FEDERAL RESERVE BANK
OF MINNEAPOLIS

SPECIAL RESEARCH REPORT

NOVEMBER 1963

the timber economy of the ninth district west

by CLARENCE W. NELSON

A study of the timber industry in the western states of the Ninth Federal Reserve district, its status, its prospects, and some policy matters as viewed through theory of resource allocation and conservation.


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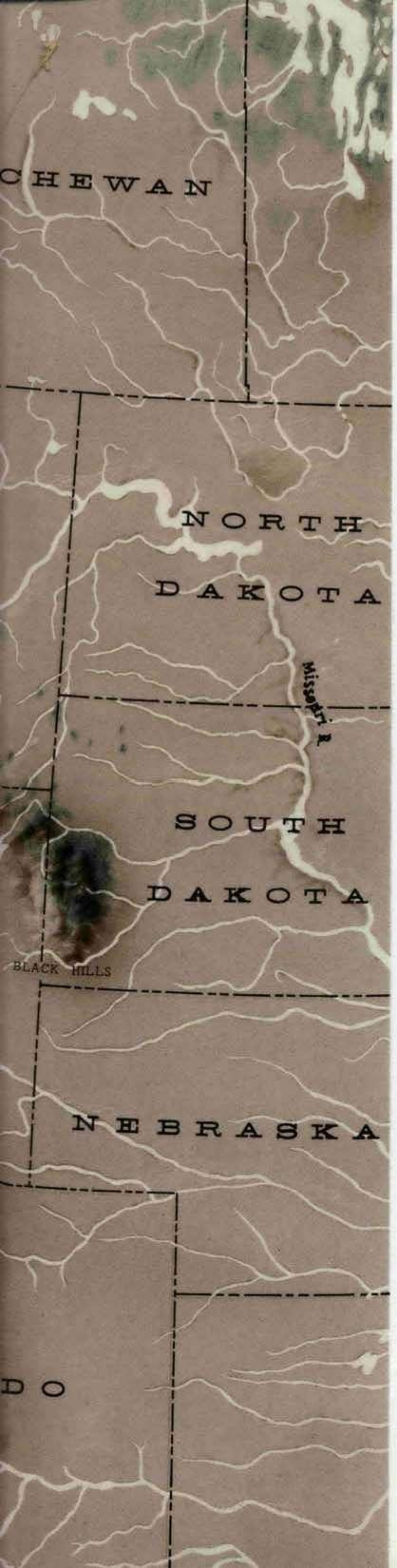

THE TIMBER ECONOMY OF THE NINTH DISTRICT WEST

Clarence W. Nelson, Economist

Federal Reserve Bank of Minneapolis

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PREFACE

This study of the timber resource of the western Ninth district will focus geographically on the timbered sectors of Montana and on the Black Hills of western South Dakota. In first describing the district's timber industry and then appraising prospects facing the industry, we shall follow the traditional approach to regional studies. But in addition, we shall discuss the broader theoretical problems that resource allocation and conservation pose for the nation's economy. Although this topic will be treated separately in the final section of the report, the concepts of resource allocation theory will appear throughout the earlier sections and will influence especially the framework within which the descriptive material is presented.

The author acknowledges the assistance of many persons in industry and government, as well as the direct and indirect contribution given by the source materials cited in the references. The report was reviewed by individuals in the Forest Service, in private industry and in other interested organizations; their valuable help is acknowledged, but they of course share no responsibility for correctness of facts or soundness of interpretations put forth in this report.

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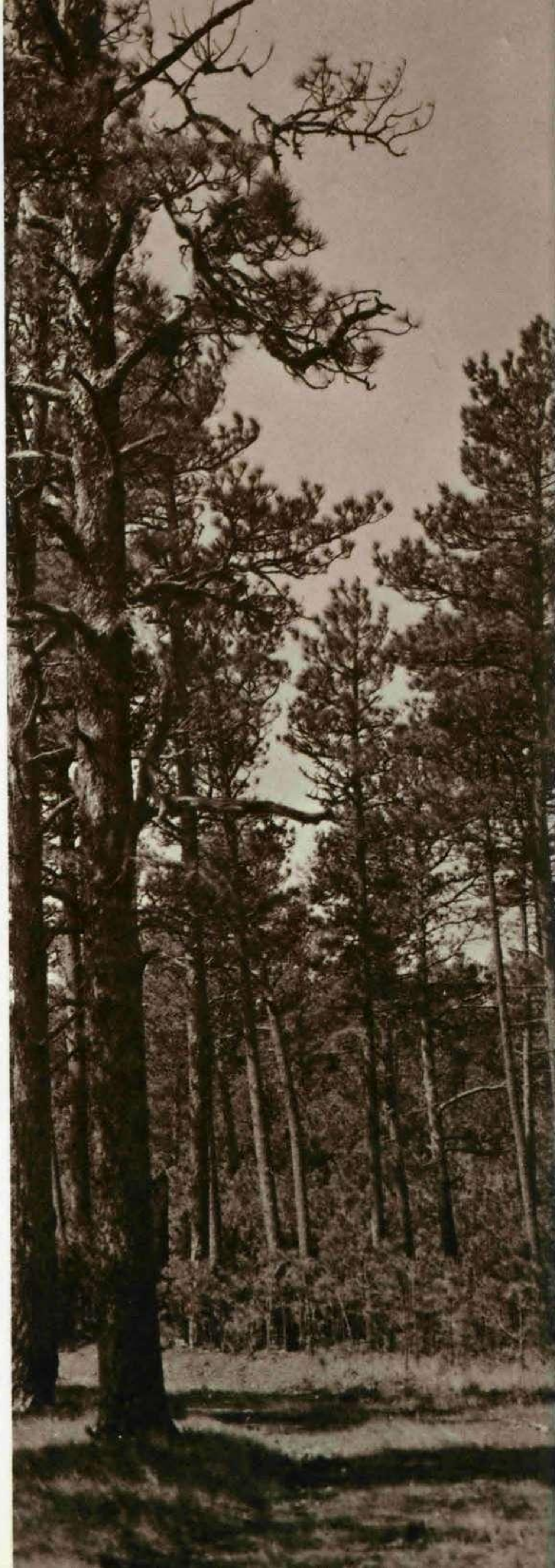


Custer National Forest, southeastern Montana
U.S. Forest Service Photo

I TIMBER RESOURCES OF THE NINTH DISTRICT WEST: PHYSICAL AVAILABILITY

It's been said that the West begins at the hundredth meridian. For a look at the West in the Ninth Federal Reserve district, the Missouri river makes a better jumping-off place. Let's make that jump and travel westward—in imaginary flight of course—for a quick scouting of the region of our study.

The land we skim as we set out lies flooded in the sort of eye-squinting treeless brightness that marks much of our district's western span. But enter the West and cross it; you'll soon meet broad uplifts with dark cloakings of forest. The first of these appears so darkly struck from bright surroundings that it bears the name, *Black Hills.*

Move now across southeast Montana's sunbright, arid expanse. You'll spot in quick succession (with help, perhaps, from the inside-cover map) many islands of timber perched on hills and elevated lands. To be sure, some of these patches of pine struggle to exist in toeholds of forests so scant and open that foresters prefer to call them 'woodlands.' Yet, in favored places, thick forests grow here, too.

Continue on our westward course. Soon into view arise the front ranges of the Rockies, abrupt and tall—the Bighorns, the Crazys, the Belts, and the Bear Paws—and, beyond, the Rockies' knobby backbones that here and there poke barren rock above the bristling green cover of forest. Ahead lies more forest, denser and broader, with much of it still remote and difficult of access.

Cross the continental divide. Leave the Missouri river drainage, and enter the Columbia basin over mountain ridges a mile or two above sea level. Trees no longer group themselves in separated islands parted by broad, dry valleys as was the pattern to the east. By the time we reach Montana's northwest corner, the forest looks to be an almost continuous blanket.

This, then, is the forest whose use is the subject of our study—a store of wood that stands cathedral tall (or in places choked and stunted). If it's a store, then here's the key: trees are living things that grow and die and are consumed—if not by man, by nature. The spread of timber we've surveyed in our imaginary westward sweep may well have held this same green pattern for centuries before man carved into them deeply for his own needs. But even then, before man's relatively recent immigration, the forest was not at rest—for fires burned when lightning struck, and insects, rot, and strangling mistletoe killed. Trees decayed and died—and new trees sprang up even before scarred carcasses of old ones fully fled their ground.

The forest is thus a thing of inevitable change. Change, too, characterizes the industry built around the processing of wood. Much of our story, in fact, is a chronicle of change—past and prospective. Our first task, however, is to defy this change and draw a 'still' picture of the region's forest today. Let us turn then to examine the physical character and dimensions of the region's timber resource.

THE REGION'S FORESTS: HOW MUCH AND HOW GOOD?

The forests of the Ninth District's West contain some 16 million acres of western softwoods, a big woodyard, indeed. The quantity of timber physically available for processing from this vast acreage is extremely large. Forest inventory figures prepared by the Forest Service of the United States Department of Agriculture will give us various measures of the physical dimensions of the resource and some clue to its maximum availability. But numbers alone do not mean much. First we must have some background information about the variety and quality of our wood resources.

Sometimes for convenience we will discuss the region's forest resource as if it were a single commodity measurable by a single volume figure. But wood and forests are actually very heterogeneous things. In fact, wood's physical properties (color, strength, and a host of other features) and its consequent suitability for various uses may differ from one part of a single tree to another—from *sapwood* to *heartwood*, and even from the darker, denser *summerwood* part of each growth ring to the adjoining lighter *springwood*. But of greater commercial importance is the variation in quality between different species.

Geography is important too: stands of a given species grown on more westerly sites in our district tend to be of higher quality, in general, than stands of the same species grown on drier, more easterly sites. Our best stands, in turn, usually rank below those grown on Pacific coastal sites. This site-to-site variation also may show a local character: wood from the same species cut from old growth (virgin) forests tends to be stronger, closer-ringed, denser and more uniform than does its counterpart in second-growth stands nearby—or even on the same site at different points in time.

FOREST SPECIES AND THEIR GEOGRAPHIC OCCURRENCE

Figure 1 portrays the geographic distribution of non-reserved *commercial* forest land in the region. Such land excludes about 6 million acres of forest in which cutting may not legally take place (national parks and wilderness areas) as well as additional acres of sparse or difficult forest lands not regarded as having commercial usefulness as sources of timber. All this so-called commercial forest land is found in the moister valleys or on elevated sites. The nearly 16 million acres is stocked almost entirely in western softwood species or conifers. Some hardwoods or deciduous trees (such as cottonwood along the river bottoms and aspen in the mountain valleys) grow there, but these are insignificant commercially.

The softwood forests contain five principal species:

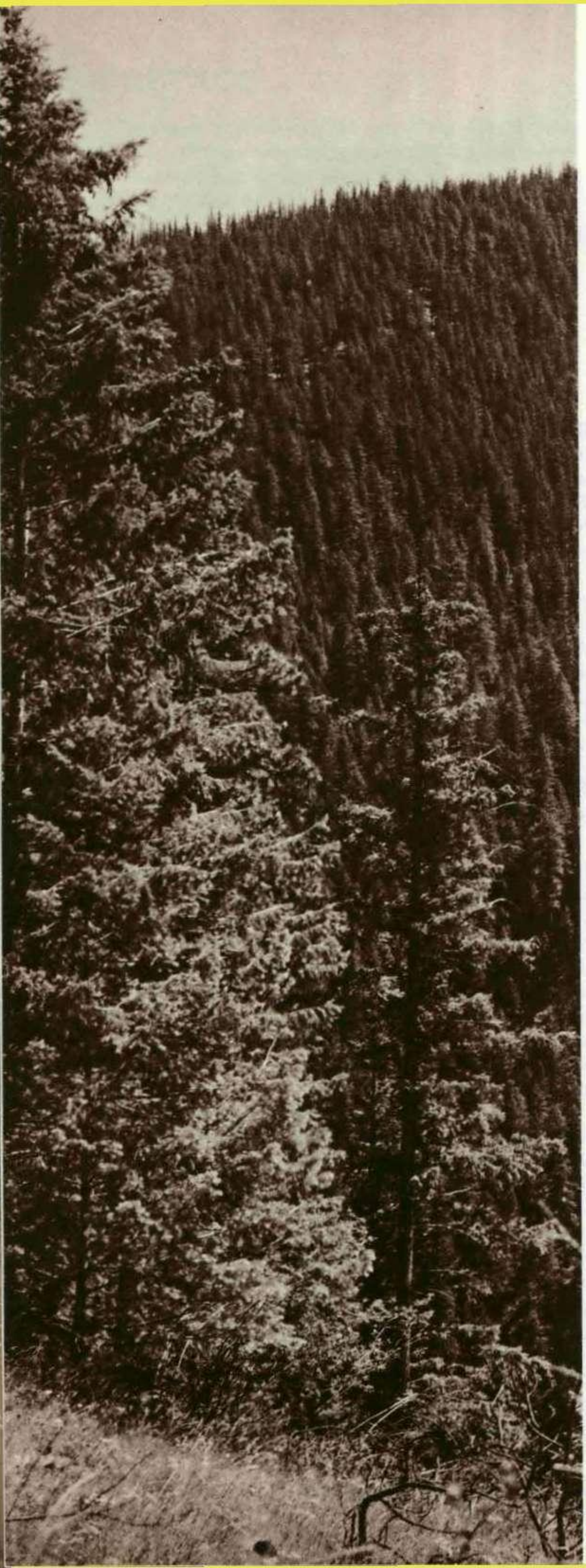
Ponderosa pine (Pinus ponderosa)
Lodgepole pine (Pinus contorta var. latifolia)
Douglas-fir (Pseudotsuga menziesii var. glauca)*
Western larch (Larix occidentalis)
Engelmann spruce (Picea engelmanni)

*The hyphenated spelling of Douglas-fir is commonly used to indicate that it is not a true fir; it is a separate species, closely related to hemlock.

Although many other species exist, the five above comprise 94 percent of timber volume in the region's forests. We will therefore discuss the regional occurrence of these five species, in three major areas: (1) the Black Hills, (2) Montana east of the continental divide, and (3) Montana west of the continental divide.

FORESTS OF THE BLACK HILLS

Forests of the Black Hills, for practical purposes, consist of pure stands of a single species—*ponderosa pine.* Ponderosa pine is the premium species among the major species considered here. In the forest the mature ponderosa pine is a distinctive tree, with orange-brown bark in large platy sections and clusters of very long needles. It can grow to 150 feet in height with trunk diameters of 2 or more feet, although normally it does not reach that size in the Black Hills. One of the most widespread species in the West, ponderosa tends to occupy open or park-like stands and to favor south slopes and lower elevations. Ponderosa pine has been one of the most important species for lumber, its logs often being cut into finish or shop lumber. The wood properties that make it suitable



Kootenai National Forest, northwestern Montana
U.S. Forest Service Photo

for such high-value uses include: smooth, uniform grain, easy workability with hand tools, and the ability to take nails and finishes well. Ponderosa pine has been important as a lumber log almost everywhere in the district, its value "on the stump" exceeding that of other major species.

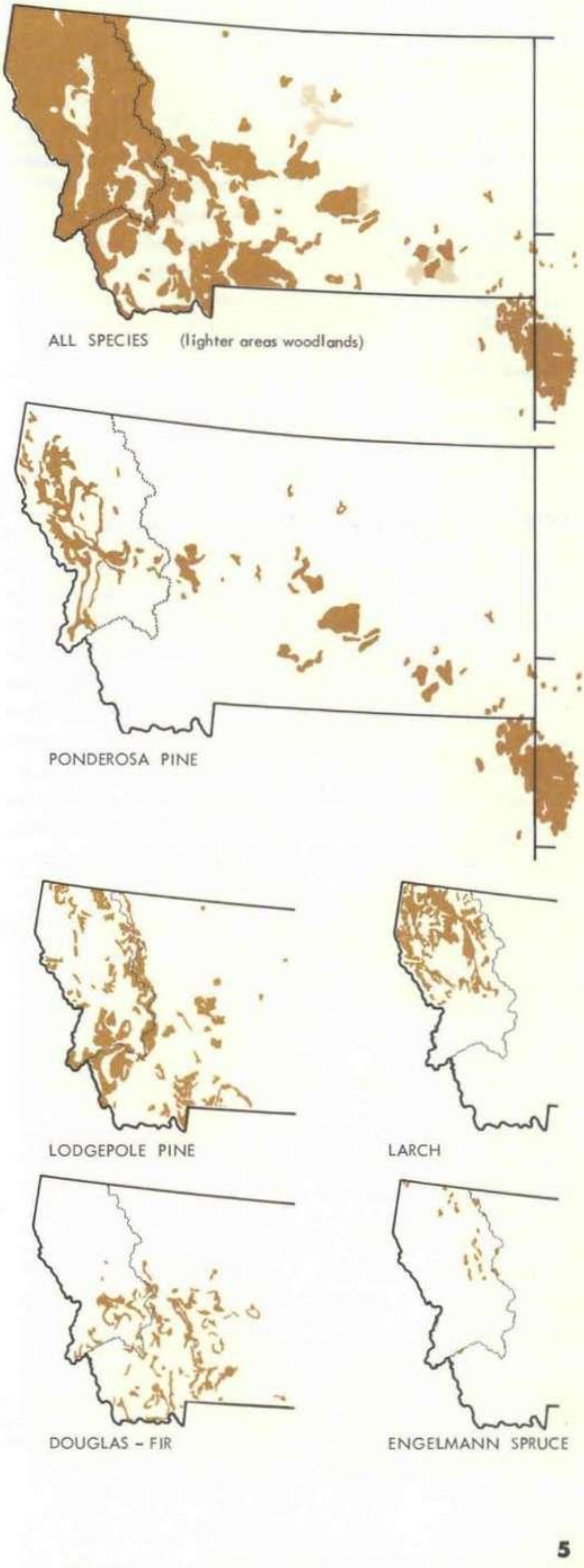
FORESTS OF EASTERN MONTANA

Southeastern Montana's forests are mostly islands of ponderosa pine—like the Black Hills, only smaller and usually less dense. Some of the areas marked on Figure 1 are barely 25 percent forested. Beginning in the Pryor and Beartooth Mountains, somewhere south of Billings and then westward, the first important stands of *lodgepole pine* can be found.[1] Lodgepole pine is by far the most abundant tree in eastern Montana. A small tree, even at maturity, it grows typically in dense, tight stands, often replacing a burned-out stand of some other species. Crowding may hold the average tree to a diameter of 8 or 12 inches and a height of 50 to 75 feet. Much like ponderosa pine in strength, color, and texture, lodgepole wood has the added advantages of narrow rings and small knots. But, mainly because of its small size, it has had the least commercial value of any of the five species described here. In spite of this size drawback, the abundant lodgepole pine has been the focus of important sawmill expansion in the past decade.

The third principal species met in eastern Montana is *Douglas-fir*, Montana's most important tree in terms of timber volume. It often grows in mixed stands and can reach a rather substantial size—up to 3 or more feet in diameter and up to 200 feet in height. Because of its relative strength, straightness, and nail-holding ability, it is chiefly a structural wood and most often is sawed into *dimension*[2] stock. In many areas Douglas-fir is also the most important softwood used for veneer and plywood, but in eastern Montana this species tends to be too knotty.

Douglas-fir shows great regional differences in characteristics. In fact, the trees grown along the western slopes of the Cascades reach diameters of over 15 feet and heights over 300 feet, and in commercial use might be distinguished almost as a separate species (though botanically they are not) from the Douglas-fir of the drier

Figure 1 — Distribution of commercial forest land by dominant species



[1] These mapped areas of species indicate the predominant forest type. The usual criterion is that the particular species named represent more than 50 percent of the acreage of forest in the area mapped. Some species, such as lodgepole, tend to grow in fairly pure continuous stands; that is, an area of several acres or more will contain only one species. Other species at other locations may be highly intermixed, a variety of them growing within a few feet of one another.

[2] Lumber can be loosely classified into two quite general categories from the standpoint of marketing and usage: (a) *dimension* consists mostly of 2-inch lumber, from 2"x3" to 2"x14" in cross section and is used, for example, in forming the structural skeletons of houses; (b) *boards* or 1-inch lumber measuring from 1"x2" to 1"x12" in cross section, is used, for example, as siding, subflooring, and subroofing nailed onto the skeleton of dimension lumber.

regions to the east. Table 1 indicates a few comparative differences in average properties of Douglas-fir among the three broad producing areas.

TABLE 1 — COMPARATIVE WOOD PROPERTIES OF DOUGLAS-FIR GROWN IN THREE DIFFERENT REGIONS

PROPERTY (air dry to 12% moisture)	REGION* Coastal type	Intermediate type	Rocky Mountain type
DENSITY lbs. per cu. ft.	34	31	30
MODULUS OF RUPTURE lbs. per sq. in.	12,200	11,200	9,600
MAXIMUM CRUSHING STRENGTH lbs. per sq. in.	7,430	6,720	6,060

*__Coastal type__ includes Washington and Oregon west of the Cascade mountains; **Intermediate type** includes eastern Washington and Oregon, northern Idaho, and western Montana; **Rocky Mountain** includes Montana east of the continental divide, Wyoming and other states.

Source: Forest Service [40]

FORESTS OF WESTERN MONTANA

In the comparatively small quarter of Montana west of the continental divide, we find the three species we have previously met in more easterly locations—ponderosa pine, lodgepole pine, and Douglas-fir; and in addition we meet the first important stands of two new ones. The broad regional imprint on each of these species is evident in the presence of more of the large-size trees and more productive sites.

Western larch is so similar in strength and other wood properties to the Douglas-fir of western Montana that the two species are frequently cut together and marketed under the single name 'Douglas Fir-Larch.' Larch frequently grows in mixed stands with Douglas-fir, reaching heights up to 200 feet with diameters to 5 feet. The larch tree (like its eastern cousin, the tamarack) drops its lacy, yellow-green foliage each fall and regrows it again in the spring. The wood is very strong and, for a softwood, very heavy. In addition to its wide use in general construction, larch is a frequent source of tall poles and has recently become an important plywood species in western Montana.

Engelmann spruce, which ranks fifth in total wood volume in district forests, has not been used in large volume until recently because its affinity for high, moist mountain basins has made it relatively inaccessible to logging. Engelmann spruce is of moderate size (to 130 feet in height, 3 feet in diameter), carries dense blue-green foliage, and grows both in pure stands and mixed with other species. The wood is lighter and less strong than that of the other species discussed, although it is one of the strongest for its weight. Spruce has qualities useful as dimension wood in rough construction or as boards in interior finish. Some properties of the five species are summarized in Table 2.

RELATION TO SURROUNDING FOREST REGIONS

The inside-cover map makes it clear that our study area consisting of the Black Hills and the Montana Rockies has been cut out somewhat arbitrarily. Forest cover continues in natural extensions into surrounding states and provinces in the Northern Rocky Mountain and Pacific Northwest regions. In fact, the 16 million acres of commercial forest land in our region represent only a

TABLE 2 — SELECTED PHYSICAL PROPERTIES OF WOOD FROM FIVE MAJOR LUMBER SPECIES

PROPERTY[1]	PONDEROSA PINE	LODGEPOLE PINE	DOUGLAS-FIR[2]	WESTERN LARCH	ENGELMANN SPRUCE
DENSITY lbs. per cu. ft.	28.6	29.2	31.8	39.4	24.1
STATIC BENDING STRENGTH[3] lbs. per sq. in.	6300	6700	7400	8300	5500
IMPACT BENDING STRENGTH[4] foot drop	17	20	27	35	18
MAXIMUM CRUSHING STRENGTH[5] lbs. per sq. in.	5270	5370	6720	8110	4770
HARDNESS[6]	450	480	600	830	350
EASE OF WORKING WITH HAND TOOLS	easy	medium	difficult	difficult	easy
PAINTING PROPERTIES[7]	group 3	group 3	group 4	group 4	group 3
WOOD COLOR	orange to reddish brown	light reddish brown	orange-red to red, sometimes yellow	russet to reddish brown	nearly white

[1]Samples in general taken as air dry wood at about 12 percent moisture content. [2]Intermediate type. [3]Fiber stress at proportional limit. [4]Height of drop of 50 lb. hammer causing complete failure. [5]Compression parallel to grain. [6]Load required to embed a 0.444-inch ball to ½ its diameter in side grain. [7]Group 3 does not hold paint as well as Groups 1 and 2; Group 4 not as well as Group 3.

Source: Forest Service [40].

TABLE 3 — COMMERCIAL FOREST LAND AND TIMBER DENSITY BY REGION, MID-1950s

REGION	COMMERCIAL FOREST LAND (millions of acres)	DENSITY (cubic feet per acre)
Oregon-Washington, Coastal	25.5	4,440
British Columbia, Coastal	15.3	4,360
California, Coastal	7.4	4,100
California, Inland	9.9	3,660
Oregon-Washington, Inland	19.9	1,660
Idaho	13.4	1,590
British Columbia, Interior	55.6	1,470
Wyoming	3.5	1,180
Alberta	68.4	1,040
Western Montana	9.6	1,030
Eastern Montana	6.1	1,020
Black Hills	1.3	1,020

Source: Forest Service **[20] [39]**, Guthrie **[32]**, Davis **[28]**

small fraction of the timber resource of the northwestern United States. The Pacific Northwest states of Washington and Oregon account for about one-fourth of the nation's timber cut. These two states, representing the nation's chief reservoir of softwood sawtimber, cannot help but dominate the larger regional picture. In our district timber stands contain smaller trees and only one-fourth to one-third the wood volume per acre found on the West Coast (see Table 3); in addition our commercially usable timber may have much more unusuable timber interspersed with it, making it more costly to log. These factors, together with favorable freight rates for shipments from coastal sources, led to early extensive development of West Coast areas, while many forest expanses in the Northern Rocky Mountain region were being by-passed as economically unattractive. Signs point to some redressing of the balance, as we shall see later.

DIMENSIONS OF THE TIMBER RESOURCE

1. TIMBER AS A STOCK RESOURCE

In measuring the potential resource base, we will find it useful to look at the district's forest from three different viewpoints: as a *stock* resource (depletable), as a *flow* resource (renewable), and as a production *process*. We'll start first with the stock viewpoint.

Timber quantity is measured in units of volume (rather than of weight). Two principal units of measurement are used, the *cubic foot* and the *board foot*. Briefly summarized, *cubic foot* estimates of tree volume are applied to growing stock[3] and include all the wood in the cylindrical portion of the main tree stem from stump height to a diameter of about four inches under the bark. *Board foot* estimates are applied only to sawtimber[3] trees and furthermore measure a considerably smaller portion of the wood in the tree, ranging from about 30 to about 60 percent of the measured cubic footage, depending on tree size. The portion measured is the approximate amount of wood that ends up in lumber after losses in logging and sawing are accounted for. Even so, this estimate usually understates by several percentage points, the actual board foot volume of lumber cut, when measurements are made on the lumber actually coming out of the sawmill.[4] The former quantity must be distinguished from the latter; the former measure will be designated *board feet, log scale* while the latter will be *board feet, lumber tally.* It is important first, to bear in mind the particular scale in which wood volume estimates are expressed, and second, to realize that only certain approved portions of certain eligible trees are included.

[3] *Growing stock* is defined to include all live trees (except cull trees) 5 inches and larger in diameter at breast height (d.b.h.). *Sawtimber* has been defined to include all live trees 11 inches and larger d.b.h. containing at least one sawlog. See Appendix A for further details about measurement practices.

Estimated standing volume of timber

The total physical volume of softwoods in the western Ninth district, under the conventions in measurement we have just discussed, is estimated to have been 17 billion cubic feet at the beginning of 1953. In 1956 approximately 180 million cubic feet of wood were removed from these forests for various uses by man. If the forests were to be considered a fixed, minable source of wood, their inventory would amount to about a 95-year supply at current rates of removal.

Over half the measured volume lies west of the continental divide in Montana where, as Table 4 shows, Douglas-fir and larch are the leading species. Volume

TABLE 4 — DISTRIBUTION OF SOFTWOOD TIMBER VOLUMES ON LIVE TREES FIVE INCHES AND LARGER IN DIAMETER BY SPECIES AND SUBREGION, JANUARY 1, 1953

SPECIES	VOLUMES IN MILLION CUBIC FEET		
	Western Montana	Eastern Montana	Black Hills
Ponderosa pine	1,581	650	1,260
Lodgepole pine	997	3,080	
Douglas-fir	2,589	2,095	
Western larch	2,390		
Engelmann spruce	819	565	27[a]
Other softwoods	696[b]	433	
Total All Species	**9,072**	**6,823**	**1,287**

[a] Black Hills spruce (actually white spruce, **Picea glauca** var. **albertiana**).
[b] Includes 232 million cubic feet of western white pine, **Pinus monticola,** and 253 million cubic feet of true firs, **Abies lasiocarpa** and **A. grandis.**

Source: Forest Service **[39] [20]**.

[4] Even here, by convention, the designated board foot volume of sawn lumber overstates the actual cubic footage of wood substance. E.g., a rough 2"x4" is actually 1¾"x3¾" in cross section and a finished 2"x4" is actually 1⅝"x3⅝" in cross section. This conventional practice of *scant* measurement is based on the old standard practice of having to cut rough lumber to full 2"x4" sizes in order to dry and surface properly to 1⅝"x3⅝" net thickness. More accurate sawing methods allow mills to scant saw their rough lumber today.

honors in eastern Montana go to lodgepole pine. Ponderosa pine volume in the Black Hills is double that of eastern Montana and about 80 percent of that west of the continental divide in Montana.

But, as we have pointed out, rainfall, evaporation rates and other factors at growing sites have affected the trees so that the larger, more salable volumes of timber are concentrated more heavily to the west than the data of Table 4 indicate. To demonstrate this fact we can cite a number of comparisons. Thus from Table 5 we can see that some two-thirds of total sawtimber volume is found in western Montana, while only slightly more than half the total timber volume occurs there, if smaller tree sizes (five inches to eleven inches d.b.h.) also are taken into account.

TABLE 5 — SOFTWOOD SAWTIMBER NET VOLUMES ON TREES 11 INCHES AND LARGER IN DIAMETER, LOG SCALE*, BY SUBREGIONS

	VOLUMES IN BOARD FEET
Western Montana	39.4 billion
Eastern Montana	15.7 billion
Black Hills (Wyo. incl.)	3.2 billion

*International ¼-inch rule except Scribner in Black Hills.
Source: Forest Service [39] [20].

Not only average log size, but also average log quality is greater in western than in eastern Montana. Table 6 shows distribution of volumes by log grades. Differences in strength between intermediate type Douglas-fir and Rocky Mountain type Douglas-fir, given in Table 1, suggest that some of western Montana's timber may show a similar advantage in strength as compared to timber from the drier, more easterly sites.

TABLE 6 — PERCENTAGE DISTRIBUTION OF SAWLOGS: STANDARD LOG GRADES BY SUBREGION

LOG GRADE	DESCRIPTION	PERCENTAGE DISTRIBUTION Western Montana	Eastern Montana
1	Surface clear logs	15	3
2	50 percent surface clear	20	11
3	Numerous small-and medium-tight knots	40	50
4	Low common	25	36
	Total All Grades	100	100

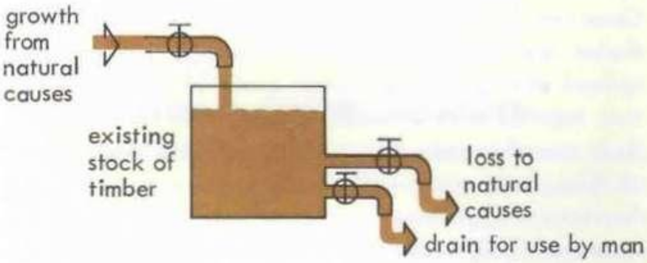
Source: Forest Service [20].

In summary, Forest Service survey data indicate that the stock of live timber, measuring only the merchantable portions under conventional usage, contains some 17 billion cubic feet of wood with considerable variations in quality. There also may be an additional 1 to 2 billion cubic feet of dead standing timber that could be salvaged for some uses. This figure gives us a measure of the limits of cutting under a mining approach to timber resources. Finally, we recognize that we have been looking at a 'still' picture of a very volatile world. Our measure of the size of the physical resource may have been correct for January 1, 1953; but for today or for tomorrow it is increasingly out of touch with the facts. We turn now to a different way of looking at the timber resource.

2. TIMBER AS A FLOW RESOURCE

Because living trees annually accumulate a growth of new wood, and because they also produce seed from which new generations of trees may develop, timber can be regarded as a crop to be harvested perpetually instead of as a large, fixed reserve to be mined out over a period of years. Although the mining viewpoint was widely held in the early part of this Century, the continuous crop view is more popular today. "Tree Farm" is now a common expression, and the idea of a continuous flow of wood dominates public and much private policy. So our concern in this section will be with the measurement of the flow of timber under some arrangement of continuous and perpetual production.

The concept of timber *flow* is basically a physical one, a compound of four elements as depicted in the following diagram:



The quantity of wood represented by the stock of live timber fluctuates over time depending on the balance or imbalance between new growth on the one hand and the combined effect of losses to nature and drain by man on the other. The quantity of timber in stock is no more than a secondary consideration under this viewpoint, while the flows are the essential features of interest—in particular that flow we have termed "drain for use by man." We seek to gauge its *potential*, by which of course we mean the highest rate at which timber could be drained continuously into industrial use from the standpoint of physical possibility. This should give us a clue to the maximum scale of industrial activity that could be sustained on the basis of the timber resource.

As we have noted, the timber stock in the western Ninth district, consisting of more than half a billion live trees of larger than five inches diameter, currently stores an estimated 17 billion cubic feet of potentially merchantable wood. Some 316 million cubic feet were added in growth to our district's basic stock during the survey year 1952—a two percent accumulation. At the same time, other natural factors have been and are eating away at the wood inventory daily. These factors are listed under the heading of *mortality*. During 1952, mortality claimed 126 million cubic feet, or something under 1 percent, with causes attributed as follows:

Mortality in million cubic feet	Cause
76	insects
6	diseases
2	fire
42	other (weather, animals, suppression, etc.)

This year, however, saw a particularly bad insect loss, so the figures indicated are not valid as longer-term averages. Normal mortality based on earlier decades would be closer to 55 million cubic feet annually or less than one-third of 1 percent. Of course this deduction from timber inventory will vary year by year, and so the balance between what is added by growth and what is trimmed away by natural forces may vary also; in 1952, there was an estimated net addition of 190 million cubic feet.

Man, of course, takes his timber supply from the forest, and as he does, he necessarily will alter the natural balance—not only the stock and the drain, but also the growth. In 1952, some 125 million cubic feet of wood were cut from the forests of the district.

During that year, then, given all the factors adding to and depleting the stock, our total inventory of live wood showed a net gain of about 65 million cubic feet, or less than one-half of 1 percent.

We have oversimplified the picture in referring our growth and drain figures to one big common pool of wood. For in place of a single over-all balance many individual balances may be struck somewhat independently. Different species, different grades of logs, different localities—each of these variables strikes a somewhat different balance. In some areas and for some species, withdrawals actually exceeded growth, so that the standing inventory in some cases was reduced.

Actual and potential growth rates

Let us now turn from a picture of *what is* to a picture of *what could be*, considering first the possibilities for growth. We have pointed out that total annual growth for the district currently exceeds 300 million cubic feet. Net annual growth, after we deduct for natural mortality, is reduced to around 190 million cubic feet (enough wood to build roughly 100,000 average houses). Net growth is a measure of the amount man can cut without depleting the current stock. If drain were to exceed net growth, the difference would have to come at the expense of the existing inventory of trees.

About an eighth of the district's net growth occurred in the Black Hills, and more than half of the remainder took place in eastern Montana. On a per-acre basis the over-all growth rate has amounted very roughly to 20 to 30 cubic feet annually. Potential growth rates, however, are higher. Here are some estimates by area:[5]

	Western Montana	Eastern Montana	Black Hills
Potential net growth rate in cubic feet per acre per year	69	47	60

If these potentials were achieved, they would mark a net annual growth of nearly one billion cubic feet—more than five times the rate of 1952, and almost eight times the amount actually cut. On the basis of these estimates of potential growth rates we can already see, then, that substantial opportunity exists for expanding timber growth.[6] Attainment of these potentials requires a far greater expenditure of effort in forest management than that commonly reached in the past, and would take at least a century to reach.

We would expect growth rates ultimately to set limits on the rate of drain, if timber yield is to be perpetual. However, in any current program—even with an ultimate goal of sustained yield—an appropriate rate of drain might be very different from either the actual growth rate today or the long-range potential growth rate. We are going to examine the reasons for this, and in the process we shall gain some important insights into the time dimension of timber flows.

Sustainable yield and rotation

In measuring the forest as a flow resource we are interested in a rate of harvest we can keep up indefinitely, or what foresters call a "sustainable yield." For an idealized forest[7] the rate at which wood can be cut on a sustainable basis is related directly to the age of the trees or stands of trees at the time they are cut—the so-called *rotation age*. If the rotation age selected for a forest is too low, no advantage is taken of the most rapid-growing middle years (for ponderosa pine about 60 to 100 years of age). If, in contrast, the rotation chosen is too long, too much forest land is occupied by tired, old trees, long past the time of any positive contribution to growth.

Let us see how sustainable yield under ideal conditions is related to the native growth properties of the forest. Imagine that we start with a one-acre plot of moderately

[5] Forest Service personal communications (1963).

[6] Of special commercial significance are growth rates for sawtimber. Estimated current net growth rates are:

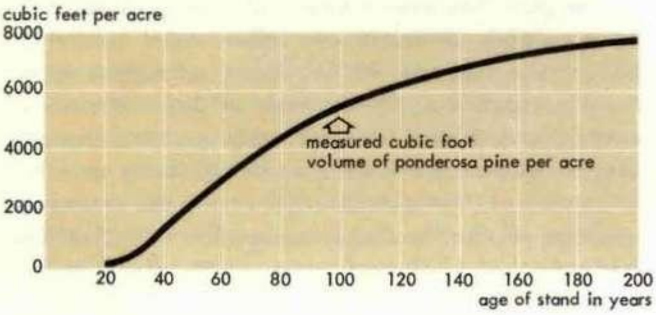
	Western Montana	Eastern Montana	Black Hills
Current sawtimber growth rate in board feet per acre per year	69	38	48

Yield capabilities for sawtimber, on the other hand, are estimated as follows:

	Western Montana	Eastern Montana	Black Hills
Potential sawtimber growth rate in board feet per acre per year	350	219	90

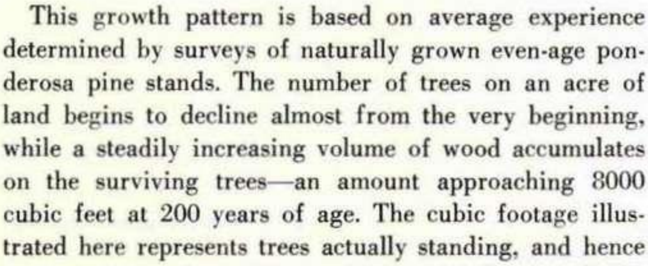
[7] Among other things, we imply by the word "ideal": (1) that a fresh batch of seedlings begins to grow on the harvested site after each stand is cut, and (2) that there is a completely balanced range of ages so that each year the same number of trees reach cutting age.

good[8] forest land freshly planted with ponderosa pine seedlings. Suppose we could patiently watch its growth (over the course of two centuries). We would expect the measurable volume of wood on trees 7 inches and larger in diameter to trace out a growth curve as follows:



This growth pattern is based on average experience determined by surveys of naturally grown even-age ponderosa pine stands. The number of trees on an acre of land begins to decline almost from the very beginning, while a steadily increasing volume of wood accumulates on the surviving trees—an amount approaching 8000 cubic feet at 200 years of age. The cubic footage illustrated here represents trees actually standing, and hence a *net* volume after all losses from natural causes.[9] The curve, therefore, shows the volume of expected harvest for each chosen age of stand at the time of harvest. At age 100, for example, about 5400 cubic feet could be cut.

In such a situation, namely one in which we wait 100 years to cut 5400 feet, the average yield per year would be 54 cubic feet (although we cut it all at once, at the end of our chosen rotation). This figure, called *mean annual increment,* can be calculated for each age of stand by the simple formula: accumulated volume divided by the age of stand. The result is the following curve,



which in effect tells us the sustainable yield (average volume per year) for any choice of cutting age. For if we re-establish seedlings on our idealized one-acre plot immediately after our first harvest, we could make a repeat cutting at the end of an identical rotation period, and the mean annual increment as read from the above chart would be sustainable indefinitely.

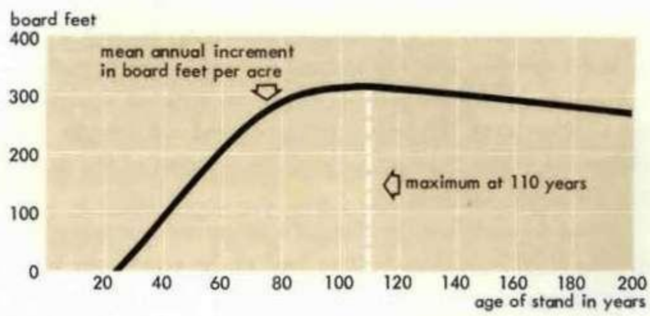
Note that one harvest age gives a greater sustainable yield than any other. In this case an 80-year rotation gives us the *maximum sustainable yield*—about 55 cubic feet of wood per year. Of course if we had only a single acre tract this harvest would be made in the amount of 4400 cubic feet once every 80 years. If in practice we wished a steady annual harvest, we would require a large forest area with a balanced distribution of ages such that some tracts were coming into harvest age each year.

All of this applies to one grade of land; we would get different results on better or poorer land. But the principle is the same, and once we have committed our forest to sustained yield, the choice of a rotation period is a key factor in determining what our rate of cut can be.

It should be pointed out that knowledge about forest growth characteristics is too inexact to allow us to choose the optimum rotation and determination of yield as precisely as the above curves might suggest. Yield curves have been built up for many species based on extensive surveys across a wide range of site quality, but the results come from stands that have grown to a given age under natural conditions. These growth curves have not always turned out as well as might be desired in predicting growth on managed forests.

Rotation depends on product

The choice of rotation for maximum sustainable yield will vary with the product you want to grow. Sawtimber, for example, with its emphasis on large logs, requires longer rotations for maximum yield. In fact the particular log scale used to estimate board foot recovery makes a considerable difference in estimated harvest age for maximum yield. If we take the very same plot illustrated above and the same trees (those larger than 7 inches d.b.h.) but this time portray mean annual increment measured in *board feet* by the International ⅛-inch log scale, the following yield curve results:



Thus, to get the maximum sustainable yield of sawtimber we would choose a rotation of 110 years (the

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[8] Technically we are using site index 80 land which means roughly that average trees at 100 years of age reached an 80-foot height, as defined in USDA Technical Bulletin 630, Meyer [35]. Average site index for Montana is 65, for the Black Hills, 55.

[9] Cumulative loss from age 20 to age 200 averages about 3800 cubic feet, and roughly half this loss occurs by age 100.

technical maximum, although because of the flatness of the curve in that vicinity, we would lose very little if we picked 100 years as rotation). Since sustained yield planning in our region is usually directed at production of sawtimber, long rotation periods of the order illustrated here are the rule. The Forest Service uses the following rotations in estimating potential yields from medium sites in Montana:

Species	Rotation in years
Ponderosa pine	120
Lodgepole pine	100
Douglas-fir	140
Western larch	130
Engelmann spruce	130

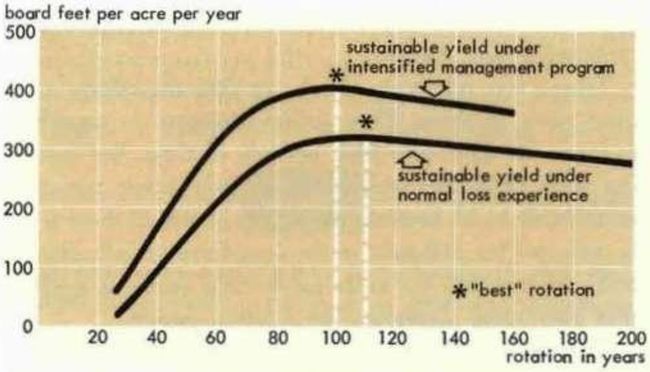
The highest rotation used is 160 years for ponderosa pine and Douglas-fir on poor sites. At best the time spans involved in forest management planning are very long—a fact that we will find especially significant in our later consideration of economic factors.

The hypothetical rotation choices discussed here are subject to a number of practical qualifications. We have assumed no delays in restocking of freshly cut stands; in practice, however, several years may be added to the length of the rotation because of the time it takes for a cut area to reseed. Furthermore, some areas may come back preferentially to the wrong species so that the quality of the new growth changes over time.

The harvest, too, is subject to practical limitations. The amount of cut forthcoming at any one year and in any one locality has to be of sufficient size and otherwise suitable for commercial harvest if a sustained yield management program is to work. This means that actual cutting programs may include stands that have aged either too long or too little for the theoretical maximum flow of timber. Nonetheless, the rotation concept is basic to the planning of forest management programs, in view of the fact that the various possible levels of sustainable yield, including maximum sustainable yield, can be thought of as functions of the choice of a rotation period.

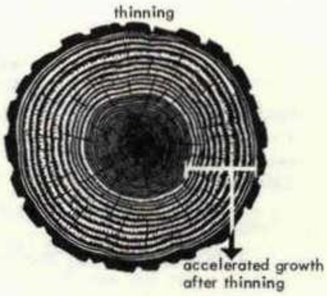
The relativity of sustainable yield

Sustainable yield and maximum sustainable yield depend, as we have seen, on productivity experience of forest land and on biological characteristics of trees. But they are also *relative* to the *degree of management practiced on the forest.* Our yield curve is derived from average natural growth experience, which represents a *net* figure, after average forest mortality is deducted. Therefore any cultural efforts applied to the forest that will (a) increase gross (total) growth rates or (b) reduce loss rates will theoretically raise the sustainable yield curve, and probably shorten the rotation for maximum yield. The following curves portray this effect:



The "intensified management" results shown here are arbitrarily taken as the natural performance from standard yield tables of a higher quality site (site index 90) than that on which we have based our norm (site index 80).

How can we increase growth rates or decrease loss rates? Among more direct and intuitively obvious efforts, we could: (1) apply fertilizer to the forest (not a measure that would be given much serious consideration today for conditions in Montana and South Dakota, but nonetheless perfectly good in principle), (2) reduce damage from forest fires through intensified protection programs, and (3) reduce destruction by forest insects and disease through control programs. Perhaps the most important measures are those directed at harvest of overmature stands, salvage of sawtimber killed by natural forces, and other work that comes under the heading of improvement and sanitation cuttings. The diagram reproduced at left of a tree trunk cross section shows how growth is adversely affected after damage to a tree. A damaged or dead tree left in the forest occupies a growing site that could otherwise support a healthy, fast-growing tree. Thus optimum forest productivity requires that dead or damaged trees be removed at an early date. Removal of excessive numbers of trees in an overcrowded stand can have a stimulating effect on growth, as illustrated by the trunk cross section at right. Less direct measures to improve yield would include: (1) control of the way in which forests are logged in order that, for example, erosive loss of forest soils be minimized or



natural reseeding be facilitated, (2) planting of seedlings on all nonstocked forest land where natural regeneration is not immediate and thorough, or (3) thinning of overcrowded young stands.

Trees grow relatively slowly, so that the effects of actions such as these taken today cumulate to significant proportions only over long periods of time. But instituting such programs would immediately boost maximum sustainable yield, because the effects of any of them would be reflected immediately in the long-term growth expectations from which the sustainable-yield curve is derived; they also could accelerate the rotation period.

The day-to-day practice of these and other measures affecting forest growth, whether designed or inadvertent, *constitutes the state of forest management in effect at the* time. It is important to recognize that any estimate of maximum sustainable cut has an implied assumption of some given intensity of management. Moreover, the physical or biological factors give us no answer to the question, "How do we select an appropriate intensity[10] level of forest management?" We are therefore confronted with a dilemma: We cannot discover an area's physical capacity to produce without using some essentially arbitrary assumption that in part determines our answer.

With these factors in mind, let us turn to estimates of the region's timber production potential as made by the Forest Service.

Sustainable yield possibilities

Estimates for this district's sustainable annual yield of wood, based on Forest Service studies, are given in Table 7. Total sustainable cut for the district works out to be 456 million cubic feet annually, which is about half the long-run potential growth rate we presented earlier. Slightly more than 40 percent of this sustainable cut is being taken currently. However, most of the proportion *not* taken is in the smaller size category; in sawtimber, current usage is running about 77 percent of 'capacity,' while in poletimber it runs to only about 8 percent.

Current drain expressed as a percentage of sustainable yield also varies sharply by subregion, as follows: western Montana, 56 percent; Black Hills, 41 percent; and eastern Montana, 19 percent. Current drain is summarized, by size category and subregion for comparison purposes, in Table 8. You'll note the great range in potential expansion; in some areas and sizes, expansion may be several-fold, while in western Montana sawtimber sizes are being used nearly to the full extent of the sustainable annual cut.

In summary, the estimates of physically sustainable levels of timber removal from the forests of the region show that, in terms of sheer cubic volume, *at least* twice as much timber could be taken as is currently taken. This headroom for expansion of drain, then, serves as a measure of potential. The reason why much of the available volume is *not* taken today is partly hinted at in the data of Tables 7 and 8. The fact that the great bulk of the unused capacity lies in the smaller sizes of trees suggests that economic considerations are the essential limiting factors today. The economics of timber resources will be the subject of Part II.

Adjusting to sustainable yield: allowable cut

One other important forest management guide applied to national forest lands is the *allowable cut* concept developed by the Forest Service. Sustainable yield, as we have learned, is a hypothetical figure which can be calculated for any forest to indicate its long-term potential. Allowable cut is a more practical, day-to-day working guide to how much ought to be cut from any given forest during, say, its period of adjustment to full sustainable yield.[11] Allowable cut for a given forest area can differ very markedly from sustainable cut. One thing that could cause this difference is the condition and volume of the existing forest stock. An existing forest may be stocked too heavily in mature and overmature trees. In such cases of unbalanced age structure, the annual allowable cut may be larger than either the maximum sustainable rate or the actual current growth rate for a period of many years. This essentially amounts to a planned mining of the forest until the forest area has been converted to better balance

TABLE 7 — ESTIMATED SUSTAINABLE ANNUAL PRODUCTION IN CUBIC FOOT EQUIVALENTS (MILLION CUBIC FEET)

	WESTERN MONTANA	EASTERN MONTANA	BLACK HILLS
Trees 11 inches and larger d.b.h. (sawtimber)	145	65	14
Trees 5 inches to 11 inches d.b.h. (poletimber)	123	101	8
All Timber	**268**	**166**	**22**

Source: Forest Service [20] and correspondence.

TABLE 8 — ANNUAL CUT OF TIMBER IN CUBIC FOOT EQUIVALENTS, 1957, BY SUBREGION AND SIZE CATEGORY (MILLION CUBIC FEET)

	WESTERN MONTANA	EASTERN MONTANA	BLACK HILLS
Sawtimber size	141	22	9
Poletimber size	8	9	1
All Sizes	**149**	**31**	**10**

Source: Forest Service [20] and correspondence.

[10]Intensity of management might be represented by, say, an index of expenditure of effort and application of equipment and materials used in tending the forest.

[11]Technically, allowable cut excludes some material which could be cut but for which there is no steady market (called unregulated yield).

between "thrifty," rapidly growing younger stock and the older stock.

At the other extreme, if a forest area has been heavily overcut or burned in the past, allowable cut may be well below maximum sustainable cut for that forest land. The cut would be low to permit the inventory of trees to increase to the point at which full advantage may be taken of the forest's growth characteristics.

Allowable cut is based on the latest available forest inventory data, and hence subject to revision every ten years or oftener. In calculating the allowable cut, the Forest Service may apply one of a number of formulas which tend to arrange the timing and amount of cut so as to achieve the two intermediate objectives on the road to maximum sustained yield: (1) bring the forest into a *balance* among different age classes by about the end of the first rotation, and (2) produce a maximum *even flow* of wood material from the forest during the intervening period. Forest Service policy in the West stresses the even flow aspect. Any temporary swelling of timber cut, it is felt, might induce undesirable expansion of industry, with the result that later adjustments to sustainable rates of cut would create idle industry and idle community facilities. Since the intermediate objectives are partially conflicting, in practical cases compromise is necessary.[12]

Ultimately, allowable cut on national forest lands should match sustainable yield on those lands. In the meantime, since so much of our region's forest has scarcely begun to approach the balanced condition, allowable cut will continue to be a very important administrative concept bearing directly on the scale of industry here. In actual experience, allowable cut on western Montana national forests has more than tripled over the past ten years.

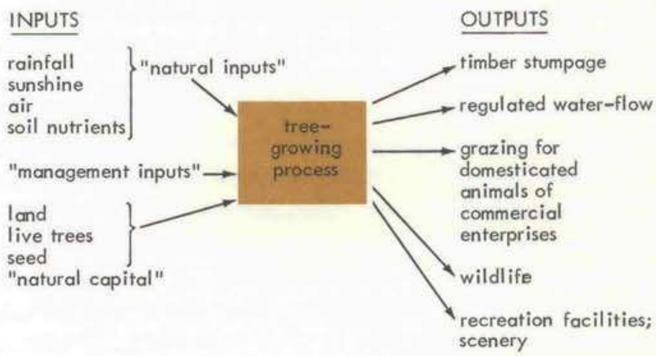
3. THE FOREST AS A PRODUCTION PROCESS

A somewhat different way of looking at the forest is to think of it as representing a process with inputs and outputs, identical in format to any of a great number of production operations at various stages in the flow of goods from basic raw materials to final finished products. This notion, more fully considered in some of our later discussion of economic aspects, will help us to see why the *flow resource* concept is not adequate in itself to answer key questions it raises.

A production process is an activity, for example a factory operation, that combines certain *inputs* (raw materials, labor, and capital equipment) and produces certain *outputs* (manufactured products, byproducts, and waste materials). Usually, but not always, the manager of the process buys the inputs and sells the outputs. Inputs are conventionally divided into two categories, (a) *direct* or *variable* inputs (e.g., labor, raw materials, supplies) that go directly into and are fully used up in some specifiable quantity for each unit of output, and (b) *distributed* or *fixed* inputs in which only a small part of the service life

of a piece of capital equipment is consumed in each unit of output. This seems suitable as an abstract description of a sawmill. But we may also view the forest in the same way, with the same general elements present.

Consider the forest as a production process. In this forest factory go certain inputs, such as sunlight, rainfall, soil nutrients, and carbon dioxide which are usually available free from nature, as well as labor, supplies, and capital equipment which are not available free. From the forest factory we obtain an output, wood. Wood itself then becomes an input to later stages of production, where it is combined with other inputs (labor, capital equipment, energy, and other physical materials) into subse-



quent outputs. These outputs in turn may be inputs to further processes until final consumption is reached.

Forests produce not only wood but also an assortment of other products—joint products and even competing products. Suppose we refer to it simply as the *tree-growing industry*, and for the moment ignore any outputs beside wood. Timber output as represented here is simply wood accumulated on standing trees in the forests. It is added to an inventory from which both man and nature withdraw quantities of wood. Annual production of this process is equivalent therefore to gross annual timber growth. Timber thus grown is an input to the *log-producing industry*, which is the next stage in the industrial flow of wood.

The tree-producing industry is, in some ways, very unlike all later stages of production processes. The tree-producing industry is a 'runaway' factory that can go on producing in the absence of any actions by man. That, obviously, is because it is a natural process; its capital plant (land, seed, and trees) is given by nature, and its

[12]For a discussion of factors involved in allowable cut, see Davis *et al* [29].

essential variable inputs (water, air, sunlight, and nutrients) are provided free by natural occurrences.

Management inputs refer to both distributed and direct inputs, including materials, equipment and labor—often delivered in conjunction with log production, but rightly chargeable to tree growing. These are the ingredients that man controls in order to increase or decrease the production of timber or other forest outputs.

As we have noted, when management inputs are altered—more equipment-hours and man-hours applied, for example—effects are sometimes noticeable immediately; but it may take many years before significant accumulations of wood (or alternate results) have taken place. Planning periods characteristic of tree growing are long, yet not different in principle from those in other production processes. All processes have to accommodate some amount of delay between the expenditure of initial effort (say, plant construction) and the realization of income from the end-product. All have to face the problem of balancing efforts between present production and future production.

The production-process viewpoint offers a useful framework for explaining the significance of forest management programs. It draws our attention to the resources which are allocated as *inputs* to the tree-growing activity. The resources we are talking about are scarce economic resources—land and labor, capital equipment, supplies and materials, energy—resources that could in principle have been applied to some other process to produce an alternative product (say, concrete blocks or aluminum castings).

We know that the application of capital equipment, human effort, and materials to the tree-growing industry could greatly increase growth rates. If our objective were to raise maximum sustainable yield to its highest attainable levels, and if we were willing to apply the necessary inputs, the potential drain conceivably could be raised to at least double the presently conceived levels.

But we also know that such an endeavor would cost something. The direct physical cost could be measured in terms of the other products we could have produced with the resources we have instead applied to tree-growing—products we have decided to do without in order to have more timber. We can see now that when we select the level of expenditures on forest management (a decision that must be settled before timber flow potential can be specified) we are making a very far-reaching choice. It essentially involves a decision on behalf of society in favor of one class of product and against another. The theme of Part II is this decision-making process.

RESUME OF PHYSICAL OUTPUT POTENTIAL

Keeping in mind that our measurement of maximum timber output potential in no way demonstrates either feasibility or desirability, we have tried in Part I to provide some gauge of (1) the natural basis for the timber industry in our region and (2) the physical or biological limits to which the drain of timber may be expanded. Even here we discovered that the problem cannot be left in physical terms, for the biological growth potentials for timber depend on the level of certain management inputs, which themselves involve a choice between allocating input resources to timber or allocating them to other possible activities of value to society. Such a choice is essentially an economic one.

The following table, then, indicates some timber output capacities (quantities that can be cut annually) for the region's forests under various hypothetical programs of cutting.

Program	Annual output capacity (million cu. ft./yr.)	Capacity as a multiple of current take
Mine out all stands completely over a ten-year period	1,800	9.5x
Maximum sustained yield given management intensity envisioned by Forest Service estimates	456	2.4x
Current allocation decisions	190	1.0x

Thus, we see that much more could be taken than is taken; physical capacity is high and obviously is not the active limiting factor in our region's production. We have looked at timber from three points of view: as a stock, as a flow, and as a production process. All three shed some light on the nature of the forest resource. We shall now explore the economic dimensions and appraise the level of output likely to be attained in the future.

II TIMBER RESOURCES OF THE NINTH DISTRICT WEST: ECONOMIC AVAILABILITY

As we have seen, the western Ninth district has a substantial physical volume of wood that could be harvested. This volume is well beyond the quantities currently being taken, even if the forest resource is viewed as a crop whose harvest must be maintained indefinitely. Why is full capacity not now being cut? What are the prospects for expanding production to use up some or all of this excess capacity? Those are the questions Part II sets out to examine.

In Part I, where our objective was to estimate the raw, basic capacity of the forest land to grow woodstuff, we tried as far as possible to avoid discussing the role of man and his industries in using the forest. Even there, however, we found that capacity to grow wood is directly dependent on the economic decisions man makes in handling the forest.

We will now turn our attention to the general factors that affect decisions about resource allocation in the region's timber industry and explore briefly some of the mechanics of decision making. With this background we shall be in position to assess more meaningfully the region's potential for timber production.

THE BASIC MECHANISM: PRICE AND PROFIT

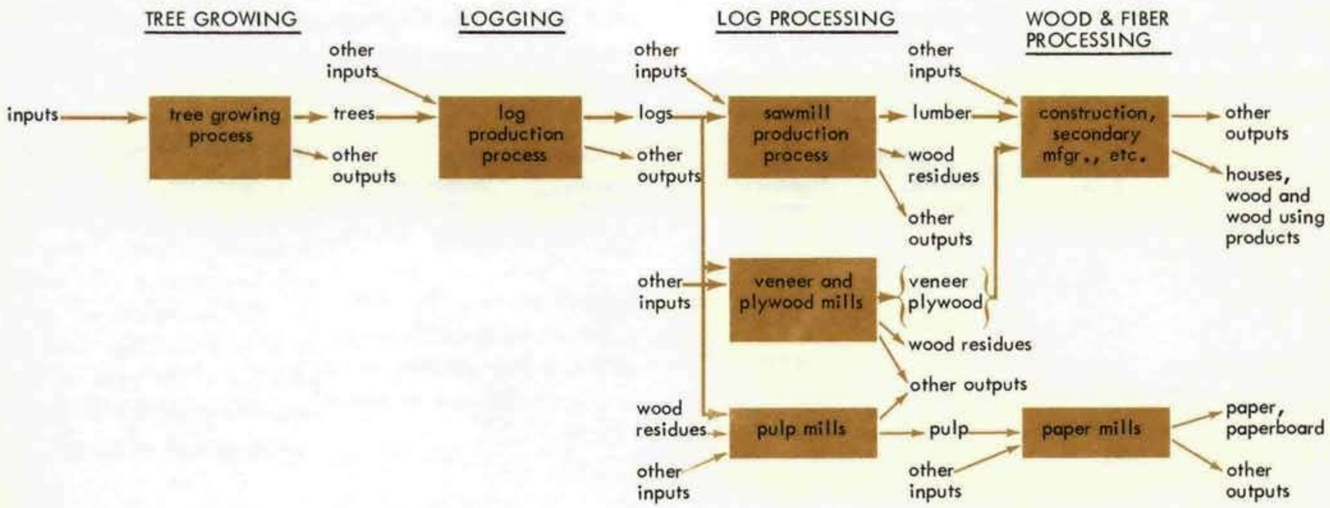
Decisions about what timber products to produce and how much to produce are made by a large number of private, profit-seeking firms. Essentially all production, all trade, and movement of material from the logging stage onward are conducted by these private firms. Their numbers are relatively large even within our geographically restricted region of study, their sizes relatively small, and their markets competitive. Expectations of profit chiefly determine the kind and amount of timber output.

For purposes of analysis we will arbitrarily divide the district's timber production process into a sequence of four main stages: *tree growing, logging, log processing,* and *wood processing* (including wood fiber processing).

Each stage has one or more production processes, and we may represent it diagrammatically as in Figure 2 by simply adding extensions to the diagram of the tree-growing process depicted in Part I. The timber and timber-related industries as a whole are tied together by the fact that wood outputs of earlier stages are inputs of subsequent stages. All of the inputs and outputs represent physical flows in the broadest sense. They can be measured in terms of specifiable units and rates, for example: man-hours per week, machine-hours per week, cubic feet per minute, board feet per shift, BTU's per hour, and so on.

In principle a market exists at the points where the wood material changes hands from one stage to the next. In practice individual firms within this broadly defined

Figure 2 — Input-output relations of several stages of production processes for a regional timber economy



timber industry may corporately integrate under a single company name several or all of the stages shown. Many firms operate independently within only a single process, such as logging or sawmill operations, however. The price associated with each input or output may be a market price at which the unit is actually traded, or it may be an *imputed* price corresponding to a fictitious sale within a corporate organization. In principle, then, a profit calculation can be made at each stage for each firm or individual operation in the industry.

The actual profit results for a series of past periods, if adverse, may force an operation to shut down. Expectations of future profits, as calculated on the basis of probable prices, may lead to the opening of a new production opportunity, or the expansion of an existing operation. Let us now see how such price and profit factors affect the tree growing, log producing, and primary log processing stages, respectively.

1. THE TREE-GROWING STAGE

Institutional features

The tree-growing stage differs in two important respects from all later stages in the timber industry: (1) a large segment of the production capacity is owned and operated by government, and (2) the profit motive is not an essential factor in decisions—chiefly those of the government—affecting a large part of the industry. In this region, the three main classes of owners and corresponding acreages held are:

Government ownerships	11.5 million acres
Large private ownerships	2.5 million acres
Small private ownerships	3.0 million acres

The acreages indicated here do not precisely mirror the importance of holdings if measured in terms of either standing volume of timber or potential growth rates, since private holdings usually contain the better sites and, if not greater actual volumes, at least greater potential growth. These better lands are mostly in and adjacent to the valleys on which early development and construction of sawmills took place. The government domain now in national forests has typically contained the more remote timber and lesser quality sites.

In total perhaps some 2.5 million acres of the region's 17 million acres of forest land are owned by a relatively few large corporations, including the Northern Pacific Railroad Company, the J. Neils Lumber Division of St. Regis Paper Company, Anaconda Company, and Homestake Mining Company. The first of these, a land-grant railroad, operates no sawmill of its own but instead sells stumpage to various mill operators and contractors. The others operate sawmills which produce a variety of lumber and products in addition to mine timbers.

About an equal acreage total is found in other private holdings—mostly small holdings on farms and ranches. Table 9 gives a breakdown of private ownership holdings.

Of the 11-plus million acres owned by governmental units, less than one million acres are state and county forests and the remainder are federal holdings. In our district, as in most parts of the West, the Forest Service is *the* major timber grower and consequently the major source of supply of wood for the later processing stages. These, then, are the major groups of landholders who make the district's decisions about tree growing—each with a characteristically different approach. We will look at each briefly after presenting an abstract framework through which their approaches may be compared.

Production economics of tree growing

The notion of tree growing as a production process can be applied in general to any forest holding. Like any other industrial process, tree growing can be analyzed for profitability by examining all associated revenues and expenditures.

A profit figure can be calculated after the fact—say for the past year's operations—by the usual formula. That is, compute the revenues received by selling the outputs (price of each output times the quantity of each output sold) and subtract the expenses (price of each input times the quantity of each input purchased). Some of these prices will be actual and perhaps recorded in contract (for example, the man-hour wage or the gallon price of diesel fuel). Some, however, will be imputed (for example, the machine-hour price of a tree-planting machine paid for at the time of purchase but expected to operate over a period of years).

TABLE 9 — PRIVATE OWNERSHIP HOLDINGS OF COMMERCIAL FOREST LAND BY SIZE CLASS, 1953

	MONTANA		SOUTH DAKOTA	
	Thousands of acres	Number of owners	Thousands of acres	Number of owners
50,000 acres and larger	1,875	4	—	—
5,000 to 50,000 acres	222	16	*	*
500 to 5,000 acres	1,625	1,671	45	8
100 to 500 acres	840	5,471	143	353
under 100 acres	295	7,374	408	17,602
All Private Holdings	**4,857**	**14,536**	**596**	**17,963**

—None recorded.

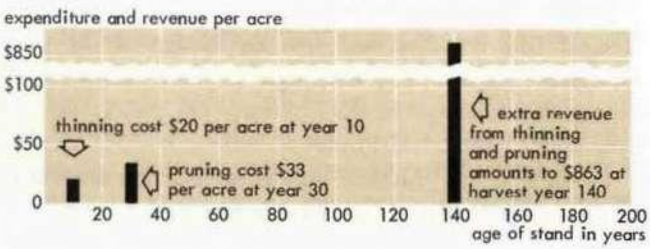
*Included in next smaller size class to avoid possible disclosure of individual owners.

Source: Forest Service **[39]**.

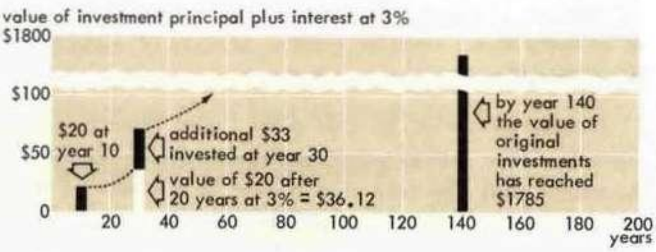
Note that the combination of inputs in the tree-growing process produces stumpage, and that the sale of stumpage is required to produce revenue. As in any business, there is the possibility of building up inventory by growing more than is sold, as well as of drawing down inventory by selling more than is grown. In the extreme it is possible to generate revenue by selling all the standing timber for immediate cutting.

In investment decisions—decisions, for example, about the kind of forest management program, if any, to undertake or to continue—expectations about future profits is a crucial ingredient. More exactly it is important to any private investor in a tree-growing program to take into account how much and when he is required to invest, and the timing and amount of revenues which the program is expected to generate. Above all, *time* is important, because there are many alternatives for invested money.

Take this example: Thinning out trees in dense young stands and pruning away lower branches will result in improved growth rates over the rotation and increased stumpage values at harvest. Forest Service studies[13] in western Montana indicate that thinning and pruning of ponderosa pine on medium sites will increase harvest values from an estimated $100 per acre without treatment to an estimated $963 with treatment. The thinning cost is estimated at $20 per acre and pruning at $33—in other words, $53 invested brings a net return of $863. But, as the following diagram indicates, the time span is long:



Suppose instead that the money were placed for the same length of time in a savings account paying 3 percent interest, compounded annually:



As the second diagram indicates, a 3 percent savings certificate can be expected to return about twice as much as the same money invested in the pruning and thinning effort. The *rate of return* on investment in thinning and pruning calculated from the above data turns out to be about 2.4 percent.[14]

Rate of return is perhaps the best single criterion in private investment decisions, since it provides a measure of the efficiency with which a firm's money may be put to work in various alternative uses. An expected rate of return of 2.4 percent is much too low for most private corporations in the United States, and it becomes even less attractive when the possible risks of any long-term timber growing venture are considered. But the Forest Service, which effectively uses a zero interest rate as an acceptable minimum standard, might find such a venture attractive.

Planning for maximum financial return in a forestry program committed to sustained yield normally results in choices of rotation that do not maximize the physical flow of wood. Consideration of interest rates and the "cost" of money puts a premium on getting things done sooner. Let's see how this works.

Suppose we examine the prospect of investing in a ponderosa pine enterprise starting from scratch and growing sawtimber for sale as stumpage. Assume our expectations about the future are as follows: (1) we can establish pine seedlings on our land for $15 an acre (roughly the cost of aerial seeding); (2) we will pay $.18 per acre as a regular annual management expense over the entire rotation; (3) merchantable board-feet volumes will accumulate on trees 7 inches and larger according to the average natural yield tables on site-index-80 land; and (4) we can sell the accumulated board-foot volume (International ⅛-inch rule) in any year we choose at $20 per thousand board feet, net. With these assumptions we can compute a rate of return for any choice of rotation. A rotation of 110 years, which gives us maximum sustainable yield, would show these expected money flows:

$15 per acre outflow at year 1
18¢ per acre outflow each year from 1 until 110
$688 per acre inflow at year 110

This scheme of investment and recoupment has an equivalent rate of return of about 3¼ percent compounded annually. If we similarly calculate a rate of return for

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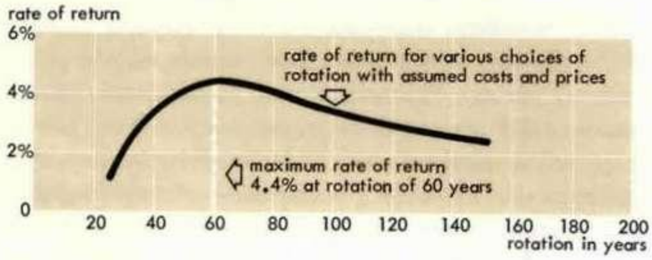
[13] See Hutchison *et al* [6], Wikstrom *et al* [24].

[14] The equivalent rate of return, or "internal rate of return," on a stream of investments and receipts can be found by solving for r in the following equation:

$$\sum_{j=0}^{j=n} F_j (1+r)^{n-j} = 0$$

where F_j is the net cash flow (expenditure minus revenue) for the year j, and where j can take all integral values from zero (the year the enterprise starts) to n (the year the enterprise plan ends). This is normally solved by an iterative, 'trial-and-error' procedure.

each of the other possible rotation choices, and compare them graphically, we obtain:



From this information we see that the private investor committed to sustained yield would select a rotation of 60 years if he wished to get the most out of the use of his money (4.4 percent). At this rotation, by the way, the sustainable yield would average two-thirds as much in board-foot volume as would be forthcoming under maximum sustainable yield (at a rotation of 110 years).

The value figures we have chosen above are purely illustrative. Aerial seeding, at $15 an acre, may not be adequate to do the job (some firms figure aerial seeding has only a one-in-four chance of establishing medium stocking); if we had to resort to hand planting to get our tract going, initial costs might reach $45 an acre and more. In this circumstance our best expected rate of return would be knocked down considerably below the 4.4 percent maximum we calculated earlier.

Moreover, we assumed that stumpage value would be constant at $20 per thousand board feet. We could just as well assume increasing values per thousand board feet for older trees—either because the increased size of logs is of greater value to sawmills, or because we expect increasing scarcity and inflating stumpage prices in the distant future. If we assume increasing values, we would choose a longer rotation for best rate of return, and our rate of return might indeed be higher. Inclusion of additional revenue from possible intermediate cuttings prior to final harvest would also improve our rate of return. On the better sites, which are very limited in availability, return would be higher; on poorer sites (public-owned lands on the average tend to be heavily weighted with *these), return would be correspondingly lower.*

The rotation-versus-return curve illustrated above is specific to some assumed level of management intensity. If the level of management intensity (measured, say, by expenditures on forest treatment) were changed, the expected returns would also change, and a new and different "best" rate and "optimum" rotation would result.

The biggest obstacle to the use of strict economic criteria in planning for maximum return on a sustained yield timber enterprise is lack of knowledge about the way forest growth will respond to various timber management measures. Theoretically, some one level of management expenditure will lead to the highest maximum return.[15] The profit maximizer's job is to select a level of management intensity and a rotation that yields the highest possible return for the forest in question — equivalent to finding the high point of the hill in Figure 3. He must then decide, given the risk he sees in the enterprise and the returns that are open to him from an alternative use of his funds, whether or not the expected rate of return is adequate. If it is not, the profit-oriented investor presumably would refuse to invest.

In general, financial yield on sustained-output forest enterprises appears to be very low—of the order of a few percent or less. For the bulk of private owners committed to sustained yield, considerations other than profitability of tree-growing are overriding. For most owners whose forest land has some merchantable timber already on it, the most profitable decision from the standpoint of expected return is probably the immediate sale and removal of as much of the timber as the market will bear. Many private owners, particularly small-tract owners, find the economic pressures to "mine" the forest almost irresistable.

Decision factors in practice

The foregoing framework for decision making in tree growing is a theoretical one. The task of constructing a schedule of future revenues and expenses must be based on expectations of conditions about which there is considerable uncertainty. Profit maximizing of this hypothetical sort requires complete knowledge of the technological possibilities, although in fact many input-output relationships in tree growing are poorly defined even under *today's* conditions.

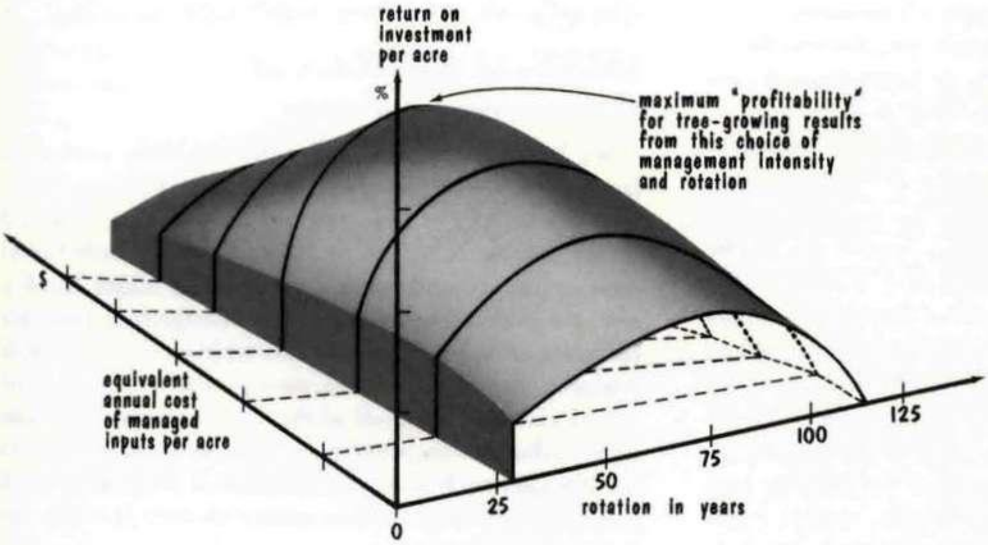
In spite of the practical difficulties and the uncertainties in computing an expected-earnings stream, this basic approach can be used, in principle, by any tree grower as a guide to decisions about the appropriate level at which to operate the tree-growing process. As it turns out, most of the forest holdings are *not* operated this way. Let us see how the various ownership classes do approach tree-growing decisions.

a. Small private owners

Almost no owner in this class views himself as an operator of a tree-growing enterprise. More commonly he might play the role of a broker in the sale of trees that happen to be standing on his property. He does this because, in the first place, a small property cannot be operated effectively as a sustained yield unit by itself. Rotation periods are long compared with the life of a human

[15]Subject only to the plausible assumption of diminishing returns to management inputs in the tree-growing process. A general assumption in this analysis is that the managers attain maximum technical efficiency for any given level of expenditure on inputs.

Figure 3 — Theoretical relation of rotation and management intensity to rate of return for a tree-growing enterprise



individual, and only a few periodic sales could be made from a small forest during this span. Therefore, long stretches between paychecks would occur, during which sunk costs including taxes and management expenses would have to be carried.

Just as important, the small landowner rarely has the required knowledge about technical production possibilities. He lacks sufficient 'feel' of the timber industry and the market to make smart decisions about his holdings. He may prefer to use the forest land in other ways—as grazing land, as a building site, or simply as a speculative possession. As a result, the small private owner tends to be least concerned among the ownership classes with the long-run outlook or with consequences of his actions on the forest. Even when he conserves forest stands in order to accumulate wood for future sale, he generally applies a minimum level of management in order to hold down the costs sunk into the property. Financial crises may force him to liquidate existing stocks of merchantable timber. In general, cutting on these lands tends to be in excess of sustainable yield levels — especially in times of keen demand and high stumpage prices.

b. Large private owners

This group stands closest to the position of the profit maximizer in management of the tree-growing process. The bulk of the land in this category of ownership belongs to large, private corporations which usually integrate several stages of the timber operations within a single company, such as sawmills, veneer mills, pulp mills, and various types of secondary manufacture.

Most of these companies have adopted some form of sustained yield program in managing their forest holdings. This long-range emphasis results partly from the indefinitely long life of corporate organization, which requires planning for operations well beyond the lives of many of the individuals doing the planning, and partly from public pressures or potential pressures. Operations in general are not keyed to maximum physical flow but rather to some lesser sustained harvest resulting from a combination of rotation period and level of management intensity that contributes more to return on the companies' funds.

Rarely does the timber processing company have sufficient holdings to supply all its company needs. As a result almost all companies depend to some extent on other sellers, notably the Forest Service. The price at which such companies sell their own timber to themselves, an internal accounting transaction, will be relatively stable over short periods of time, reflecting the longer-term nature of the costs of a timber management program, the acquisition of land, the inputs, and interest charges.

During periods of low demand, and hence relatively low stumpage prices, the alternative of buying stumpage from the Forest Service or from other private sellers becomes attractive. But of course, circumstances of weak demand would limit the ability of most companies to take advantage of outside purchases. The capital gains arrangement for taxation of timber income could also modify a company's outside purchase decisions. In general, all the large private holders are very responsive to changes in financial factors.

c. Forest Service holdings

Forest Service decisions with respect to tree growing are especially important, not only because the Forest Service manages a majority of the district's forest acreage, but also because its policies have strong influence on the actions of other forest land holders. The Forest Service considers economic criteria in its decision making. Yet one important way in which it differs from private industry is that it does not place the premium on current income as opposed to future income that private decision makers must.

Although national forest policy as defined in law is not specifically committal[16], Forest Service decision makers lean toward maximum sustained physical flow of wood; thus, they probably pick longer rotations than would private decision makers in control of the same forest lands. Just how much longer is impossible to say because as we have already pointed out, determining a maximizing rotation is inherently an imprecise task, depending upon arbitrary decisions such as the choice of scale by which volume is measured, and technological assumptions about how fully the log is utilized.

The level of management intensity on national forests is generally keyed to production objectives the Forest Service deems necessary to meet future wood requirements.[17] However, available finances largely determine the level attained. Cash payments for inputs required to meet the Forest Service's chosen intensity of management are financed from two sources: (a) congressional appropriations; (b) payments by private firms and individuals under special contractual requirements connected with stumpage sales.[18] In addition, special forest management efforts required of the stumpage buyer at the time of logging also contribute toward achieving management objectives on national forest land.

Forest Service policy publicly avows two basic principles: *multiple use* and *sustained yield.* Multiple use recognizes that forests produce other valuable outputs beside wood. The five classes of outputs recognized in Public Law 86-517, cited earlier, are: outdoor recreation, range, timber, watershed, and wildlife (including fish). The relative importance of these outputs may vary from one locality to another, but the principle of multiple use requires that each be taken into account—with greater or lesser weight depending on the local situation—in forest management planning.

Sustained yield, already discussed in connection with tree growing, is a concept applied in Forest Service policy to all five outputs. Because these outputs do not necessarily reach their respective maximums under the same management program (for example, maximum grazing use might conflict with maximum timber production), the notion of *maximum* sustainable yield is not used. Instead, the phrase "high-level output" is used in the wording of the law. For our purposes, the importance of this policy guide to Forest Service decision making is the fact that forest lands, viewed as producing several outputs, must compromise the best interests of all outputs; thus, in some cases the need to protect waterflows or recreation values may force adoption of a program that does not result in maximum timber yield.

[16]Forest Service objectives in national forest management, delineated in Public Law 86-517, 86th Congress, H.R. 10572, June 12, 1960, declare that, ". . . the national forests be managed . . . with consideration being given to the relative values of the various resources, and *not necessarily the combination of uses that will give the greatest dollar return or the greatest unit output* . . . (and administered for) the achievement and maintenance in perpetuity of a *high-level* annual or regular periodic ouput of the various renewable resources . . ." (Italics added.)

[17]See Forest Service [*39*], "Hearings . . ." [*33*].

[18]Stumpage payments proper go directly to the United States Treasury.

Effects and interaction of tree-growers' decisions

We have sketched the viewpoints of three groups of landowners whose individual decisions add up to determine the amount of tree growing in the district, now and in the future. It serves to indicate broad institutional peculiarities at work at the tree-growing stage. In general, the Forest Service directs its management program basically toward predetermined physical production goals; large private owners, though also aiming at perpetual yield, set the level of their management programs in accordance with profit prospects, while small private holders tend to look upon their timber more as a stock and give little heed to the capacity of their land for future timber growth.

While each of these groups may choose its course of action independently, based on its own characteristic approach to forest holdings, their decisions interact in many ways. Of greatest interest to us are those reactions which take place through the market system, in which effects often offset each other.[19] For example, a Forest Service action that reduced the amount of its stumpage available to the market today, would tend to raise current and near-term stumpage prices (and possibly to lower expected prices for the far future, assuming the purpose of the action was to foster higher growth and sales in the far future). This change in prices would induce private growers to supply more timber out of current holdings and to reduce future availability, thus tending to partly offset the effects of the Forest Service action. Note that prices here serve as the signals through which the actions are effected.

As one further illustration, recall that one of the peculiarities of the tree-growing stage (considered as a production process) is the large size of live wood inventory in relation to annual growth. As a result, sales decisions can be detached from tree-growing decisions over long periods of time. In order to sell stumpage, however, the seller must find a buyer who desires to buy at a price established between them. But tree inventory is also the capital plant of the tree grower, and decisions about the level of this plant are part of a management program. Thus, if buyers do not buy what is grown for sale, this reflects back upon, and effectively alters, the

[19]As though operating under an economic version of Le Châtelier's principle, which might be stated as follows: if a change is applied to a system in equilibrium, the equilibrium is shifted in a way that tends to undo the effect of the change.

management program. Therefore, management decisions, however physically or silviculturally oriented, cannot be divorced from the economics of the industry. This serves to confirm our hunch that the "size" of the timber resource cannot be measured on the basis of technological considerations alone.

DECISION FACTORS IN THE LATER STAGES OF THE TIMBER INDUSTRY

Later stages in the timber industry, such as log production and log processing, are on the receiving end of the flow of timber sold by the tree grower. The motivations behind these later stages are much simpler to define. All of them, up to and including the manufacture of final consumer products, involve private profit-seeking firms. In general, these firms are numerous and not individually dominant in the markets in which they sell.[20] And since their products are fairly standardized, their markets display the kind of competitiveness that caught the eye of the classical economist. Here prices are all-important and beyond control of the individual profit-seeking firm. The firm buys inputs and sells outputs. If in the course of this effort it earns an adequate return, it remains in business. If not, it folds up. It is almost as simple as that.

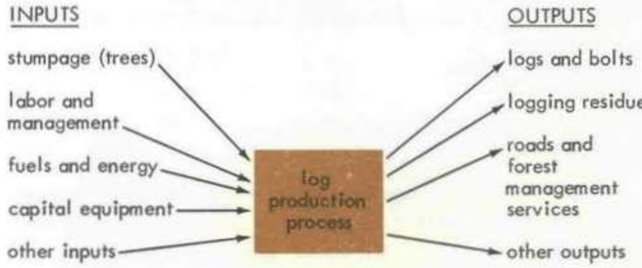
We shall now specifically consider how profit is determined in the logging and sawmill operations and how the several stages are related through markets.

2. THE LOGGING STAGE

Production economics of logging

The logging process transforms the tree standing in the forest into logs delivered to the mill. It essentially performs the service of shaping and delivering the natural wood source. The mechanics of the process, for those not familiar with it, are described briefly in Appendix C.

Inputs are the standing trees which the firm purchases, plus labor, equipment and supplies. Expenses are the payments for these inputs. Revenues are derived from the sale of the logs and bolts produced and the other outputs. The firms in this business are all private and profit-



seeking, hence the scale of operations depends directly on profit and the prospect of profit.

The prices received by the logging industry per thousand board feet of delivered logs are, of course, the prices paid by sawmills. The logger gets paid more for premium species and for higher quality, larger logs. Veneer plants and pole treating plants can generally outbid sawmills in price for the special qualities they most want in a log, although sawmills would also prefer to get the higher grade logs.

Both log price and the price of stumpage tend to be *residual* prices. Competition has the effect of raising stumpage prices on the higher quality and premium species for which the logger would ordinarily get higher log prices. Thus, competition among loggers tends to keep the spread between stumpage and delivered log prices pretty much down to the level of logging and transportation costs, plus a competitive return on the enterprise.

Before we look into stumpage costs, we should briefly spell out some of the factors affecting the basic process costs of the logging operation. These costs will vary in proportion to (1) the roughness and difficulty of access of the terrain, (2) the size of trees involved (more handling per thousand board feet being required for smaller trees), (3) the density of trees (net volume per acre), (4) special contractual requirements in logging and hauling, (5) the length of transportation to the mill and character of the road network, and, of course, (6) any unexpected delays or breakdowns due to weather, fires, accidents, and failure of equipment.

Some average logging costs by phase of operation are shown in Table 10. Development costs (road building, etc.) and transportation costs are especially variable. As road networks in an area become more thoroughly developed the general level of these costs would decline. The costs shown here by area are based on timber actually taken in recent years and, therefore, do not necessarily represent the cost levels associated with the potentially available timber not now taken in each region.

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[20] A recent tally for Montana showed 222 logging camps and contractors, 233 sawmills and planing mills, and 38 primary wood processing firms. Some idea of the relative sizes of firms can be obtained from the following breakdown of 247 sawmills in Montana and the Black Hills.

Sawmills and planing mills, 1958

Size of firm (number of employees)	Number of firms
1-19	196
20-49	27
50-99	15
100-249	6
250-499	1
500 and over	2
Total	**247**

Source: 1958 Census of Manufactures.

TABLE 10 — AVERAGE ESTIMATED LUMBER LOGGING COSTS, 1960-1962, BY AREA, DOLLARS PER THOUSAND BOARD FEET (LOG SCALE)

ACTIVITY	WESTERN MONTANA	EASTERN MONTANA	BLACK HILLS
Development	$ 6.02	$ 2.87	$ 4.00
Felling, bucking, skidding and loading	10.74	13.24	12.74
Transportation	9.93	9.54	12.04
Slash disposal	1.50	1.89	1.50
Administration	4.01	4.00	2.10
Total	$32.20	$31.54	$32.38
Average Log Haul Mileage	31.7	33.7	35.0

Source: C & NW Railway [15], Forest Service correspondence.

In general, unit logging costs east of the continental divide can be expected to be higher, since the smaller average tree size results in greater weight per thousand board feet of lumber recovered.

The stumpage market and determination of stumpage prices

The demand for stumpage is derived ultimately from users of wood and wood products through the chain of several processing stages. Hence, when user demand is high and product prices high, stumpage prices tend also to be high.

The Forest Service arranges many sales in each national forest annually, in quantities ranging from a few million to seventy or eighty million board feet, designed to conform to the Forest Service's general management program. In the three-year period ended July 1, 1962, *some 1.7 billion board feet of timber was sold from* Montana national forest land in 278 sales, each more than 2 million board feet.

The procedure is as follows: The Forest Service will survey the timber to be offered for sale and set an *appraised price*. The appraised price is the residual arrived at by starting with some going or anticipated market price for the lumber, and deducting average costs of production and allowance for profit and risk. We can illustrate this with some representative figures. Starting with an assumed average selling price of mill products per thousand board feet (log scale):

selling price	$81.00	
deduct		
estimated production costs	65.25	(mill cost plus logging cost)
margin for profit and risk	9.72	(divided between logger and mill)
costs plus margin	$74.97	

The net stumpage price is set at $81.00 - $74.97, or:

stumpage per MBF	$ 6.03

which is the officially appraised price for the timber.

The timber is then advertised for sale, with the appraised price being a minimum below which no bid will be accepted. The sale normally is made to the highest bidder and the amount bid may be the same as or greater than the appraised price. Various contractual requirements included in the sales contract effectively require the logger to produce other outputs for which he is paid and charge him for some of his outputs that must be disposed of.

One such item is the so-called K-V deposit. This is a charge made to the buyer, authorized under the Knudson-Vandenberg Act, to be used for reforestation and stand-improvement work in the sale area. The K-V deposit varies, but $2.00 might be a representative figure. In that case the appraised value of the timber in the sale would actually run $4.03 per thousand board feet (log scale).[21]

Estimated production costs include an item called "development"—an amount for construction of roads and other capital improvements on the forest land. These improvements are made to meet the specifications of the Forest Service in keeping with its "prudent operator" concept, but are often more costly and extensive than those the average private logging firm would have undertaken for timber harvest purposes in the absence of special requirements. After an area acquires a well-developed network of roads, the development cost per thousand board feet of timber cut is reduced.

Thus, one result of buying stumpage from the federal government is that the buyer is required to undertake a *series of special conservation measures (really a part of* his outputs), for which he is in effect granted an allowance covering the estimated average cost of the measures.

The logger buying stumpage from private owners might be confronted by fewer special requirements, but the general economics of the process is similar. Price of stumpage still tends to be a residual reflecting market price of the logs (and lumber) and the accessibility, quality, and other production cost factors in competition with public timber. The basic operating motive remains the same—to buy stumpage and other inputs, to sell logs and possibly other outputs, and to make a profit in the process.

Some logging may be performed by integrated firms from their own timber lands. In this case the price of stumpage is no longer a readily determined value as set by contract with the Forest Service or with a private seller, but represents a problem in internal accounting.

[21]It is also valid to view $6.03 as appraised value. The $2.00 K-V is simply a government financed improvement measure that is dependent on sales. For a popular treatment of Forest Service timber appraisal and sales procedures, see *Timber, Story of a Timber Sale on a National Forest*, USDA Forest Service PA-545, April, 1963.

The decision about profitability then must take into account the profitability of the tree-growing business as one part of an integrated operation.

Finally, we might point out that the stumpage market is inherently less perfect than the product markets, because it is broken into a number of smaller, semi-isolated geographic areas each containing a greatly reduced number of firms. This geographic isolation is due to the bulkiness and low value of logs which make transportation of them for sawmill purposes uneconomic at distances of more than 50 to 100 miles. The character of the various submarkets varies substantially, while the market positions of firms within any one market are also highly variable. In general, though, buyers are relatively few at the local level; some individual logging firms, quite large in relation to the market, can therefore influence the market price directly and perceptibly when they make bids to purchase. They must take this influence into account when making their decisions. In some areas bids made consistently at minimum appraised prices strongly suggest gentlemen's agreements on the part of bidding firms.

The suppliers' side of the market is even more imperfectly competitive (oligopolistic, as the economist would say) because of the greater concentration of merchantable timber in the hands of a few sellers. Overshadowing all sellers, the Forest Service by its timber sales policies cannot help strongly influencing the level of stumpage prices and, through market channels, the level of timber product prices.

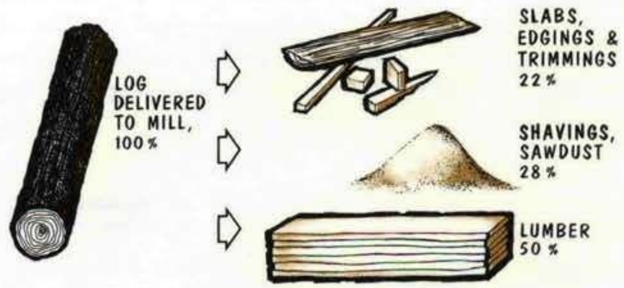
3. PRIMARY PROCESSING STAGE

Sawmill production economics

Let us now consider the inputs and outputs of the sawmill process. For readers not already sufficiently familiar with the mechanical aspects of sawmill operations, a brief description appears in Appendix D.

From an abstract standpoint, the sawmill's economics are simple enough. It buys various quantities of each of the *input* items, for which it pays some prevailing price in money terms either explicitly or implicitly. The inputs are combined according to the management's recipe, and the several outputs result. The various outputs—products, byproducts, and waste—are sold or disposed of. The major classes of outputs are indicated in Figure 4.

Figure 4 — Product yield from a representative district sawmill



In theory a price is associated with each of the outputs. For the principal product this theoretical price is not difficult to visualize: the sale of lumber at its market price is the chief source of operating revenue. For other products, such as bark and unusable residues, the price may be zero or even negative; a negative price means that the sawmill has to pay something for the disposal of this output—the cost per unit of residue of operating the burner, for example. For residues used, say to generate power, the sawmill pays itself for some of its residues which also constitute an input actually recycled in the process. The appropriate price in such a case would be the equivalent price of power it might otherwise have to buy from the cheapest alternative source.

On the input side, price-times-quantity relationships are direct in the cases of sawlogs purchased, man-hours hired, and many inputs. For capital equipment, however, the quantities consumed are prorated over the life of the equipment, and the appropriate price is that imputed on the basis of the original cost of the equipment.

Some inputs are not voluntarily purchased, for instance, those general government services that are in a sense purchased by the payment of taxes. Some of these services seem to have only the remotest connection with production of lumber. Yet insofar as these inputs help promote a stable society and an enduring legal and political framework for the business transactions, they are ultimately as much a part of the cost of producing lumber as is the advertising expense to promote a product sale or the legal expense to formulate a contract. Services more direct and easily associated with costs of production include police and fire protection in lieu of more costly insurance rates.

The facts that lumber may be produced but not sold and logs purchased but not processed in any one period —these must be accounted for by changes in stocks or inventories, and revenues and expenses must be adjusted accordingly.

Expense factors in lumber manufacture

The sawmill purchases logs and combines these with its other inputs—labor, power, supplies, and capital equipment. These form the expenses; each expense item is theoretically the product of some physical quantity of input times the price at which it is purchased (or a price imputed to it). An illustrative range of expenses for sawmills in our region is as follows:

	Cost per thousand board feet of lumber produced	
	Average	Range
Log costs (delivered)	$40	$20 - $80
Manufacturing costs	33	$20 - $40
Total cost of production	**$73**	

We want to look briefly at each of these two groups of costs.

a. Log costs

The illustrative log cost of $40 per thousand board feet delivered at the mill is a rough average. The range of log costs for particular sales is great, depending on the species involved, size and quality of logs, and the conditions prevailing at the time the purchase or contract to purchase is made. Species and grades of logs whose cut products bring the highest revenue per board foot tend to have high log costs per board foot. For those firms with integrated logging and sawing operations, the log costs become a matter of internal accounting, but in principle they are the same as for firms buying their logs from independent loggers on the basis of some delivered contract price.

If logs are purchased at a price of, say, $50 per thousand board feet, where the wood volume contained in the log is estimated on the basis of a log scale, the log cost per thousand board feet of lumber produced is typically a lower figure. If *overrun* is 10 percent,[22] then logs costs per thousand board feet of lumber output would be only $45.45 (or 50 ÷ 1100). This is merely an accounting peculiarity, not a bonus to the mill, because the market for logs and stumpage takes overrun into account when log and stumpage prices are established.

The very great range of delivered prices is caused by a number of factors. One is species differences, as shown in the following breakdown:

Species	Average delivered price per thousand board feet log scale
Ponderosa pine	$65
Lodgepole pine	40
Larch—Douglas-fir	45
Spruce	45

Actual log cost for any one mill could vary several percentage points from these figures (in some isolated cases as much as 50 percent), depending on the quality of the logs, competitive conditions at the time of purchase, and distance and difficulty of transportation from logging sites to the mill.

b. Manufacturing costs

Manufacturing and selling costs can vary considerably from one mill to another, and experience over one recent year in our region shows that this might vary over the range of twenty to forty dollars per thousand board feet or more. An approximate breakdown for band sawmills in Western Montana in 1952 is given in Table 11.

TABLE 11 — AVERAGE MANUFACTURING COST IN BAND SAWMILLS IN THE INLAND EMPIRE, 1952, EXCLUSIVE OF INCOME TAXES AND INTEREST

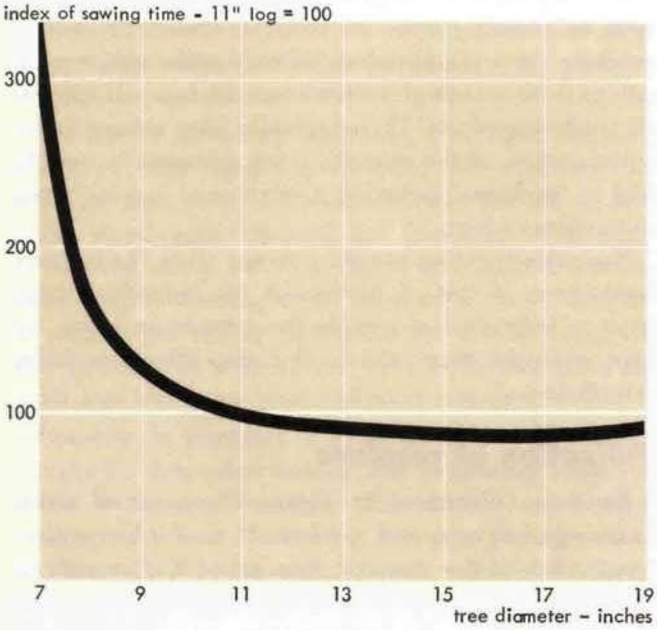
ACTIVITY	COST PER MBF	
PROCESSING		
Sawmill	$9.75	
Yarding & Handling	7.31	
Planer	4.42	
Dry kiln	1.59	
Total Processing		$23.07
SELLING		
Total Selling		2.41
OVERHEAD		
General expenses	5.80	
Taxes	.49	
Depreciation	1.79	
Total Overhead		8.08
TOTAL MANUFACTURING AND MARKETING COSTS		$33.56

Factors influencing manufacturing costs include: wage rate, degree and efficiency of mechanization, cost of equipment, degree of processing, and amount of handling per unit of wood output.

Manufacturing costs are higher per board foot for smaller size logs. Figure 5 shows this relationship for lodgepole pine, indicating that costs rise very sharply as trees fall below about 10 inches in diameter. Grade of log (percentage of defect) and species will also have a bearing on costs. These are the input factors. Quality of capital equipment will also be influential. Newer, more

[22]Overrun is the proportion by which actual lumber tally of the output lumber exceeds the log scale measurement of the input log. It may result from: (1) normal bias of the log scale procedures used and (2) efficiency of the manufacturing process. Overrun tends to average 8-15 percent in our region.

Figure 5 — Index of lumber sawing time per thousand board feet



Source: Forest Service [22].

efficient equipment could improve on the costs shown in Table 11.

Degree of processing obviously has an influence on total manufacturing costs, but it also has an effect on revenue. For example, the milling operation in Table 11 includes a cost item for a planer. Without this, the mill's total costs might be less by $4.42 per thousand board feet. But rough lumber brings a lower price than planed lumber. Elimination of the dry kiln, too, would reduce the total cost of producing a thousand board feet of lumber, but green lumber would, of course, bring a lower price than kiln-dried lumber.

The revenue picture: lumber

In practice two categories of outputs are directly significant to revenue calculations: *lumber* and *residues* (see Figure 4). Let's start with output labeled lumber. In physical volume terms lumber averages about 50 percent or more of the whole wood content of the input log, but it consists of a more or less great variety of grades, sizes, and species of lumber product, depending on the log input and the execution of the sawing process. While all these products are measured in common units —board feet or thousand board feet—there exists a hierarchy of prices depending on grades, sizes, and species.

So the average revenue per board foot that a mill may obtain by selling its product depends on how that product breaks into grades, species, and sizes. The more of the better grades, the higher will be the average selling price. The lumber yield in turn depends on the size and quality of the logs put into the mill, as well as the inherent efficiency of the sawing process.

Consider the effect of species and product on average revenue. In the case of dimension lumber cut from Douglas-fir (or larch), the lumber grade recovery and average realized price might work out roughly as follows:

Grade	Percent of recovery by grade	Average selling price per thousand board feet
Standard and better	75%	$65.00
Utility	20	42.00
Economy	5	15.00
All Grades	**100%**	**$57.90 average realization per thousand board feet**

A higher *average realization* results from ponderosa pine, assuming a representative grade recovery and recent mill selling prices:

Grade	Percent of recovery by grade	Average selling price per thousand board feet
Select	10%	$200
Shop	15	90
Common	75	70
All Grades	**100%**	**$ 86 average realization per thousand board feet**

Thus species and the consequent product yield have a distinct impact on mill unit revenue.

Log size and quality also influence recovery by grade, and hence the average realization per unit of output. Here are two illustrative examples of grade recovery from ponderosa pine: One set of grade recovery figures comes from a mill in western Montana sawing old growth pine, the other comes from a mill in the Black Hills sawing second growth pine.

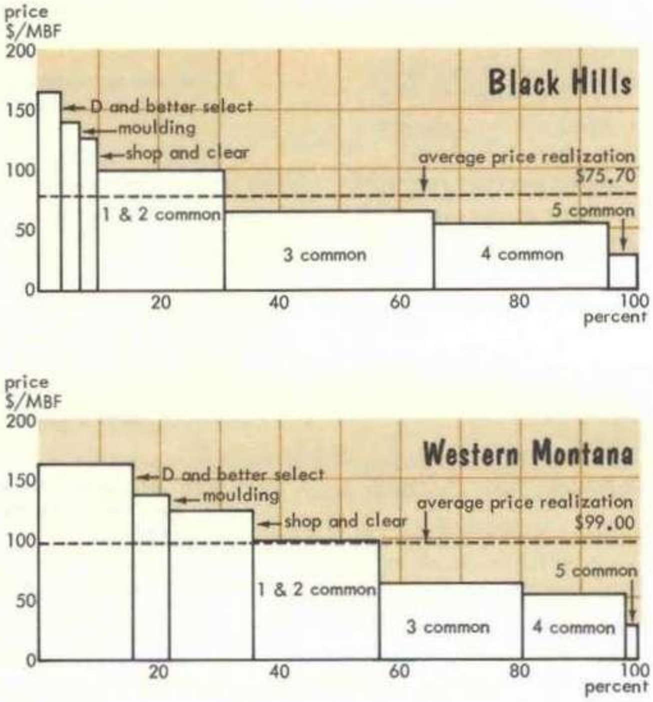
Lumber grade*	Percent of lumber recovery by grade: Western Montana old growth	Black Hills second growth
D and better select	16	4
Moulding	6	3
#1 shop, #3 clear	14	3
1 and 2 common	21	21
3 common	24	35
4 common	17	29
5 common	2	5
	100	**100**

*For an illustration of these grades, see Appendix D.

The western Montana mill obviously produces a much larger proportion of the higher-priced select grades and so earns a higher revenue per board foot of log run through the mill than does the Black Hills sawmill ($99 versus $76, as is diagrammed in Figure 6). Both size and quality differences are at work here.

Part of the higher unit revenue from larger logs results from the fact that wider boards can be sawed, and premiums are usually associated with wider boards.

Figure 6 — Lumber grade recovery, mill prices, and average realization price for ponderosa pine lumber, hypothetical Black Hills and western Montana sawmills, 1962



The effect of log quality by itself shows up in the following data for Black Hills ponderosa pine logs. Grade differences (based on the amount of surface knots, blemish and defect) can make differences of up to thirty dollars per thousand board feet in value of output:

Log grade	Average realization per thousand board feet
#1	$97
#2	$77
#3	$75
#4-6	$68-70

The quality and size of log are critical in determining the assortment of lumber that can come out of a mill. Thus, from the standpoint of revenues generated per unit of wood output, a mill finds it advantageous to process the larger logs, the higher grade logs, and the higher ranked species. The effect of differential preference for logs is reflected, of course, in the prices paid for logs; hence, to a greater or lesser extent the per-unit revenue advantages of higher grade logs are offset in sawmill profit figures by higher unit log costs.

It is important to recognize that each mill must depend upon an average realization from all species cut. Forest products are a joint-product industry and average realizations to be meaningful must cover all logs, all species, all finished products. These variables often are not under direct control of the sawmill, since stumpage is usually sold in 'packages' including a mixture of species, sizes, and grades of logs.

Normal accounting practices do not allow for accurate breakdowns of cost of production for individual items or even individual species in the manner in which we have analyzed them above. But the principles hold, nevertheless.

Utilization of residues

Residues (illustrated in Figure 4) consist of slabs, trimmings, edgings, and sawdust. If no further utilization is made of this material, disposal of it represents an additional cost to the operation through both capital and operating costs on the beehive burner (a characteristic landmark of the sawmill community). If residue materials are utilized, however, some offset to costs or even a net addition to profits may be achieved.

Under average mill conditions in our region, anywhere from one-fourth to as much as one-half of a log's solid wood content gets sliced or chewed away by the machinery that converts the log into lumber. Residue can be divided into two classes: *coarse* residues (slabs, edgings, and trimmings cut from the log, often carrying bark), and *fine* residues (consisting mostly of sawdust).

Residues are utilized to some extent at almost all sawmills. They may be burned as fuel to generate steam and power; they may be compressed to pressed-wood products; and the larger whole wood pieces may be salvaged as stock for box-making and for other small wood products. Yet great volumes—perhaps one-third of all residues—are burned simply to dispose of them, and it costs the mill something to handle its residues in such a way. Hence a market for residues is a welcome development for sawmill operators.

The major use for coarse residues is as fuel, but an important and growing use is the production of chips for pulping. In many regions chip making outweighs all other residue uses. Coarse residues from nearly all our region's softwood species make suitable pulping stock—provided they can be freed from attached bark which is objectionable in pulping. Fine residues are mechanically less suitable, although beginnings have now been made in sawdust use for pulping.

Chip production requires additional equipment: a *debarking* machine to remove bark from the log prior to sawing, and a *chipping* machine to convert the bark-free coarse residues into chips. The requisite equipment is expensive—debarking and chipping machinery runs perhaps $125,000 to $250,000. Smaller sawmills often do not have sufficient volume or stability of operation to justify the installation.

The use of debarking machinery may have favorable effects on other operating revenues and expenses. Removal of bark prior to sawing increases the life of saw-blades significantly (because grit imbedded in the bark is removed along with the bark) and reduces maintenance and sharpening costs. Further, greater efficiency in guiding the sawing operations on the debarked log may increase or improve the yield of lumber from the input logs and hence improved total revenue.

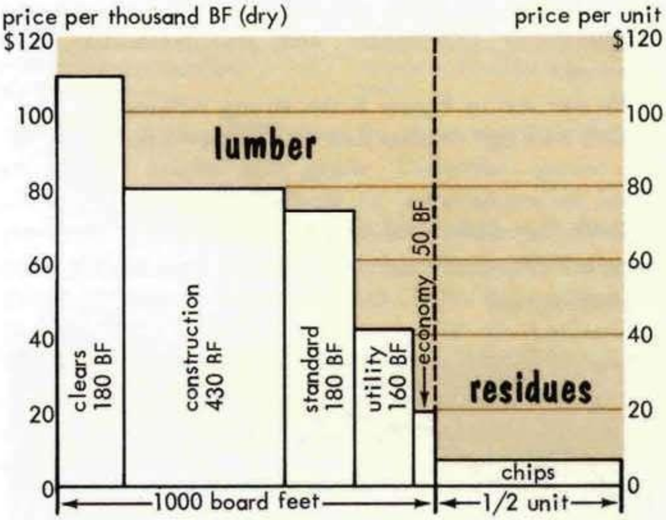
Consider in summary a hypothetical sawmill sawing Douglas-fir dimension lumber and producing chips out of its whole-wood residues. The relative contribution to revenues of such a byproduct operation is diagrammed in Figure 7. Revenue received will depend, of course, on the price per *unit*[23] of chips. In our district there is no chip market, so the price is negotiated in contract between suppliers and the sole consumer of chips. An illustrative price is $8 per 200 cubic foot unit net at the pulp mill.

Mills that do not produce chips with the full quantity of available residues may receive some revenue from the sale of other residue materials, either in their natural form or after processing. Thus residue sale augments mill revenues, although the money involved is small relative to total revenues, as can be seen in Figure 7.

Obviously, chip manufacture or any other market disposition of mill waste is feasible to a profit-seeking firm only if the additional revenues sufficiently exceed the net added costs of handling the waste.

This has been a generalized survey of factors affecting decision-making in the region's timber industry. We have not discussed some processing industries, such as pulp- and paper-making, and veneer and plywood manufacture. These industries show analogous business response to that of the sawmill. While markets for inputs and outputs of these processors differ in detail, each firm must still determine its profits through the price relationships existing in the markets; these profits in turn determine the size of the flow of wood through each plant. In short the essential decision criterion is *profitability*, and prices are the means by which the necessary information about changing profit prospects is transmitted to the decision maker. Poor profit prospects, then, is a factor that helps to explain why much of our region's timber resource has gone untouched—why in our region only 190 million cubic feet of timber has been cut annually, rather than the estimated 450 million cubic feet sustainable cut that could be taken each year.

Figure 7 — Revenue by product class per thousand board feet of lumber sawn, based on hypothetical yield for mill sawing Douglas-fir



BEHAVIOR OF TIMBER PRODUCT PRICES IN PRACTICE

We have already noted that the market for lumber is highly competitive, since there are many firms, no one of which is large enough to influence prices significantly by itself. Furthermore, the consumer finds difficulty in differentiating the product (brand names mean little to him); therefore, he is very responsive to price differentials for any given grade. Finally, in many uses a number of competitive substitute materials are available.

One other feature that characterizes the region's lumber market is its wide swings in strength and weakness. Our major product, softwood sawtimber, goes primarily into the home-building industry, where demand is strongly influenced by the cyclical nature of home building. In Montana, for example, softwood lumber constitutes nearly 90 percent of the volume of wood products output. No data are available about the disposition of this wood, but *national* usage estimates show that softwood lumber goes preponderantly into construction. For example, of

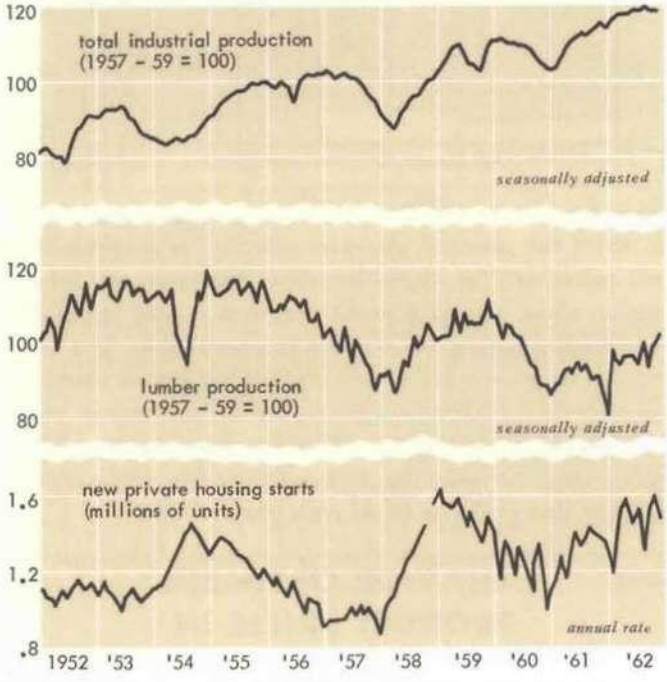
[23]Chips are bought and sold in terms of *units*. One *unit* of chips contains 2400 pounds of dry wood chips and is approximately the quantity of wood in a cord. An average sawmill can produce about half a unit of chips for each thousand board feet of lumber sawn. This figure may vary with type of equipment roughly as follows:

Equipment	Units of chips per thousand board feet
No barker	0.2
Slab barker	0.3
Log barker	0.5

an estimated 41.5 billion board feet of lumber used in the United States in 1952, 31.4 billion board feet went into construction activity, 4.0 billion into manufactured products and the remaining 6.1 billion into shipping uses. Of the 31.4 billion board feet construction total, approximately 13.0 billion went into residential construction.

We can see in Figure 8 the strong influence of residential housing construction on lumber production at the national level. In particular, we might look at two periods when lumber production departed from the general cyclical pattern of total industrial output. From late 1954 to mid-1957 industrial production climbed while lumber production skidded; from early 1959 to the end of 1960 industrial production remained on a somewhat uneven plateau though lumber production again slid off. In both cases lumber output presumably took its cue directly from housing starts.

Figure 8 — U.S. industrial production, lumber production, and housing starts (seasonally adjusted rates)

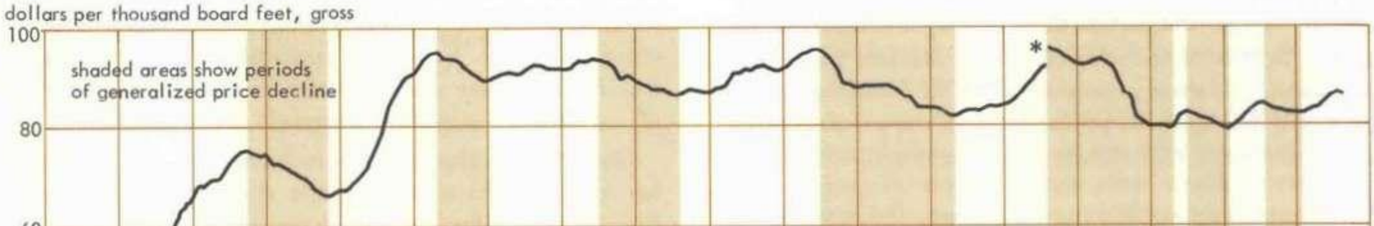


To place some quantitative measure on the historical fluctuations in the market due to housing starts, consider the peak annual rate (1954-1955) of about 1.4 million units and the 1957 level of about 1.0 million units. The decline of 400,000 annual units at an estimated average usage of 10,000 board feet of lumber per dwelling, is a difference of 4 billion board feet, or about 10 percent of total 1952 use for all purposes. Prices correspondingly show considerable fluctuation (see Figure 9). There is no reason to think that the market for our region's lumber output is proportionately any less variable in demand from year to year than the national figures we have considered.

In summary, the behavior of the lumber market shows: (1) strong fluctuations in demand, with rises or drops of 10 to 20 percent within a few years time; (2) coincident fluctuations of prices of about the same proportions; (3) the strong influence of the housing market reflected in both of the foregoing; (4) fairly strong seasonal patterns carrying the monthly output rate over a range of 50 percent; and (5) fairly high susceptibility to displacement by competitive products as lumber's relative price increases.

This sort of market behavior leads to considerable uncertainty in sawmill price expectations and hence in planning for future operating patterns. However uncertain, price expectations represent one ingredient of op-

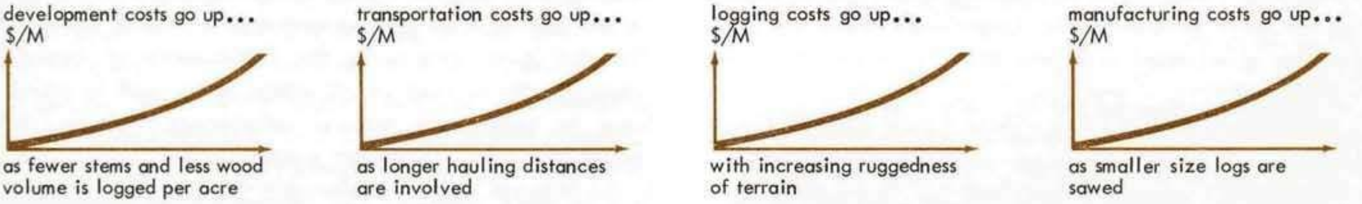
Figure 9 — Average mill realization price of ponderosa pine lumber over the postwar period



* series basis shifted

Source: Western Pine Association.

Figure 10 — Technological factors affecting costs at any one point in time



erating decisions; their very uncertainty results in high relative costs of funds.

Because capital equipment needed in setting up a small operation is not as expensive as that required in most industries, many small "shoestring" operations have come in and out of the lumber market depending on market conditions. One study of recent experience[24] concludes that much of the temporary expansion of output during cyclical peaks in demand comes from small, low-capital mill operations, which move in to fill the gap during the boom periods when market prices are high. When prices decline, these mills may stand idle while the owners seek income from ranching or other sources. They may change hands during the recession, when market prices are too low to permit adequate returns even to individual operators willing to accept low wages for their own labor and low return on their own capital. But the number of such operations is declining as the increasing amount of capital needed for primary processing and residual utilization has reduced the opportunity of the marginal mill to "come and go."

During periods of slumping demand and declining lumber prices, extra pressures have in the past been placed on production of the better-earning species such as ponderosa pine. In addition, mill operators tend to drop unprofitable contracts for stumpage acquired during higher price periods, to renegotiate sales, or to pick up small sales at lower prices. All these trends have imposed particular pressures upon long-range forest management programs by accentuating the relative loss of higher quality trees and species.

Recently, however, the earlier notions of preferred species have been challenged by the market: Ponderosa pine, which was a premium wood, has been losing markets to prefinished plywood, aluminum, steel, or it has simply been eliminated by architectural changes. Demand for plywood and dimension, on the other hand, suggests an increasingly strong potential market for such species as larch and Douglas-fir.

RELATIONSHIP OF THE REGIONAL INDUSTRY TO NATIONAL MARKETS

The general level of lumber and wood product prices is determined at a national level. Buyers recognize certain broad quality differences for their uses by species, geographic origin, and grade. Particular species or grades or sizes can fluctuate in price somewhat independently according to special circumstances affecting each. But even so, prices of lumber from different geographic origins cannot get far out of line for comparable product class at any particular point of destination. Hence, allowing for differences in transportation costs, no one mill in our district can do much more than accept a market-dictated price for lumber products it wishes to sell at any given time. It has only the limited option of holding some kinds of stock off the market in hopes of a better price later.

[24]Bolle [2].

In any discussion of our district's timber output, we must remember that it is a relatively small element in the national supply picture and that its market influence except in restricted trade areas is accordingly slight. The major geographic source of softwood sawtimber for the United States markets is the Pacific Northwest (see Table 12). Gross changes in the supply of timber available from this area *do* have a definite impact on national price levels. All areas have experienced gradual removal of the more accessible, higher quality old growth stocks. This attrition has increasingly necessitated a shift into the less accessible, higher cost sources of stumpage, often with a loss of log quality (see Figure 10). As a result of increasing delivered log costs and handling costs, the selling price necessary for competitive return was increased. (The historical improvements in technology and methods have only partly offset changes in unit costs.) Higher prices have helped influence a relative drop in

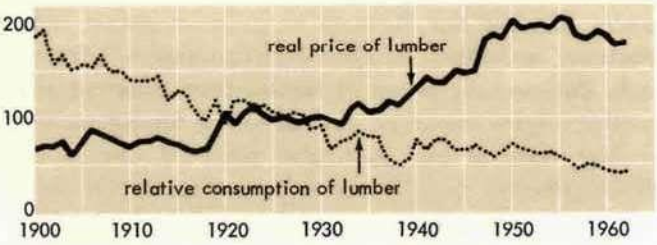
TABLE 12 — TIMBER PRODUCTS OUTPUT, UNITED STATES AND MAJOR REGIONS, 1952

	SOFTWOOD SAWLOGS FOR LUMBER, ETC.	SOFTWOOD VENEER LOGS AND BOLTS	SOFTWOOD PULPWOOD
	(million board feet)		(thousand cords)
North	1,946	2	3,957
South	9,610	38	12,973
West	19,877	1,509	4,478
Pacific Northwest	12,455	1,230	3,899
California	4,902	271	269
Ninth District	731	0	140
Other West	1,789	8	170
Total United States	**31,433**	**1,549**	**21,408**

Source: Forest Service **[39]**.

demand over the past half century as users have shifted to substitute materials or cut back the quantities of wood used in their products. The longer-term trend in this direction is indicated in Figure 11.

Figure 11 — Index of lumber price relative to general wholesale prices and index of consumption of lumber relative to consumption of all physical-structure materials, 1900-1962



Source: Forest Service [39], data after 1952 calculated by author.

If we ignore for the moment any changes in technology (which tend to be stimulated at times of strong competition and to reduce unit costs), we may note that a declining supply in the face of persistent demand results in higher prices; these prices both reflect and allow higher costs of operation. While the higher real price necessarily implies some decrease in the aggregate quantity demanded, it does not necessarily imply a decline in production from *any one region*. In fact, areas of extensive forest resources which would formerly have been regarded submarginal may actually profit from the transition as increasing quantities of their timber supplies become usable under the existing technology.

Given this relationship, our region may have more to gain as the nation moves further into the margin of its timber supplies, because we have a greater amount of submarginal timber relative to our existing base. As prices go up, many higher-cost operations in our region may become profitable for the first time.

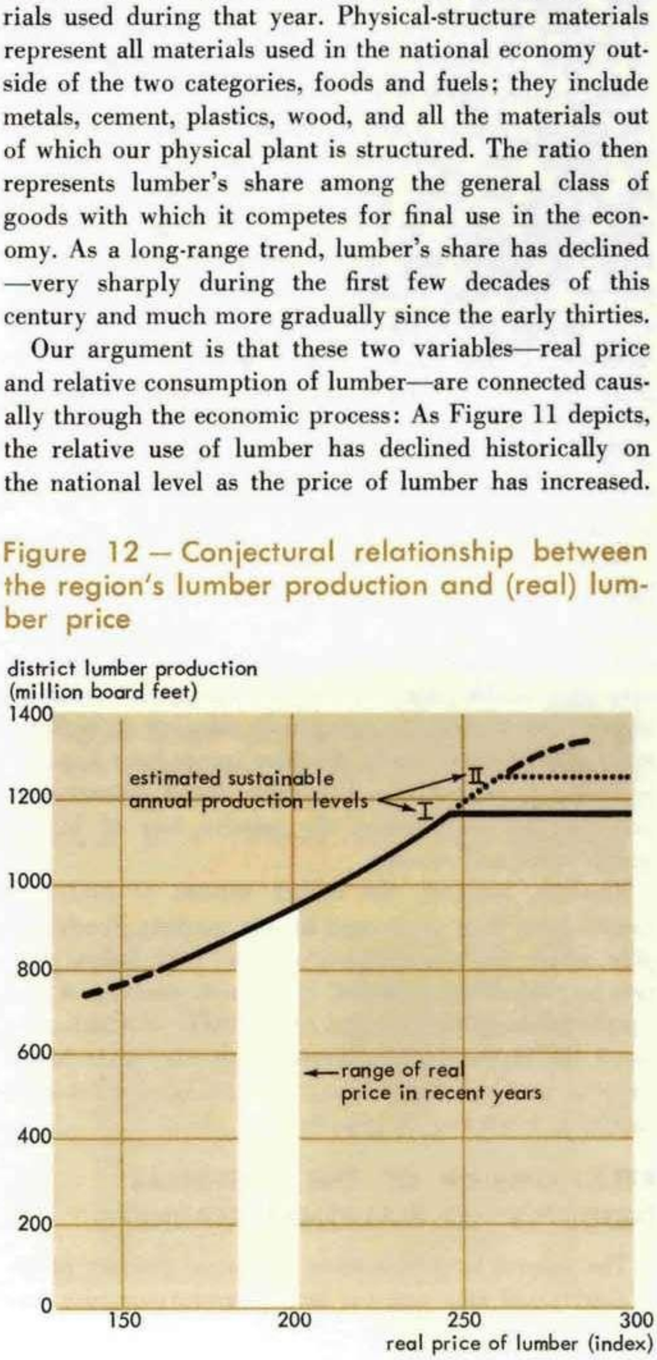
We can represent a price-output relation somewhat appropriate to portions of our district as in Figure 12. This estimated relationship is based on a Forest Service study of the Headwaters Timber Development Unit[25]—an area adjoining our region and having many forest characteristics in common with eastern Montana. If this hypothetical relationship is correct, then an increasing real price for lumber would increase lumber production from our region in spite of a concomitant decline in national output.

Some historical evidence supporting this relationship is shown in Figure 13. Here, first for Montana and then for the United States as a whole, we have plotted the relationship between two variables. One of these is the *real price of lumber*, which is the average lumber price annually expressed as a ratio to some general price level for all commodities and computed as an index number. The real price represents the relationship of lumber prices to the average of all other prices and in effect helps to cancel out general inflationary changes, or changes in price which are simply a result of changes in the value of money. Historically the trend in lumber's real price has been upward.

The second variable shown is the *relative consumption of lumber*. Relative consumption, as used here, is a ratio of the physical quantity of lumber consumed in any one year to the quantity of all physical-structure materials used during that year. Physical-structure materials represent all materials used in the national economy outside of the two categories, foods and fuels; they include metals, cement, plastics, wood, and all the materials out of which our physical plant is structured. The ratio then represents lumber's share among the general class of goods with which it competes for final use in the economy. As a long-range trend, lumber's share has declined —very sharply during the first few decades of this century and much more gradually since the early thirties.

Our argument is that these two variables—real price and relative consumption of lumber—are connected causally through the economic process: As Figure 11 depicts, the relative use of lumber has declined historically on the national level as the price of lumber has increased.

Figure 12 — Conjectural relationship between the region's lumber production and (real) lumber price



[25]Forest Service [7].

Both the declining share and the higher price reflect the longer-term national trend toward removing the best, most accessible timber and moving further into more remote stands formerly regarded as submarginal.

But for Montana the relationship has been different, as shown in Figure 13. Since 1930, the relative consumption of Montana lumber (annual consumption here taken to be equal to production) has gradually risen as real price of lumber has increased. The explanation for this is as we have given. Montana's relatively large endowment of less accessible smaller timber has permitted an actual expansion. These rather gross relationships do not account for all that has happened. Changes in technology and in species acceptance have been a part of the story.

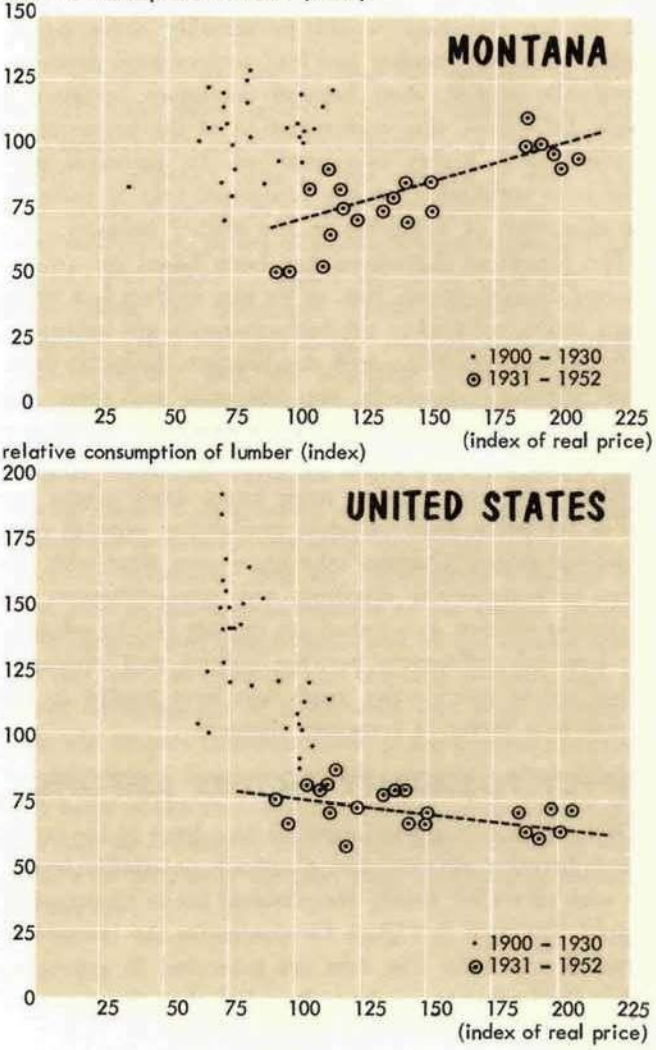
The broad national picture shows that, except during the Depression, the production of lumber has remained at very roughly constant levels for several decades; production in the northern states has declined, production in the southern states has declined even more sharply, and production in the western states has climbed upward to fill the gap. The expansion in Montana has exceeded the average western increase, which in recent years has been largely attributable to developments in southern Oregon and northern California.

ECONOMIC DIMENSION OF THE RESOURCE

We have seen that the physical dimension of a timber resource and its economic dimension are two different things. While the physical dimension of our region's timber is itself ambiguous enough, the economic dimension is even more difficult to measure, depending as it does on a prevailing system of decision making. The question really becomes: What are the decisions that lead to removal of timber from the region's forests, and how are these decisions made? By answering this question we are broadly defining an allocative system. Our existing system, we have seen, is largely a market and price system, although considerable room for administrative discretion exists at the tree-growing stage. The administrative aspect may be thought of as tending to ration the quantity of timber cut on public lands and to hold this within certain predetermined bounds.

Since one of the key variables is price, we might consider the economic measure of potential output to be not some single quantity but rather a *schedule* of profitable quantities corresponding to various potential prices. Such a schedule, based on some of the relationships discussed in this part, was given in Figure 12. This relationship, while labeled in terms consistent with current values of output and price, is primarily intended to be illustrative. At best it would apply approximately at the present and for the near future. Over any longer

Figure 13 — Relative consumption of Montana lumber and United States lumber vs. price



Source: Forest Service [39], Montana data calculated by author.

period various adjustments would begin to take place. Improvements in technology that favor our region would shift the curve upward by making it profitable to produce more at any given market price. There is some evidence that recent increases in output here in the face of steady or even declining lumber prices reflect changes in technology applicable to our district.

The estimated sustainable levels of production shown in Figure 12 are based on Forest Service studies. Level I allows for allocating some of the available trees of sawtimber size to veneer and pole plants in a balance-of-industry program contemplated by the Forest Service study.[26] Level II simply allocates all of the potential expansion to sawmills. If the Forest Service had effective

[26]Forest Service [*20*].

control over the stumpage supply, then we might picture the region's current supply curve to be that shown by the solid line. More probably the curve would follow the broken line extension upward, because rationing of Forest Service stumpage would presumably drive prices higher on private timber and lead to increased drain on non-public stands, even beyond maximum sustainable levels. Of course, this representation of the price-output relationship is highly oversimplified. Its principal purpose is to emphasize the key functional role of *price* in the allocation of resources in the timber industry.

The foregoing discussion has been based on an *aggregate* district output. But, as we saw in Part I, a great many individual timber product categories are independent of or in competition with one another. Actually, then, there are many products, not just one; and there are many markets, not just one. Each must strike its own balance. Some species may be cut faster than sustained yield rates at most existing price levels, while others are cut at far below their physical availability even at zero stumpage prices. Changes take place over time with respect to commercial standing and competitiveness of particular species, as we shall see in Part III. In general, the inherent differences between species that appeared important to users many years ago have tended to diminish as a factor in consumer demand.

SUPPLY POSSIBILITY PICTURE AMPLIFIED

With the better appreciation we now have of the interaction between physical and economic possibility levels, we wish to review briefly the physical limits of potential supply. The data in Figure 14 summarize the immediate physical potentials. The data are presented in aggregate cubic foot volumes, so keep in mind that these results mask a variety of quality, size, and species differences.

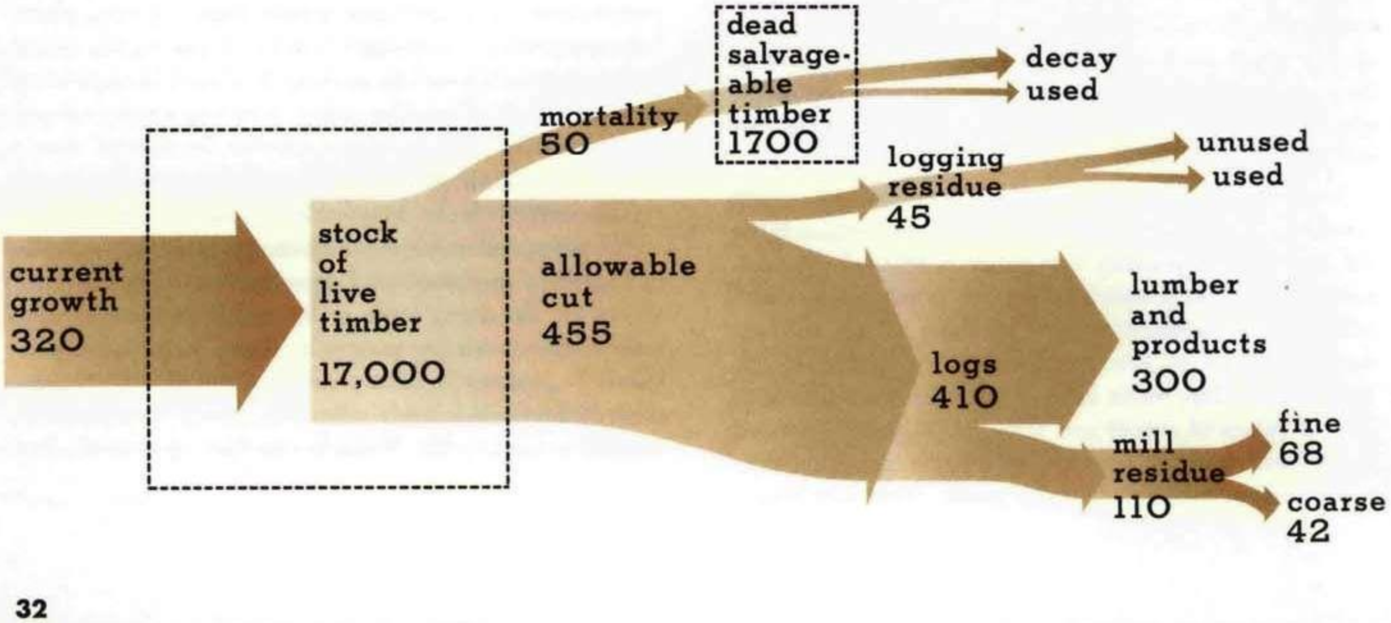
An allowable cut of 455 million cubic feet annually as shown is adapted from the Forest Service figures as a provisional measure of the outside size of feasible timber drain from the forests in our region. The considerably lower current actual cut, as we have noted, is a function of the prices of outputs and inputs and the technology of the processes used. If product prices were for some reason to advance sufficiently while other factors remained unchanged, then actual drain could conceivably rise to exceed the allowable cut with the full weight of the excess cut occurring on private holdings. Hence the 455 million cubic feet shown for cutting potential represents not the maximum supply that is physically available, but only a maximum feasible take within a management program based on current information and views.

Even the latter concept, maximum sustainable yield, is relative to economic factors. Were the price of products to increase sufficiently in relation to input prices, private decision makers might profitably increase the intensity of management of forest stands—by more intensive cultivation, raising of growth rates, reducing of mortality rates, etc.—so as to enlarge sustainable cut.

The allowable cut shown exceeds current growth for reasons discussed in Part I, and this fact simply emphasizes that the allowable cut is based on some potential growth rate, not necessarily an existing one.

If we now trace out the flow of wood material cut, assuming it to be cut at the 455-million-cubic-foot-per-year level of the allowable, then we can see some additional physical supply possibilities: These come from the residues left in the forest after logging operations and from the residues resulting from lumber and veneer manufacture at the mill. Based on an annual cut of 455

Figure 14 — Physical supply possibility diagram, western Ninth district, figures in millions of cubic feet per year



million cubic feet, more than 45 million cubic feet of logging residues would be produced in the forest and more than 110 million cubic feet at the mills. Fuller use of these waste materials could increase substantially the physical volume of product output.

Here we recount merely the *physical availability* of wood material; the extent of *actual use* at any one time depends on the economic feasibility of measures a profit-making concern might adopt to utilize these materials.

A fraction of both logging residues and mill residues does find its way into current uses either sold by the plant as a byproduct or recycled to displace inputs that might otherwise have to be purchased from outside. But these uses could be expanded greatly, given sufficient technological advance.[27]

Another substantial source of raw wood for processing is the stock of dead but salvageable timber physically available in large quantities and suitable for many uses. Economic considerations are paramount here as in the case of residue use; and with sufficiently attractive prices for products and higher prices of conventional live input material, this type of timber could be attractive for industrial use. The stock of dead timber is added to, at an average annual rate of 50 million cubic feet; how fast it is reduced beyond salvage by decay, fire, etc. is unknown. Some years may witness additions of dead timber in particular species and locations in epidemic proportions, making rather special supply situations for short periods. We will discuss an example of this in Part III.

In summary, we can see that the physical basis for industry—the sheer quantity of wood material available—is substantially greater than currently is used. Whether much or relatively little of this amount is used in the near future depends on a variety of basic economic factors: technology, prices of products as determined by the market, and prices of inputs the mills must buy. In a sense, then, the maximum physical quantity can be stretched, given the appropriate technology and suitable profit incentive. But, the practical economic potential of the region's industry depends on several factors that will be determined largely outside our region; most of these are economic variables which will be resolved only through market interaction with a multitude of other sectors in our national economy.

In our discussion thus far, little direct attention has been paid to the special features of the timber industry in our region and specific problems on the current scene. We turn next to examine the regional industry and the recent developments of importance that have affected it. This will at once illustrate some of the general principles we have been discussing, help us gain a closer touch with some of the more specific features of timber production and processing in our region, and provide a background to our more detailed look at regional potential in Part IV.

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[27]Guthrie and Armstrong [32] suggest that technological change in the industry in past decades has centered largely on utilization of residues rather than adjustments in the basic process that would reduce the fraction of residues produced. They contend that this trend has reduced the incentive to improve the basic process and to strengthen the economic interest in maintaining a high proportionate flow of residues.

III THE REGION'S TIMBER PROCESSING INDUSTRY: PAST AND PRESENT

Our discussion up to this point has been mostly in terms of general factors affecting profitability. Many of our comments in principle could well apply to some other regions. But now we want to look more closely at the geography and recent history of the processing industry in our region.

LOCATION OF THE TIMBER PROCESSING INDUSTRY

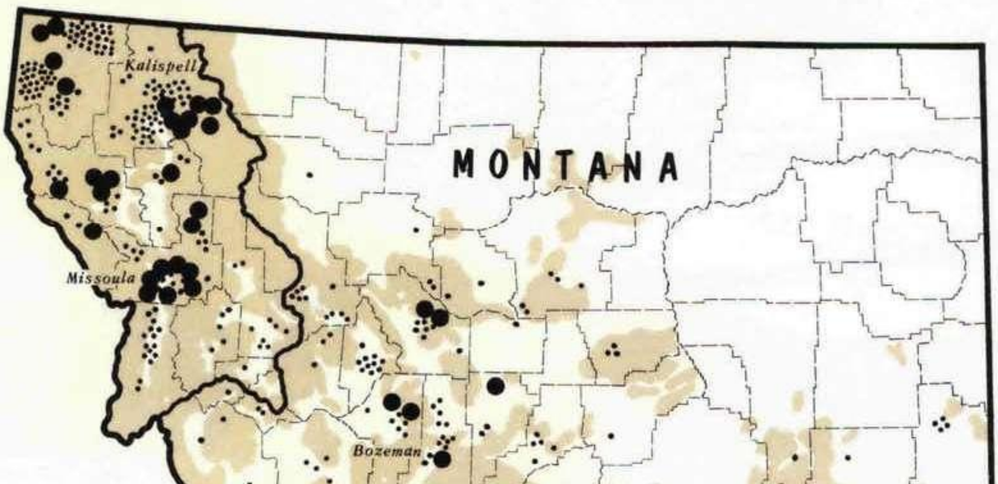
Historically, western Montana was the earliest area to be fully exploited, and some of its sectors have more mill capacity than timber production capacity on a sustainable basis. As a rough estimate, about two-thirds of the sawmill capacity in the region under study is found in Montana west of the continental divide. In Figure 15 we can see that the bulk of mills, especially the large mills, are concentrated there. In other parts of the region, where mill capacity has been substantially below sustainable timber output, recent years have seen increasing numbers of lumber operations.

The present geographic pattern of sawmills in our region, depicted in Figures 15 and 16, is the result of past decisions by hundreds of individual firms locating their operations and determining expansion plans principally guided by expected profit. The network of dots on the maps may give a misleading sense of fixedness and precision in defining the number and location of timber-processing firms. These dots merely approximate the location of active sawmills as of some time in 1956. At best this figure represents a snapshot of a very dynamic process. In 1956, as a glance back at Figure 9 will show, market prices had reached an historical peak. Subsequent retrenchments have cut at least a hundred sawmills from the operating list. In 1962 nearly half the district's sawmills were idle. Longer-term trends are also at work to animate these dots, and the trends will form a major part of the subject matter of this section.

CHANGES IN SAWMILL LOCATIONS AND NUMBERS

Significant changes in numbers and locations of sawmills have taken place. Some of the change represents basic trends suggesting the shape of further changes to come. Other changes represent the response to traditional cyclical swings in prices and demand. The number of active sawmills in the region at any one time is always difficult to determine because of the volatility of the industry. In recent years this number has ranged from about 200 to 400, with sharp fluctuations (up to 150 mills) from year to year. One recent study[28] of the Flathead Valley in northwestern Montana showed that the number of mills dropped from an estimated 104 in 1956 to about 60 in 1957, in response to the very sharp break in the lumber market that occurred at that time. Against this backdrop of cyclical fluctuations in mill numbers as well as the frequent change of hands of some of the smaller operations particularly, many new mills have been con-

Figure 15 — Location of Montana sawmills, 1956



[28]Bolle [2].

Figure 16 — Location of Black Hills sawmills, 1956

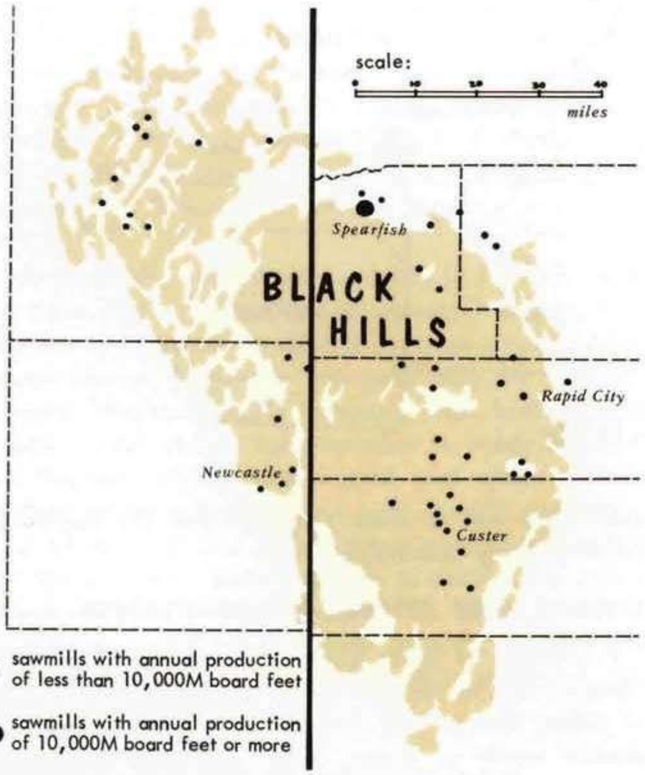


TABLE 13 — SURVEY OF NEW SAWMILL CONSTRUCTION, 1952-1957

ORIGIN	Western Montana	Eastern Montana and Black Hills	Total District
	LOCATION		
"New" starts	10	11	21
Transfers	5	16	21
Total	**15**	**27**	**42**

TABLE 14 — ESTIMATED SINGLE-SHIFT CAPACITY OF NEW MILLS OPENED 1952-1957, THOUSANDS OF BOARD FEET

ORIGIN	Western Montana	Eastern Montana and Black Hills	Total District
	LOCATION		
"New" starts	287	49	336
Transfers	185	504	689
Total	**472**	**553**	**1,025**

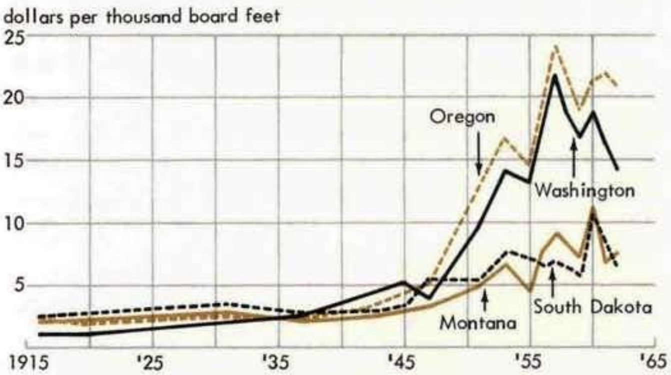
structed in the past decade where none existed previously. A survey by the author indicates that 42 new mills were constructed during the period 1952-1957, some of these under the specially instructive circumstances which will be explored next.

NEW MILLS AND INTERREGIONAL MOVEMENT

The results of a survey of new mills constructed during the five-year period, 1952-1957, are summarized in Tables 13 and 14. It can be seen that the transfers—firms previously in operation at different locations—account for about half the new mills. Here we detect the impact of changing timber supply relations in the Pacific Northwest. During the thirties and early forties stumpage prices were still relatively low, and the superior quality and lower costs of operation gave the Pacific coastal timber areas a strongly preferred position for production. But competitive conditions changed. Stumpage in that area has become increasingly scarce. A great many firms, finding themselves without dependable supplies of their own or having exhausted cutting from their own cheaply purchased timber of the past, were forced to buy timber at increasingly higher prices. Stumpage prices of timber for Pacific Northwest states rose substantially after World War II relative to prices in northern Rocky Mountain forests (see Figure 17).

Part of the rise in average west coast prices shown in Figure 17 is the result of heavy bidding for the higher quality logs used by the rapidly expanding plywood industry; the graph probably exaggerates the increase of average stumpage price for sawlogs. But these changes had a definite impact on the timber industry of the

Figure 17 — Stumpage prices for timber on national forest land



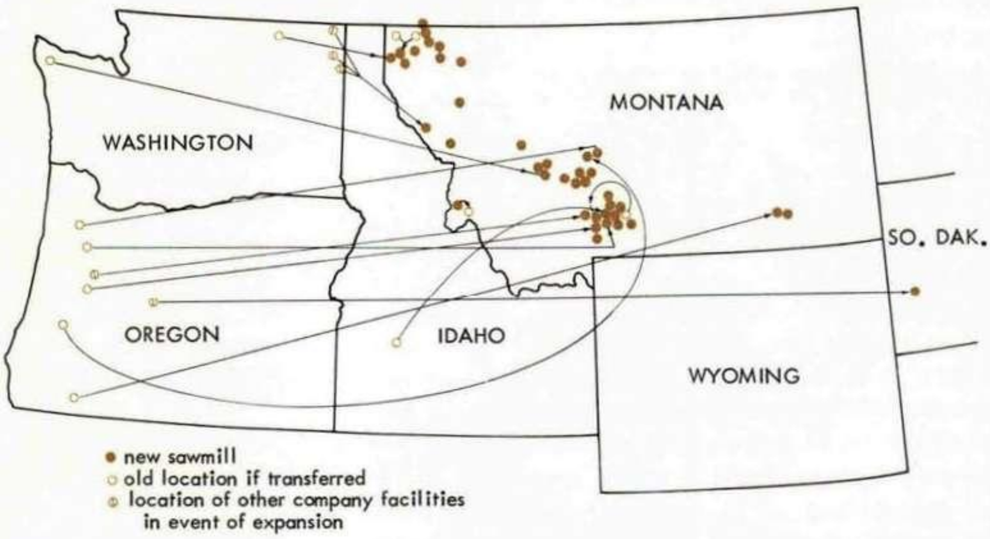
Pacific Northwest.[29] Many mills, particularly the smaller ones, have been squeezed out in the competitive struggle. The number of mills in coastal Oregon, for example, dropped from 1,265 in 1948 to 744 in 1954.

Prices are, of course, a signal in a private enterprise economy. In this case the increasing prices of inputs to the firms signaled rising costs of doing business in the coastal localities relative to the interior mountain localities. As a result, developers turned to sites in Montana and the Black Hills that would not have been considered in earlier years.

[29]For documentation see, for example, Lewis and Clark and Reed College [*30*], Guthrie and Armstrong [*32*].

Roughly half of the relocated mills entering the tally in Table 13 actually transferred their operations from Pacific coast states. This relocation has touched our district at points all the way from western Montana to the Black Hills (see Figure 18). Many additional inquiries were made by coastal mills about the possibilities of transfer into Montana. The pressures behind this development were basically economic—of the sort discussed earlier that motivate decisions about resource allocation by private profit-seeking firms. But in most of these cases the Forest Service, as the chief supplier of timber in these areas, had to be a silent partner to the move. That is, the Forest Service had to arrange individual timber sales much larger than usual in order that the known raw material supply under contract to each proposed mill would be large enough to justify (in the eyes of the private operator) the capital investment needed to build and operate a modern sawmill. Several sales, each involving 50 to 90 million board feet, were arranged by the Forest Service; as a result, several new mills were constructed.

Figure 18 — Geographic source of new sawmills, 1952-1957



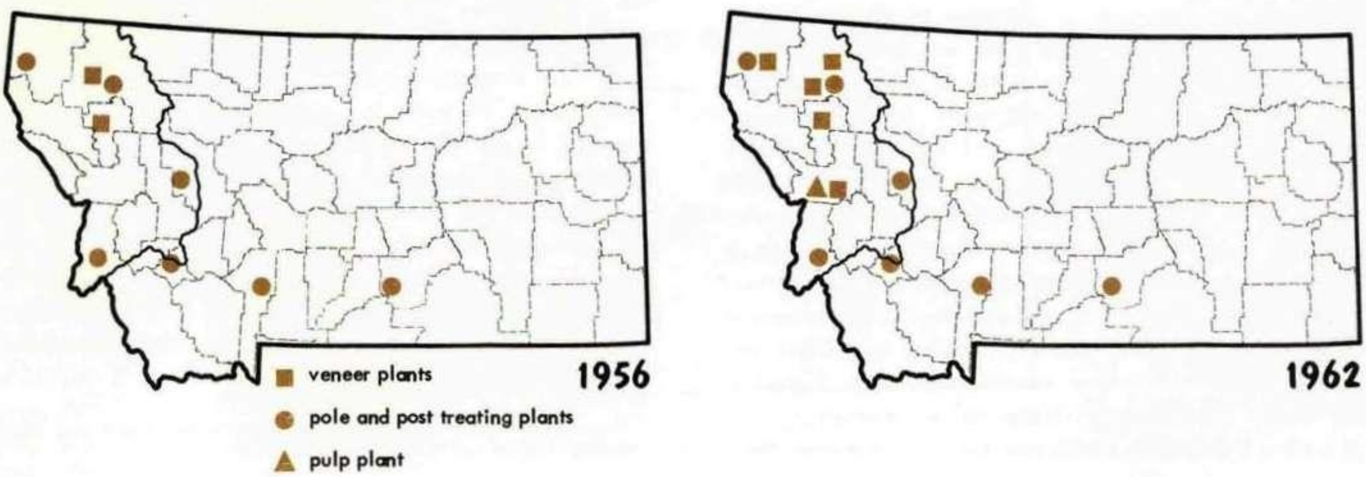
As we continue to examine the figures in Tables 13 and 14, other points of interest emerge. We can see that almost twice as many of the new mills opened up east of the continental divide as did west of it. This is because most areas west of the divide have been exploited more fully over a longer period and because mill capacity approaches and in some places exceeds the limits of current cutting possibilities.

OTHER NEW TIMBER-USING PLANTS

Production of other kinds of timber products has changed, too, in the last few years. While some kinds of plants, such as pole treating plants, have shown no definite trends in output, others including pulp and veneer have introduced to the region relatively new kinds of processing activities (see Figure 19). These "new" types of timber-using plants have, in fact, been the most active factor behind the expansion of employment that has occurred in Montana's timber industry in the past decade (Figure 20).

Montana forests hold large quantities of pulpwood, yet only minor cuttings are being made for direct use in pulping. Prior to 1945 the pulpwood cut—at peak 10,000

Figure 19 — Miscellaneous wood-using plants, 1956 and 1962



to 15,000 cords a year—was shipped to mills in eastern Washington. After 1945, mills in Wisconsin began to take increasing amounts as an outgrowth of policies restricting their former sources in Ontario. Shipments to Wisconsin—largely of lodgepole pine from eastern Montana—increased rapidly until as much as 100,000 cords annually were shipped by the early 1950s. In recent years, amounts moving to mills in eastern Washington and northern Idaho have exceeded 30,000 cords in some years, while shipments to Wisconsin have declined (most pulpwood to Wisconsin is now sent as chips rather than logs).

Not until the mid-fifties did industry find it economical to build pulp- or paper-making capacity within or near Montana's boundary. In spite of the large potential pulpwood harvest, Montana's first pulp mill, the Waldorf-Hoerner Paper Products Company plant built at Missoula in 1957, did not use poletimber so widely available in the state's forests, but instead used wood residues turned out as a byproduct of local sawmill operations. Some twenty Montana mills within a hundred-mile radius of Missoula have gone into chip production to supply chips to the Missoula pulp mill. The Waldorf-Hoerner mill, with a 500-ton daily pulp capacity, requires the equivalent of 180,000 cords of wood in chip form per year.

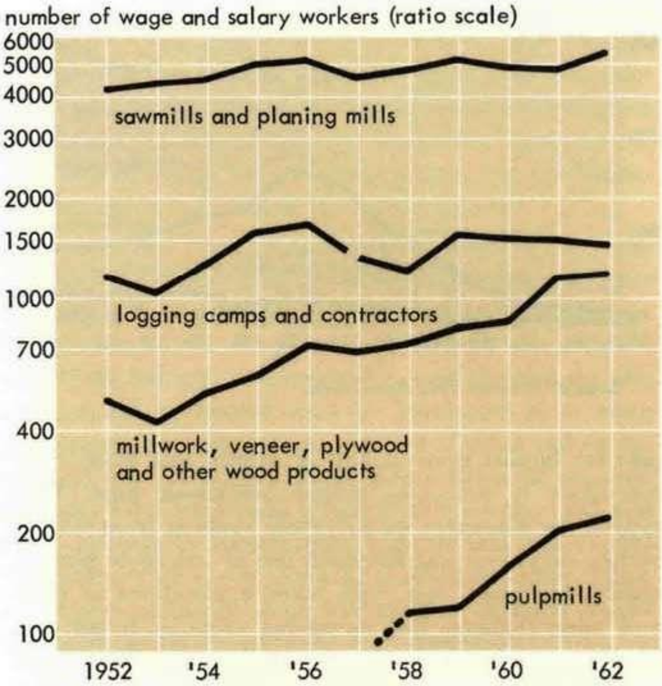
RECENT TRENDS IN PRODUCTION

In addition to changes in the numbers and locations of sawmills, marked changes in the volume and composition of lumber output have occurred over the past decade. Data on annual softwood lumber production since 1949 are shown in Figure 21. While total United States production has remained relatively constant at about 30 billion board feet annually, both South Dakota and Montana outputs of lumber have gained significantly.[30] The net effect of the allocation decisions in the national economy thus has been to draw increasing quantities of wood from our region.

In the Black Hills, the expanded output has come from ponderosa pine stands. In Montana, some rather broad changes in species composition have occurred. Figure 22 illustrates several shifts in species cut during the postwar period. Three particularly noteworthy changes are: (1) the large relative growth of lodgepole pine; (2) the extremely rapid growth and subsequent decline in production of Engelmann spruce; and (3) the sharp expansion in output of Douglas-fir and larch coinciding with the decline in Engelmann spruce. We shall

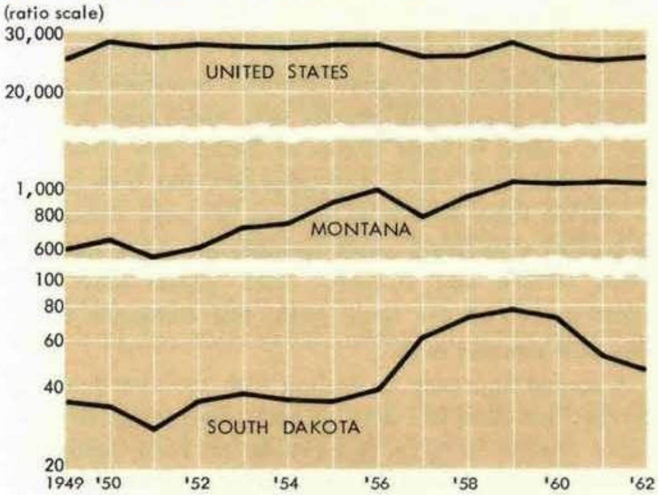
[30]Destruction by fire in 1960 of one of the Black Hills larger and newer sawmills, and closing of some obsolete mills account for the decline in South Dakota production in the last few years. Potential cut has not declined.

Figure 20 — Average annual employment in Montana forest products industries, 1952-1961



Source: Montana Unemployment Commission.

Figure 21—Softwood lumber production, 1949-1962, in millions of board feet



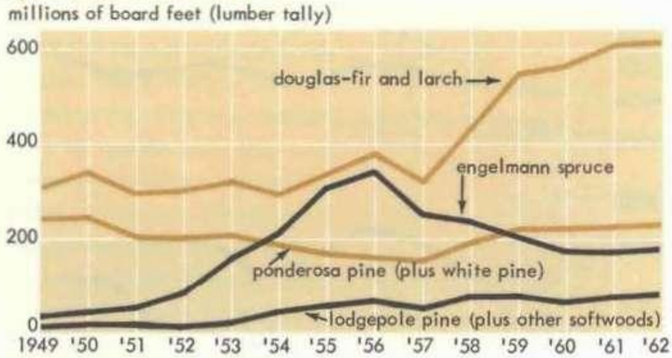
Source: U.S. Bureau of Census, Western Pine Association.

now examine the factors behind the first two of these changes.

Lodgepole Pine: Competitive Possibilities

The increased lumber production from lodgepole pine is closely related to the new construction in sawmill capacity discussed earlier. We noted in Part I that the abundant lodgepole pine has not been used much in the

Figure 22 — Montana lumber production by species, 1949-1962



Source: Western Pine Association.

past for lumber even though in quality and wood characteristics it resembles prized ponderosa pine. With typical log diameters for lodgepole running from 6 to 12 inches, pulpwood was the main use of lodgepole pine up until a few years ago, with other applications as poles and mine timbers. But increasing costs of larger logs of other pine species, coupled with the notion that a mill designed specifically to deal with small sized sawlogs might handle lodgepole pine efficiently, have led to construction of several substantial sawmills.

Lodgepole pine sawmills face marketing problems as well as technological production problems. The odd widths and narrow boards which form an appreciable part of the output face difficulties of acceptance on the market. To utilize the small diameter lodgepole log efficiently, the production process may yield quite a number of boards in such widths as 7-inch and 5-inch, or even 4-inch and 3-inch. One approach has been to try to market these boards to dealers or large consumers as part of a package, which includes the more standard width (8-inch and 10-inch). Such efforts have been partly successful for some mills, but consumer resistance still remains high.

A second approach in dealing with the abundance of narrow, odd sizes has been to glue edge-to-edge to form wider boards or glue side-to-side to form laminated timbers. A number of the lodgepole sawmills have installed high-speed gluing equipment which permits them to edge-glue, for example, a 3-inch and a 5-inch board to form a single 8-inch board. Such measures do not offer a universal competitive solution, since gluing adds to production costs without a compensating increase in board price over that of an unglued board of equal width.

A third approach followed by some lodgepole mills has been to perform some secondary manufacture on the primary stock to increase its market value. This may include, for example, the machining of boards into various forms of interior paneling: textured, grooved, or plain. Paneling brings the material into a higher product price range than that applicable to plain boards.

But the market for pine paneling, glued, or otherwise, has been severely reduced in the last several years as prefinished plywood has taken over more and more of that market. So most lodgepole today goes into 2"x4" studding material, and many small, marginal stud mills produce it. The problems that lodgepole presents for lumber manufacture are still considerable. Although lodgepole yields a high proportion of #1, #2, and #3 common boards[31] and although its knots tend to be small and tight, it nevertheless produces almost no clear boards to help build up the average realization price. Furthermore, logging costs per unit of sawmill output are sharply higher for lodgepole pine than for the conventionally larger logs of other species.

For many years average prices for lodgepole have been below those of ponderosa pine. Part of this price difference reflects size and grade differences in average runs of logs, but some of the discount reflects traditional buyer preference. Thus, the prospects for success of the lodgepole sawmill in competition with the more conventional operation depend not only on technological developments but also on consumer acceptance. Market acceptance has been poor, but it is gaining. The outcome is uncertain, but the recent industry expansion based on lodgepole pine processing holds out promise.

Engelmann spruce: the bark beetle epidemic

Far more dramatic than lodgepole among recent shifts in species cut, as shown in Figure 22, is the substantial boost in spruce output. Much of this boost is of an emergency nature and will not be sustained at the levels it reached in 1956. Nonetheless the increase is of interest for the lessons it teaches. The problem began when windstorms caused heavy blowdowns of spruce stands in the northwestern Montana area in 1949-1950. Great numbers of dead, fallen spruce trees became breeding grounds for the spruce bark beetle, and within a few years live stands were heavily infested. By 1954, spruce trees containing more than two billion board feet of timber were killed by the insect's tunneling habits.

As we pointed out in Part I, spruce tends to grow in high, moist, mountain basins which are largely inaccessible. But the remoteness of the stands spelled trouble when the epidemic hit, because the only really effective control measure is removal of the infested trees. Thus, a crash program of road building and spruce removal was launched. Emergency sales of bug-killed spruce were held by the Forest Service, and roads were built to permit logging of the stands. In all, twelve million dollars

[31]Forest Service [23].

of public and private funds were spent in the construction of access roads.

Logging and hauling problems were by no means the only obstacles. Equally important was the problem of moving the unprecedented volumes of spruce onto the market and integrating the flood of spruce into the operations of sawmills in the area. Fortunately, this movement of large volumes just happened to coincide with a very active lumber market. The industry, cooperatively through the Western Pine Association as well as through individual firms, carried on an extensive advertising and promotion campaign. While inventories of spruce logs piled up rather heavily at many mills, marketing efforts were successful in moving unusually large volumes of spruce.

The efforts of public agencies and lumber companies to salvage the beetle-killed spruce are reflected in the jump to first place in log production in western Montana of spruce in 1956, where it comprised 38 percent of all log production. More than half the cut came from dead trees it is estimated, and in some forests, the proportion of dead spruce to total spruce cut exceeded 80 percent.

Perhaps one of the more interesting lessons to be learned from the whole experience was the way a market was found for a previously little-used species. Stumpage prices required to move infested spruce during the early part of the program were quite low, as would be expected—at most a few dollars per thousand. However, later sales, even of dead spruce, were made at surprisingly high prices of $14 or more per thousand board feet, reflecting the firmer market position. While future volumes will not reach the levels of the 1954-1956 emergency (growing stocks of spruce have now been materially reduced), spruce is now much more firmly established in the market, and its output will probably be maintained at a substantially higher level of production than during the pre-epidemic years. Basically spruce is a sound species and it may now have a good future in plywood.

The spruce experience illustrates one additional lesson: there is an ever-present possibility that natural catastrophes may upset established operating programs and patterns in the timber industry.

INVESTMENT AND EXPANSION

Basic to the expansion in capacity and to the shifting pattern of output of recent years is the process of capital investment—that is, the purchase of equipment, plant, and facilities, and the assembly of these things into operating units. Actually the full tempo of capital investment activity is considerably broader than is indicated by the number of newly created sawmills and wood-using plants cited earlier.

The constellation of firms and their capital facilities is continually changing. Ownership changes and consolidations have occurred for large and small sawmills alike in the past decade. Of greater significance are the changes in physical capital and financial investment requirements. Data in this regard are extremely scarce, but the following discussion will sketch the major patterns.

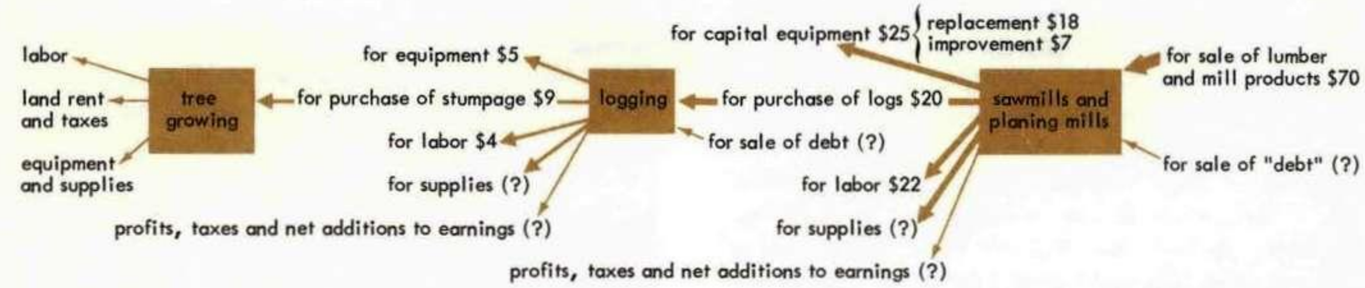
An estimated book value of capital assets in the Montana timber industry is $220 million. But every year part of this capital wears out or becomes obsolete and must be replaced simply to maintain the industry at a constant size. If the industry is to *expand* as over the past decade, then capital equipment must be purchased at an even greater rate. Assuming an average life of plant and equipment of ten years, then about $22 million is required annually for replacement alone. Data from the 1954 and 1958 Censuses of Manufactures indicate that *new* capital expenditures have run about $7 million annually. Thus, as a rough estimate, about $29 million annually would flow into capital replacement and expansion.

This financial expenditure must come out of earnings, new financial investment funds, or borrowings. As one might suspect because of the risks and instability in the industry, small firms can rarely arrange to borrow funds under conditions meeting commercial bank standards. For the most part, the owner's risk capital provides the funds for such smaller enterprises, with borrowed capital taking the form of high-interest equipment credit from equipment suppliers. In general, financial capital is hard to get and interest rates are high. Nonetheless, the resiliency of small firms under favorable market conditions shows that the owners somehow manage to scrape together enough financial capital to operate when the opportunities for reward seem ripe. Credit, largely from equipment suppliers, may prolong the existence of virtually bankrupt mills in anticipation of improved conditions.

Larger firms tend to have more channels of access to financial capital and in particular to longer-term funds, which better equips them to adjust to the cyclical pattern of demand. The two largest sawmills in Montana are owned respectively, by St. Regis Paper Company and Anaconda Company, both of which obviously have ready access to equity money in the stock markets and to commercial loan funds in the major money markets. Connections of this sort enable the larger firms to secure funds at a relatively low average rate.

We have attempted in Figure 23 to construct a flow of funds diagram corresponding to our input-output diagram for the district's timber industry. This representation is only approximate but it does indicate that a relatively

Figure 23 — Diagram of annual flow of funds for the timber industry of Montana, in millions of dollars



large share of inflowing funds goes out for repair and enhancement of the capital plant. The new capital expenditures at about $7 million annually are enough to construct five to ten substantial-size new sawmills. Of course, new mills have been added each year as part of the general expansion, but much of the new capital expenditure is made at existing mills, in the form of improved equipment or modernized plant layout.

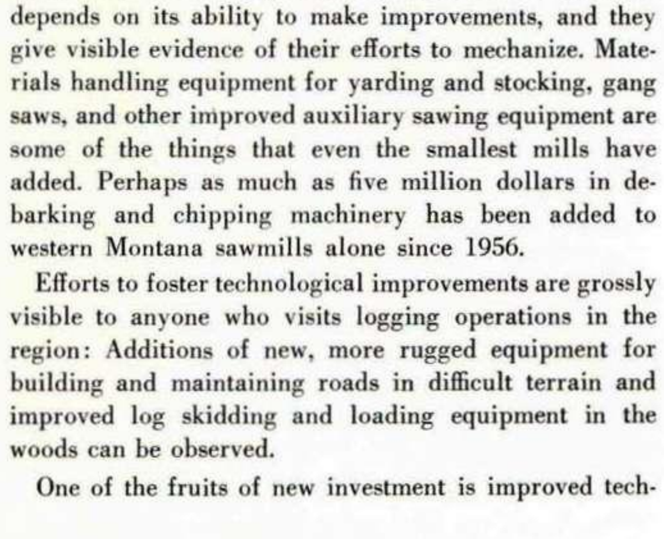
Mills in every size category have joined the scramble to promote efficiency; managers of small mills recognize, as do those of the large, that survival of the firm itself depends on its ability to make improvements, and they give visible evidence of their efforts to mechanize. Materials handling equipment for yarding and stocking, gang saws, and other improved auxiliary sawing equipment are some of the things that even the smallest mills have added. Perhaps as much as five million dollars in debarking and chipping machinery has been added to western Montana sawmills alone since 1956.

Efforts to foster technological improvements are grossly visible to anyone who visits logging operations in the region: Additions of new, more rugged equipment for building and maintaining roads in difficult terrain and improved log skidding and loading equipment in the woods can be observed.

One of the fruits of new investment is improved technology—improvements both in methods and machinery. Figure 24, showing estimates of average lumber production per employee at Montana sawmills, documents an improvement in net labor productivity during a decade in which many ventures were made into more difficult processing situations.

Assessment of the quality of the capital expenditures program is difficult. Not all capital spending is of equal longer-term significance. Some of the spending, including the spending for reorganization of methods and activities, may have effects on a firm's eventual over-all productivity which are great but only gradually discernible. Quantitative measure of the current dollar volume of such spending naturally fails to gauge its true worth.

Figure 24 — Average lumber production per employee at Montana sawmills and planing mills, 1952-1962



Source: Annual average employment at sawmills and planing mills —Montana Unemployment Compensation Commission; annual lumber production of softwoods—Western Pine Association.

RESEARCH AND DEVELOPMENT

Research and development expenditures are particularly important aspects of capital spending because of their potential impact on productivity and profitability of operations. Most firms in the district are too small to conduct formal research and development programs of their own. However, they do in a sense pay for such programs through their purchase of equipment, since equipment manufacturers must cover through sales price the considerable costs of equipment research and development they conduct to improve their products and adapt promising innovations of their competitors. Firms pay also through association dues; the Western Pine Association, for example, supports a research laboratory with a current budget of about $120,000 per year. Companies and their associations also contract out research to colleges and other institutions.

The federal government maintains a research and development program in many phases of timber industry operations. One such expenditure of particular interest to this region is the recent authorization of a $175,000 Forest Service research laboratory at Bozeman, Montana, to study methods of handling and processing small-diameter logs. Through government expenditures such as this the timber industry receives an extra infusion of developmental capital funds. The importance of the capital expenditure program to the future level of industry operations in the region can hardly be overestimated.

Evidence is clear that the region's industry has responded significantly to the pressures for investment and expansion during the postwar decades. Shifting into new species and new types of operations, meeting the challenge of destructive forest epidemics, expanding private investment in capital equipment to step up output and general efficiency, and opening new avenues to more complete utilization of the forest resource—these are some of the dimensions of change.

Specific developments, such as those we have cited, have contributed to the long-term general uptrend in district timber output, documented in Figure 21. These developments, while often forced by conditions beyond the control of the private decision makers, are essentially effected through the medium of the profit-motivated private decision process, tempered, of course, by the effect of the Forest Service policies. In this manner allocation decisions about the district's forest resources have been made. And, by recent criteriá, these decisions have led to the expanded output of this region's timber, both by extensive and intensive utilization. Our review of these changes has shown us where the industry has been and in what direction it may be headed. A closer look at the prospects for the district's timber industry will occupy us in the next part of this report.

TABLE 15 — SELECTED CAPITAL EXPANSION PROGRAMS DURING THE YEARS 1956-1962

NAME AND LOCATION	NATURE OF EXPANSION	DATE	ESTIMATED COST
Durable Wood Products Trout Creek, Montana	New mill	June 1961	$ 650,000
St. Regis Paper Company Libby, Montana	Plywood plant	Spring 1962	4,500,000
St. Regis Paper Company Libby, Montana	Pilot plant for Stractan*	1962	300,000
Montana Forest Products Company Philipsburg, Montana	Sawmill and boiler plant	October 1961	1,500,000
Dupuis Bros. Lumber Polson, Montana	New sawmill	1960	750,000
Plum Creek Lumber Company Pablo, Montana	Sawmill, Box plant	1959 (?)	1,500,000
Cascade Division of U.S. Plywood Corporation Polson, Montana	Plywood and other expansion	1961	750,000
Waldorf-Hoerner Paper Products Missoula, Montana	Pulp and paper mill	1960-1961	12,000,000
Van Evan Plywood Missoula, Montana	Plywood and various additions	1960-1962	2,500,000+
Timberweld Manufacturing Company Columbus, Montana	Timber laminating	1957	200,000
Douglas Studs, Incorporated and Vollstedt Kerr Lumber Company White Sulphur Springs, Montana	2" x 4" stud mill	1958	
Double AA Lumber Company Livingston, Montana	Sawmill, dimension	1959	
Canyon View Lumber Company Livingston, Montana	Sawmill	1959	
Rushmore Lumber Co. Rapid City, South Dakota	Lumber mill	1956**	600,000
Anaconda Forest Products, Bonner Mill Anaconda, Montana	Sawmill, planing mill, large overhaul and expansion	1962-1963	4,500,000
Montana Plywood Whitefish, Montana	Veneer plant	1961	
Northern Timber Company Deer Lodge, Montana	Stud mill	1962	
Burkland Studs, Incorporated Livingston, Montana	Stud mill	1957	
Donna Timber, Incorporated West Yellowstone, Montana	Stud mill	1961	

*St. Regis trade name for arabinogalactan, a gum extracted from butt logs of western larch.
**Subsequently burned down, not replaced.

IV

FUTURE PROSPECTS FOR THE REGION'S TIMBER INDUSTRY

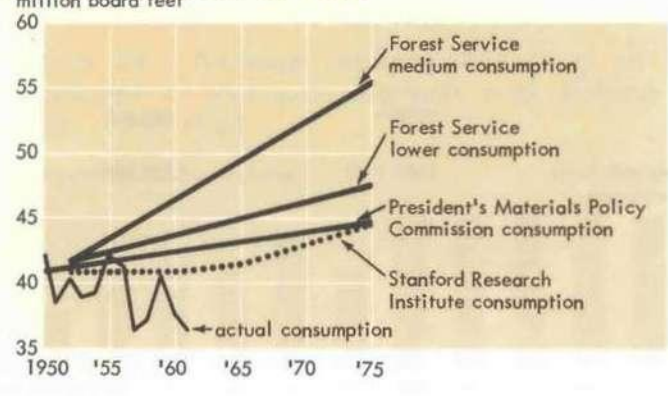
General market prospects for forest products have been treated in a number of extensive studies[32] within the framework of an expanding and progressing national economy. Given the things we have learned about our regional timber situation, we can simply see what these findings suggest about our area.

These studies foresee *expansion* in timber production generally as well as in most specific timber products. Presumably an economy with a rapidly growing population, with an even more rapidly growing appetite for raw materials, and with a suitably improving level of technology, would demand increasing quantities of wood from its forest industry sector. This, of course, assumes that the cost of obtaining the expanded quantities is not prohibitive. All of the studies have attempted to take some account of the impact of possible price changes on demand. Let us look at their projections of demand.

PROJECTED NATIONAL DEMAND AND ASSOCIATED PRICE EFFECTS

Projections from three studies of lumber prospects are summarized in Figure 25. Lumber production is not, of course, the only outlet or potential outlet for our region's timber, but it is particularly significant in any appraisal of the future for our region, since it represents the dominant consumption use of the western softwoods grown here. Currently nearly 90 percent of the cubic volume of timber cut in the region goes into lumber, about 8 percent into other whole wood uses (poles, posts, mine timbers, etc.) and about 1 percent into pulpwood. Production of veneer logs and bolts is still relatively minor in our region, but it has expanded in recent years.

Figure 25 — Projections of United States lumber consumption to 1975



The projections made in these studies are conditional statements, rather than predictions, for they are based on several major assumptions about the state of the economy, its productivity and level of activity.[33] Most of the studies assume that: (1) the added volume of materials called for may be forthcoming only at higher real prices, and (2) that the higher prices, in turn, will stimulate the substitution of other materials for wood and the redesigning of wood-using products to get by with less wood. These conditions would largely extend long-term trends of the past.

All of these projections call for an expansion in United States lumber consumption by 1975 of several billion board feet above the mid-century level of about 41 billion feet. Interestingly, however, the actual amount of lumber consumed annually since these base data were projected, suggests if anything a downward drift, with sharp fluctuations superimposed from year to year.

By and large, the studies claim that United States lumber production can expand only by drawing on more of the higher cost sources and with accompanying higher prices and some substitution of competing materials. In its work, the Stanford Research Institute specifically assumed that lumber prices would continue to rise more rapidly than the prices of competing materials. The Forest Service allowed for two possibilities: that real price of lumber would advance about one-third, an assumption which yielded the lower

[32]See for example Davis [*28*], Guthrie and Armstrong [*32*], Stanford Research Institute [*38*], Forest Service [*39*].

[33]As a rule, later studies have tended to revise upward the expectations for level of economic activity, that is, real Gross National Product. Stanford Research Institute assumed a 1975 level of GNP of $586 billion and a population of 212 million; the Forest Service used a GNP figure of $630 billion and a population level of 215 million. Guthrie and Armstrong, in presenting their revisions of the earlier estimates, have assumed a GNP of $770 billion and a population of 224 million. Projections of United States lumber consumption were made as follows for 1975: Stanford Research Institute, 44.6 billion board feet; Forest Service lower level estimate, 47.6 billion board feet, Forest Service medium level estimate, 55.5 billion board feet; Guthrie and Armstrong, 46 billion board feet. Forest Service figures include board foot equivalent of net imports.

level projections; and that real prices would remain about the same, an assumption which gave rise to the medium level projections. The Royal Commission on Canadian Economic Policy, considering the outlook for both Canadian and United States production and use in view of the above study, projected a probable lumber price increase of about 20 to 25 percent. Taking these projections as representative of studied opinion about the prospects for general consumption and price levels, what is implied for our region? In general, the answer is continued expansion in timber output. And, for reasons we have discussed earlier, the rate of regional production growth should exceed that for the United States as a whole.

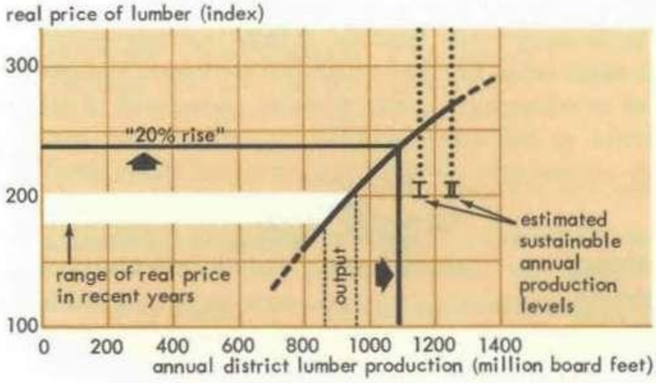
Most studies agree that the largest share of any projected increase in lumber production in the United States must be supplied by western softwoods. Western softwoods currently account for two-thirds of the nation's lumber supply, and it is felt that the forests of the West must be relied upon to supply essentially the full amount of the projected expansion to 1975. The Rocky Mountain states in general and our region in particular have substantial marginal forest lands into which industry progressively must extend itself in response to growing national demands and to eventual depletion of the accessible and desirable old growth stands located principally in the Pacific Northwest. Improved technology and machinery, too, help push at this margin from the other side, to make formerly bypassed stands commercially feasible. Additionally, the relatively small and scattered market for lumber in the Mountain states is expected to grow fairly rapidly during the years ahead.

These trends support the conclusion that prospects for continued expansion of the timber industry in our district are good.

HOW MUCH EXPANSION POTENTIAL?

Any attempt to project regional output quantitatively is hazardous at best. We can derive a very crude indication of the possible magnitude of attendant expansion by applying a projected price increase to the schedule developed in Part II. This is done in the following diagram. For our purposes we might assume, as a reasonable outlook, that the real price of lumber will rise about 20 percent from current levels to 1975. If other circumstances remain unchanged, such an increase would expand the economic range of profitable timber operations in the district. A corresponding output increase of roughly a tenth or more is indicated to be physically feasible, but it pushes output fairly close to the sustainable levels of sawlog production.

However general this projection, it should serve to emphasize that several of the basic factors that have stimulated expansion in our region in the postwar period are likely to continue in force over the next decade or longer.[34] The magnitude of expansion is not limited, not



by physical factors, since the physical potential is great, nor by Forest Service management policy because of the divided pattern of ownership. The magnitude of expansion will be limited principally by the extent to which profitable opportunities exist, and in these opportunities product price is one key factor.

PRODUCT AND AREA OUTLOOK: A MORE COMPLICATED PICTURE

As we have already amply stressed, to speak of a single general demand for timber very much oversimplifies the case. In practice, we have a great variety of grades of raw materials and a variety of products, each of which has a somewhat different market outlook. Some of the forest materials available in the district have special problems associated with them, and conditions vary from area to area within the district. Estimates of sustainable production prepared in the Forest Service study cited earlier provide a more realistic insight into expansion prospects. The estimates are summarized in Table 16. It should be emphasized that the particular product breakdown shown is not a prediction of what is likely to happen. But it does reflect a division of logs among a varied grouping of industries that appeared to Forest Service analysts to offer balanced utilization of material and to correspond to a desirable management program if applied to all forests.

The data shown in Table 16 illustrate several worthwhile points. In general, we can note that most of the physical expansion potential lies in smaller size and

[34]Guthrie and Armstrong [*32*] offer a somewhat different premise: the amount of timber cut from a state or region will tend, over the long run, to move toward an equilibrium level such that each state or region is producing lumber approximately in proportion to its standing volume of sawtimber. On this basis projected 1975 output from western forests is parceled among the states such that Montana ends up with 4.1 percent—actually a somewhat lower percentage than the state is currently cutting.

lesser quality products. Expansion factors are very large for poletimber products in all areas and very small for sawtimber products.

TABLE 16 — ESTIMATED SUSTAINABLE ANNUAL PRODUCTION UNDER A FOREST SERVICE RECOMMENDED MANAGEMENT PROGRAM COMPARED WITH ACTUAL 1957 PRODUCTION FOR VARIOUS PRODUCTS, BY AREA

Table 16a — **Western Montana**

PRODUCT	ESTIMATED 1957 PRODUCTION	EXPANSION PERMISSIBLE TO ESTIMATED SUSTAINABLE PRODUCTION LEVELS
Lumber and dimension	812MM bd. ft.	—62MM bd. ft.
Veneer	8MM bd. ft.	72MM bd. ft.
Large poles (30′ & longer)	10MM bd. ft.	15MM bd. ft.
Subtotal	**830MM bd. ft.**	**25 MM bd. ft.**
Small poles (less than 30′)	93M pieces	407M pieces
Pulpwood	4M cords	1,230M cords
Fiberboard	0	200M cords
Fence posts	270M pieces	3,330M pieces
Chemical wood	0	88M cords
Fuelwood	94M cords	6M cords
Subtotal (cu. ft. equivalent)	**8,264.5M cu. ft.**	**114,975.5M cu. ft.**

Table 16b — **Eastern Montana**

PRODUCT	ESTIMATED 1957 PRODUCTION	EXPANSION PERMISSIBLE TO ESTIMATED SUSTAINABLE PRODUCTION LEVELS
Lumber and dimension	130MM bd. ft.	185MM bd. ft.
Veneer	0	48MM bd. ft.
Large poles (30′ & longer)	3MM bd. ft.	17MM bd. ft.
Subtotal	**133MM bd. ft.**	**250MM bd. ft.**
Small poles (less than 30′)	91M pieces	309M pieces
Pulpwood	23M cords	961M cords
Fiberboard	0	160M cords
Fence posts	464M pieces	2,836M pieces
Chemical wood	0	92M cords
Fuelwood	86M cords	0
Subtotal (cu. ft. equivalent)	**9,252M cu. ft.**	**91,363M cu. ft.**

Table 16c — **Black Hills**

PRODUCT	ESTIMATED 1957 PRODUCTION	EXPANSION PERMISSIBLE TO ESTIMATED SUSTAINABLE PRODUCTION LEVELS
Sawtimber products	50MM bd. ft.	35MM bd. ft.
Poletimber products	12M cords	108M cords

Source: Forest Service **[20]**, correspondence.

Western Montana

In western Montana, in fact, the sawtimber potential on balance is largely used up. Some localities, as pointed out earlier, have more headrig capacity than timber production potential. Hence, in the Forest Service's view, based on the information available, some reduction in sawmill capacity is called for in western Montana. Indeed, the industry in general looks for no great expansion possibilities in lumbering in that area.

Table 16 indicates that a considerable jump in sawlog output would be allotted to veneer production. There is no doubt by now that veneer production, attuned to the rapidly expanding plywood market, offers the best prospects for growth in the wood-using industry of western Montana. In fact, the area's industry has already set its sights well beyond the veneer log consumption level suggested in Table 16. The Van Evan plywood plant alone (with two 8-foot lathes and one 4-foot lathe at Missoula) could produce an estimated 15 million square feet of ⅜-inch plywood per month. Production at this level would require roughly 78 million board feet of logs per year.

The problem of dividing the available larger material (sawtimber-size logs) in western Montana between various possible uses will have to be worked out by the timber processors in response to market criteria. There does not appear to be any appreciable excess of large logs, so that competition will probably force considerable readjustment in the industry's operations.

Most western Montana plywood producers will prefer to take large logs but not the best grade logs, since the sheathing plywood produced at these plants does not require clear logs. Most would prefer to sell clear-type butt logs to sawmills and use the large (even coarse) common logs at lower prices in their plywood plants. Eventually only small common and large clear logs may go into lumber.

Market adjustments in species may be in the offing, too. Increased demand for Douglas-fir and especially for larch to meet expanding plywood and dimension requirements may eventually boost prices of these species above those of the pines, reversing the traditional preferences.

The smaller material (poletimber) in western Montana shows very large expansion possibilities. Most of this is allocated in Table 16 to pulpwood, which we shall discuss later.

Eastern Montana

In eastern Montana, the potential for sawtimber expansion is relatively greater. The figures in Table 16 indicate that production of lumber could be at least doubled, along with increased cutting of sawtimber-size trees for veneer and large pole operations. Actually some of the expansion of sawtimber cuttings in eastern Montana would depend, according to the Forest Service calculations, upon the development of industries using the small trees also. This is necessary so that: (1) the costs of developing these stands (which tend to be more remote from mill sites than those in western Montana) can be shared by several users, and (2) balanced cuts can be made as best suits the over-all management plan. The indicated 185 million board feet of lumber expansion potential would supply roughly ten moderate size sawmills (80 MBF per day lumber output).

Several new types of utilization operations, including fiberboard and chemical wood plants not now present in Montana, are visualized in the Forest Service figures; these operations would take advantage of some of the sizes and grades of materials not usable in more conventional operations. But the sector with the most impressive expansion potential, as alloted, is *pulpwood.*

Black Hills

Black Hills timber output is currently well below its capabilities. A private survey of the Black Hills area examining possibilities for sawmill expansion verified that at least one new sawmill of moderate size could be supported by the available timber.[35] As in Montana, competitive elimination of many marginal mills is likely to continue. The unused pulpwood or poletimber potential is still substantial.

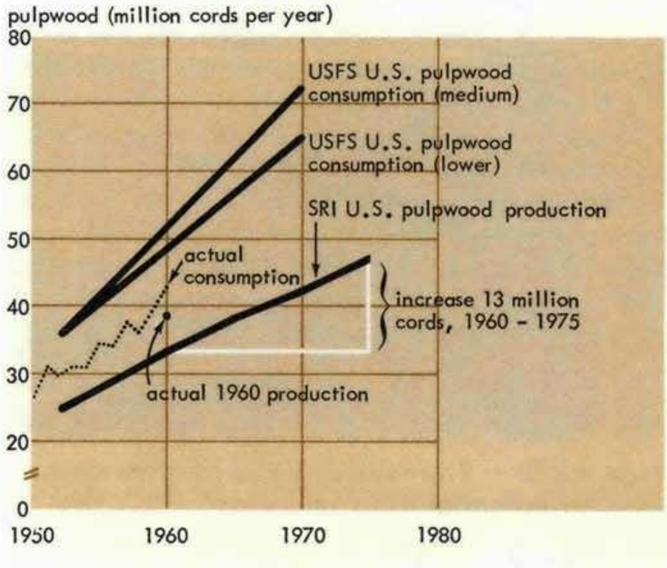
PULPWOOD RESOURCES AND REGIONAL PULP AND PAPER INDUSTRY

Pulp-making prospects present a different evaluation problem from that of lumber and whole wood products. It is true that future demands for wood fiber products are universally expected to continue to expand sharply and that this district has very large supplies of pulpwood available at low cost at the site. Nevertheless, the economics of pulp- and paper-making is much different from that of lumber, and one cannot foresee the extent to which the national pulp and paper industry will choose to depend on district wood sources by the year 1975. We saw in the case of softwood lumber that, if the economy wants to obtain the increased quantities projected, then the Mountain states must share more heavily in its production. The alternatives open to the pulp and paper industry, however, are diverse in terms of location as well as type of raw material.

Until very recent years the pulp and paper industry has tended to avoid the Mountain states in locating its pulp-making facilities. Mills in Wisconsin have used some softwood pulpwood from Montana and Colorado rather than shifting a portion of their capacity to the site of readily available softwood supplies. One of the big drawbacks of this area has been its considerable distance from major markets. A mill located in the Mountain states would have been in poor position to compete with Pacific coast mills for coastal markets or with Lake States mills for midwest and eastern markets. Major expansions in facilities in postwar years have occurred in the South and Pacific Northwest. Although pulpwood supplies in these areas have become increasingly committed to existing plants, ample headroom still exists for expansion in both areas, especially in the South.

If national pulp requirements grow substantially as is expected,[36] sizable new pulping capacity will have to be added. But, plant sizes and capital requirements in the paper industry are very large, and hence location decisions must be based on a careful weighing of many market, raw material, and operating factors. Projections made in the studies we have cited earlier indicate a near doubling of pulpwood consumption over the quarter century 1950 to 1975, as shown in Figure 26.

Figure 26 — Projections of United States pulpwood consumption and production to 1975



Taking an average indicated rate of growth, we see that the projected expansion would require pulpwood consumption to expand between 1960 and 1975 by 13 million cords equivalent annually in order to turn out an additional 19 to 20 million tons of paper and board annually. Translated into plant investment this would require the equivalent of roughly 60 large new pulp and paper plants (300,000 tons annual capacity). Just how much of this new capacity might find its way into our district by 1975 is an open question.

[35]Chicago & Northwestern Railway [*15*].

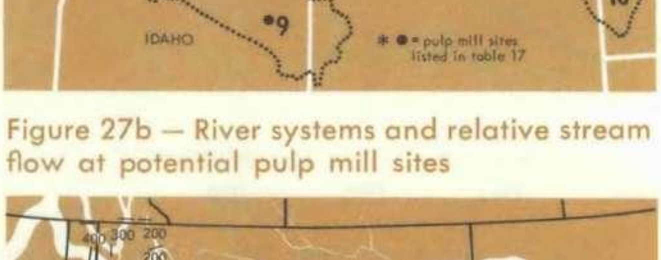
[36]Current pulp output levels actually exceed a number of vintage 1950 expectations for growth. Lumber production, in contrast, has fallen well short of most projections of a decade ago.

The Stanford Research Institute's projections for major regions suggest that about 60 percent of the expanded output will come from forests of the South. About 20 percent will come from western states, mainly arising from expanded use of mill residues. The great bulk of the western states' pulp-making capacity is located in coastal Washington and Oregon, and most of the future expansion is expected to occur there. Western pulpwood requirements are projected by SRI to move from six million cords in 1960 to nine million cords annually by 1975.

Given the general outlook for growing national demand and the prospect that population growth and industrial development within the Rocky Mountain-Great Plains area will also continue, the likelihood that additional pulp- and paper-making capacity will be located in the region seems great. Montana's first pulp and paper mill has now been operating for some five years, and a second one was proposed about the same time, although actual construction has been delayed indefinitely. Plant expansion, now an accomplished fact in western Montana, indicates that the threshold of profitability has been reached for some types of pulp and paper production.

Figure 27a — Possible pulpwood supply areas and pulp mill sites

Figure 27b — River systems and relative stream flow at potential pulp mill sites



Source: Forest Service [8] [21] [22].

The Forest Service, from its study of Montana's capabilities, concluded that under its hypothetical allocation of products more than two million cords of pulpwood could be cut on a sustainable basis. Since the state's live pulpwood cut is small and since the new pulp mill operating at Missoula uses only sawmill residues, practically no inroads have been made on the immense live wood potential.

Potential pulp mill sites

In contrast to the fairly widespread availability of sawmill sites, the number of sites suitable for pulp mill operations is relatively restricted. For one thing, under foreseeable circumstances there can be no such thing as a *small* pulp mill. In order to be efficient and competitive today, pulp mills must be constructed on a large scale. Perhaps a minimum suitable capacity would be about 200 tons of pulp a day. Capital requirements for such a mill would be greater than $5,000,000, compared with about $500,000 to $1,500,000 for a medium sawmill (100,000 board feet per day) and less than $100,000 for a small stud mill.

Pulp mills need very large volumes of water, not so much for the process itself as for diluting of wastes that ultimately must be discharged for the operation. Location requirements therefore include not only central access to a sufficiently large supply of timber or mill residues, but also a site along a stream course with an adequate rate of water flow.[37]

Modern process improvements have reduced water volume requirements, but the pollution control normally results in net additions to costs. The most compelling incentive for pollution reduction remains public pressure or penalty. The water requirements for pulp making are sufficiently large that only the major river courses are deemed feasible mill sites in the district. Potential sites are depicted in Figure 27 along with estimates of sustainable annual pulpwood harvest in the vicinity.

Total pulpwood requirements of pulp mills if all specified sites were used to the capacity indicated would be about one million cords per year, which is well within the

[37]A pulp mill of 200 tons daily capacity would require about seven million gallons of water per day to produce unbleached kraft pulp and about eighteen million gallons per day to produce bleached pulp. Organic wastes dumped into a stream will reduce oxygen levels in the water for some distance downstream. If oxygen is reduced too far, objectionable results, including killing of fish, may follow. An average 200-ton sulfite pulp mill using a calcium base process produces an oxygen demand equivalent to the sewage discharge of a community of 700,000 people, while that of a sulfate or kraft mill is equivalent to about 80,000 people. Waste ponding and other pollution control measures can alter minimum water requirements.

two-plus million cord per year potential pulpwood cut indicated for the region as a whole.

Western Montana offers the best site feasibility in the region. All mill sites are closer than they are in other parts of our region to blocks of timber and to larger concentrations of sawmills from which chipped mill residues may be taken. In eastern Montana, for example, stream flows are not quite as large or regular, and otherwise suitable sites are located in wide open areas far from blocks of timber. Some sites already have too much existing pollution (e.g., the Billings-Hardin area), according to surveys made in conjunction with the United States Public Health Department and the Montana Board of Health.[38] The Black Hills uplift has no really adequate stream flow for pulping, although private interests have investigated without apparent success the possibilities of a small mill (50 tons per day) using well water to augment local stream flow.

Thus, the best early potential seems to lie in Montana west of the continental divide, where presently the only pulp mill is in fact located. Eastern Montana's very large pulpwood potential could be realized as its higher-cost sites become attractive to investors, but for the immediate future it will probably do no more than ship some pulpwood as chips to Wisconsin. The Black Hills could sustain a pulpwood cut of 100,000 cords of ponderosa pine annually, but site feasibility for local pulping seems nil. Small quantities of Black Hills pulpwood have moved to Wisconsin, and conceivably the freight advantage of its sites over central Montana's lodgepole sites may improve the volume of shipments in future years.

Although we have talked in terms of supplies of live pulpwood, the actual potential raw material base for pulp operations is larger. For the western states as a whole, sawmill residues offer a far better opportunity for expansion than do whole wood logs. In Montana some capacity for expanded use of mill residuals exists. The Waldorf-Hoerner plant at Missoula, with a 500-ton daily pulp capacity, requires some 180,000 units of chips per year. Existing Montana sawmills, given their current operating capacities, conceivably could produce more than half a million units of chips annually. Most of this capacity is located in northwestern Montana. Were it proven economic to use even half of this material, an additional pulp mill the size of the existing one at Missoula could be supported.

While the economics of procurement remain unknown, vast stores of dead wood exist, as discussed in Part II, and much of this wood is suitable for pulping. Tests by the USDA Forest Products Laboratory show that the dead trees retain excellent pulp properties, even after long periods in dry storage on the stump.

In short, the physical availability of raw material for pulp making in the district's west is enormous. Eventually, given continued national growth, several of the potential pulp mill sites will be actively occupied. The pace of expansion, however, will probably continue to be slow.

SUMMARY OF PROSPECTS AND IMPLICATIONS

The available, unused timber volumes in our region could support an increasing harvest of wood from all major areas in response to growing national demands. The form and location of added processing capacity will vary, with the best opportunity for pulp expansion in western Montana and perhaps the best opportunity for additional new sawmill capacity in eastern Montana.

As we mentioned before, western Montana is closer to saturation in sawmill capacity, and in some sections an overcapacity is felt to exist. The Forest Service considers that the higher quality species such as ponderosa pine actually are being taken at a greater than sustainable rate in this sector of Montana. But even with these qualifications we can see that the potential for expansion in wood volume, given suitable species and sizes, is considerable. Sawmill numbers actually may decline under the circumstances, but a larger volume of wood processing is possible.

The picture is different in eastern Montana, where the greater room for expansion has brought a relatively more

TABLE 17 — DATA ON POTENTIAL PULP MILL SITES ILLUSTRATED IN FIGURE 27

PULPWOOD SOURCE AREA	HYPOTHETICAL PULP MILL SITES	ANNUAL SUSTAINABLE PULPWOOD CUT (thousand cords)	SULFATE PULPING CAPACITY THAT SUSTAINABLE CUT WOULD SUPPORT (tons)	PERMISSIBLE SULFATE PULPING CAPACITY BASED ON STREAMFLOW (tons)
1	Three Forks	442	740	200
2	Livingston	127	210	200
3	Great Falls	172	290	200
4	Hungry Horse Dam	397	660	400
5	Libby	330	550	300
6	Albeni Falls	1,188	1,980	400
7	Mouth of Clearwater River	1,356	2,260	200
8	Paradise	507	850	1,000
9	Roberts	157	260	200
10	Deadwood	100	170	—
1-3-8*	Anaconda-Warm Springs	120	200	—

*Alternate possibility at vacated industrial site.
Source: Forest Service **[7] [8] [22]**.

[38]Forest Service [*21*] [*22*].

rapid growth in sawmills in recent years. The potential is still large, although not as large perhaps as originally thought, because of the rough topography and increasing development and logging costs. Continued expansion in sawmill operations depends to a large extent on the success of the new sawmills designed to handle the smaller size lodgepole pine. There is room for expansion of sawmills, however, as well as for the development of various other whole wood products using larger tree sizes.

In the Black Hills area moderate sawmill expansion is possible, while the substantial pulpwood or poletimber potential is largely untapped.

The foregoing survey of expansion possibilities, even if correct in general direction, overlooks many complexities. Product markets for lumber and many derived wood products are subject to strong cyclical fluctuations. Supplies of public timber may be subject to their own constraints (for example, policies of making sales in small quantities or so as to maintain existing mills) and may thus not be effectively available to support the commitment of large capital investments for future expansion. Natural catastrophes (such as the spruce bark beetle infestation) may create pressures for temporary expansion in particular species or products.

Thus the real-world market does not allow for steady and predictable introduction of new plants. Owners may complete capital expansion, planned to take advantage of expected longer-term growth in demand, only to face a slump in the market and depressed product prices for two or three years. The inroads that may be made in the meantime by wood substitutes, new uses, or wood products from areas outside the district, may throw other difficulties in the way of profitable operation. Decisions in the past have had to be made in just this sort of environment. No matter how strongly past trends suggest that the future market will ultimately grow, decisions to invest in such facilities inevitably involve a gamble.

JOB POSSIBILITIES AND LOCAL IMPACT

Throughout our discussion so far we have used cubic volumes of timber as a measure of industry size and industry growth potential. We could have used other measures of magnitude, such as number of jobs, wages generated, or capital expenditures. From the local viewpoint, the number of jobs or amount of salary payments generated is often considered the most significant measure of the industry.

A Forest Service study of Montana's timber output potential[39] projected the employment levels in the state that might be associated with the full use of estimated sustainable cut, including both primary activity and secondary manufacture, as follows:

	Man-years required in Montana	
	1957	With full use and development
Primary production	9,000	28,000
Secondary manufacture	1,600	14,000
Total	**10,600**	**42,000**

The 10,600 man-years of labor estimated for 1957 were exchanged for approximately $56 million in wages. And this figure, to be sure, makes up a respectable portion of the 725 million-dollar wage and salary income for all industry in Montana during that year. Using 1957 relationships, wages from timber operations at the projected "full use and development" level could reach $230 million annually in Montana—a several-fold increase over the current level. While the full potential may not be economically realizable in the near future, any significant expansion of the area's output of physical product could add appreciably to the area's income flows.

From our discussion about the basic characteristics and changing environment of the timber economy in the western part of the Ninth district, we have concluded: (1) that physical potential or capability to expand is large; (2) that the region's industry has demonstrated an active "vitality" through its recent expansion efforts; and (3) that prospective economic conditions and past trends suggest that a good part of the unused expansion capability will be realized some day. A large, though not necessarily proportionate, job and income growth also may occur in the district.

And now we turn from our regional survey to a brief concluding section: an attempt to understand the broader meaning of the regional activity we have been considering.

[39]Forest Service [*20*].

V

ECONOMIC THEORY AND RESOURCE USE

Throughout the first four parts of this report we have become acquainted with many details about the region's timber industry and forest resources. Special emphasis was given to displaying the decision-making apparatus that somehow determines which of the district's half billion or more trees to cut, where to process them, and what kinds of products to make from them. We have observed the results of past decisions: some parts of the region's forest resource have been cut heavily, other parts only sparingly, and on balance there is much sustainable growth potential that has not been tapped commercially.

But our treatment of regional particulars is now finished, and in this final part of our study we embark on a brief, 'armchair' tour of a very different world—a world of theory. During the course of this tour we shall meet three contrasting viewpoints about the use of resources. These will illustrate some economic principles underlying the more practical problems of growing and cutting, buying and selling that have occupied us up to this point.

Our focus in this study has been timber. But we must now remind ourselves that an economic system is relatively indifferent to any particular physical ingredient of its production processes. For this reason the economist has built his theoretical systems on the broadest and most general plane, without need to recognize the specific existence of a natural resource called timber, or to grant it special status. Our effort, however, will be to single out several of the working ideas of the modern theorist and apply them to the timber industry and to some of the unusual characteristics of the industry we have already noted.

We turn first to an economist's viewpoint about the nature of resource allocation.

THE ALLOCATION PROBLEM AND THE ALLOCATION SYSTEM

To the theorist the *allocation problem* is that of bringing into balance the production and consumption choices of independent, self-seeking groups of decision makers in a way that will maximize efficiency and human economic welfare. An *allocation system* is simply the total existing apparatus for adjusting all the necessary decisions about use or non-use of available resources in the flow of production from basic raw materials to ultimate consumption. This system resolves the problem of balance. For the timber resource in particular the allocation system also solves the sub-problems of choosing a national level of timber production and determining the proportion forthcoming from any one region. The allocation system solves the *problem of conservation* as well; that is, it balances present against future needs for the use of natural resources.

When we talk about an allocation system in this way, we run the risk of making things sound more deliberately organized and engineered than they really are. Although some economies in the modern world have been organized by blueprint to meet given national goals, our economic system was never designed in that manner. Public policy makers, of course, have always entered into our decision-making process, modifying its results in accord with their view of desirable objectives in resource allocation and conservation. Moreover, national economic goals have played an increasingly important role in our economy in recent decades.

It is still true that in the United States (as in many other countries) the economy is an arrangement that "just grew," an evolutionary product of several centuries of institutions in which independent private ownership and individual enterprise were dominant. In a word, ours might best be described as a *decentralized* allocation system, signifying that the bulk of the decisions are made relatively independently at the level of the individual producer, consumer, and resource holder.

It is significant that individual private decision makers have never viewed themselves particularly as allocators working to meet some master plan for the use of resources. More often they simply have been out to make money, to improve their own position, and enhance personal satisfactions. Yet it has been observed that such a system—in spite of its predominantly self-seeking, individualistic approach to decisions about resource use—behaved and achieved objectives as though it did have an over-all organization. It was this "as though" characteristic that caught the attention of economists. Adam Smith's "Invisible Hand" is a vintage reminder of an early recognition of some sort of collective order in the private market system. Modern economists have analyzed decentralized allocation systems in a considerably more advanced and more rigorous way. In doing this, they have developed a large body of theory about the mechanism of operation and allocative potentialities of such a system.

THE COMPETITIVE MODEL

Basically the theorist has made his way by building a "model" of a decentralized economy, appropriately referred to as a *competitive model.* Actually the model is a pencil-and-paper construction fashioned of logic and mathematics to simulate the workings of a true-life economic system. The model is presented in a variety of forms in many texts and references. It is always abstract and it always treats of a greatly simplified world. Sometimes the competitive model is presented in highly involved and sophisticated mathematical language. For our present needs, however, a very brief word summary of the model's main attributes will suffice.

In the competitive model a number of statements describe the behavior of each individual participant in the economy, the rules that constrain or limit the possible choices he can make, and the ways in which the actions of the many participants are inter-related. There are normally three groups of participants: (1) *producers* choose individually how much of their particular goods they will produce—motivated only to maximize profits within the limitations imposed by the technology of their processes and the availability of resources; (2) *consumers* and (3) *resource holders* choose how much of each product they will buy and the amount of their resources including labor they will sell—motivated only by individual desire to maximize satisfactions and limited only by their incomes or resource holdings. The model is an interacting system tied together by *price* (or prices), since it is through price that the wishes and capabilities of each participant are communicated.

COMPETITIVE EQUILIBRIUM: OPTIMALITY

The particular statements chosen for any model (defining rules of behavior, limitations, and inter-relations of the participants) are known as the *assumptions* of the model. Under suitable assumptions it can be proved that the competitive model has a rather neat way of working through its price signals to adjust production and consumption amounts until an equilibrium is reached. By definition, "equilibrium" means that the system has no tendency to further adjustments in its prices, amounts produced, or amounts consumed—unless or until there is a change in consumer tastes, in technology, or in resource availability. When such a change does occur, the adjustment mechanism will start operating to generate a new equilibrium. Another thing that the theorist can prove, given the appropriate assumptions, is that a competitive equilibrium is *optimal*, which loosely translated means that the competitive model achieves some sort of best possible state. In the theorist's language, the competitive model achieves two things: *technical efficiency* and *allocative efficiency*.

Technical efficiency applies to the producer and requires that for any given set of inputs each producer obtains a maximum value of output, and that no shifting of inputs among the various producers would result in a greater total value of output for the given cost of inputs. This production condition is often referred to as the *least cost combination of inputs.*

Allocative efficiency (sometimes called *optimality)* applies to the consumer, and is a state of the abstract economy in which no one consumer could be made better off without making at least one other consumer worse off. Suppose, for example, it were possible to rearrange the output and distribution of goods to consumers in such a way that one person is moved to a position of higher satisfaction on his scale of preference while everyone else is at least as well off as before in their own eyes (though possibly with a somewhat different collection of goods). Then the revised state would be better than the previous one, according to the optimality criterion. When, through all such possible rearrangements, we finally have reached a condition in which no further improvement can be made, then we have attained a maximum value of total output as well as *optimality*. While optimality so defined is a "weak criterion" of social welfare from the standpoint of the policymaker, it is nonetheless a halfway house fairly widely acceptable to the theorist.[40] From the standpoint of individual consumer satisfaction, we could not find an unequivocally better assortment of national outputs given the same level of technology and quantity of inputs.

THE COMPETITIVE MODEL AND THE REAL WORLD

The theorist has been forced in the interest of rigor to look very penetratingly at the logical structure of the

[40]Optimality as a criterion of national or social welfare is at least an acceptable minimum: whatever else one would require of a state of general social welfare, one would want to have allocative efficiency. Otherwise it would be possible to squeeze out some additional product with no additional expenditure of effort. There is considerable economic literature on the problem of constructing a stronger criterion of social welfare. However, any stronger criterion necessarily requires the imposition of some sort of arbitrary judgment about the worth of some one person's satisfaction over that of another. That is, it would require judgments of the sort: reducing the satisfaction of Mr. X is less important to the national welfare than increasing the satisfaction of Mr. Y.

competitive model. He has examined in particular all the assumptions necessary in order that the competitive model produce an equilibrium which is technically efficient and optimal. The needed assumptions fall into two groups: (1) assumptions about the way the economic universe is, so to speak, constructed (structural conditions); and (2) assumptions about the way the human participants should behave (rules of the game). Armed with a necessary minimum of assumptions, the theorist can logically guarantee that the model will in fact generate an optimal solution to its allocation problem.[41]

Now let us look broadly at how the theorist proposes to use the model. First, he sees he has created an abstract operating replica of an allocation system. But his interest is caught by the optimal result the system reaches, so he would like to use his model as an ideal, or "norm," with which he can make judgments about the real world economy. Briefly then, his logic is to look at conditions in the real world economy in the light of the required optimizing assumptions. If they are violated—for example, if the world isn't built the way the technological relations in the model require, or if people will not play according to the rules of the game—then the theorist would judge that the real world economy will fail to attain optimal resource allocation. At least, he is sure that a violation of the corresponding assumption in the competitive model would guarantee a non-optimal result.

He might make further use of the "ideal" competitive model in prescribing some policy action. For example, he might recommend antitrust action under certain conditions to make firms behave more nearly as they ought to under competitive model assumptions, in the belief that it would bring the economy closer to optimal resource allocation.

THE COMPETITIVE MODEL AND TIMBER PRODUCTION

Technological efficiency and optimality are, of course, conditions that apply to the total economy. In a sense we are going to tackle the problem somewhat naively, for we shall examine the relationship of competitive model assumptions to timber production as though all other major sectors of our economy fully satisfied the competitive assumptions, which they do not. But let us see particularly how conditions in the timber industry meet or fail to meet the assumptions of the competitive model.

The fact is that our timber allocation subsystem has a great many primitive similarities to the competitive model. The reader will recognize that much of the discussion in the earlier parts of this paper was set up so as to emphasize parallels between institutions and behavior in the real world and the properties of the competitive equilibrium model.

For example, the allocation decisions of private profit-motivated firms, responding to price signals, were identified as the cause of the shift of several sawmills from the Pacific Coast to sites in our district—in effect, a composite decision to take a little bit more of Montana-South Dakota timber and a little bit less of Washington-Oregon timber. This is equivalent to a resource allocation decision affecting in principle the whole national economy.

Yet if we press our inquiry further, we can discern some gaps between the "ideal" of the model and the arrangements of the real world. Within the timber industry, the tree-growing stage in particular is hardest to fit to the competitive model.

Among the competitive model's assumptions about producers are: (1) that firms are sufficiently small relative to the market so that they have no perceptible influence on prices by their own individual actions; (2) that they have complete knowledge of the production possibilities open to them; and (3) that they act so as to maximize their profits.

As we have learned, a large share of the means of production in tree growing is under public ownership. The Forest Service, obviously a dominant producer, can influence price strongly by its decisions, and so can some larger private holders in particular geographic areas. Thus, on the face of it, the classical institutional features of the competitive model are violated.[42]

Furthermore, the "rules of the game" seem to be violated—by the Forest Service, since it explicitly does not use the same maximization-of-return criterion that the producer theoretically should; by some large private producers, since some sustained yield operations seem to indicate very low rates of return; and by most small producers, partly from lack of knowledge of the possibilities open to them, and partly through explicit intent to pursue some objective in forest ownership which is not compatible with maximizing return.

One final assumption that is violated by conditions in the tree-growing industry has to do with prices. Prices play such a key role in the competitive model that any of a number of obstacles which distort the price structure

[41]To show this the theorist uses involved mathematical proofs which we do not discuss here, but which may be consulted in many texts; see, for example, reference [34] and the literature cited therein.

[42]It should be emphasized here that in the theorist's view the allocative efficiency goal is not limited to any one kind of institutional arrangement. If allocative efficiency is accepted as paramount, any institutional arrangement—whether private ownership alone, private ownership with government regulation, or public ownership—is theoretically feasible as long as it meets the model's results; that is, as long as the applications it makes of resource inputs, the choices it makes for production outputs, and the way it distributes ouputs for consumption are identical to those reached by the ideally functioning competitive model.

and thus prevent prices from giving their proper signals to the producer, consumer, and resource holder can prevent the model from attaining optimality. The economist refers to these kinds of price-distorting obstacles as *external effects.*

EXTERNAL EFFECTS AND MULTIPLE FOREST OUTPUTS

One type of external effects particularly important in the case of the multiple outputs[43] of forest lands, carries the rather imposing name of an *external diseconomy of production.* This simply means that some part of the costs of operating a particular firm may not appear on its accounting records and in its own cost calculations; therefore, when it calculates the scale and assortment of products it will produce, it does not react to all the price signals it should to achieve an aggregate optimum.

As an illustration, suppose a logger seeks to maximize his profit from a logging operation in a particular mountain drainage basin and, in the process, takes all possible short cuts: he skids logs across stream beds, scars the ground, and includes no culverts or other erosion control measures in his road and trail construction. In this operation he has maximized his profit and therefore has operated efficiently from his own technical standpoint. However, among the outputs of his operation are increased erosion, increased turbidity of waters downstream, and increased silting behind downstream dams and reservoirs. In this hypothetical case, he may be able to ignore these consequences of his operation; some other people, however, cannot. They must pay the increased costs that are associated with the change in the quantity and quality of water downstream. This is an external diseconomy.

If such circumstances occurred in a competitive equilibrium model, the producer responsible for the external diseconomy would produce too much (since he overlooks some of the actual costs) and would draw away from the rest of the economy too many resources for optimal allocation. Price would then be lower for the product with the external diseconomy because of the windfall cost advantage; it would be higher (reflecting higher cost) for all other products because of the reduced number of input resources available to them. Thus, consumers, responding to the price signals, would end up buying more of his product and less of some others than they would have taken were the true costs reflected.

There can be little doubt that technological relationships at the tree-growing stage of the timber industry are susceptible to this kind of external effect. The problem arises because the outputs of forest land are several, as we discussed earlier, and widely varied in form and geographical impact.

Some of the outputs cannot be given a suitable market price, which means that the price system cannot act to allocate resources properly to their production. These are goods for which there exist *external economies of production* or *external economies of consumption*—sometimes called *public goods* by the economist. Some of the forest land outputs, such as timber rights and grazing rights, pose no special theoretical problem, because they can be put up for competitive bid on a unit basis, for example, in units of so many board feet of stumpage or so many acres of forest grazing land for a season.[44] But some of the outputs, such as *water* (including quantity, quality, frequency, and geographic distribution, and excesses or deficiencies of flow) or *scenery* (including, for example, the visual effects of commercial exploitation of lands adjoining forest highways) cannot be priced adequately because they have no workable market. This problem arises for public goods, because once a group of consumers or producers has offered to pay enough to have the good produced, then other consumers or producers can enjoy the benefits without paying. The individual, therefore, has an incentive not to indicate by poll or through purchase the true value to him of that service.[45] Once someone else has paid and the good is produced, he enjoys it free.

For example, after a first party (producer or consumer) has paid for upstream watershed management, then any second party living in the downstream flood plain or using the downstream water for various domestic or commercial purposes, gains free benefits. Or a second party may enjoy free the scenery along a forest road which some first party had paid to preserve as an inspiring scenic drive. The importance of these effects, which

[43]Namely: timber, grazing, waterflow, recreation, and wildlife.

[44]*In actual practice the allocation of grazing land rights is not* handled on a strictly competitive basis; we are merely discussing theoretical possibilities.

[45]The problem of devising a rule for determining what price to put on the production of this public good or output is even technically severe. This class of goods has long been recognized. In a practical way the allocation decision is often met by putting the production of such goods (roads, bridges, integrated river basin developments, etc.) in the hands of public authorities and taxing all recipients of the good, theoretically in proportion to the benefit received from it. In practice, of course, there is much maldistribution of the price or cost, and considerable argument often arises over the correctness of the evaluation made by administrative decision.

clearly exist at the tree-growing stage, is that their theoretical counterparts[46] would prevent the competitive equilibrium model from reaching optimality. Because of the inability of price under these circumstances to reach a level sufficiently high to reflect the true relative value to the users of the output, too little of this type of good gets produced relative to the amount that would be produced at the theoretical optimum.

Thus, private decentralized decision-making, which finds theoretical support as an appropriate mechanism to handle the job of allocating resources optimally in other phases of the timber industry, lacks this rationale at the tree-growing stage. The use of some form of administrative guidance to balance tree growing against the other values of the forest seems theoretically justified if the goal of allocative efficiency is chosen.

TIMBER CONSERVATION AND THE COMPETITIVE MODEL

In popular usage *conservation* is often an ambiguous term, standing for such general expressions as "wise use," or "the greatest good for the greatest number." But where its intent has been made clearer, conservation generally connotes special treatment for some particular resource or class of resources, usually the natural resources.[47] To some, conservation is saving or preserving; but to the forester, conservation tends to mean increased use or more active management.

In our case timber conservation will be given more specialized meaning in order that we may relate its implications to competitive model optimality. As the theorist might define it, timber conservation is a program to augment future use of the timber resource beyond the level that would be reached under some alternate program or in the absence of any deliberate program.

There are several things to note about this definition. For one thing, conservation is always a program for resource allocation. Secondly, the conservation program is a plan that looks ahead to the future; none of it is realized or attained. Thirdly, conservation is always *relative* to some other resource allocation program, present or potential. Thus conservation is not absolute; if any two programs are compared, one will represent a conservation program, the other a 'depletion' program. Finally, conservation is a program that proposes to increase future use of the resource in question over that which would occur if the conservation plan were not adopted. Conservation often implies a stronger weighting of far future years relative to the present or near future years.[48] In order to be precise, the span of future years which the program encompasses (the "planning horizon") should be specified. In the case of timber, this might extend for several rotation periods.

GENERAL APPROACHES TO CONSERVATION

A conservation program may be implemented in either of two rather different ways, with relatively similar economic effects. The first is *conservation by postponement.* In this case we simply abstain from use during the present or near future so that the quantities of the resource not used today may be added to our normal take in future decades. The quantities we are talking about are flow quantities, although this approach to conservation tends to emphasize the stock aspect of the resource. The approach further requires that the resource in question be capable of storage for long periods without significant deterioration. So this kind of conservation applies more to minerals than to timber.

The second approach is *conservation by investment.* This might involve no reduction in current consumption of the resource in question, but simply an increase in so-called restorative expenditures (an increase in current spending on inputs) that will make greater quantities available for use in future years. Both approaches actually may be used in a timber conservation program in practice, but the forester will emphasize the second and consider the first inapplicable. To the economist, however, there are important ways in which their respective impacts on the allocative efficiency of the competitive model are similar. As we turn to examine the reasons for this, we should emphasize that we are here developing a particular viewpoint on resource use—one we might term the "allocative efficiency viewpoint."

ECONOMIC IMPACT OF TIMBER CONSERVATION

Timber viewed as an input to the total allocation system is but one kind of input among many. Within the timber production process are other classes of inputs—capital equipment, labor, management, materials, and energy—which are as necessary as raw wood itself in order that any stage of its products can be brought into existence. The same applies to any other natural resource or industry. By the time the economy's flow of materials has reached the final consumption-goods stage, the successive merging of inputs in the various processes has reduced wood, by and large, to a secondary character-

[46] For example, a (mathematical) statement to the effect that some consumer's satisfaction depends not only upon the goods he chooses in the market but also upon some other person's choice of goods.

[47] For a general discussion of conservation viewpoints, see Scott [*37*].

[48] See Ciriacy-Wantrup [*27*].

istic; the form and function of the product have become the primary characteristics and the ones for which the product is purchased and consumed. With this framework in mind, we can visualize the essential impact of conservation.

In essence, all conservation theoretically involves doing without today in order to have more tomorrow. In the case of *conservation by postponement* we decide to do without a quantity of wood that people otherwise would consume in the years immediately ahead, in order to have greater amounts in the far future. This does not make much forestry sense, but for purposes of hypothetical argument, consider timber as a non-deteriorating stock resource and say that the conservation program is instituted by a government edict which reduced the annual timber cut by 50 percent during the next ten years. This means that housebuilders, for example, will have to make do with less wood in the immediate future. In order to meet the demand for housing, then, greater quantities of substitute materials will have to be produced, and perhaps we will choose to buy fewer houses because of higher costs. The theorist, arguing from the competitive model would say: either the production of these substitute materials will require greater inputs of other resources than would have been required to do the job with wood, or else the consumers of houses will end up in a less satisfying position. In either event, the participants in the economy face the immediate prospect of getting less for their money. This holds provided the former program was already optimal.

Conservation by investment, on the other hand, requires no reduction in the amount of wood currently used. Such a program might be instituted, say, by an act of Congress that tripled spending on forest management in order to boost our output of timber for all future time, beginning right now. But note the economic effects of this move from the standpoint of the competitive model: Increasing our expenditures on current restorative maintenance means that we have shifted some inputs (such as labor and capital equipment) into the timber industry from some activity outside it and therefore necessarily have reduced the quantities of some *other* outputs that our consumers would have enjoyed.[49] Again provided that the former solution was optimal, the shifted inputs are less efficient at providing consumer satisfaction in timber products than they would have been in their former uses. In this case, consumers also do without, but outputs *other than timber* are the ones we do without today in order to increase our timber take tomorrow.

Hence, both kinds of conservation program, whether they arise from: (1) a government edict to reduce cutting of timber or (2) an increase in government forest management expenditures, are similar in their broader allocative effects. In either case the consumer sector does without something today, and in return it gets an increased supply of timber for the future.

NATIONAL TIMBER CONSERVATION POLICY

We should mention in passing that the United States does have some elements of a national timber policy representing national objectives. Since the establishment of the National Forest system late in the Nineteenth century, there has been federal awareness that some form of special treatment of the nation's forest resources was desirable. National policy in this regard is many-sided, but its basic outlines originate through congressional act and administrative decision within the executive branch —in particular within the Forest Service. The following quotation reflects a policy view that the timber resource should play some predetermined role in the national economy:

> ". . . The Forest Service believes that the medium projection offers a reasonable and desirable objective as a matter of public policy. This is so for two reasons: (1) It is desirable to grow a continuing supply of wood as a basic and renewable raw material *in such amounts that wood may continue in the future to occupy about the same role in the national economy as it does at present;* and (2) the amount of timber that must be grown to meet the medium projected demand is shown to be reasonably obtainable although rapid acceleration and intensification of forestry will be required."[50]

The legal weight of such conservation policy really falls on National Forest land. This situation gives rise to some peculiarities we have already discussed, namely, that in total national impact the conservation efforts of the Forest Service tend to be weakened through the offsetting actions of owners of private forest lands responding to the changed market signals that conservation efforts on public forest lands bring about.

THEORY AND POLICY

We have now looked briefly at some ideas of the competitive model theorist and some ways in which he might examine and interpret the effect of conservation. We have left much unsaid about competitive equilibrium theory, but we've said enough to indicate a few general

[49]This argument assumes full employment of resources.

[50]Forest Service, *Timber Resources for America's Future* [39], p. 16, italics added by the author.

policy prescriptions the theorist might make, stemming from his treatment of allocation systems.

One of his most fundamental policy positions is that where the competitive model ideal is closely approximated, private enterprise firms acting as independent, profit-seeking decision makers constitute a very efficient arrangement for making decisions about resource allocation. Furthermore, this sort of arrangement would be applicable to much of our national economy, including for example, the processing level of the timber industry.

At the tree-growing stage, however, such an institutional arrangement would not produce quite the right decisions to meet the theorist's idea of optimality for the reasons we've discussed. It could only produce optimality if there were some overriding external control to induce the system to operate the way it "ought to." So the competitive theorist sees a rationale for some government role in the tree-growing phase, whether it be ownership or regulation. In practice, of course, virtually all western nations do regulate forestry in some way.

But our competitive theorist would maintain that the government should operate, or influence the forest sector to operate, as would a competitive decision apparatus if it were so rigged as to respond correctly to all the necessary price signals. In thus idealizing the competitive solution, our theorist might quarrel with current national forest policy. Based on his premise that investment funds should flow only to those activities which promise the highest return, and judging by the fact that the expected return on so much of the investment is so low, he would probably say that we are putting too much emphasis on timber production. As a result his policy recommendation would be to reduce spending on forests.

The theorist might then, with the use of his competitive model, trace out the probable consequences of such a decision: We could expect reduced availability of stumpage in the future, and consequently (for any given technology and state of consumer tastes) the relative price of stumpage could be expected to rise. At some point, stumpage prices would be high enough to raise the expected rate of return on forest management until it reached competitive levels. At that point (or in advance of it, but in anticipation of it) private owners and the government following an investment return criterion, would be induced to invest—but only up to the limits of competitively dictated return. This, according to the theorist, would produce just the "right" balance of wood products in relation to other product alternatives open to the economy. And best of all, he might conclude, the question of how much timber to produce would now be settled "impartially" by the competitive allocation system, and we would no longer have to make arbitrary judgments about the amount of effort to apply to the timber sector.

"Not so," the timber conservationist would reply. Joined in his protest by many economists, he would go on to challenge the contention that the competitive model result is truly impartial: A national policy, our conservationist would point out, is not just for the living, but also for generations yet unborn. The competitive result, with its heavy discount on the future does not give sufficient weight to future generations. Furthermore, since we do not sufficiently understand the present range of technological possibilities in the production of forest outputs, let alone how well future technology can keep us stocked with non-wood kinds of materials, we simply cannot afford to be anything but *conservative* in our planning. Forests are logical candidates for conservation measures designed to maintain their inherent productivity, because they represent one of the few major raw material sources that are perpetually renewable in nature.[51]

The critics of competitive optimality might raise other, more technical arguments. They might challenge the optimality criterion used in the competitive model as falling far short of a desirable social welfare criterion—it is indifferent to the distribution of income, for example. They could also object that the competitive theorist is not logically entitled to apply his prescriptions to *parts* of a system when it is known that other sectors of the system are subject to distorted or non-competitive relationships (and many such sectors could be identified in the United States economy today). Clearly, when theory moves to the policy front, there arise a number of conflicts which can be resolved only by recourse to judgments outside the realm of the theories themselves.

REGIONAL DEVELOPMENT VIEWPOINT

The regional (local) development viewpoint provides an instructive contrast to both the positions we have considered. The actual recommendations of regional development proponents about timber resource use will differ from one area to another, depending partly on whether the area is a net exporter or a net importer of timber materials. Since our region is a net surplus area,

[51]The extreme condition of deforested and eroded slopes in many Mediterranean countries is often cited as an example of the kind of legacy this nation has an obligation to avoid.

local interest naturally tends to favor a maximum of local activity based on the forest resource present.

For example, the Forest Service estimates presented earlier indicated that the forests of Montana are capable of supporting 28,000 man-years annually in primary production stages and perhaps an additional 14,000 man-years annually in secondary manufacture based on existing levels of productivity. Such a level of employment, if attained, would represent a fourfold increase over 1957 levels. Local interest would seem to be optimally served by a policy that would promote attainment of the maximum, for this would infuse a maximum community income flow through employment and other purchases by timber processing firms, and through supporting services and related community activity.

More technically, ideal allocation from the local viewpoint might be that which achieves a *maximum* possible value for the inputs to the production process. From society's standpoint, however, this may be looking at it the wrong way about: Man-hours and equipment-hours allocated to timber production are costs; society wants to obtain its needed wood supply with a *minimum* of costs. Thus, the fewer units of labor and capital resources that can be allocated to obtain a given timber output, the better. As the economist would emphasize, it is the *uses* to which timber products are put that society wants to obtain through its allocation system; consequently, other materials (or even ideas for better materials use) may indirectly replace "man-hours in Montana or South Dakota timber" to fill more effectively society's wants.

Thus, a fundamental conflict can exist between the welfare of a region as viewed locally and the welfare of the larger economy of which the region is a part.[52] The local view of an ideal solution to the allocation problem may, we repeat, be very different from either that of the allocative efficiency or the conservation viewpoint.

CONCLUSION: THE PROBLEM OF BALANCE

By way of capsule summary, we might contrast the three viewpoints we have now examined: The timber conservation viewpoint places its emphasis upon the *outputs* of a single natural resource industry and tends to build its criterion of excellence around the achievement of certain physical production goals with respect to these outputs. The regional development viewpoint, on the other hand, stresses *inputs* to the productive process and considers a suitable objective to be the attainment of maximum spending on these inputs within the geographic area concerned. Finally, the allocative efficiency viewpoint places its stress upon a *system* which would supposedly achieve some sort of objective balance among outputs and inputs of *all* productive processes, through some mechanism, largely that of price.

The three viewpoints, as we have said, are hypothetical. Others might be developed. In the everyday world, proposals and discussion about allocation and conservation questions usually contain a blend—and sometimes an incongruous mixture—of these and other considerations.

Our purpose has been to explore resource allocation in theory. Several theoretical concepts were presented to help define the rational structure of three major prevailing views, and to uncover the ultimate value judgments on which their respective supporting arguments are based. Prescriptions for policy arising from the three viewpoints may be ultimately irreconcilable in terms of logic, because they entail basic differences in *values* about how resource allocation ought to be handled. Nevertheless, the effort to tease out the nature of their logical relationships can help to clear away pseudo-problems and to bring the real issues into clearer focus. The regional development viewpoint is not a serious contender for inclusion in a rational public policy, since its prescriptions quickly reduce to absurdity if carried to their logical extreme. It is in the arena between objectives of allocative efficiency and objectives of timber conservation that the basic problem of reconciliation lies, requiring further theoretical work.

One of the problems the conservation viewpoint faces, for example, arises from the relativity of conservation. This is the problem of selecting an appropriate *degree* of conservation. In the quotation cited earlier the Forest Service proposed that in the future wood should have the same relative share in the economy that it has today. But the questions that continue to lurk in the background of any decision of this sort are, "Why prescribe just that much importance for timber? . . . Why not a little bit more? . . . Or a little bit less?"

Other, more practical difficulties still hinge around the side effects of a national timber policy that applies only to publicly owned lands. Policy-offsetting reactions on non-public forest land, induced through the economic mechanism in response to Forest Service action, might well receive further study.

[52]Much of the essential substance of this argument also can be applied to the arguments advanced for protection against competition from imported timber—it is eminently rational from the standpoint of interests which have been hurt, but is not broadly rational to society from the standpoint of the proponents of allocative efficiency.

To the economic theorist the challenge to critical study of the resource allocation model is equally strong. Development of substantial theory in the area of resource allocation which could accommodate such questions as the role and function of technological change and the "proper" weighting of the welfare of future generations, would be desirable. If general allocation theory is to be accepted as a useful tool by the policy formulator, it must develop as a more sophisticated representation of the real world, able to account for major practical aberrations in our nation's economic system today.

As we promised at its outset, the tone of this final part of our study has been reflective, and its content abstract and theoretical. Its most significant 'conclusions' are merely the questions it may force us to raise about our conventional ways of looking at familiar things, and the challenge to further our understanding of the fantastically complex economic machinery that serves us.

REFERENCES

DISTRICT

1. Bolle, A. W. "The cooperative study of multiple use of natural resources in the North Fork of the Flathead Valley;" *Montana Business Review*, v. 12, no. 3, Mar. 1960. p. 2-10.
2. ...."The timber industry and the market for woodlot products in the Upper Flathead Valley;" *Montana Business Review*, v. 12, no. 4, Apr. 1960. p. 3-11.
3. Fechner, G. H. *A survey of the pole resources in the northern Black Hills;* Rocky Mountain Forest and Range Experiment Station, Fort Collins. U. S. Dept. of Agriculture, Station paper no. 28. 1957. 12 p.
4. ....*A survey of the pulpwood resources in the northern Black Hills;* Rocky Mountain Forest and Range Experiment Station, Fort Collins. U. S. Dept. of Agriculture, Station paper no. 20. 1956. 21 p.
5. Hutchison, S. B. and Kemp, P. O. *Forest resources of Montana;* Northern Rocky Mountain Forest and Range Experiment Station, Missoula. U. S. Dept. of Agriculture, Report no. 5. 1952. 76 p.
6. Hutchison, S. B. and Roe, A. L. *Management for commercial timber Clark Fork unit, Montana;* Intermountain Forest and Range Experiment Station, Ogden. U. S. Dept. of Agriculture, Research paper no. 65. 1962. 32 p.
7. Hutchison, S. B. and Wikstrom, J. H. *Industrial opportunities in the Headwaters Timber Development Unit;* Intermountain Forest and Range Experiment Station, Ogden. U. S. Dept. of Agriculture, Research paper no. 45. 1957. 70 p.
8. ....*Resource factors affecting the feasibility of pulp mills in Eastern Montana;* Northern Rocky Mountain Forest and Range Experiment Station, Missoula. U. S. Dept. of Agriculture, Station paper no. 34. 1952. 35 p.
9. Hutchison, S. B. *Market prospects for mountain states timber;* Intermountain Forest and Range Experiment Station, Ogden. U. S. Dept. of Agriculture, Research paper no. 50. 1957. 28 p.
10. ....*Production - distribution trends and freight rates as they affect mountain states lumber producers;* Intermountain Forest and Range Experiment Station, Ogden. U. S. Dept. of Agriculture, Research paper no. 59. 1959. 13 p.
11. Johnson, Maxine. "The lumber and wood products industry in the state economy;" *Montana Business Review*, v. 9, no. 11, Nov. 1957. p. 3-10.
12. Kemp, P. O. and Dickerman, M. B. *Montana forest resource and industry statistics;* Northern Rocky Mountain Forest and Range Experiment Station, Missoula. U. S. Dept. of Agriculture, Station paper no. 25. 1950. 49 p.
13. Kotok, E. S. and Newport, C. A. *Lumber recovery at a ponderosa pine sawmill in the Black Hills;* Rocky Mountain Forest and Range Experiment Station, Fort Collins. U. S. Dept. of Agriculture, Station paper no. 19. 1959. 14 p.
14. Landt, E. F. *Forest industries of the Black Hills area, South Dakota and Wyoming;* Rocky Mountain Forest and Range Experiment Station, Fort Collins. U. S. Dept. of Agriculture, Station paper no. 60. 1961. 14 p.
15. *Lumber manufacturing possibilities in the Black Hills: a prospectus;* Chicago. Chicago and Northwestern Railway System, Rev. 1962. 34 p.

16. Nelson, C. W. *Pulp and paper in the Upper Lakes region;* Minneapolis. Supplement to Federal Reserve Bank of Minneapolis *Monthly Review*, July 1956. 28 p.

17. Newport, C. A. *A history of Black Hills forestry;* Pierre, S. D. Dept. of Game, Fish and Parks, 1956. 114 p.

18. Pissot, H. J. and Hanson, H. E. *Forest resources of western Montana;* Intermountain Forest and Range Experiment Station, Ogden. U. S. Dept. of Agriculture, U. S. Forest Service Resource Bulletin INT-1. 1963.

19. *The pulpwood resources of the Black Hills;* Chicago. Chicago and Northwestern Railway System, 1956. 19 p.

20. U. S. Forest Service. *Report on full use and development of Montana's timber resources;* Washington, D. C. Govt. printing office. Senate doc. no. 9, U. S. 86th Cong., 1st session. 1959. 35 p.

21. U. S. Public Health Service. *Summary report on pulp mill sites in relation to mill effluent effects on water quality in streams in western Montana and northern Idaho;* Washington, D. C. Govt. printing office. 1955. 13 p.

22. Warrick, L. F. and Anderson, H. A. *Pulp mill sites in eastern Montana in relation to effects on water quality of Upper Missouri and Yellowstone Rivers;* Northern Rocky Mountain Forest and Range Experiment Station, Missoula. U. S. Dept. of Agriculture, 1952. 7 p.

23. Wikstrom, J. H. *Lodgepole pine—a lumber species;* Intermountain Forest and Range Experiment Station, Ogden. U. S. Dept. of Agriculture, Research paper no. 46. 1957. 15 p.

24. Wikstrom, J. H. and Wellner, C. A. *The opportunity to thin and prune in the Northern Rocky Mountain and Intermountain regions;* Intermountain Forest and Range Experiment Station, Ogden. U. S. Dept. of Agriculture, Research paper no. 61. 1961. 14 p.

25. Wilson, A. K. "Brief look at the pulpwood situation in Idaho and Montana;" *Pulp and paper*. Oct. 1960. p. 122.

26. ....*Montana lumber production, 1956;* Intermountain Forest and Range Experiment Station. Ogden. U. S. Dept. of Agriculture, Forest survey release no. 2. 1958. 7 p.

GENERAL

27. Ciriacy-Wantrup, S. V. *Resource conservation: economics and policies;* Berkeley. University of California Press, 1952. 395 p.

28. Davis, John. *The outlook for the Canadian forest industries;* Ottawa, Royal Commission of Canada's Economic Prospects, 1957. 261 p.

29. Davis, K. P. et al. *Determination of allowable annual timber cut on forty-two western national forests;* U. S. Dept. of Agriculture, Report of the Board of Review, Forest Service. 1962. 40 p.

30. *The forest products industry of Oregon* (Part 2); Portland. Lewis and Clark and Reed Colleges, 1956. 56 p.

31. Goundrey, G. K. "Forest management and the theory of capital;" *Canadian Journal of Economics and Political Science*, v. 26, no. 3, Aug. 1960. p. 439-451.

32. Guthrie, J. A. and Armstrong, G. R. *Western forest industry, an economic outlook;* Baltimore. Johns Hopkins Press, Published for Resources for the Future, Inc., 1961. 324 p.

33. *Hearings before the subcommittee on forests of the committee on agriculture House of Representatives* (May 14 and 15, Serial Y); Washington, D. C. Govt. printing office, U. S. 86th Cong., 1st session. 1959.

34. Koopmans, T. C. *Three essays on the state of economic science;* N. Y. McGraw, 1957. 231 p.

35. Meyer, W. H. *Yield of even-aged stands of ponderosa pine;* Pacific Northwest Forest Experiment Station, Washington. U. S. Dept. of Agriculture, Technical Bulletin no. 630. Rev. 1961. 59 p.

36. *Report to Congress on price trends and relationships for forest products;* Washington, D. C. Govt. printing office, House doc. no. 195, U. S. 85th Cong., 1st session. 1957. 58 p.

37. Scott, Anthony. *Natural resources: the economics of conservation;* Toronto. University Press, Canadian studies in economics no. 3, 1955. 184 p.

38. Stanford Research Institute. *America's demand for wood 1929-1975;* Tacoma. Weyerhaeuser Timber Co., 1954. 94 p.

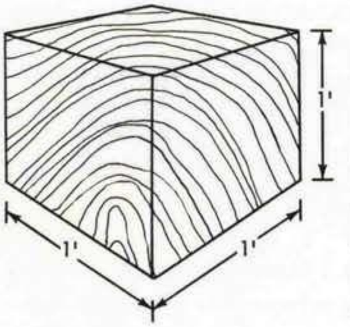
39. U. S. Forest Service. *Timber resources for America's future;* Washington, D. C. Govt. printing office. U. S. Dept. of Agriculture, Forest research report no. 14. 1958. 713 p.

40. U. S. Forest Service Forest Products Laboratory. *Wood handbook;* U. S. Dept. of Agriculture Handbook No. 72. Washington, D. C. Govt. printing office, 1955. 528 p.

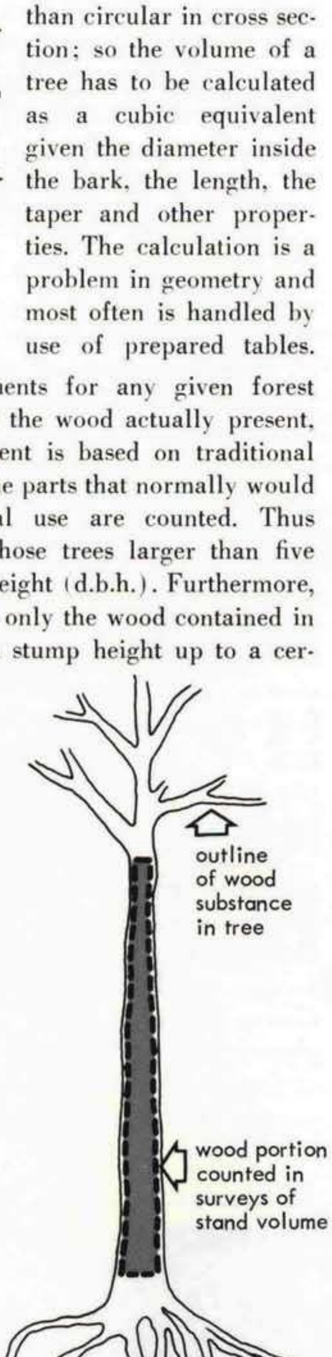
41. Worrell, A. C. et al. *A general review of U. S. Forest Service timber appraisal policies and procedures;* U. S. Dept. of Agriculture, Timber Appraisal Review Committee, Forest Service. 1963. 40 p.

APPENDIX A MECHANICS OF MEASURING WOOD VOLUME

Three common units of measurement are the cubic foot, the board foot, and the cord. By definition, a *cubic foot* contains the amount of wood illustrated in the following figure. Wood in trees, of course, occurs in the form of stem, branch and twig cylinders, often tapered, slightly curved, and oval rather than circular in cross section; so the volume of a tree has to be calculated as a cubic equivalent given the diameter inside the bark, the length, the taper and other properties. The calculation is a problem in geometry and most often is handled by use of prepared tables.

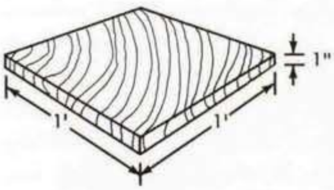


Timber volume measurements for any given forest tract will count only part of the wood actually present, but not all of it. Measurement is based on traditional commercial practices: only the parts that normally would be removed for commercial use are counted. Thus measurement is limited to those trees larger than five inches in diameter at breast height (d.b.h.). Furthermore, within this size class of trees only the wood contained in the main stem (trunk) from stump height up to a certain minimum diameter (say four inches) is counted. Thus the wood (a) in the stump and roots, (b) in the branches, and (c) above the point where the tapered stem reaches four inches in diameter is excluded. By convention, then, perhaps 30 to 40 percent of the wood substance physically present in a forest tract is not counted in volume estimates.



Obviously, volume figures for any large forest area could not be obtained by measuring every tree. They are instead the result of sampling procedures where actual measurements are made on selected scattered plots of perhaps 1/5-acre each; and the total for the forest is estimated by statistical methods. Hence, the published figures are *approximations* to the true volumes so defined, and while they will come fairly close for broad categories, they necessarily involve some sampling error. New data are periodically acquired, and forest volume estimates are revised accordingly.

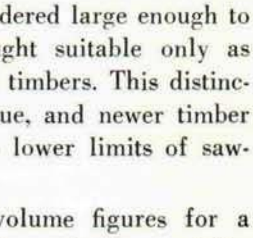
The second common unit of measurement, the *board foot*, is slightly trickier in concept. It can be visualized in physical terms as the quantity of wood in a board one inch thick and one foot square. However, when the measure is applied to stands of timber, it has several peculiarities also growing out of commercial practices.



First, the measure is applied only to a special size-class of timber called *sawtimber*. All trees over five inches d.b.h., collectively called *growing stock*, are subdivided into two categories: trees five inches to eleven inches d.b.h. are called *poletimber*, and trees eleven inches and more d.b.h. are called *sawtimber*. The latter category reflects older commercial usages, when trees less than eleven inches d.b.h. were not considered large enough to saw into lumber, but were thought suitable only as poles, posts, and other roundwood timbers. This distinction is no longer commercially true, and newer timber volume estimates have shifted the lower limits of sawtimber down to nine inches d.b.h.

Furthermore, the *board foot* volume figures for a sawtimber tree do not estimate total wood volume within the specified portions of the tree as do cubic foot figures; instead, they are estimates of the board foot volume of lumber that can be *sawed* from logs when run through the sawmill. Board foot volume estimates are made indirectly from measurements of tree diameter and height to the upper limit of the sawlog portion of the tree (the portion up to a diameter that may vary from about six inches for small trees to twenty-two inches for large trees), using one of several conversion scales in use.

The scale used in the Forest Service figures presented here, is called "the International ¼-inch Kerf Log Scale." It estimates how much standard lumber can be cut from an ideal cylindrical log using a saw that chews up a ¼-inch wide slice *(kerf)* for each cut made through the log. Further, an allowance is made for visible defect (rot

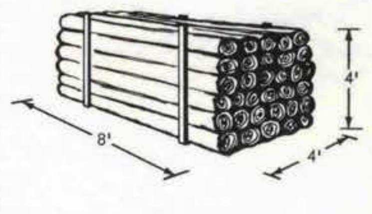


or scars) on the sawlog portion of the tree. The board foot volume of a tree, then, is calculated by taking measurements of tree dimensions and referring to standard tables that estimate the lumber yield.

But another important feature in the practical commercial applications of log scales arises from the fact that most logs are not perfect cylinders, but are slightly tapered and often oval in cross section. The diameter taken in measuring practice is usually the shortest one, and as a result the sawmill operator is able to squeeze out a few extra boards and so produce a greater number of board feet of lumber than is actually predicted by use of the log scale. The extra is called *overrun* and is an everyday experience in lumber production. The amount of overrun varies with the particular milling practices, diameter of the logs being sawed, and the log scale used. For example, cutting more 2-inch stock (in contrast to 1-inch boards) will save kerf and build up overrun. In western Montana, using the International ¼-inch Log Scale, overrun averages about 15 percent of the volume cut. Other scales commonly used are the Scribner Scale which gives estimates of board foot volume about 5 to 12 percent less than does the International ¼-inch Log Scale; and the Doyle Scale which estimates an even smaller volume, hence, an overrun considerably greater.

Because of the inherent ambiguities of these traditional board foot measures as indicators of forest volume, consideration has been given to an improved system of measures that would permit more meaningful inventory determination for forest management planning.

Finally, the *cord* is a gross measure of timber volume, usually applied to poletimber, based on early convention in stacking logs. A cord of wood by traditional measurement is the amount of wood in a pile of eight-foot logs stacked four feet high and four feet wide. Naturally the amount of wood present in a stacked cord will vary depending on whether bark is present or not, how thick the bark is, if present, and the shape (and to some extent, size) of the logs. As a rough average, one cord of poletimber contains approximately 85 cubic feet of wood as measured by the log scale discussed above.

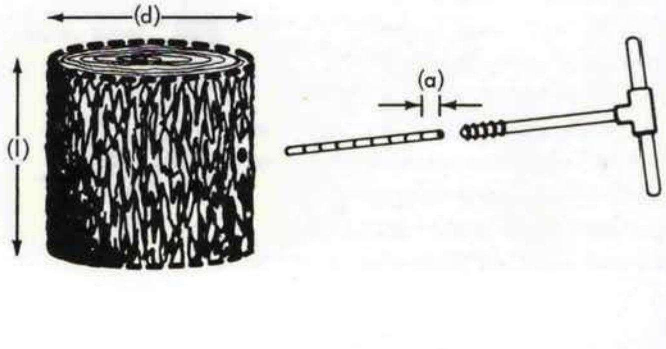


APPENDIX B MECHANICS OF MEASURING GROWTH RATES

The conventional units of volume measurement are used in measuring growth rates, whether for an individual tree or an entire forest area. For aggregate growing stock, and for poletimber separately, growth is usually measured in *cubic feet per year* or in *cords per year;* these two measures take account of the total volume of additions to roundwood within the merchantable portion of the eligible trees. Growth so measured comes from two sources: (a) the addition of wood growth rings including height growth to existing live trees in the five-inch and larger category, and (b) the entry of new trees into the small end of the size category, counting the whole of their merchantable cubic volume for the first time.

Sawtimber growth rates are measured in terms of *board feet per year* and count only the growth on sawtimber size trees, i.e., trees 11 inches d.b.h. and larger. The measure is not a true assessment of the total cubic volume added in the merchantable portion of these trees. Instead it is an estimate of the number of board feet of lumber that can be cut from the added log volume according to the conventional scale of conversion. As we indicated, using the International ¼-inch Kerf Log Scale, this estimate tends to understate slightly the true volume of lumber which would be measured in the yard after the logs are cut. Sawtimber growth also may come from two sources: (a) measurement of additions to the girth and height of existing live trees already in the sawtimber category, and (b) a tally of all of the scaled board foot volume in trees which have graduated from the poletimber category during the year.

Tree growth rates are estimated by examining tree rings. Borings from sampled trees give the thickness of tree rings. Combining these measurements with the diameter of tree and total length of the merchantable portion, an estimate of the volume added during a given number of recent years (and hence average annual growth rate) can be obtained. Ingrowth, or the addition of previously too-small trees into the size category in question may be estimated by surveys of sample plots in the forest.

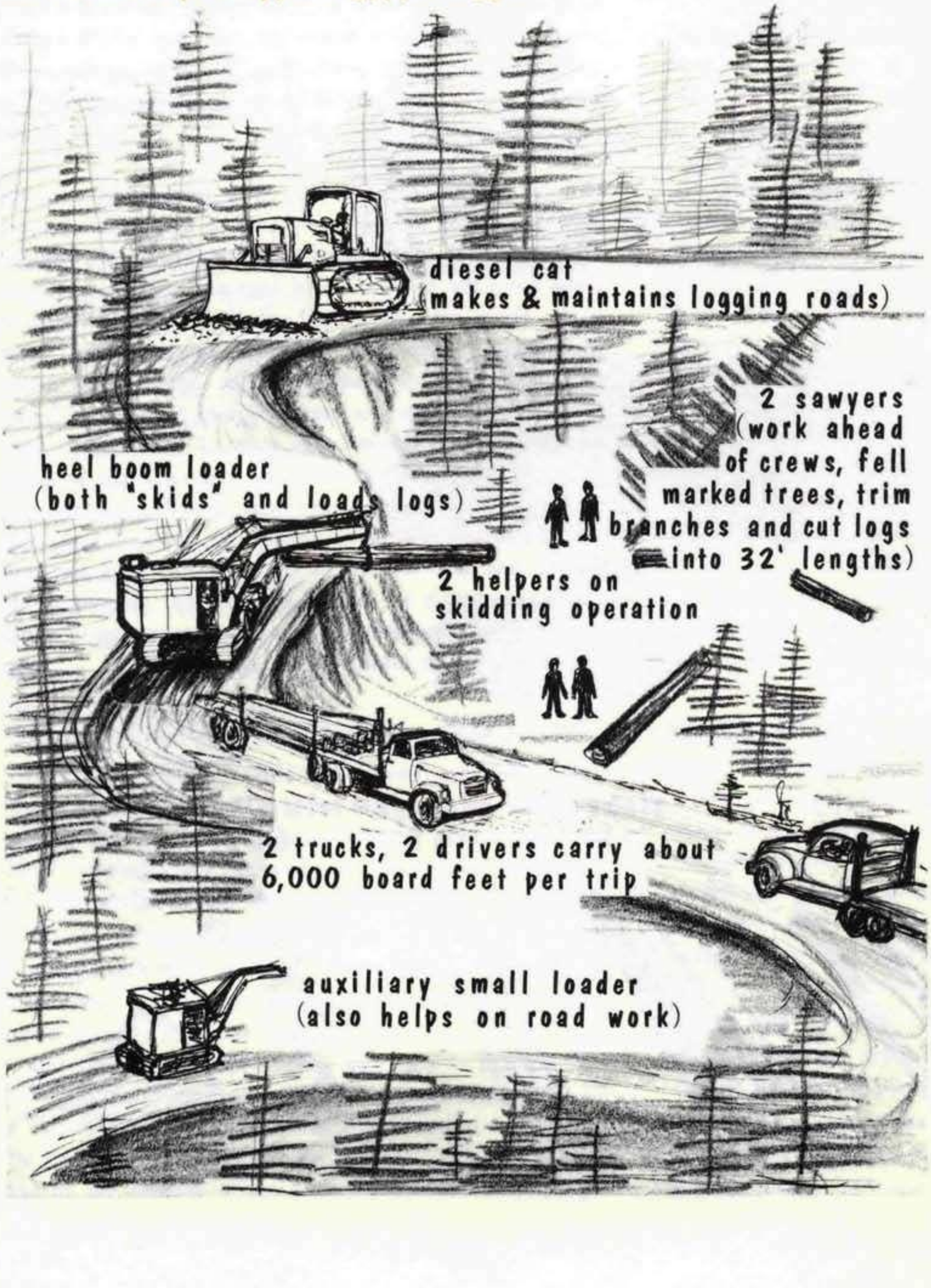


MECHANICS OF A LOGGING OPERATION

Logging operations have the principal task of converting stumpage (that is, trees standing on the stump in the forest) into logs of appropriately selected species and sizes delivered to the mill or other user. Some loggers may operate as independent firms (called a *gyppo* in the trade), buying stumpage, labor, equipment, and the other inputs, and in turn producing and delivering logs to a buyer, usually a sawmill, located some distance from the site of cutting. In the process an assortment of other outputs (including tops of trees, stumps, slash, and other logging residues left in the forest; roads and logging trails; and possibly some disturbance of undergrowth and ground cover) is also produced.

We have illustrated the basic woods operation in Chart 1 for a representative small firm from the Bitterroot area of western Montana. Stumpage in this particular operation has been purchased from the Forest Service. The trees to be cut under this sales contract are marked by the Forest Service (usually after the sale has been made). The contract specifies where and what quality roads are to be constructed, provisions for handling slash, tops and other residues left from logging, and methods of felling and handling trees.

Chart 1 — Setup of typical gyppo logger



This operation is conducted in a rugged mountainous terrain. One bulldozer and its operator are engaged in building or improving the necessary logging roads in advance of the logging itself. Two sawyers, who in this case are independent subcontractors to the logger, work ahead of the main crew. Felling of the selected trees is done with gasoline-powered portable saws, and many aspects of felling, such as maximum stump heights, may be prescribed by contract terms. The sawyers then trim branches from the merchantable part of the felled tree, and cut it into 33-foot lengths or multiples of 16 feet plus ½-foot trim per 16-foot log (called *bucking*). The bulk of the woods crew (in this case four men) assisted at times by a truck driver, are engaged in the job of *skidding* (hauling the cut logs up to roadside) and *loading* the logs onto the trucks. The workhorse in this operation is a heel boom loader which performs both operations: skidding, by reeling in its long steel cable on a winch, and loading, by swinging logs from roadside onto the truck bed with its boom. Two trucks are employed in continuous shuttle in this operation. These are special logging trucks whose rear trailer wheels jackknife up onto the truck for easier travelling on the empty return run to the logging site.

Sales are usually made in units of thousand board feet. The volume included in a particular timber sale operation (or *show* as it's termed in the trade) is often estimated by a cruise of the area prior to the sale. Or it may be tallied using a conventional log scale either on the ground at the landing or directly on trucks at a scaling station as they leave the national forest boundary. An operation of the sort illustrated here—nine men and about $200,000 worth of equipment—might produce about 75,000 board feet of logs per day, each truck running about four round trips to the mill buying the logs. Wear and tear on the equipment is high, and the operation is hazardous and strongly seasonal.

APPENDIX D MECHANICS OF A SAWMILL OPERATION

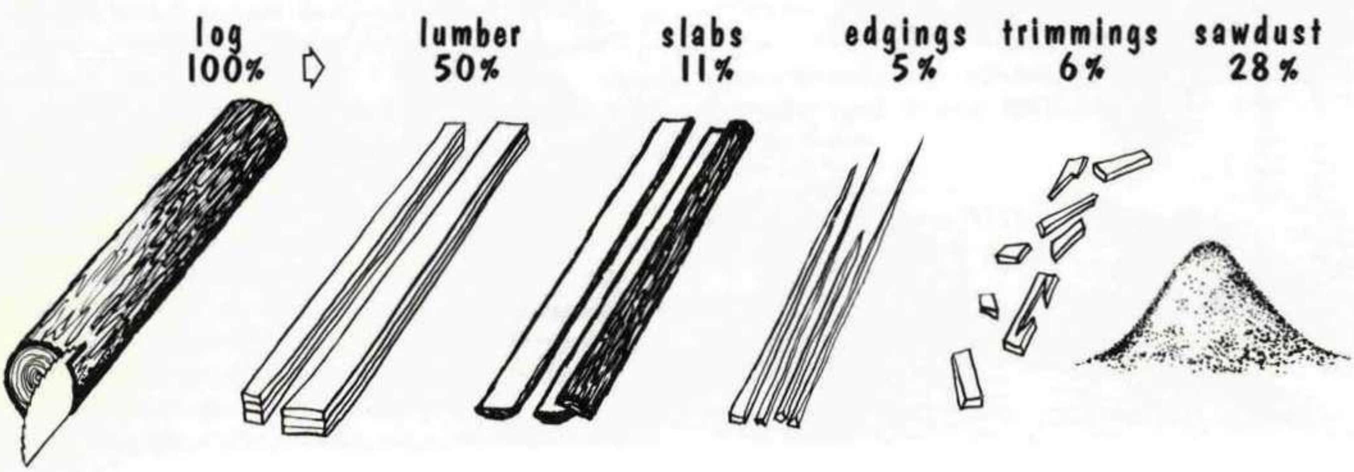
A small sawmill operation is illustrated in Chart 2, based on an actual operation in the Bitterroot Valley of western Montana. This operation can handle about 10,000 board feet per day. This is smaller than most mills, so not very typical in size, but will serve to illustrate all the major operations. Large sawmills in the western Ninth district range in capacity from about 40 MBF to more than 250 MBF per eight-hour shift.

In this mill wood flows through as follows: Logs are purchased from a gyppo contractor, hauled in by truck, and dumped either into the log pond or in stacks alongside the pond. Logs are floated onto a *jack-chain* which carries them into the mill. Ponding the logs has certain advantages apart from facilitating the sorting of logs for input to the mill; it helps remove the saw-dulling grit from tree barks, reduces checking resulting from logs drying out, and reduces dust problems in the mill. However, some yards do not use log ponds. Transportation of logs is restricted mostly to summer months, so a sizable inventory is built up for the winter.

The key piece of cutting machinery in the mill is the *headrig;* its capacity determines the capacity of the sawmill. Each log is in turn, dogged on a moving carriage and delivered lengthwise against the blade of the headsaw which rotates at high speeds. As each slice is removed it falls onto a moving roll case which carries it forward along the production line. The carriage then returns, under the control of the head sawyer, and the log is repositioned for another swipe by the headsaw blade whose position is fixed.

Each run produces a new slice that drops onto the roll cases, until the log is reduced to a smaller squared-off timber or cant. Some of the slices are partly rounded slabs from the outer sides of logs and consist mostly of bark. These may be routed off the production line as wastes or residues, and collected on a moving chain underneath the mill's working deck. Some of the pieces coming off the headsaw may be sliced to standard board or dimension thickness (one inch or two inches) with a ragged edge or edges (with or without some bark adhering) or they may represent boards finished and squared to rough lumber dimensions depending on how the log has been worked by the sawyer. Rapid decisions about how much to cut off and in what manner to cut them are very important in obtaining a maximum width and highest value lumber from each log.

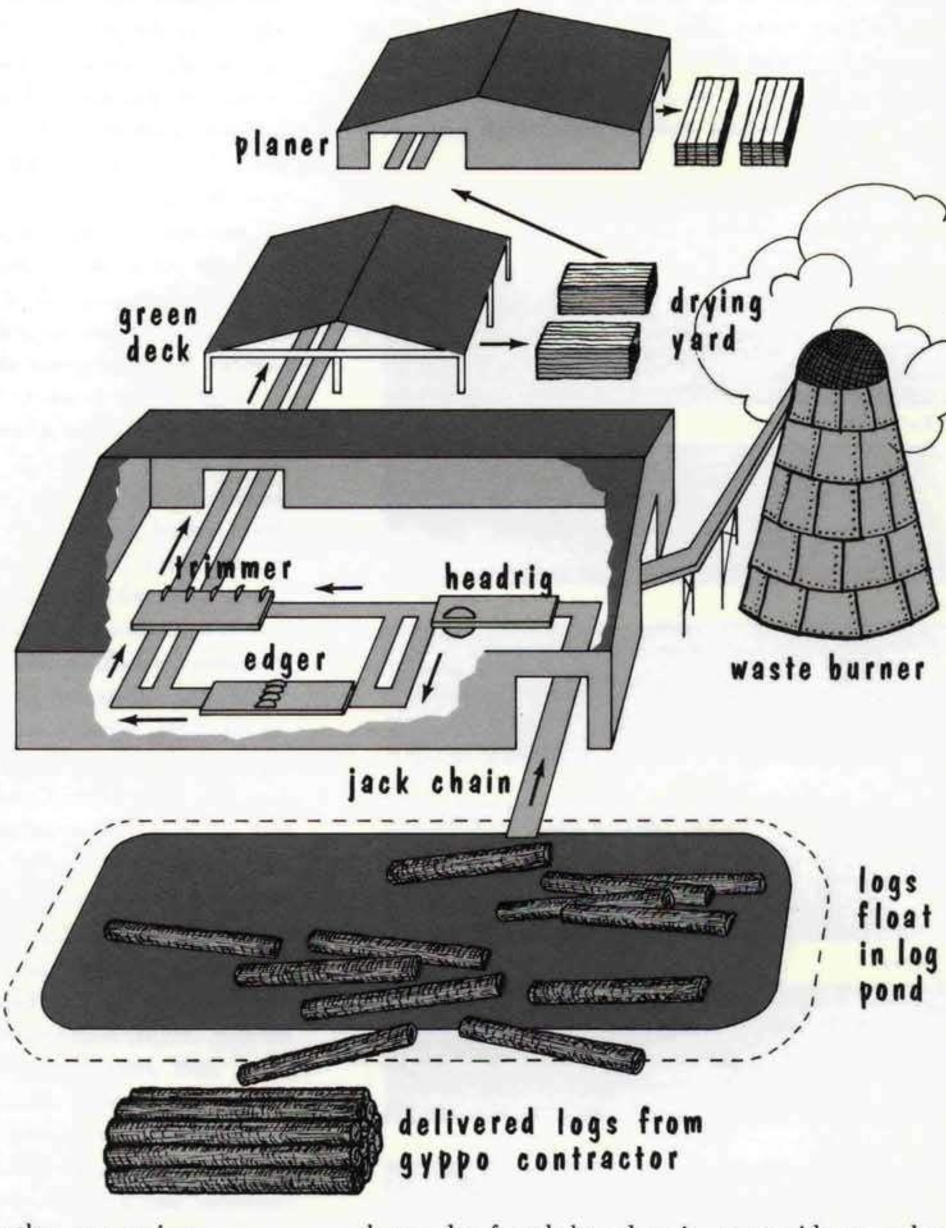
Chart 3 — Product yield from typical small circular sawmill



This sawmill is classified as a *circular sawmill* because of the form of its headsaw. Circular headsaws are more common in small operations. The wide bit (kerf) of such a saw converts a high proportion of the log into sawdust during the cutting process. The other broad category of sawmills, the *bandsaw mill* (also named after the form of its headsaw), requires a more costly initial investment but converts less of the log into sawdust.

Four kinds of outputs from the headsaw as illustrated in Chart 3 are: (1) sawdust, which is collected and dumped onto a lower level residue conveyer, (2) unusable bark-covered slabs, which are likewise dumped onto a conveyor that hauls them out to the waste burner, (3) rough sawn boards which are squared off in cross section by the headsaw; these are channeled straight ahead to the *trimmer*, and (4) rough sawn boards whose edges are not squared off in cross section because they bear some of the taper or curvature of the log and possibly some bark. These go to the *edger* for further processing.

Chart 2 — Setup of small sawmill

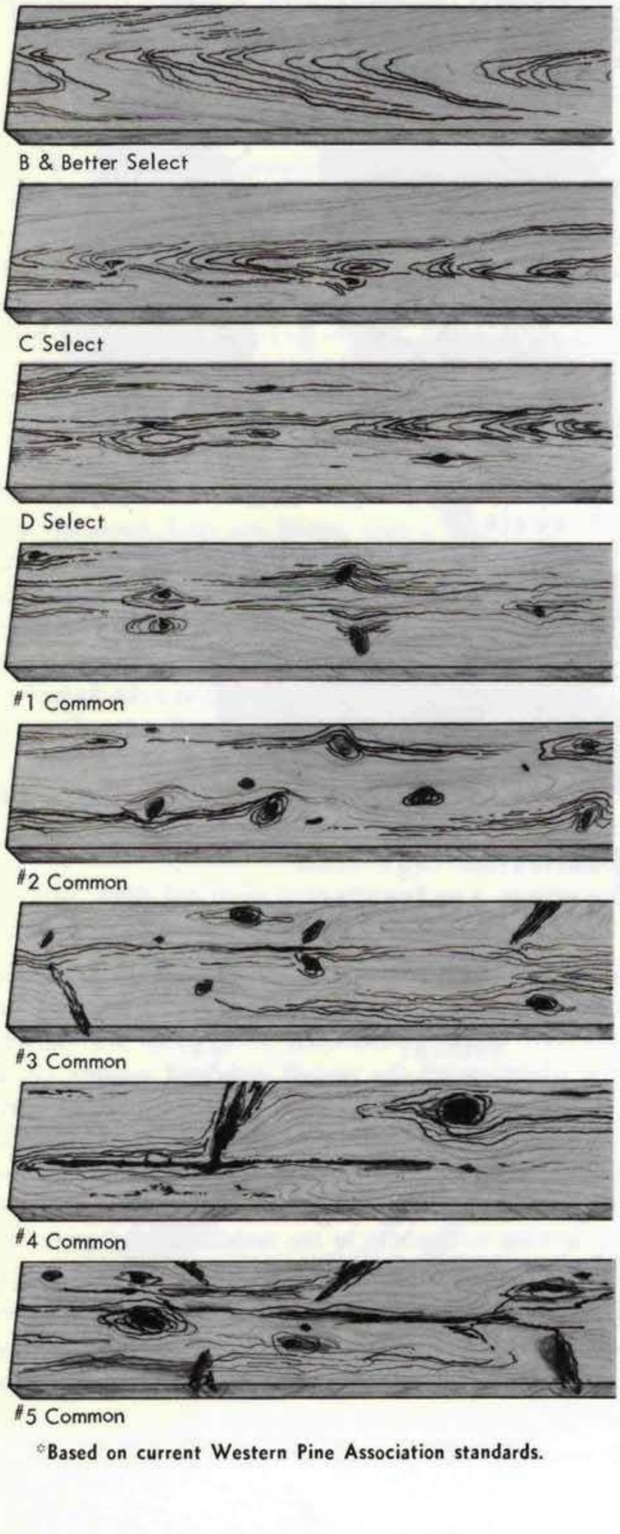


At the edger, the boards are moved parallel to their length and are ripped in cross section by cutting them to somewhat narrower average widths. Scraps from the edger (edgings) are dumped onto the residue conveyors; the rectangular boards then are conveyed to the trimmer.

Boards of approximately log length (about 16 feet) now approach the trimmer at right angles to their length; some have been routed through the edger, while others arrive directly from the headsaw. They now move one at a time through the last sawing operation in this particular mill. The trimmer consists of a lineup of saws poised at two-foot intervals across the full twenty-foot width of the trimmer, and ready to be dropped in any combination at the control of the trimmer operator. He judges the needs of each board as it moves sideways along the conveyors. For a full-width, squared board this may involve two quick simultaneous slices from the outside saws, trimming off the ragged ends and passing out a completely end-trimmed rough-sawn board of an even number of feet in length (say 18 foot). Some boards, however, still may be tapered or irregular near one end; or they may have sections of bark, rot, or other defect showing somewhere in the middle. The trimmer operator will then lower other saws and trim out or trim off the defective parts. This yields end-trimmed, shorter-length boards—always in multiples of two feet. Scraps from trimming operations are, as before, dumped onto a conveyor to be collected with other residues, which in this particular mill are carried directly to the burner.

This by no means represents a model sawmill; a great many improvements can be made in the name of efficiency although its flow chart illustrates all the basic operations. In many mills an extra unit called a *resaw* is added in the flow sequence, to which pieces can be consigned directly from the headsaw and through which pieces cut once by the resaw may be recycled for a second (or third) run. Boards from the resaw may be run either to the edger or the trimmer, as desired. This device permits greater range of choice in cuts at the headsaw, increases its capacity by freeing the headsaw to do more of the basic work on the logs, and increases lumber recovery when, by judicious sawing, mill operators have learned to recover greater yield from each log.

Chart 4 — Illustration of appearance of various lumber grades*



*Based on current Western Pine Association standards.

From the trimmer, rough-sawn green boards are moved edgewise out of the building to a covered shed where the boards are drawn off at various points along the so-called *green chain* according to species, size and grade. Lumber from the green chain may be sold to other mills as rough green lumber. But most of it is stacked in a manner that permits free air circulation around the lumber to dry or season it. The drying process may take roughly 30 days to three months. Mills may instead use a steam-heated dry kiln, in which case drying time is cut to a few days. After drying, the pieces are run through a *planer* from which seasoned and finished lumber, sorted by grade, is then ready for sale. Chart 4 is an illustration of appearance characteristics of principal lumber grades.

This has illustrated a very minimal sawmill operation, yet all of the region's sawmills, however large, are simple elaborations on this basic plan. The major elaborations take two directions. One is the utilizations of residues and the other is secondary manufacture applied to the basic sawn lumber. The latter brings wood to a more advanced stage of processing (moulding, etc.).

The processing of a single log as depicted in Chart 3 yields only about 50 percent of the whole wood volume contained inside the bark of the log as rough sawn lumber. Slabs, edgings, and trimmings, with or without some bark attached, account for some 22 percent of the wood hauled in from the forest, while sawdust accounts for the remaining 28 percent. In the mill illustrated in Chart 2, all the residues are carried by a chain conveyor into a waste burner where they are burned, no use being made of the heat generated except to keep the log pond from freezing during the winter.

Some mills, however, may utilize in one way or another all of the residues from the sawing process (including planer shavings), by cutting lath and crate stock from some of the smaller pieces, using chips and chunks in pressed wood products, using some of it for generating steam and/or power requirements, and other uses. In order to more effectively utilize the whole-wood residues, larger mills install debarking machinery which removes bark from the logs prior to delivery to the headsaw. Whole-wood residues free of bark are converted into chips for pulping. This also produces log-free bark, which in some instances can be of greater commercial value than pulp chips (used for mulches, etc.).