-Central Region be considered an entity and the situation evaluated from a standpoint of balancing regional supplies and demands. Indeed, Zivnuska (1967) reported

"... there is a need for a reassessment of the importance of present and prospective *international* developments to evaluations of the timber resources of the United States."

The demands on the forests of the Nation as they relate to both domestic and international needs must be considered first in this study. The role that tree improvement can play in contributing to the production and quality of forest trees in the Region will be considered within that framework.

1 *Cliff, Edward P. Wood needs of the future and how they will be met. Statement before Subcomm. on Retail, Distrib., Market. Pract. of Select Comm. on Small Bus., U.S. Senate, Nov. 26, 1968.*

The Timber Trends Report

The current and projected demands on the Nation's timber supply are well analyzed in *Timber Trends in the United States* (USDA Forest Service 1965a). In summary the report reached the following conclusions:

1. Demands for timber products are projected to increase about 80 percent by the year 2000. To meet these projected demands for roundwood, the cut of sawtimber in the Nation's forest, after allowances for imports, is estimated to rise from 48.4 billion board feet in 1962 to 81 billion board feet in 2000.
2. Population is assumed to rise from 187 million in 1962 to 325 million by 2000 – a 74 percent increase.
3. Continued technological improvements in production and marketing in the forest industries will be essential to achieve projected demands for timber.
4. Imports of timber products are likely to increase somewhat, but most of the timber required to supply future U.S. markets is expected to come from domestic forests. Some increases in net imports of lumber and pulpwood products are expected, mainly from Canada, which has extensive undeveloped softwood timber resources.
5. Prospective timber growth and inventories in the U.S. under current levels of forest management *appear sufficient to meet projected demands for the next two or three decades, but not for the later years of this century*. By 1990 projected supplies of sawtimber approximately equal the projected cut but fall short of the projected cut by about 16 percent, or roughly 13 billion board feet, by the turn of the century.
6. Declining quality of timber resources represents a major problem for wood-using industries. Only a part of the total volume of timber growth and inventories is economically suitable raw material. Further reductions in tree size and quality are to be expected if timber cut and growth follow the projections and management continues at recent levels.
7. The outlook is favorable for the pulp and paper industry, but not as encouraging for the the lumber and plywood industries. In recent years, the pulp and paper industry has greatly increased its use of hardwoods. Use of chips from sawmill and plywood plant residues has risen even more sharply.

For the lumber and plywood industries, the timber supply situation in most regions is much less favorable. The adequacy of raw material supplies for these industries does not depend on the total inventory of fiber, but rather on the operable supply of wood of desirable quality and size.

Other Projections

All projections are not as optimistic as those of *Timber Trends.*

Hair (1967) presented alternative ways of projecting long-run trends in demands for paper and board. His projections for pulpwood in 1985 are about 44 percent above those in the Forest Service report. Given this much increase in the cut of pulpwood, and assuming the cut of other timber products and levels of forest management would be about the same as stated in the *Timber Trends* study, projected timber supplies would fall far short of the total timber demanded around 1980. This prospective imbalance, along with declines in the size and quality of harvested trees, points to an increase in the competition for timber and concurrent increases in production and marketing costs beyond the levels that appeared likely in the *Timber Trends* analysis.

Hilliker[2] reported that the most recent projections of future wood requirements indicate total consumption of timber may increase by about 76 percent by the year 2000. However, the major wood products will not share equally in this growth, nor will the major timber-producing regions. A continuing decline in per capita consumption of lumber is expected, with total consumption approximating present consumption. Hardwood plywood and veneer consumption could increase 300 to 400 percent over the next 30 years, but imports and synthetics will control the larger share of the market. He reported pulpwood consumption in the year 2000 could reach two or three times the current level, increasing to 50 prcent or more of total industrial roundwood consumption.

Of greatest significance in these later projections is the greatly reduced estimate of projected lumber consumption and larger increases in demands for veneer, plywood, and pulpwood when compared to the earlier projections in the *Timber Trends* study.

Table 1 summarizes the projections for National consumption, allowable cut, and deficit between cut and consumption. *This deficit reflects the amount by which roundwood production must be increased by intensified forest man-*

---

2 *Hilliker, Richard L. Projecting future trends for Lake States timber. 1969. (Unpublished Ph.D. thesis on file at Univ. Wis., Madison.)*

Table 1.—*Domestic consumption of timber in the United States, 1962, with projections to 1980 and 2000 for consumption, cut and deficit*[1]
(Billion cubic feet, roundwood equivalent)

Timber product	Consumption 1962	Consumption 1980	Consumption 2000	Cut 2000	Deficit 2000
Lumber	2/ 5.9	6.9	8.4	6.9	1.5
Softwood	2/ 4.7	5.5	6.6	5.5	1.1
Hardwood	1.2	1.4	1.8	1.4	.4
Veneer and plywood	2/ 1.0	1.8	2.6	2.0	.6
Softwood	2/ .8	1.4	2.0	1.6	.4
Hardwood	.2	.4	.6	.4	.2
Pulpwood	2/ 3.3	5.4	3/ 13.2	7.4	3/ 5.8
Softwood	2/ 2.3	3.6	7.9	4.4	3.5
Hardwood	1.0	1.8	5.3	3.0	2.3
Other	2/ .5	.5	.5	.3	.2
Softwood	2/ .3	.3	.3	.2	.1
Hardwood	.2	.2	.2	.1	.1
Total	2/ 10.7	14.6	24.7	16.6	8.1
Softwood	2/ 8.1	10.8	16.8	11.7	5.1
Hardwood	2.6	3.8	7.9	4.9	3.0

1/ Source: USDA Forest Service (1965).
2/ Estimated.
3/ Based on projection by Hair (1967) of 1985 demand for pulpwood to be 44 percent above projections of Timber Trends.

agement, including tree improvement, if demands are to be met.

What demands will be made on the forests of North-Central Region to supply the major wood products — pulpwood, plywood and veneer, and lumber? Although changes in technology may bring about new demands for forest products and entirely new types of industries in the Region, the future needs of *today's* industries must be considered in planning the source of supply for the future. Changes within the industry can at least be estimated. Considering the investment that various industries now have in the Region, it seems reasonable to plan long-range programs to supply the same type of end product — pulpwood, plywood and veneer, and lumber — rather than speculate as to what new industries may locate in the Region. It would be feasible, for example, for a sulfate pulpmill to change its major species from aspen to spruce, if spruce were available in larger supply and at a more favorable price; it would not likely be as economically feasible for a sawmill to convert to a fiber mill.

Pulpwood

In 1966 about a tenth of the paper-making capacity of the United States was located within the North-Central Region (USDA Forest Service 1965b, Blyth 1966). Sixty-two of the plants produced a daily total of 11,015 tons of wood pulp (Blyth 1967).

Forty-eight of the mills, producing over 9000 tons of pulp daily, are located in the three Lake States; half of this capacity is in Wisconsin. The remaining 14 pulp and paper plants are in the States of Iowa, Illinois, Indiana, and Missouri. Their capacity is about 1,500 tons per day; of this, Illinois contains over half.

Recent expansions in the paper industry nationally have been in the South because of the rapid growth of its forests and its ample water and labor supply. However, the industry is rapidly using up remaining potential mill sites and swiftly closing the gap between available annual growth and the demands of the future. Also, the rapidly expanding use of southern pine logs for plywood, is creating some local competition for roundwood (Hair and Ulrich 1969). As this happens expansion in the Lake States becomes more likely (Casey).[3]

Expansion of the pulp industry in the Lake States has, indeed, started. Actual and potential publicized mill construction and expansions indicate a rise in the area pulping capabilities of 10 percent between 1966 and 1970. In the Central States for the same period, plans for only one new mill have been announced. However, three new mills proposed for Kentucky will receive much wood from Indiana, Illinois, and Missouri (Blyth 1967). There are five major types of wood pulp used in the manufacture of paper and board; they show widely divergent trends in national consumption. These trends are evident in the North-Central Region. The increased use of sulfate and semichemical pulping processes give the pulp and paper industry greater leeway in

[3] *Casey, Samuel A. The pulp and paper industry; a dynamic force in the National economy. Address to Wis.-Mich. Chap. Soc. Amer. Forest., February 1968.*

selecting species. The sulfite process which is declining in importance in the Region, depends almost entirely on spruce, tamarack, and balsam. At least two sulfite mills in the Lake States have recently closed to be replaced with kraft facilities (Blyth 1967).

The use of spruce is declining because it is in short supply and can be substituted by other species in the sulfate and semichemical pulpmills (fig. 1). The use of jack pine, on the other hand, has risen since it is available in quantity and is used largely in the sulfate process.

Also, the use of aspen has risen tremendously. In 1965 Lake States mills used more than 2.3 times the amount consumed in 1946. Aspen is pulped mainly by the semichemical and the sulfate process.

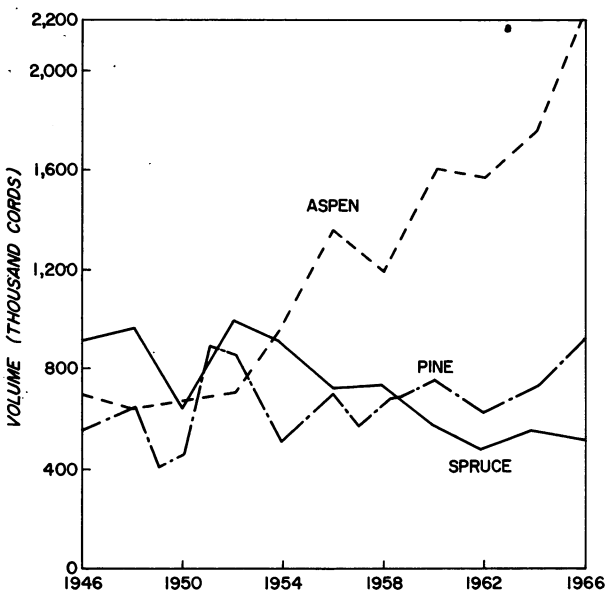


Figure 1.—The trend in use of aspen, pine, and spruce pulpwood in the Lake States, 1946-1966. (Sources: Horn 1965, Blyth 1966, 1967)

It is significant that the use of tamarack is increasing. The rather sudden interest in this species may reflect recognition of its high density and good yields using the kraft (sulfate) process. It is heavier than jack pine and yields as much as 20 percent more fiber. Tamarack yield also compares favorably with hamlock, balsam fir, and spruce under similar pulping conditions (Blyth 1968a, USDA Forest Service 1964).

Other species commonly used are balsam fir, birch, white and red pine, and mixed hardwoods. The industry needs species of various characteristics to manufacture the many grades and qualities of pulp necessary to supply the markets.

Anticipated Production Trends in the Region's Pulp Industry

The pulp and paper industry is recognizing the need to develop new concepts of fiber production. It accepts that it must concentrate its fiber production on fewer acres. Because of the adverse tax structure of most States and increasing harvesting costs, it is increasingly more difficult to profitably hold land for the length of rotation. These long, 30-year-or-more rotations added to the unfavorable tax situation do not attract investors. The treatment of capital gains from timber growing is also becoming more restrictive (Casey).[3]

Rising transportation costs tend to discourage continued large scale imports from Canada and the West.

A short-rotation, highly intensive management system using specially bred varieties and hybrids of trees adaptable to specific sites is under study by various companies and agencies (Westell 1969, Larson and Gordon 1969).

There is a need to use all the wood cut. Perhaps as much as 50 percent of the cellulose produced by the tree is wasted in present logging methods.

Finally, equipment that will mechanize the wood harvesting system is needed and is in the process of development (Gabriel 1968).

Regardless of the silvicultural systems that may come into practice, the pulp manufacturer will require large quantities of timber possessing the following characteristics:

1. High yield of fiber per acre.
2. Uniformity in tree size and growth rate, to facilitate mechanical harvesting.
3. Relative uniformity of fiber length within and between trees of the same species.
4. Relative uniformity of spring-wood/summer-wood ratio within and between trees of the same species.

Although the newer pulping processes are adaptable to many species, a variety of species in the area is necessary to supplying the diverse product demands. It is essential, therefore, for the economics of the industry that a large renewable supply of a number of improved species be available.

Pulpwood and Tree Improvement

The possibilities for meeting the increasing demands for pulpwood through tree improvement concomitant with other intensive management practices are good. Industry has amply demonstrated its abililty to adequately utilize the fibrous material available when this material is in adequate supply and in the right place. Factors of quality such as color, fiber length, and objectionable tars and resin have been dealt with largely through technical innovation in processing. The utilization of an ever increasing variety of species, sawtimber by-products such as chips, and substitute plants such as kenaf all illustrate the versatility of the pulp and paper industry and the rapidity with which technical processes can be evolved and adapted.

The adequacy of the supply of fiber, its relative uniformity within the species, and species suitabililty for sites close to mills are problems to which tree-improvement programs can well be directed.

Plywood and Veneer

The per capita use of plywood and veneer has risen steadily and National demands are expected to continue to rise. The *Timber Trends* report (USDA Forest Service 1965a) predicted that by the year 2000, demand for plywood and veneer would rise to 270 percent of the 1962 consumption. The projection indicated that softwood plywood would account for most of the increase.

Domestic logs are the raw material for practically all of the softwood plywood and veneer consumed in the United States. Douglas-fir, the major species used in the manufacture of plywood, accounted for 88 percent of the total softwood veneer logs used in 1962. An increasing number of other softwood species is being utilized, including western hemlock, western pines, larch, true firs, redwood, cedar, and southern pines.

Tree improvement, as well as other silvicultural research, is very active in the South and West. The intensification of forest management that is expected to follow will assure that the projected demand for softwood plywood in the United States will continue to be supplied from these areas, although changes in plywood tariffs could affect the outlook (USDA Forest Service 1965a).

In the North-Central Region at the present time there are no reported softwood veneer plants operating. There is, however, a large hardwood veneer industry. Seventy-nine veneer mills were operating during 1966 in the Region. Thirty-five were container veneer mills and the others manufactured face, core, crossband, or specialty veneers.

In the Lake States yellow birch, hard maple, and red oak veneers were manufactured in that order of volume. Nearly 28 percent of the birch was imported from Canada whereas virtually all of the maple and red oak veneer logs were produced in the Lake States. The demand for birch is increasing while the local supply is decreasing. There are strong indications that imports of birch from Canada will have to increase to meet the demands (Knutson 1967, Blyth 1968b).

In the Central States in 1966, 24 mills produced commercial and face veneers and 12 container plywood. More black walnut was cut for veneer than any other species: nearly 15 million board feet. Cottonwood logging accounted for another 6.2 million board feet, the second highest species volume cut. Minor amounts of other species were used

Anticipated Production Trends in the Region's Hardwood Veneer and Plywood Industry

National continued rapid growth in per capita consumption of hardwood plywood is anticipated.[1] Consumption of hardwood-based panels could increase by 300 to 400 percent over the next 30 years but imports and synthetics will control large shares of the market. However, the Region is one of the largest suppliers of quality native hardwoods. Although regional trends indicate that the supply of hardwood veneer logs could possibly meet the demands for domestic hardwoods through the year 2000, the quality is declining and some species would have to be substituted for others. Much of the existing timber inventory consists of small trees of low-value species. In the years after 2000 hardwood veneer logs of even mediocre quality would be in short supply under our present intensity of management.

The Black Walnut Situation

The future supply and projected demands of black walnut have been considered intensively in recent years because of its past and present extremely high market value. Future demand for black walnut timber will depend largely on per capita income and consumer preference changes. Demand will probably continue to be strong but it will be increasingly difficult to obtain the quality of wood desired.

A comparison of current growth and cut using medium growth estimates and the latest timber cut estimates converted to standard units shows that the current annual cut of all grades of walnut timber is slightly less than the growth occurring annually on commercial forest land.

However, when quality is considered, the picture is different. The annual cut of high quality materials exceeds the annual increase in equal quality material. Supplies of quality logs are dwindling (Quigley and Lindmark 1966).

The outlook for high-quality walnut timber of sufficient quantity to supply current and increasing demand is not good. Both growth and cut will probably decrease in future years (Fig. 2). Intensive management of our present resource and the establishment and management of walnut plantations of superior stock are the only sure ways to provide increasing quantities of high-quality walnut timber.

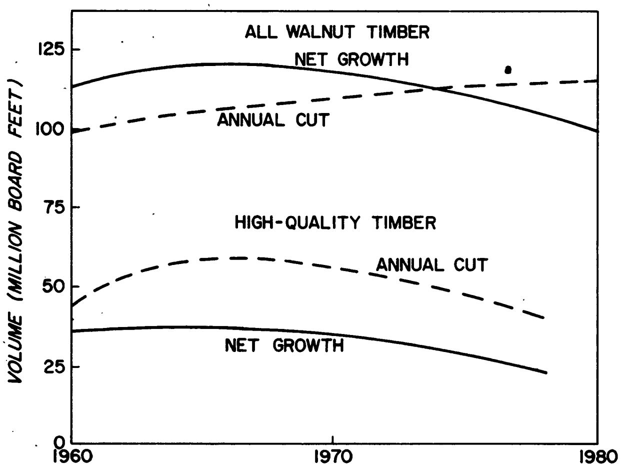


Figure 2.—Probable growth-cut relationship for walnut timber. (Source: Quigley 1966)

Hardwood Plywood and Veneer and Tree Improvement

Because the climate of the Region is uniquely favorable to growing high-quality hardwoods, attention could logically be given to improving the quality and quantity of these species and thus develop the full potential of the Region's forests. Tree improvement programs can contribute to both of these objectives.

Opportunity also exists for increasing yield and quality by means of timber stand improvement.

Tree improvement to increase the veneer quality of hardwoods will likely have little impact upon market situation before the year 2000 and for several decades thereafter.

Lumber

Projections of lumber consumption in the year 2000 vary greatly. The *Timber Trends* report predicted National demands for lumber would rise 43 percent over the 1962 level while Hilliker[1] projected demands in 2000 to be about equal to the demands of 1962.

Currently 88 percent of the Nation's lumber production is concentrated in the West and South. Hilliker[1] estimated that slight intensification of forest management practices in these areas will probably meet the projected demand.

In general, the relative importance of the Region as a lumber producer has diminished greatly since the start of this century. The present industry and the outlook for lumber production varies from State to State. Wisconsin's share of total domestic production, for example, has declined from a high of about 10 percent in 1900 to about 1 percent in 1954. On the other hand, in Illinois, although the number of mills decreased drastically after World War II, the production of lumber increased 38 percent. But the quality of saw logs as well as veneer logs is generally decreasing. Much timber stand improvement will be necessary to maintain the present industries (Essex and Gansner 1965).

Annual lumber-log production in Missouri is expected to reach 500 million board feet by 1989, a level attained only at the turn of the century and during World War II. Logs will decrease in quality and softwoods will represent an increasing percentage of the total volume (Gansner 1965).

The precise place of the North-Central Region as a supplier of lumber in the future is difficult to define. The supply of lumber beyond the year 2000 will be to some extent determined by the cuts of timber for veneer and pulpwood, both products which apparently will be in greater demand.

It would appear that with good management the demand for quality hardwood veneer could take most of the maple, yellow birch, and oak. An expanding Lake States pulp and paper industry will probably utilize the aspen and low grade hardwoods, plus the smaller pine and spruce.

The Area and Condition of the Commercial Forest Land Within the Region

In the Central States (Indiana, Illinois, Iowa, and Missouri) the economy is largely agricultural and industrial, yet 1 out of 5 acres is still forested. This 25-million-acre area of commercial forest land is 98 percent hardwood, mostly in the oak-hickory and bottomland hardwood type. In these States, 90 percent of the forested land is privately owned (USDA Forest Service 1958; Dickerman 1954). The forested region of the Lake States contains 51 million acres of commercial forest land, 70 percent of which is in hardwood types. Private ownership amounts to 60 percent (table 3 in Appendix).

Although it appears certain that changes in land use will continue, it is difficult to estimate their extent. Competition among farm, urban, and forest use for rural land probably will continue for the next several decades. Urban use will replace agricultural or forest use most noticeably in the southern part of the Region (Quinney and Schallau 1963).

Of greater concern to the wood producer is the inevitable shift from commercial to noncommercial uses of forest land. The multiple-use concept allows for recreation in forest management; recreational use of forest land is increasing at a greater rate than are other uses, however. Indeed, visits to National Forests are expected to increase 8-fold by the year 2000 (USDA Forest Service 1961). Today about 50 million people live within 500 miles of the center of the forests of the Lake States, a figure projected to rise to 90 million by the year 2000 (U. S. Department of Agriculture 1963). Timber growing and harvesting will have to be modified in order to satisfy the recreational needs of the future.

Tree Improvement Possibilities Within the Region's Forests

The science of genetics can be applied to forestry to increase the per-acre yield and quality of forest products but only when the improved species are planted or seeded. It becomes pertinent, therefore, to evaluate the commercial forest land in an attempt to analyze:

1. What areas will be available for improved trees to be planted when they become available.
2. In order to meet national demands, in what timber types will the planting of genetically improved trees to be the best alternative for increasing the productivity of the Region's forests.

Since the 1930's much planting has been done throughout the Region, mostly on open land, burned and clearcut areas, and abandoned farmland. Today good, open, tree planting sites are becoming scarce, and when genetically improved seedlings start coming from the Regional nurseries in quantity, high-quality open sites will be virtually nonexistent. Hence, the forest planner must look to other means of increasing productivity of his forest.

Conversion to other species that can better occupy the site, or have been developed and bred specifically for use on these sites, is a realistic alternative to continuing management of the same species (fig. 3). In other cases, conversion may be removal of an existing stand and replacing it with a stand of an improved strain of the same species, especially on good sites. Both possibilities exist in the forests of the Region.

In one recent study, Stevens and Wertz[4] were able to project a 60 percent increase in productivity just on the basis of matching species to site. The National Forests of the Region plan type conversion on over 200,000 acres of poorly stocked land in the next 10 years. Conversion is thus not only desirable, but is being actively practiced within the Region.

Much commercial forest land in the Region is relatively unproductive at the present time. Of its 76 million acres, over 45 million acres — nearly 61 percent, are classed as "poor" or "medium" sites on the basis of existing forest cover. Included are about 18 million acres in the oak-hickory type; about 7 million acres in the aspen-birch type; about 6 million acres in the maple-beech-birch type; and about 5 million acres in the elm-ash-cottonwood type (Table 4, Appendix). This vast acreage scattered throughout the Region offers a challenge to the forester and to the practice of tree improvement.

The approximate condition of the Region's forests and possibilities of stand conversion are *generally* portrayed in Figure 3. In practice, each

---

[4] *Stevens, Mervin, and Wertz, William. Soil-timber species mix, a study. (In preparation for publication, USDA Forest Serv., Eastern Reg.)*

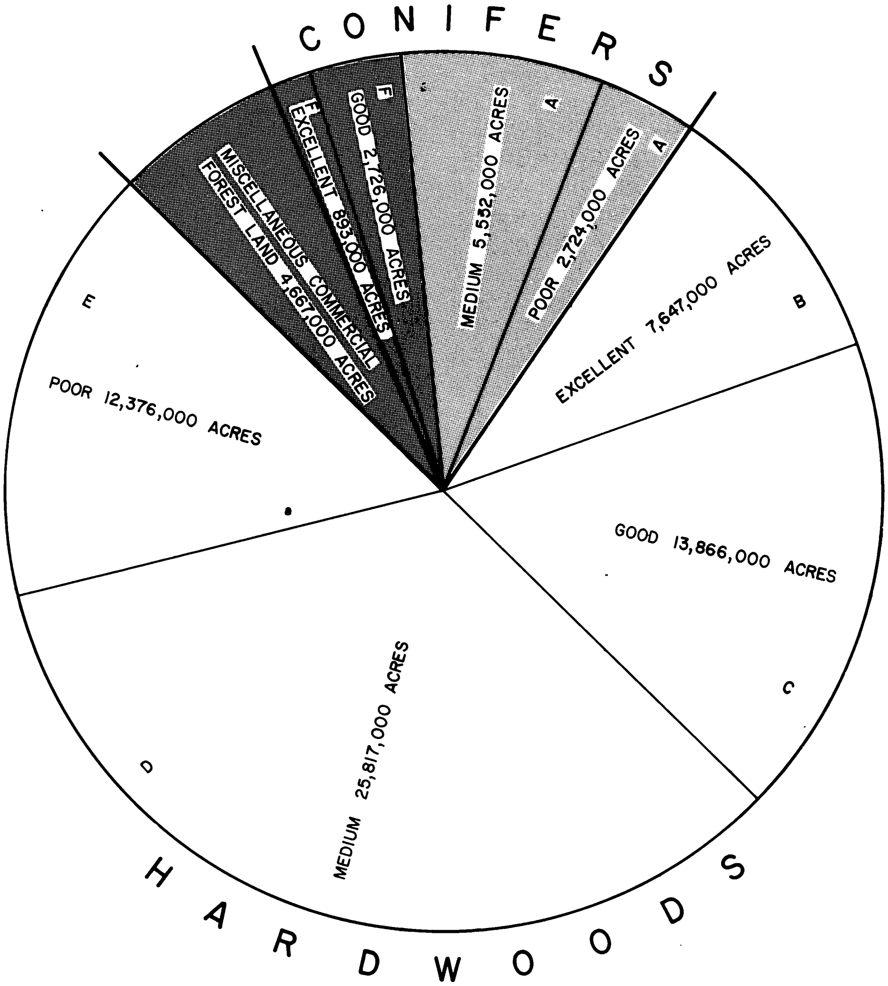


Figure 3.–Acreages of commercial forest land by site classes showing tree improvement possibilities.
A – Convert to species better adapted to site.
B – If improved stock is available, plant to convert to better hardwoods.
C – Plant to improved hardwoods or change species composition by timber management.
D – Consider conversion of some acres to softwoods or other hardwoods.
E – Consider conversion to conifers.
F – Reserve for highly improved stock.

stand needs to be thoroughly appraised before accurate judgments and recommendations can be made.

No attempt should be made to improve trees for poor sites *for that species*. The genetic potential of a species can best be realized when grown under optimum site conditions. It probably will be, particularly in the case of high-value hardwoods, the best practice to plant the improved trees on the best hardwood sites. However, utilizing the less demanding species on the poorer sites is an accepted forestry practice. There are fewer alternatives to increasing yields or the quality of product from a poor site. Timber stand improvement practices such as thinning, pruning, etc., cannot offer much hope of economically increasing the value of the timber on these sites.

All forest stands with a low site index are not reasonable candidates for conversion to other species, or improved strains of the same species, because other species may not produce well on the particular site either.

In the Lake States emphasis should be put on tree- improvement programs to develop species lines that can be used to convert poor-site aspen-birch, maple-beech-birch, and spruce-fir types. Selection and development should be concentrated on species that will likely be in demand and are able to use these sites most efficiently.

In the conifer types the need for conversion to other species is not so well defined. White cedar, tamarack, and black spruce types occupy a high percentage of medium and poor sites, yet the opportunities for substituting species on these sites appear limited.

Perhaps the best opportunity for improving the production on the upland conifer areas by means of tree improvement is by replanting stands as they are harvested to improved types of the same species. There is need for more species alternatives from which to choose for these locations.

In the Central States the biggest problem is the poor oak-hickory sites, if we are to consider them a part of the commercial forest acreage. At present, it is not economical to manage oak-hickory stands on the poorer sites. As the demand for forest products increases, the pressures on the land for all uses intensifies, and as property taxes rise, conversion of these stands to species that can better utilize the site may become more practical.

The better sites of both the elm-ash-cottonwood and the oak-hickory may well be managed to produce the species that are there now – or they may be replanted with improved types of the same species as they become available. Some stands in these types, however, could also be modified to include high-value hardwoods such as black walnut.

Alternatives to Meet Projected Demands

The Nation's commercial forest land is capable of producing much more than the growth projected on the basis of current forest management (USDA Forest Service 1965a). A number of technical forestry measures could be strengthened to bring future supplies of timber in line with projected demands.

1. Timber stand improvement holds the most promise for increasing the timber supply over the next few decades. In many areas, timber stands of desirable trees could be developed by thinning, removing cull trees, or other cultural work.
2. *Planting or seeding productive sites, particularly to genetically improved trees, also offers opportunities for increasing future yields of timber, particularly after the year 2000. Although nationally tree planting has covered about 1.3 million acres annually in recent years, more than 100 million acres of commercial forest land are at present either "nonstocked" or "poorly stocked" with trees of acceptable quality or species.*
3. Increased protection from fire, insects, disease, and other destructive agents offers additional possibilities for expanding wood supplies. Losses have been greatly reduced in recent decades, but mortality in 1962 still totaled 20 billion board feet or 35 percent of the net annual growth of timber.
4. Closer utilization of timber in the woods and in manufacturing plants also would stretch the available timber supplies. Salvage of dead timber and greater use of logging and other manufacturing residues could augment supplies of round timber.
5. Continuing increases in efficiency in forest industries would permit a larger output of products from a given supply of raw material.

Although tree improvement programs and practices can, in some cases, help meet the increasing demands for forest products in the Region, they are not the *only* means to economically increase the supply or improve the quality of our wood products. Alternatives for reaching the desired objectives are available and should be recognized in setting program priorities.

Reasonable forestry alternatives for meeting demands diminish as the quantity of material required increases simply because there is so much more acreage and so many more individual trees involved. For example, it may be possible to apply intensive timber-stand improvement practices on a few thousand acres each year; it is out of the question on millions of acres. There is a practical limit to the area that can be effectively treated in this manner. Similarly, the cost of insect and disease control may become prohibitive as the acreage of affected stands increases.

The rotation ages of the various species also influence the choice of forest practice to increase yield or quality. The cost of any one timber stand improvement operation must be prorated over the length of the rotation when considering returns on investments. Hence, tree improvement may offer an attractive alternative for short rotations when the annual prorated cost of other practices would be too high.

Another factor to consider is the relative unit cost of the wood produced. Although the future relative cost of any species is difficult, if not impossible, to determine, the general laws of supply and demand can be applied to make some rational judgments. If the unit value of wood is high and remains high at the time of harvest, there can be a greater investment in timber-stand improvement. As the unit value increases, alternatives for yield or quality improvement increase.

These general concepts point out that in the North-Central Region, tree-improvement programs can be used to best advantage in increasing the supply of pulpwood, with lesser advantage when applied to species intended for other purposes. The projected demand for pulpwood in the Region is much greater than the projected total demand for hardwood veneer and plywood or lumber. Similarly, the unit value for pulpwood is much lower than for the other products. Hence, tree improvement programs along with intensive culture and total tree utilization appear to offer the best alternatives for increasing the supply.

Also, there is sufficient commercial forest land in the Region in good and excellent site classes to meet the demand for many species utilized mainly for veneer or lumber with intensified timber-stand-improvement practices. There are, for example, over 5 million acres of excellent to good oak-hickory sites capable of producing high yields of those species without the use of genetically improved species. There are over 3 million acres of the maple-beech-birch type (largely sugar maple) in excellent or good site classes which, with intensified management, could greatly increase the production of sugar maple.

Considering that to meet the National demand for all hardwood products (veneer and lumber), only 0.6 billion cubic feet needs to be added to the projected cut, quantity demand for these products could generally be met by practices other than tree improvement.

Tree Improvement as an Investment

Cost-benefit analysis is desirable when evaluating management alternatives for individual species or stands. At present published data are insufficient for precise evaluations of this nature (Namkoong, Barefoot, and Hitchings 1967). However, it is possible to predict in general terms the investment returns on tree improvement programs.

The analysis of red and jack pine improvement program models given by Lundgren and King (1966) presents long- and short-term alternatives. The short-term program bases the selection of clones for seed orchards on 5-year progeny tests. For both species the highest return on invested capital under most conditions favored the short-term programs. A slightly higher increase in site index would be necessary with jack pine than with red pine to yield comparable rates of return. Increasing the site index of class 55 land by only 2 units resulted in a calculated investment return of 7.5 percent for red pine and 6 percent for jack pine. Thus only a slight gain in site index would be necessary to justify any of the suggested programs. Lundgren and King stressed the fact that the best rates of return could be attained on the best sites for the species.

Pitcher (1966) discussed the cost of white spruce seed obtained from established seed-production areas. He calculated that an increase in rotation volume yield of as little as 0.25 percent would offset all the costs of development.

Similarly, Lester (1969) discussed genetic improvement of white spruce as an investment alternative. Assuming a compound interest rate of 4 percent, he calculated the cost of improved seed to be $10.35 per acre. Considering a 45-year "breeding period" and a 75-year rotation, a 9.2 percent increase in yield would be necessary to justify this cost. Current genetics research indicates increases in white spruce yields of about 25 percent. This would mean a per acre profit of $17.81 over costs or $1,252,300 for the 70,000 acres that were assumed to have been planted.

Swofford[5] determined the internal rates of return based on expected gains resulting exclusively from genetic improvement of nursery stock. Costs included tree selection, orchard establishment, and progeny testing. Expected benefits were estimated for (1) rotation age reduction, (2) quality gain, and (3) volume gain. Calculated internal rates of return were:

Longleaf pine	14 percent
Loblolly pine	18 percent
Slash pine	19 percent
All species	15.5 percent

Clearly, tree-improvement programs can be sound investments that yield respectable rates of return.

---

[5] *Swofford, Thomas F. An economic evaluation of tree improvement on the Alabama National Forests. USDA Forest Serv., Southern Reg. 1968.*

Status of Genetics Knowledge

Applied tree-improvement projects must be founded on genetic principles. Information derived from basic genetics research, therefore, becomes extremely relevant. The tree breeder must have some genetic guidelines to start with, or he will find the work diverted to studies set up to determine *how* to accomplish the desired gains rather than projects basically designed to produce improved trees. It is extremely important to recognize that there must be close coordination between action or developmental programs and research. There must be a continuous flow of information from genetics research to tree-improvement projects and a feedback of information from these applied programs to research. Management and research must be closely linked.

An extensive review of all forest tree genetics research relating to potential tree-improvement programs in the North-Central Region would be too voluminous to consider as part of this analysis. The work is well documented, however, in several bibliographical publications (Wright 1955; Libbey *et al.* 1956; Wright and Finn 1960; Wright and Rudolf 1962).

Genetics Research Programs in the Region

The earliest forest tree improvement in the area began before 1900 when tests of the adaptability of several exotic tree species were included in some of the early forest planting. However, planned experiments to determine variation within a forest tree species did not begin until 1928, when Carlos Bates of the Lake States Forest Experiment Station began a study of red pine seed sources. This has been followed by other genetic and forest tree improvement research at the North Central Forest Experiment Station, the State universities and colleges, and forest industries (Rudolph 1956).

Limstrom (1965) reported the latest research findings and considered judgment of foresters experienced in tree improvement for species used in planting programs in the Central States.

Rudolph (1966b) reported on genetics and related research at the Lake States Forest Experiment Station during the period 1924-1965. This report listed 172 papers published by staff members of the Station with indexes by subject matter and species names.

More recently, Jeffers[6] summarized 10 years of research at the North Central Station's Institute of Forest Genetics. Work at the Institute has concentrated on *Picea* spp., *Betula* spp., *Pinus banksiana, Larix laricina, Abies balsamea, Thuja occidentalis*, and *Pinus strobus*.

Some genetic research has also been published through the auspices of several regional forest tree improvement committees:

1. The Lake States Forest Tree Improvement Committee
2. The Northeastern Forest Tree Improvement Committee
3. The Central States Forest Tree Improvement Committee
4. The Committee on Forest Tree Breeding in Canada.

The committees have sponsored conferences annually or biennially, the published proceedings of which report on a broad variety of genetic research studies.

Provenance—or seed-source—testing has been conducted as a cooperative project with the "NC-51 Committee." The Committee is composed of one forest research scientist from each of 10 State Agricultural Experiment Stations in the North Central Region, a representative of the USDA Forest Service, and a representative from the U.S. Cooperative State Research Science as organized in 1960 under provision of the Hatch Act. The purpose of the project is to conduct a cooperative research program in forest tree improvement through selection and breeding. Range-wide provenance tests have been started with 12 species. Results of work of the NC-51 project are rather limited due to the short time the studies have been in progress.

Rudolph (1966a) summarized basic and applied genetics research by species, agencies involved, and subject matter. In 1965 there were 133 research projects conducted by 12 agencies in Wisconsin, Michigan, Minnesota, and North Dakota.

---

[6] *Jeffers, Richard M. Ten years research at the Institute of Forest Genetics, Rhinelander, Wisconsin. (In preparation for publication, N. Cent. Forest Exp. Sta., USDA Forest Serv., St. Paul, Minn.)*

The following agencies in the Region were reported to have forest genetics research in progress: North Central Forest Experiment Station, University of Minnesota, University of Wisconsin, Michigan State University, University of Michigan, University of Illinois, Iowa State University, Purdue University, University of Missouri, Michigan Technological University, U.S. Forest Products Laboratory, and the Institute of Paper Chemistry. Several other organizations and agencies are involved in applied breeding and developmental work (Rudolf, 1966a).

Significantly, of all the research projects in the Lake States, 73 percent are concerned with three genera: *Pinus*, *Picea*, and *Populus*.

Work in progress on the genus *Pinus* includes 52 studies involving *Pinus resinosa*, 47 studies relating to *Pinus banksiana*, and 35 studies concerning *Pinus strobus*. *Pinus sylvestris* is the only exotic pine that has been the subject of any significant studies in the Lake States (22 studies).

Picea glauca was the subject of 52 (or 46 percent) and *Picea mariana* of 22 (or 20 percent) of the spruce studies (Rudolf, 1966a) (fig. 4).

Among the hardwoods, the genus *Populus* has received most research attention (fig. 5). In the Lake States, 92 of the 142 studies dealing in the genetics of hardwoods involved the genus *Populus*. Although most of the studies in the Lake States involve *P. grandidentata* or *P. tremuloides*, internationally there has been much research on the genetics and breeding of the *Aigieros* poplars. The genera *Betula* and *Juglans* are the subject of more recent studies in the Region.

Shortleaf pine *(Pinus echinata)* is currently receiving attention in tree-improvement programs in Missouri. Dorman (1962) reviewed the literature on the species and outlined a proposed breeding program.

Vegetative propagation techniques for the species of interest in the Region are well established by a number of authors. Although more knowledge regarding air layering, rooting of fascicles, and more basic knowledge of the physiological processes involved is needed, it is possible to start improvement programs with the knowledge

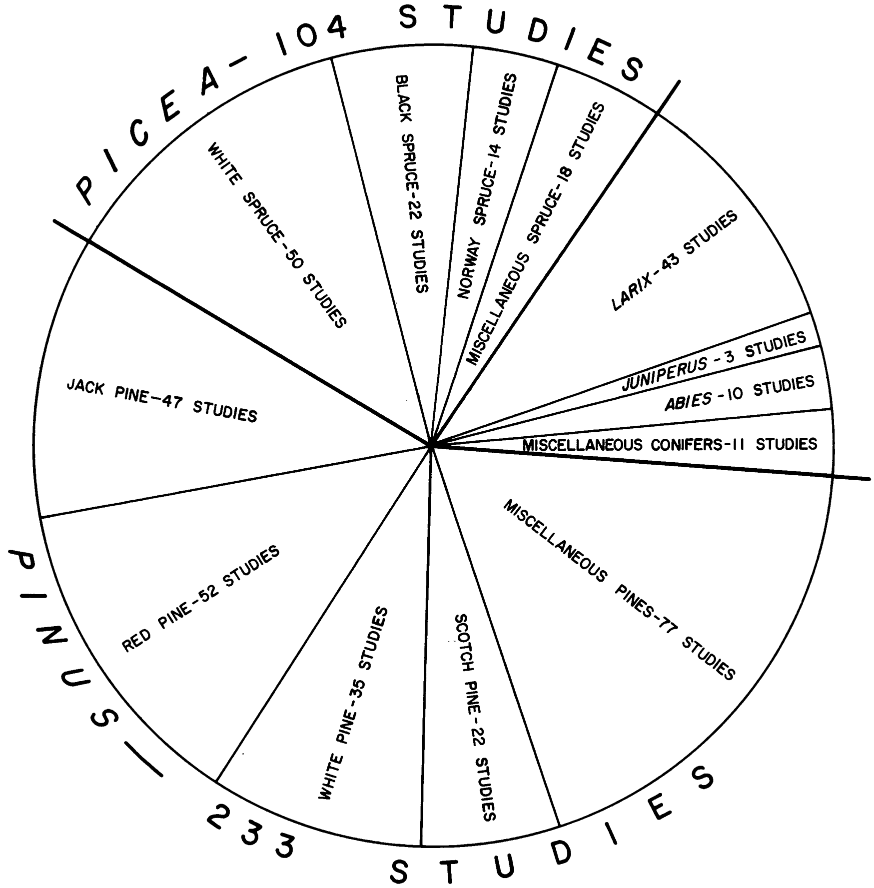


Figure 4.—Species or genus of 404 genetics research studies of conifers in the North Central Region in 1965.

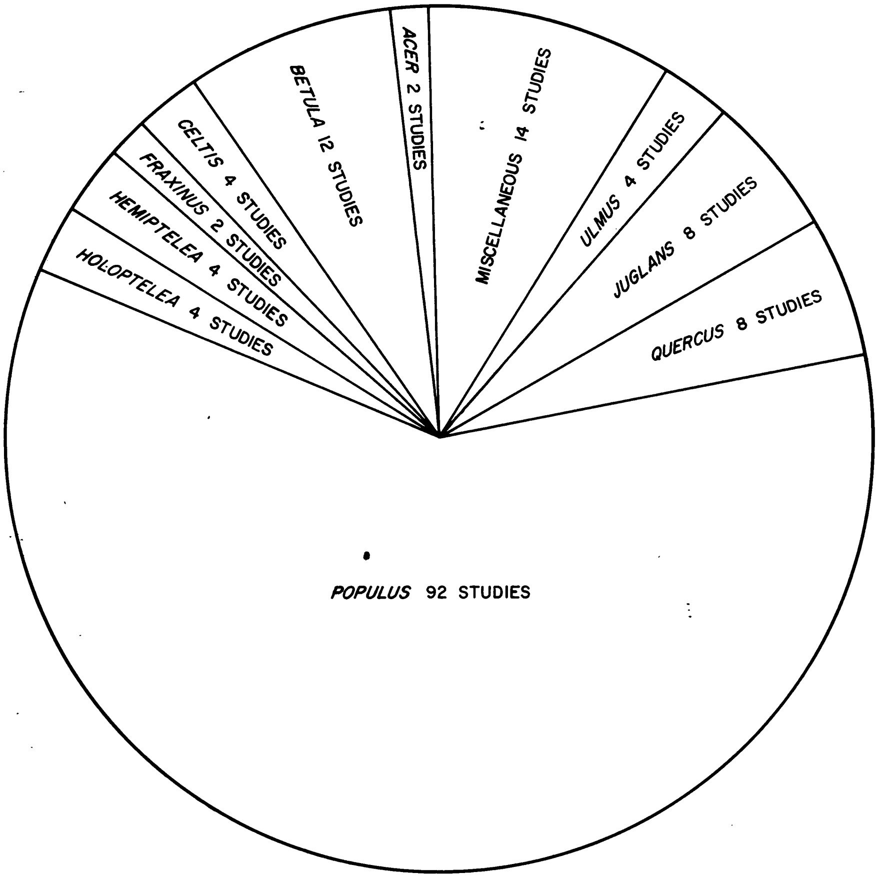


Figure 5.—Species or genus of 154 genetics research studies of hardwoods in the North Central Region in 1967.

available. These techniques as they apply to the Region is probably best summarized by Nienstaedt (1959) and Nienstaedt *et al.* (1958).

It is evident from the literature that the most genetics research has been done on the following 11 species currently of economic importance in the North Central Region:

Pinus resinosa	*Pinus echinata*
Pinus banksiana	*Betula* spp.
Pinus strobus	*Juglans nigra*
Picea glauca	*Larix* spp.
Picea mariana	*Populus* spp.
Pinus sylvestris	

Although much additional research is needed, sufficient genetic knowledge has accumulated on these species to provide agencies contemplating tree-improvement programs with enough information to begin.

Developmental Programs in the Region

There are a number of developmental programs underway within the North Central Region. These programs differ in intensity but they do indicate the extent of the interest in developmental work. A brief summary of these programs will illustrate the point.

Industry

Forest-tree-improvement research in the Lake States so far has concentrated on basic or quasi-basic problems in an effort to accumulate a store of knowledge that may eventually be adapted to practical forest management. Because of the nature of the general program, the momentum of this work has been set by public and educational research organizations. But many of the projects could not have come so far without the cooperation of the Lake States forest industries.

Cooperation by industry in tree-improvement research work has been in three general categories:

1. Grants of money to support research. (The Institute of Paper Chemistry's genetics program, which is supported by paper companies, is an example of this type of cooperation.)

2. Release of land or other facilities for use by the research institution.

3. Actually sharing the work. (Some of the North Central Forest Experiment Station's seed source studies are this kind of cooperation.)

In addition to cooperative research studies with public agencies, several companies have developed, or plan to develop, seed orchards of *Abies balsamea, Picea glauca, Picea mariana, Pinus banksiana, Pinus resinosa*, and *Pinus strobus*. Others have reported the establishment of red pine seed-production areas.

In application of tree-improvement knowledge, industry has taken the lead in one field — the growing of forest planting stock from seed of presumably better-than-average genetic quality. The seven industrial forest nurseries in the Lake States produce about 7 million trees annually. All of these nurseries have a seed-quality program wherein at least part of the seed they require is collected under direct company supervision from selected trees and stands (Macon 1960).

The Institute of Paper Chemistry at Appleton, Wisconsin, has had an industry-supported program in "Aspen Genetics and Tree Improvement" since 1954. Aimed primarily at improving growth rate, form, and wood quality, an action program was begun in 1968 by the Institute of Paper Chemistry to demonstrate the biological potential of natural and improved aspen.

The American Walnut Manufacturer's Association supports research and development programs in black walnut, particularly through the Black Walnut Breeding Project at Carbondale, Illinois. Its members contribute plant materials for further trial and evaluation.

States and other Public Land-Managing Agencies

Each of the States in the North-Central Region is involved in developmental programs at one level or another. The State of Illinois, through the University of Illinois at Urbana, is supporting developmental breeding work with cottonwood. The State of Indiana is developing a black walnut seed orchard near Mitchell. Combined research and development programs for improved strains of red and jack pine are conducted by the Michigan Department of Natural Resources through the State universities. The Minnesota Conservation Department has participated in the outplanting of a black walnut seed source study and the establishment of red pine production areas. The Department of Natural Resources in Wisconsin is supporting research and development programs in red pine and balsam fir in cooperation with the University of Wisconsin. All three Lake States are cooperating in a joint effort with the USDA Forest Service to produce strains of white pine resistant to blister rust. The State of Missouri has a full time tree-improvement specialist assigned to developmental work in that State An active selection program is underway there in black walnut, red-cedar, and cottonwood.

National Forest-Tree-Improvement Programs

Forest Service programs active in the North Central Region involve mainly white and black spruces; red, jack, and white pines; and yellow birch in the Lake States. In the Central States programs are underway with shortleaf, loblolly, and white pine; black walnut; and yellow-poplar. Some work is also in progress with red oak, basswood, and black cherry. Major emphasis has been on volume yield in all species with consideration given to the comparative quality characteristics.

Three 50-clone seed orchards of white spruce serving separate geographic areas within the Lake States are partially established in the large 550-acre seed orchard on the Nicolet National Forest in Wisconsin. Similar orchards are planned for black spruce. A clonal breed arboretum containing over 700 rust-free selections of white pine is also planned and partially completed within this orchard complex. Selections of white pine resistant to the weevil (*Pissodes strobi*) are being cloned for later outplanting in the orchards.

A 15-acre, half-sib seedling progeny test and seed orchard was established in 1964 on the Huron-Manistee National Forest in cooperation with Michigan State University. It contains 290 individual tree collections of red pine from the Lake States area.

In the Central States, a 50-clone orchard of shortleaf pine is being developed in connection with the tree-improvement program of the National Forests in the Southern Region. Established in Arkansas, this 85-acre orchard will eventually supply up to 2,000 pounds of seeds annually for reforestation of the Clark and Mark Twain National Forests.

In the North Central Region, 33 seed-production areas were established with 6 species from 1960 to 1966. Cones have been harvested from some of these areas and seedlings outplanted on reforestation projects on the National Forests.

Additional programs are under development with these and other species in the eastern part of the Eastern National Forest Region.

Situation Summary

The National need for wood products is projected to increase 80 percent by the year 2000 and there is an estimated continued growth in demand at an unknown rate after 2000. The projected cut is short of the projected consumption by different amounts depending on the product.

According to the *Timber Trends* report and Hair (1967) the National production of roundwood for major timber products must increase by the following amounts if they are to meet the demands of 2000:

	Billion cubic feet	*Percent consumption increase*
Pulpwood	5.8	400
Softwood lumber	1.1	140
Softwood plywood and veneer	.4	242
Hardwood lumber	.4	150
Hardwood veneer	.2	250

The supply of these products must be produced on a constantly diminishing area due to uses of the land for other than timber production.

Emphasis on increasing the quantity and quality of raw material from the Region's forests should be first on pulpwood, both hardwood and softwood, and second on hardwood veneer. There is little evidence that a significant increase in the lumber industry will develop in the Region as most of the demands for lumber will continue to be met by the West and South. Generally, the first concern for tree improvers should be, therefore, increased fiber yield per acre.

It is essential to consider *all* the possibilities of improving the quantity and quality of our forest products. Timber-stand-improvement, including pruning, thinning, disease and insect control, and controlling stocking are all measures that need to be considered as alternatives to and along with tree-improvement practices.

Of the 76 million forested acres in the Region, 46 million acres (or 61 percent) are "medium" or "poor" sites. To meet the demands on the forests for wood products it seems inevitable that forest managers will sooner or later have to consider converting to other species that can utilize these sites more efficiently.

In the Lake States first priority is to develop improved species so the portion of the 13 million acres of aspen-birch types on "medium" and "poor" sites, that appears to be excellent site for other species, can be converted. Second, attention should be given to improving the species now existing in quantity on the better sites and to replace the trees there with improved strains of the same species. This is particularly relevant for the 7 million acres of "good" aspen-birch stands and the 3 million acres of maple-beech-birch stands on high-quality sites.

In the Central States tree improvement should be aligned to (1) provide improved alternate species for converting at least part of the 18 million acres of medium and poor oak-hickory sites that appear to be excellent or good sites for the alternate species; (2) improve the several native high quality hardwoods in answer to the demand for the growing veneer and furniture markets; and (3) consider the improvement of cottonwood, elm, and ash so as to better utilize the areas now occupied by these species.

Program Plans

In this analysis four factors for determining general species, priorities for the improvement programs have been explored:

1. The National demand for forest products.
2. The area and condition of the Region's commercial forest land.
3. Alternative means of meeting demands.
4. The amount of basic genetics knowledge available for various species.

Because of the status of basic genetics knowledge available, tree-improvement programs in the Region are currently best confined to the genera and species for which there are adequate genetic guidelines. The tree improver cannot effectively and efficiently breed trees without some knowledge of variability within the species and the heritability of the species traits he wishes to improve.

For the North Central Region, it has been pointed out that so far most relevant genetics background information has been accumulated on 11 genera and species, listed alphabetically:

1. *Betula alleghaniensis*, yellow birch
2. *Juglans nigra*, black walnut
3. *Larix*, spp., larches
4. *Picea glauca*, white spruce
5. *Picea mariana*, black spruce
6. *Pinus banksiana*, jack pine
7. *Pinus echinata*, shortleaf pine
8. *Pinus strobus*, white pine
9. *Pinus sylvestris*, Scotch pine
10. *Pinus resinosa*, red pine
11. *Populus*, spp., aspen, cottonwood and poplar

Some of the species in this list have much greater potential than others for increasing the quality and quantity of Regional forest products through tree improvement.

The analysis of projected demands for forest products, the availability of optimum planting sites in the future, and alternatives for meeting the demands make it possible to at least generally evaluate the probable contribution each of the 11 species, if genetically improved, might make.

Specific priorities, within the list of 11 species can best be determined by the agency or organization concerned after considering all four factors in light of its own management objectives.

The following "Species Summary" discusses the potential of each species in detail, prescribes specific developmental tree-improvement programs, and suggests applied research needed to implement the use of the improved trees.

No projection involving the demand for forest products for the year 2000 or beyond can be completely accurate. Therefore, programs following the recommendations presented here may not precisely meet the needs of the future. Because of the years involved, the danger of breeding obsolescence into our forestry programs is a very real one. Consequently, other factors being equal, those species well adapted for *several* uses are judged to be better candidates for tree-improvement programs than are "single-purpose" species.

Wright (1962) discussed the various methods available to the tree breeder and the genetic gains to be realized from each of the techniques. Where heritability for a specific trait is high, mass selection methods are effective and economical. When heritabilities are low or suspected to be low, then family selection methods can produce more genetic gain per unit cost. These concepts are considered in the recommendations presented for improvement projects.

Species Summary

Yellow Birch *(Betula alleghaniensis)*

One of the more versatile hardwoods for veneer, lumber, furniture, cabinets, and flooring, it is a decreasing component of the maple-beech-birch timber type of the Lake States. There appears to be no effective way of increasing the amount of yellow birch in the stands other than by planting. Because of the large acreages of this timber type, genetics and silvicultural work should be accelerated in this species.

Yellow birch tree-improvement programs should begin with phenotypic selection using the guides developed by Clausen and Godman (1967). Since the species flowers early and abundantly, collection of open-pollinated seed from the best phenotypes and the establishment of seedling seed orchards would seem to be the most efficient approach. Little advantage is to be gained by grafting. Heritability estimates for the important economic traits are not available. Recurrent selection within the F_1 breeding population may prove productive.

Black Walnut *(Juglans nigra)*

Although the current demand for black walnut is high, the variety of end products is somewhat restricted because of the high price. However, black walnut wood has commanded a premium price for more than 300 years and the future demand will probably continue to be high.

Black walnut fits nicely into specific ecological niches in the southern part of the Region. Some of the problems of quality – i.e., color and grain – cannot be controlled by forestry practices. As with all nut species, intensive breeding programs are expensive. Black walnut programs should probably include only the suggested steps listed below. These programs plus increasing the planted acreages and intensive silviculture should meet the demand considering the relatively moderate increase necessary.

Black walnut tree-improvement programs

should start with phenotypic selection of outstanding individuals, concentrating the selections within the optimum development range but including specimens from a north-south and east-west transect. A half-sib seedling seed orchard should be established on a good site with concurrent half-sib progeny tests at several locations. The seed orchard should be rogued of poor families at about 20 years based on mean family performance in all the progeny tests. Clonal orchards and controlled pollination seem impractical at this time, pending further heritability data. Cultural methods of weed control, fertilization, irrigation, and first-log pruning should be practiced in the progeny test only if they can be expected to be standard practices in black walnut management. Progeny tests should sample the oak-hickory types as well as the deep cove types.

Larches *(Larix)*

There is much interest in the larches because of their juvenile growth rate, their adaptation to various sites, and their excellent pulping and construction lumber qualities. Genetically, heterosis (hybrid vigor) is manifested between many crosses within the genus. The potential of the genus in the Region appears to be high. Additional basic genetics research is desirable before intensive tree-improvement programs can be started.

Tamarack selections of superior phenotypes should concentrate first on volume yield. A second selection program should aim at sawfly resistance. Separate clonal seed orchards should be established followed by progeny tests to evaluate combining abilities both within and between orchards.

White Spruce *(Picea glauca)*

White spruce is biologically a productive species. When grown on high-quality sites in southeastern Ontario, it produced 5,705 cubic feet per acre in total wood at the end of 40 years (Stiell and Berry 1967). By comparison, red pine on an excellent site in Minnesota produced 4,490 cubic feet at the end of 40 years (Buckman 1962).

Although the consumption of spruce in the pulp industry has been declining, the reason for the decline is not related to the quality of wood as a pulp species. On the contrary, its relatively long fiber length, lack of objectionable resins, and color of pulp produced make it a preferred species. Although the newer pulp-making processes are not limited to spruce and a few other species, as is the sulfite process, spruce can be utilized effectively by tnem. Should changes in economics of technology cause the demand for spruce pulpwood to decline in spite of its availability, the potential of white spruce as a plywood species is good (Shottafer, 1968). Because of these factors and the large acreage of commercial forest land in the Lake States which from an ecological point of view needs conversion to white spruce to markedly increase its productivity, intensive developmental programs are well justified.

Programs now underway in the Lake States are based on phenotypic selection in wild stands. Greatest weight should be given to volume yield and growth rate. Clonal seed orchards should be established and progeny tests set out to estimate combining abilities. Recurrent selection within the progeny tests should be productive.

On a mass selection basis, selection of superseedlings in nursery beds may be a relatively inexpensive way to obtain significant growth increases. Superseedlings could be established in outplantings as performance trials, thinned at a later date, and progeny tested. Selection and crossing in subsequent progeny tests should be productive.

Black Spruce *(Picea mariana)*

Black spruce is the superior pulping species. It occupies over 2 million acres, more than half of which are poor to medium sites. These sites offer little opportunity for conversion to other species. Black spruce has been planted and seeded throughout the Region and is in demand for sites susceptible to late spring frosts, in addition to the more moist sites not well adapted to white spruce. Because of the amount of acreage now in poor sites of aspen-birch and maple-beech-birch, black spruce could be an asset within the Region. More research is needed, however, to determine its genetic potential.

Any improvement program for black spruce should parallel that for white spruce. A mass selection program, using seed from the Lake States area, should be considered. Selection of superseedlings in the nursery followed by the establishment of seedling seed orchards to serve as progeny tests similar to the white spruce program would probably be the most efficient improvement approach.

Shortleaf Pine *(Pinus echinata)*

Considering the vast acreage of poor-quality oak-hickory sites in Missouri alone, alternate species need to be found that will make better use of these sites. Shortleaf pine has possibilities and is, in fact, being used in conversion plantings. There is sufficient research to start improvement programs with a view to conversion of poorer sites of oak-hickory in Missouri, Illinois, and Indiana. Seed-source tests to determine the possibility of extending the species range northward are suggested.

Shortleaf pine improvement programs should start with the selection of superior phenotypes, with major emphasis placed on volume yield. Of secondary importance is the improvement of stem form. Selection for resistance to Eastern gall rust appears impractical and is not of great economic importance. Clonal seed orchards should be established. Concurrent with the development of these orchards, half-sib progeny tests can be established using open-pollinated seed from the sellected ortets. Family means from these progeny tests can then be used to develop a crossing scheme to evaluate the combining ability of the clonal lines in the orchard for the mass production of F_1 seed. One or more of the F_1 progeny test areas can be rogued and used as seedling seed orchards for the production of F_2 seed.

Jack Pine *(Pinus banksiana)*

Jack pine is an important pulp species, although currently much more red pine than jack pine is being planted in the Lake States. There is great genetic diversity within the species. This, coupled with early flowering, makes jack pine a good candidate for intensive tree-improvement programs. Accurate soil-site information may indicate much more acreage on which jack pine would be better suited. As the economic pressures on pulp and paper companies lead to shorter rotations and intensive management on fewer acres, jack pine probably will become more important because of its rapid juvenile growth. Small seed source studies should be conducted to determine the feasibility of converting some of the oak-hickory sites south of its natural range to jack pine.

Jack pine lends itself readily to the seedling seed-orchard approach. Its great variability makes selection for positive phenotypes easy. Because it flowers early and abundantly there is little advantage to a clonal approach for this species. Phenotypic selection should be carried out in young natural stands and plantations. Major emphasis in selection should be given to volume yield, stem form, and apparent disease and insect resistance, in that order. Half-sib progeny test seedling seed orchards should be established. Rogued at an early age, these will start producing F_2 seed for testing on a wide variety of sites. Progeny testing should include some of the oak-hickory sites in the southern parts of the Region. Recurrent selections should be productive after the F_2 generation.

A separate selection program may be aimed at resistance to the sawfly and budworm. Since resistance to insects is usually low, these selections should be cloned, crossed, and evaluated for specific combining ability. At some later time, outcrosses to high yield and form selections can be made.

Red Pine *(Pinus resinosa)*

More red pine has been planted in the Lake States than any other species. This will probably continue to be the case in the future. Red pine is genetically relatively uniform. Although improvement is possible, the per unit gains are not expected to be as great as with other species. Added to this is the fact that available sources of seed now produce good-quality, uniform stock. In view of the projected need for this species, three separate development programs, one for each of the Lake States, are underway. Eventually they will serve to supply the seed for plantings in the area. This effort should be sufficient to meet the projected demands for the species.

White Pine *(Pinus strobus)*

Research programs now underway will do much to determine the course of future work with white pine. The results of provenance tests in the Lake States will show the best geographic sources to use in the Region. The blister rust resistance breeding project will produce some resistant types, but additional basic research is needed in relation to blister rust. Further developmental work with white pine in the Lake States depends upon an acceptable solution to the weevil problem, in spite of the fact that there is much land that could now probably be best utilized by white pine. Small seed source studies have been inaugurated to determine the possibilities of extending the range of white pine into the southern part of the Region for purposes of converting some of the oak-hickory type (Funk 1965).

Suggestions for a white pine improvement program center about its two main problems, blister rust and the weevil. Approaches to the rust resistance problem have been well documented by Heimburger (1962). Callaham (1966) gives a rather complete summary of the alternatives available to the tree breeder involved in practical programs for developing pest resistance.

Scotch Pine *(Pinus sylvestris)*

Tree-improvement programs for Scotch pine are active in European countries where the species is native. It is also receiving much attention for Christmas tree production and environmental forestry in the United States. However, considering projected demands for timber products and the alternatives available for meeting them through the use of native species, Scotch pine tree improvement programs for timber production in the Region should probably have low priority.

Aspen, Cottonwood, and Poplar *(Populus* spp.*)*

There are eight million acres of highly productive aspen sites in the Lakes States, and 10 million acres of elm-ash-cottonwood sites throughout the Region. The projected yearly increase for pulpwood consumption is seven times that of hardwood veneer. The pulp industry has learned to use the *Populus* species and some prefer it to other species. Alternatives to satisfy the demand are not very realistic when the quantity of material is considered. Although more research work needs to be done to adequately back a developmental program for *Populus*, there is already sufficient knowledge to get one started. Much genetic variation exists within the genus and significant potential for genetic improvement is apparent. The genus has rapid juvenile growth so necessary to the pulp industry of the future. Graham *et al.* (1963) reported aspen in southern Michigan growing to 80 feet in 30 years, yielding a merchantable volume of 3,450 cubic feet per acre.

Tree-improvement programs in *Populus* species will probably develop along clonal lines. Superior phenotypes in wild stands should be selected for growth rate, form, disease resistance, specific gravity, and rootability. Both male and female selections must be considered. These selections should be cloned, probably by rooting cuttings; and a clonal bank should be established. This approach will provide selected planting stock or cuttings with greater growth potential than coppice forests. One caution in establishing forests from cuttings: Do not rely on one or two clonal lines. Establish plantings using "multiclonal" lines to avoid disaster by hypersusceptibility of some clonal lines to disease pathogens. Forests established with planting stock from clonal seed orchards are not subject to the same limitations.

Because *Populus* species flower and mature seed within a short span of time, controlled pollination on cut branches under greenhouse conditions is a reasonable approach to genetic improvement. Each cross will yield large numbers of seeds for testing, a distinct advantage not possible with most other species. Crosses yielding outstanding offspring can be repeated and multiplied rapidly in clonal seed orchards.

Another approach to *Populus* improvement is concerned with polyploidy, particularly the triploid aspens that have greater growth rates than their diploid parents. Naturally occurring autotriploids have been located in the Lake States and are now under study. Some of the superior phenotypes selected for cloning may possibly be triploids.

● Table 2 summarizes tree improvement possibilities for the high priority species for tree improvement in the North Central Region. ●

Improvement of Other Species

This discussion of specific species and recommended breeding plans should not obscure the fact that to fill small but specific planting requirements for any species the established practices of tree improvement should be used. These practices include:

1. Choosing seed from proven geographic sources or sources most likely to produce the stock best adapted to the planting area.
2. Gathering seed from the best available phenotypes of the species. If planting programs of a species are to continue for some time, it may be economically feasible to establish small seed-production areas or clonal seed orchards using the untested seed that will result.
3. Screening nursery beds for the most vigorous individuals. As a minimum practice, the least vigorous individuals should be culled.
4. Silvicultural systems using "natural" regeneration methods should encourage selecting the best available phenotypes of the desired species as seed sources.

A number of other native genera and/or species show much promise for meeting the increasing demands on the forests. They have not been considered in this analysis because of a lack of basic genetics information about them. Some of these species are: *Betula papyrifera*, paper birch; *Platanus occidentalis*, sycamore; *Alnus glutinosa*, European alder; *Luriodendron tulipifera*, yellow poplar; *Fraxinus* spp., ashes; *Acer rubrum*, red maple; and *Acer saccharinum*, silver maple.

Table 2.—*Tree improvement needs, possibilities and alternatives for the high priority species for tree improvement in the North-Central Region*

Species	End use(s)	Major improvement objectives	Alternate or supplemental means of meeting projected demands	Available sites for planting	Suggested tree improvement program	Other applied forestry research needed
Betula alleghaniensis	Veneer, hardwood paneling, furniture, cabinets, flooring	1. Yield 2. Stem form (apical dominance)	1. Timber stand improvement 2. Use substitute species on poorer sites	Some of the 3 million acres of excellent and good maple-beech-birch types	1. Phenotypic selection of superior trees 2. Establish progeny test-seedling seed orchards	1. Planting techniques 2. Seed orchard management techniques, seed harvest
Juglans nigra	Veneer, hardwood paneling, furniture, gunstocks	1. Stem straightness (apical dominance) 2. Frost hardiness 3. Anthracnose resistance 4. Yield	1. Intensive timber stand improvement practices 2. Establish more acreage of black walnut plantations	Prairie soils and agricultural land not now considered commercial forest land. Some of the 4 million acres of elm-ash-cottonwood sites.	1. Phenotypic selection of superior trees 2. Establish progeny test-seedling seed orchards	1. Even-aged management studies 2. Soils and site relationships 3. Effect of thinning and fertilizing
Larix spp.	Pulpwood, lumber, poles, pilings	1. Yield 2. Larch sawfly resistance	1. Increase supply of pine, aspen, spruce, other pulp species 2. Intensive timber improvement practices in existing stands of tamarack	Full site potential yet to be determined	1. Select superior phenotypes of *Larix laricina* 2. Establish clonal seed orchards followed by progeny tests 3. Provenance tests to extend range to southern part of Region	1. Site adaptability of *Larix* hybrids 2. Management of *Larix* hybrids
Picea glauca	Pulpwood, lumber, veneer	1. Yield 2. Late spring frost resistance 3. Early growth rate	1. Plant more acreage 2. Timber stand improvement in existing stands	1. Some medium and poor aspen sites 2. Some medium and poor maple-beech-birch sites 3. Replacement on excellent white spruce sites	1. Phenotypic selection of individual trees 2. Establish clonal orchards 3. Progeny tests 4. Super seedlings	1. Site adaptability of *P. glauca* hybrids 2. Response to intensive culture short rotation systems 3. Species comparison on various sites
Picea mariana	**Pulpwood**	1. Yield	1. Timber stand improvement 2. Improvement of poor sites by drainage	1. Excellent and good black spruce sites 2. Some of the poorer, low moist aspen and maple-beech-birch sites	1. Phenotypic selection of individual trees 2. Establish clonal seed orchards 3. Progeny tests -or- 4. Mass selection 5. Super seedlings used to establish seedling orchards as progeny tests	1. Response to intensive culture, short rotation systems 2. Soil-site relationship studies 3. Planting techniques on wet sites
Pinus echinata	Pulpwood lumber	1. Yield 2. Stem form	1. Intensive timber stand improvement 2. Substitute other species which might better occupy oak-hickory sites 3. Increase acreage in pine type	1. Some of the 14 million acres of oak-hickory and oak-pine sites in Missouri, Illinois and Indiana	1. Phenotypic selection of individual trees 2. Establishment of clonal seed orchards	1. Soil-site relationships 2. Graft incompatibilities 3. Economics and techniques of conversion in oak-hickory types
Pinus banksiana	Pulpwood lumber, poles	1. Yield 2. Stem form 3. Budworm resistance 4. Nonserotinous cones	1. Substitute other pine species 2. Increase planting 3. Timber stand improvement on better sites	1. Present jack pine sites 2. Some of the poorest aspen and birch-beech-maple sites 3. Some poorer sites of the red and white pine types	1. Phenotypic selection for yield 2. Establish progeny test-seedling seed orchards and/or 3. Select for resistance 4. Establish clonal orchard 5. Progeny test 6. Outcross	1. Soils-site relationship studies 2. Techniques for evaluating insect resistance

Table 2 continued.

Species	End use(s)	Major improvement objectives	Alternate or supplemental means of meeting projected demands	Available sites for planting	Suggested tree improvement program	Other applied forestry research needed
Pinus banksiana	Pulp, lumber, poles	1. Yield 2. Stem form 3. Budworm resistance 4. Nonserotinous cones	1. Substitute other pine species 2. Increase planting 3. Timber stand improvement on better sites	1. Present jack pine sites 2. Some of the poorest aspen and birch-beech-maple sites 3. Some poorer sites of the red and white pine types	1. Phenotypic selection for yield 2. Establish progeny test-seedling seed orchards and/or 3. Select for resistance 4. Establish clonal orchard 5. Progeny test 6. Outcross	1. Soils-site relationship studies 2. Techniques for evaluating insect resistance
Pinus resinosa	Lumber, veneer, pulp, poles	1. Yield 2. Shorter rotations	1. Timber stand improvement on better sites 2. Substitute other species on poorer sites	1. Some of the 7 million acres of poorer aspen-birch sites 2. Some of the 6 million acres of poor maple-beech-birch sites 3. Some of the 300 thousand acres of poorer white pine sites	1. One parent-progeny from 1200 Wis. selections: test in 4 zones. Leave top 25% best families in a seed orchard. 2. Establish clonal seed orchard from selection of 5 best trees from 17 best families for Minn. 3. One-parent progeny from 290 Mich. selections tested in a 15-replicate design	1. Practical methods of stand conversion 2. Direct seeding techniques
Pinus strobus	Lumber veneer, poles	1. Yield 2. Blister rust resistance 3. Weevil resistance	1. Timber stand improvement 2. Substitute red pine 3. Develop alternative methods of blister rust control 4. Develop biological, silvicultural or chemical control of weevil 5. Plant only in rust hazard areas	1. Some of the medium site index aspen and about 4 million acres of poor maple-beech-birch sites 2. Possible use in Illinois, Iowa, Indiana and Missouri for conversion of medium and poor oak-hickory sites	1. Provenance test: oak-hickory sites in Central States 2. Make 700 resistant selections. Make controlled crosses with resistant pollen. Inoculate progeny in nursery. Establish survivors in clonal seed orchard	1. Control of white pine weevil through management or genetics
Populus spp.	Pulp, veneer	1. Yield 2. Shorter rotations 3. Disease resistance 4. Fiber length 5. Specific gravity	1. Substitute other pulp species 2. Intensify culture of existing types	1. 8 million acres of good and excellent aspen-birch sites 2. Some of 4 million acres of elm-ash cottonwood sites	1. Select superior clones from natural stands and plantations for growth rate, form, disease resistance. Male and female clones must be considered. Propagate by root cuttings 2. Establish rooted cuttings in clonal bank 3. Progeny test (controlled and open) all female clones 4. Establish in clonal bank all superior material resulting from seed orchard	1. Clonal silviculture 2. Planting techniques 3. Vegetative propagation techniques 4. Harvest methods 5. Management of clonal orchards for the production of hybrid seed 6. Seed collection, extraction storage 7. Intensive short rotation culture

Program Organization and Execution

Most forest land in the North Central Region is privately owned (see table 3 in Appendix). Although there is wide variation in the forest management practiced on private forest land, much of this land is not managed at all. If the projected demands for forest products are to be met, it is essential that the intensity of management on these lands be increased.

A number of research studies are needed before intensive management of privately owned forest land can be successfully launched.

Private land ownershhip, in too many cases, involves antipathy toward commercial production of timber, a lack of awareness of its compatibility with other uses, and little or no favorable motivation. On the other hand, many obvious and unfavorable social pressures affect the landowner's decisions. A thorough study of the many factors that contribute to this attitude might provide a plan for corrective action. Such a plan, for instance, might suggest the need for commercial organizations that would provide *full* forest land management services at reasonable cost to small, especially absentee, landowners.[7]

Reforestation, underplanting, and converting to more desirable or productive species are intensive silvicultural management practices. Not only motivation, but facilities necessary to carry out these practices need to be organized to take full advantage of the potential of private woodlands.

Additional nurseries to supply planting stock to the thousands of small acreages would not be needed. State, Soil Conservation District, and private nurseries could rapidly expand their production if the demand increased. Needed, however, are programs to develop and supply genetically improved seed for planting stock throughout the areas served by the nurseries.

Because of the high proportion of forest land in the Region being serviced by the State nurseries, a high priority job is the acceleration of intensive tree-improvement programs by the Departments of Natural Resources of the States of the Region, particularly the Lake States.

Although privately owned, the land of the pulp and paper, veneer, and lumber companies presents a somewhat different problem. Acreages are much larger than the average for other "miscellaneous owners." The industries owning the land have explicit management objectives; the land is frequently managed on a multiple-use basis, but in such a manner as to best provide for their own needs. Motivation is not a serious consideration in dealing with the management of industrial forests. Indeed, some of the largest industrial interests in the Region have been leaders in the forest management field. Taxation, harvesting, and transportation costs, and plenty of available wood have been the major deterrents to intensive forest management.

Tree-improvement has not been of as much concern to the pulp and paper industry in the Region as it has in the South because a surplus of pulp species has been available in the North.

However, as raw material costs increase, pulp and paper companies may find intensive, short-rotation, single-purpose management systems, using trees bred for this specific purpose and located near their mills, to be attractive. Research is needed to determine the feasibility of such systems.

The initial breeding programs, for companies using the same species, could be operated on a cooperative basis. Trees bred to furnish maximum yields of fiber on one company's land would have the same potential on the adjacent land of another. There would be a distinct advantage to selecting the best individuals from the larger combined acreages of several companies. It may not be judicious to hire a professional tree breeder for the benefit of one company, but it may definitely be productive to do so for a large program supported by several companies.

There is precedent for this type of program. The North Carolina State - Industry Cooperative has been active since 1956. Its membership is composed of 18 industries and the Forestry Division of the States of North Carolina and Virginia (North Carolina State University 1967). Similarly, in the northeast, 16 pulp and paper companies and State and Private Forestry Division of the Forest Service have joined in an informal cooperative tree-improvement program for white spruce and balsam fir.

---

7 *USDA Forest Serv. Forestry in the Upper Great Lakes Region. Forest Serv. Task Force Rep. to Upper Great Lakes Reg. Comm. 1968.*

Summary

The function of this problem analysis is to interpret economic trends and relate them to planning for applied research and developmental or action programs in forest-tree improvement.

It is impossible to develop precise quantitative methods for analyzing long range forestry programs. So this analysis is qualitative, describing general trends and judgments rather than positive or discreet criteria for choosing and conducting projects. Moreover, as projection techniques become more refined, as new technology creates new demands or erases old ones, it is likely that some of the recommendations and forecasts presented here will prove to be in error. However, there will be less chance of error than if projected demands and land-use possibilities were considered only lightly or not at all.

Recommendations in the present analysis need to be reviewed periodically and updated. New information coming from more basic forestry and genetics research, innovations of manufacturing technology, shifting social trends, and more recent projections make this review process imperative.

Finally, specific recommendations are made in this publication that somewhat restrict species alternatives open to applied research, developmental, and action programs in tree improvement. These recommendations should not be interpreted as limiting the scope of the more basic forest genetics research programs. On the contrary, they point out the need for more fundamental studies on a greater number of species. The recommendations in this problem analysis are limited by the amount of basic information available *now*. When present and future research results are available, more alternatives will be available to the tree improver.

Literature Cited

Blyth, James E. 1966. Pulpwood production and consumption in North Central region by county, 1965. USDA Forest Serv. Resource Bull. NC-2, 27 p., illus. N. Cent. Forest Exp. Sta., St. Paul, Minn.

Blyth, James E. 1967. Pulpwood production and consumption in the North Central region by county, 1966. USDA Forest Serv. Resource Bull. NC-3, 27 p. N. Cent. Forest Exp. Sta., St. Paul, Minn.

Blyth, James E. 1968a. Lake States pulpwood production drops seven percent, 1967. USDA Forest Serv. Res. Note 59, 3 p., illus. N. Cent. Forest Exp. Sta., St. Paul, Minn.

Blyth, James E. 1968b. Veneer log production and consumption, North Central Region, 1966. USDA Forest Serv., Resource Bull. NC-5. 6 p., illus. N. Cent. Forest Sta., St. Paul, Minn.

Buckman, Robert E. 1962. Growth and yield of red pine in Minnesota. USDA Forest Serv. Tech. Bull. 1272. 50 p., illus.

Callaham, R. Z. 1966. General guidelines for practical programs toward pest-resistant trees. *In:* Breeding pest resistant trees. Proc. NATO/NSF Adv. Study Inst. p. 489-493., illus.

Clausen, Knud E., and Godman, Richard M. 1967. Selecting superior yellow birch trees, a preliminary guide. USDA Forest Serv. Res. Pap. NC-20., 10 p., illus. N. Cent. Forest Exp. Sta., St. Paul, Minn.

Dickerman, M. B. 1954. The forests of the Lake and Central States Region. Soc. Amer. Foresters Meeting Proc., Oct. 24-27, 1954, p. 1-4.

Dorman, K. W. 1962. Forest tree improvement for Georgia: A problem analysis of research needs in forest tree breeding and forest genetics. Georgia Forest Res. Counc. Rep. 9, 79 p., illus.

Essex, Burton L., and Gansner, David A. 1965. Illinois timber resources. USDA Forest Serv. Resource Bull. LS-3, 56 p., illus. Lake States Forest Exp. Sta., St. Paul, Minn.

Funk, David T. 1965. Southern Appalachian white pine off to a good start in the Midwest. Fourth Central States Tree Improv. Conf. Proc., Lincoln, Nebraska, Oct. 1-3, 1964. Neb. Agr. Exp. Sta., p. 26-28, illus.

Gabriel, William J. 1968. Technological forecasting and pulpwood harvesting. Techn. Rel. 68:P-4. LSTO. American Pulpwood Assoc. New York. 2 p.

Gansner, David A. 1965. Missouri's forests. USDA Forest Serv. Resource Bull. CS-2. 53 p. Cent. States Forest Exp. Sta., Columbus, O.

Graham, Samuel A., Harrison, Robert P., Jr., and Westell, Casey E., Jr. 1963. Aspens, phoenix trees of the Great Lakes Region. Univ. Mich. Press, 272 p., illus.

Hair, Dwight. 1963. The economic importance of timber in the United States. USDA Forest Serv. Misc. Public. 941. 91 p., illus.

Hair, Dwight. 1967. Use of regression equations for projecting trends in demand for paper and board. USDA Forest Service Resource Public. 18, 178 p., illus.

Hair, Dwight, and Ulrich, Alice H. 1969. The demand and price situation for forest products 1968-69. USDA Forest Service Misc. Public. 1086, 74 p., illus.

Heimburger, C. 1962. Breeding for disease resistance in forest trees. Forest. Chron. 38 (3): 356-362.

Horn, Arthur G. 1965. Pulpwood production Lake States counties, 1964. USDA Forest Serv. Resource Bull LS-2, 19 p., illus. Lake States Forest Exp. Sta., St. Paul, Minn.

Knutson, Robert G. 1967. Lake States veneer log production shows increase in 1965. USDA Forest Serv., Res. Note NC-26, 3 p., illus. N. Cent. Forest Exp. Sta., St. Paul, Minn.

Landsberg, Hans H., Fischman, Leonard L., and Fisher, Joseph H. 1962. Resources in American's future: patterns of requirements and availabilities, 1960-2000. 1017 p., illus. Baltimore: John Hopkins Press.

Larson, Philip R., and Gordon, John C. 1969. Photosynthesis and wood yield. Agr. Sci. Rev. 7(1): 7-14, illus.

Lester, D. T. 1969. Genes, dollars, and sense. *In*: Colloquium for foresters in Wisconsin, Wausau, Wisconsin, March 10, 1969. Univ. Wis. Ext. Div.

Libby, William J., Barnes, Burton V., and Spurr, S. H. 1956. Forest genetics in the Lake States. Univ. Mich. Sch. Nat. Resources, 74 p.

Limstrom, G. A. 1965. Interim forest tree improvement guides for the Central States. USDA Forest Serv. Res. Pap. CS-12. 64 p., illus. Cent. States Forest Exp. Sta., Columbus, Ohio.

Lundgren, Allen L., and King, James P. 1966. Estimating financial returns from forest tree improvement programs. Soc. Amer. Foresters Proc. 1965: 45-50, illus.

Macon, J. W. 1960. Industry's part in forest tree improvement research in the Lake States. *In:* Fourth Lake States Forest Tree Improv. Conf. Proc., Lake States Forest Exp. Sta., Sta. Pap. 181, p. 48-50.

Namkoong, G., Barefoot, A. C., and Hitchings, R. G. 1967. Problems in evaluating control of wood characteristics through breeding. TAPPI Fourth Bio. Conf. Proc.: p. 131-142. Pulp and Paper Research Inst. Can.

Nienstaedt, Hans, Cech, Franklin C., Mergen, Francois, Wang, Chi-Wu, and Zak, Bratislav. 1958. Vegetative propagation in forest genetics research and practice. J. Forest. 56:826-839, illus.

Nienstaedt, Hans. 1959. Fall grafting of spruce and other conifers. Plant Propagators Soc. Proc. 1958: p. 98-104.

North Carolina State University. 1967. Eleventh annual report, NC State-Industry Cooperative Tree Improvement Program. School. Forest. N. Carolina State Univ., Raleigh. 42 p.

Pitcher, John A. 1966. Cone and seed yields in white spruce seed production areas. Joint Proc. Second Genet. Workshop of the Soc. Amer. Forest. and the Seventh Lake States Forest Tree Improv. Conf., USDA Forest Serv. Res. Pap. NC-6, p. 76-77. N. Cent. Forest Exp. Sta., St. Paul, Minn.

Quinney, D. N., and Schallau, C. H. 1963. Lake States forest lands in a changing economy. Land Econ. 39: 421-428, illus.

Quigley, Kenneth L., and Lindmark, Ronald D. 1966. Timber resources: *In*: Black walnut culture. USDA Forest Serv. N. Cent. Forest Exp. Sta., 94 p., illus.

Rudolf, Paul O. 1956. Laying the foundation for forest tree improvement in the Lake States. Wis.-Mich. Sect. Soc. Amer. Forest. Proc.: p. 1-7.

Rudolph, Paul O. 1966a. Forest genetics and rement research in the Lake States, 1965. USDA Forest Serv. Res. Pap. NC-1, 54 p. N. Cent. Forest Exp. Sta., St. Paul, Minn.

Rudolf, Paul O. 1966b. Forest genetics and related research at the Lake States Forest Experiment Station — an annotated bibliography, 1924-1965. USDA Forest Serv. Res. Pap. NC-5. 35 p. N. Cent. Forest Exp. Sta., St. Paul, Minn.

Shottafer, J. E. 1968. Plywood from eastern spruce. Forest Prod. J. 18 (10): 19-21.

Stiell, W. M., and Berry, A. B. 1967. White spruce plantation growth and yield at the Petawawa Forest Experiment Station, Can. Dep. Forest. Rural Develop. Public. 1200, 15 p., illus.

Stone, Robert N. 1966. A third look at Minnesota's timber. USDA Forest Serv. Resource Bull. NC-1, 64 p., illus. N. Cent. Forest Exp. Sta., St. Paul, Minn.

Stone, Robert N., and Thorne, Harry W. 1961. Wisconsin's forest resources. USDA Forest Serv., Lake States Forest Exp. Sta., Sta. Pap. 90, 52 p., illus.

Thornton, Phillip L., and Morgan, James T. 1959. The forest resources of Iowa. USDA Forest Serv., Cent. States Forest Exp. Sta. Forest Surv. Release 22, 46 p., illus.

U. S. Department of Agriculture. 1963. Resources and recreation in the Northern Great Lakes Region. U. S. Dep. Agr. Task Force Rep., 133 p., illus.

USDA Forest Service. 1961. Outdoor recreation in the Upper Great Lakes Region. USDA Forest Serv., Lake States Forest Exp. Sta., Sta. Pap. 89, 104 p., illus.

USDA Forest Serv. 1964. Pulp yields for various processes and wood species. USDA Forest Serv. Res. Note FPL-31, 3 p., illus. Forest Prod. Lab., Madison, Wis.

USDA Forest Service. 1965a. Timber trends in the United States. USDA Forest Serv. Resource Rep. 17, 235 p., illus.

USDA Forest Service. 1965b. Wood pulp mills in the United States and Canada. Spec. Rep. 20 p., illus.

Westell, Casey E., Jr. 1969. Positive planning for high yield forestry needed in the Lake States. *In:* The third forest, 1969 pulpwood annual. p. 108-110. New York: Miller Freeman Publications, Inc.

Wright, Jonathan W. 1955. A bibliography on forest genetics and forest tree improvement, 1954. USDA Forest Serv. Northeastern Forest Exp. Sta., Sta. Pap. 77, 41 p.

Wright, Jonathan W. 1962. Genetics of forest tree improvement. FAO (Rome) Forest. Forest Prod. Stud. 16, 399 p. illus.

Wright, Johnathan W., and Finn, Raymond F. 1960. A bibliography on forest genetics and forest tree improvement, 1956-1957. U. S. Dep. Agr. Misc. Public. 808, 85 p.

Wright, Jonathan W., and Rudolf, Paul O. 1962. A bibliography on forest genetics and forest tree improvement, 1958-1959. U. S. Dep. Agr. Misc. Public. 906, 93 p.

Zivnuska, John A. 1967. U. S. timber resources in a world economy. Res. for the Future Ive. 125 p., illus. Baltimore: John Hopkins Press.

Appendix

Table 3.—*North Central Region commercial forest land*[1] *by ownership*
(Thousand Acres)

State	Total land area	Total commercial forest	Federal land				State	County and municipal	Private land						
			Nat'l forest	BLM	Indian	Misc.			Total	Comm. forest land (percent)	Pulp & paper Co's	Lumber	Other indus.	Farmer	Misc. private
Illinois	35,795	3,761	188	--	--	41	11	--	3,521	94	--	17	--	2,216	1,288
Indiana	23,158	3,960	112	--	--	65	115	2	3,616	91	--	9	--	2,833	774
Iowa	35,861	2,595	3	--	1	9	22	2	2,558	95	--	--	--	2,282	276
Michigan	36,492	19,121	2,420	9	21	90	3,695	85	12,791	67	946	485	117	3,841	7,412
Minnesota	51,206	17,056	2,141	64	516	92	3,304	3,416	7,522	44	630	48	37	3,344	3,464
Missouri	44,248	14,977	1,310	--	--	51	199	25	13,391	90	--	279	--	9,228	3,885
Wisconsin	35,011	15,396	1,372	5	423	110	541	2,615	10,799	70	713	220	--	6,372	3,025
TOTAL	261,771	76,866	7,546	78	961	458	7,887	6,145	54,198	--	2,289	1,058	154	30,116	20,124
Percent of commercial forest land		100	9.8	.1	1.3	.6	10.3	8.0	70.5	--	3.0	1.4	.2	39.1	26.2

1/ Source: USDA Forest Service (1965).

Table 4.—*Timber types; North Central Region, by site class (Thousand Acres)*

Timber type	Total	Ex.	Good	Med.	Poor	Total	Ex.	Good	Med.	Poor	Total	Ex.	Good	Med.	Poor
	ILLINOIS1/					INDIANA2/					IOWA3/				
Hardwood types															
Oak-hickory	2,232	34	435	1,196	567	2,389	251	448	1,552	138	1,036		156	520	360
Aspen-birch	9			9		13	4	6	3		20		3	10	7
Elm-ash-cottonwood	1,442	380	505	517	39	554	105	148	297	4	1,219		183	610	426
Maple-beech-birch	14			14		788	92	142	529	25	78		12	39	27
Oak-pine	12				12	46		3	26	17					
Oak-gum-cypress	17			17		52	9	6	32	5					
Total hardwood types	3,726	414	940	1,753	618	3,762	461	753	2,439	189	2,353		354	1,179	820
Conifer types															
White pine	1			1											
Loblolly shortleaf	35			17	18	54	12	3	32	5					
Total conifer types	36			18	18	54	12	3	32	5					
Misc.; nonstocked, brush etc.	1										242				
Total	37			18		3,816	473	756	2,471	194	2,595				
	MICHIGAN4/					MINNESOTA5/					MISSOURI6/				
Hardwood types															
Oak hickory	2,405	586	615	672	532	1,039	65	152	372	450	11,333	85	1,240	7,495	2,513
Aspen-birch	4,675	1,626	1,426	1,209	414	6,254	740	1,865	2,162	1,487					
Elm-ash-cottonwood	1,936	495	563	518	360	1,949	116	317	508	910	2,180	248	1,031	830	71
Maple-beech-birch	5,245	654	1,354	2,230	1,007	1,009	52	167	416	374	85		37	43	5
Oak-pine											639			379	260
Oak-gum-cypress											410	43	229	128	10
Total hardwood types	14,261	3,361	3,958	4,629	2,313	10,251	973	2,501	3,458	3,221	14,647	376	2,537	8,875	2,859
Conifer types															
Spruce-fir	1,082	53	483	440	105	1,248	128	368	486	266					
Jack pine	897	5	123	729	40	885	15	158	560	152					
Black spruce	428	50	62	207	110	1,408	170	372	422	444					
Northern white-cedar	1,188	122	181	439	446	417	16	61	192	148					
Red pine	596	128	176	282	10	284	16	93	151	24					
Tamarack	176	3	33	103	37	568	23	85	182	278					
White pine	154	6	53	87	8	134		10	33	91					
Loblolly shortleaf											330		17	160	153
Total conifer types	4,521	367	1,111	2,287	756	4,944	368	1,147	2,026	1,403	330		17	160	153
Misc.; nonstocked, brush etc.						1,861									
Total	18,782					17,056					19,977				
	WISCONSIN7/					REGIONAL TOTALS									
Hardwood types															
Oak hickory	2,573	618	669	720	566	23,007	1,639	3,715	12,527	5,126					
Aspen-birch	4,611	1,059	1,380	1,388	784	15,582	3,429	4,680	4,781	2,692					
Elm-ash-cottonwood	941	151	215	260	315	10,221	1,495	2,962	3,640	2,125					
Maple-beech-birch	2,663	234	559	1,116	754	9,882	1,032	2,271	4,387	2,192					
Oak-pine						697		3	405	289					
Oak-gum-cypress						479	52	235	177	15					
Total hardwood types	10,788	2,062	2,823	3,484	2,419	59,868	7,647	13,866	25,917	12,439					
Conifer types															
Spruce-fir	373	28	140	147	57	2,703	209	991	1,073	428					
Jack pine	692	11	109	501	71	2,474	31	390	1,790	263					
Black spruce	260	31	53	101	74	2,096	251	487	730	628					
Northern white cedar	223	16	33	93	81	1,828	154	275	724	675					
Red pine	148	20	46	74	8	1,028	164	315	507	42					
Tamarack	185	6	30	84	65	929	63	148	369	349					
White pine	174	3	37	70	64	462	9	100	190	163					
Loblolly shortleaf						419	12	20	209	176					
Total conifer types	2,055	115	448	1,070	420	11,930	893	2,726	5,592	2,724					
Misc.; nonstocked, brush etc.	2,553					4,667									
Total	15,396					76,465	8,540	16,592	31,509	15,163					

1/ From Essex and Gansner (1965).
2/ From unpublished data on file at North Central States Experiment Station, USDA Forest Service, St. Paul, Minn.
3/ From Thornton and Morgan (1959).
4/ Unpublished data on file at North Central Forest Experiment Station, USDA Forest Service, St. Paul, Minn.
5/ Stone (1966).
6/ Unpublished data on file North Central Forest Experiment Station, USDA Forest Service, St. Paul, Minn.
7/ Stone and Thorne (1961) and unpublished data on file at North Central Forest Experiment Station, USDA Forest Service, St. Paul, Minn.

Table 5.—*Basal area growing stock all commercial forest land by States in North Central Region (In thousand square feet)*

Species	Illinois	Indiana	Iowa	Michigan	Minnesota	Missouri	Wisconsin	Total	Percent
Balsam fir				51,206	111,071		24,231	186,508	5.162
Eastern redcedar	307		636				157	1,100	0.030
Tamarack				5,136			7,430	12,566	0.348
Norway spruce					44,538			44,538	1.232
White spruce				14,703	14,305		** 5,618	34,626	0.957
Black spruce				17,491	129,149		6,594	153,234	4.241
Red pine				18,320	26,336		5,785	50,441	1.395
White pine				18,771	15,068		14,819	48,658	1.346
Jack pine				29,531	88,277		25,286	143,094	3.960
Shortleaf pine	1,483	831				19,106		21,420	0.592
Baldcypress	217	222						439	0.011
Northern white-cedar				77,360	42,443		26,996	146,799	4.062
Eastern hemlock				33,404			15,818	49,222	1.361
Other softwoods	114	2,728		372		* 2,430		5,644	0.155
Hard maple	5,474	14,621	998	125,929	19,541	3,101	55,675	225,339	6.236
Soft maple	12,803	5,899	6,313	75,618	14,341	2,937	37,022	154,933	4.287
Select white oak	30,926	26,341	9,738	27,972	27,950	74,876	40,081	237,884	6.584
Select red oak	9,401	12,095	6,759	40,944	39,709	13,924	64,345	187,177	5.180
Other white oak	7,585	6,277	9,269			57,600		80,731	2.234
Other red oak	27,382	20,192	5,250	23,933		96,740	31,895	205,392	5.684
Select hickory	14,768	22,856	6,875	4,899		29,201	7,051	85,650	2.370
Other hickory	8,146							8,146	0.224
Yellow birch				29,793	2,642		15,101	47,536	1.315
Paper birch				39,008	113,974		44,292	197,274	5.460
Beech	645	5,922		21,438			2,303	30,308	0.838
Black walnut	4,351	4,205	3,795	145		8,443	569	21,508	0.594
Ash	13,536	10,476	2,371	29,518	51,081	6,340	30,819	144,141	3.990
Elm	22,687	5,604	21,144	41,613	41,533		38,590	171,171	4.737
Sweetgum	3,158	2,433				1,611		7,202	0.198
Tupelo gum	732	1,635				1,256		3,623	0.100
Cottonwood	5,554	2,802	5,070	2,969	773			17,168	0.474
Aspen (bigtooth and quaking)	676	1,202	1,128	129,769	316,638		161,007	610,420	16.890

* Mostly redcedar and cypress.

** 46 percent white spruce; 54 percent black spruce reported only as spruce.

SOME RECENT RESEARCH PAPERS OF THE NORTH CENTRAL FOREST EXPERIMENT STATION

Durable Rustic Wooden Signboards, by Glenn A Cooper. USDA Forest Serv. Res. Pap. NC-29, 15 p., illus. 1969.

The Market for Wood Picnic Structures, by Jerry A. Sesco, USDA Forest Serv. Res. Pap. NC-30, 7 p., illus. 1969.

Oak Forests of the Lake States and their Management, by John L. Arend and Harold F. Scholz. USDA Forest Serv. Res. Pap. NC-31, 36 p., illus. 1969.

Wildlife Esthetics & Auto Campers in the Superior National Forest, by David W. Lime and Charles T. Cushwa. USDA Forest Serv. Res. Pap. NC-32, 8 p., illus. 1969.

Standing Timber Coefficients for Indiana Walnut Log Production, by James E. Blyth, Edwin Kallio, and John C. Callahan. USDA Forest Serv. Res. Pap. NC-33, 9 p., illus. 1969.

Climatic Conditions Preceding Historically Great Fires in the North Central Region, by Donald A. Haines and Rodney W. Sando. USDA Forest Serv. Res. Pap. NC-34, 19 p., illus. 1969.

Initial Thinning in Red Pine Plantations, by John H. Cooley. USDA Forest Serv. Res. Pap. NC-35, 6 p., illus. 1969.

Biological Growth Functions Describe Published Site Index Curves for Lake States Timber Species, by Allen L. Lundgren and William A. Dolid. USDA Forest Serv. Res. Pap. NC-36, 9 p., illus. 1970.

Defect Indicators in Sugar Maple – A Photographic Guide, by Richard M. Marden and Charles L. Stayton. USDA Forest Serv. Res. Pap. NC-37, 29 p., illus. 1970.

Estimating Sugar Maple Bark Thickness and Volume, by Charles L. Stayton and Michael Hoffman. USDA Forest Serv. Res. Pap. NC-38, 8 p., illus. 1970.

ABOUT THE FOREST SERVICE . . .

As our Nation grows, people expect and need more from their forests — more wood; more water, fish, and wildlife; more recreation and natural beauty; more special forest products and forage. The Forest Service of the U.S. Department of Agriculture helps to fulfill these expectations and needs through three major activities:

- Conducting forest and range research at over 75 locations ranging from Puerto Rico to Alaska to Hawaii.
- Participating with all State forestry agencies in cooperative programs to protect, improve, and wisely use our Country's 395 million acres of State, local, and private forest lands.
- Managing and protecting the 187-million acre National Forest System.

The Forest Service does this by encouraging use of the new knowledge that research scientists develop; by setting an example in managing, under sustained yield, the National Forests and Grasslands for multiple use purposes; and by cooperating with all States and with private citizens in their efforts to achieve better management, protection, and use of forest resources.

Traditionally, Forest Service people have been active members of the communities and towns in which they live and work. They strive to secure for all, continuous benefits from the Country's forest resources.

For more than 60 years, the Forest Service has been serving the Nation as a leading natural resource conservation agency.