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The aspens : their growth and management

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HENRY S. GRAVES, Forester.

THE ASPENS:

THEIR GROWTH AND MANAGEMENT.

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Washington, D. C., March 22, 1911.

SIR: I have the honor to transmit herewith a manuscript entitled "The Aspens: Their Growth and Management," by W. G. Weigle, Forest Supervisor, and E. H. Frothingham, Forest Assistant, and to recommend its publication as Bulletin 93 of the Forest Service.

Very respectfully,

HENRY S. GRAVES, *Forester.*

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE ASPENS:
THEIR GROWTH AND MANAGEMENT.

INTRODUCTION.

The aspens, or "popple," as they are often collectively termed, occupy a peculiar position in the forests of North America. Growing up rapidly and in great abundance over areas which have been deforested, usually by fire, they attain only a small size, produce a soft, weak wood, extremely valuable for a limited number of uses, and die at a relatively early age. They are, in fact, the first effort which nature puts forth to restock burned lands and reclothe the ground with forest, and it is this, perhaps even more than their commercial utility, that constitutes their chief value as a forest tree. Their very light foliage rarely hinders and usually protects the young growth of more widely useful but slower-growing trees, which find little difficulty in growing up through the crowns of the aspen and ultimately in displacing it. Nevertheless, the dense thickets of root sprouts or suckers which aspens ordinarily produce immediately after logging may choke out and for many years prevent the seeding in of other species. When this happens the presence of aspens becomes a distinct menace instead of a help to the establishment of more desirable trees. Because of their great abundance in many regions, their relations to other species, and their undoubted value for certain uses, the aspens will always form an important element in the northern forests.

Pulpwood logging has already badly depleted the merchantable stands of aspen in the northeastern United States. At the same time increasing efficiency in fire protection renders the natural establishment of aspen stands on their former extensive scale more and more problematic. Under these conditions aspen-pulp manufacturers must eventually either move their mills to new regions, where the supply is yet abundant, ship their wood in from these regions at an increased expense, or devise profitable means of perpetuating the supply of aspen within reach of their mills. It is the purpose of this bulletin to bring together the most important facts concerning the aspens, and with these as a basis, to suggest some methods by which aspen stands may be profitably managed.

THE SPECIES OF ASPEN AND HOW TO DISTINGUISH THEM.

North America possesses 11 species of poplar,[1] and it is to two of these, which differ somewhat from the others in their appearance and habits, that the name aspen has been given.

One of these, the "quaking aspen,"[2] *Populus tremuloides* Michx.,[3] is noteworthy as the most widely distributed American tree, while the other, the largetooth aspen, *Populus grandidentata* Michx., is much less widely distributed and owes its importance mainly to its companionship with the quaking aspen through part of its range and its usefulness for the same purposes. The name "popple" is applied to both of these species in the northeastern United States and Canada. Another species of poplar, the balm of Gilead, *Populus balsamifera* Linn., is also sometimes included under this name.

Aspens show their relationship to other poplars in their smooth, light-colored young bark, their soft, weak wood, their rather sparse foliage of roughly triangular leaves, with flattened leaf stalks and arranged alternately on the twigs, the time and manner of their seed production, and their rapid growth. They differ from other poplars chiefly and most conspicuously in their more gregarious habit, the much smoother bark of the trunk, their usually smaller size when full grown, and their relatively long leaf stalks, so slender that the least wind stirs the foliage into motion.

The two species of aspen resemble each other so closely in general appearance that they may easily be confused. They have certain peculiarities, however, by which they can be readily distinguished at any season. The most apparent of these in summer are the margins of the leaves, in winter the color and shape of the buds, and at all seasons the color of the bark.

The leaves of largetooth aspen, as its name implies, have their margins conspicuously and coarsely toothed; the leaves of quaking aspen, on the other hand, have their margins indented with much smaller and more numerous teeth and are, under normal conditions, considerably smaller than those of large-tooth aspen and of a slightly lighter shade of green.

The bark of largetooth aspen is of a light ocher-yellow tint, with which the greenish-white bark of quaking aspen makes a noticeable

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[1] Exclusive of the tulip or yellow poplar, *Liriodendron tulipifera* Linn., a large and important tree of the South, with only a remote resemblance to the true poplars.

[2] The name "quaking aspen" is used in this bulletin for *Populus tremuloides* wherever the two species of aspen are compared or contrasted. Where no distinction is necessary, the general term "aspen" is used.

[3] *Populus tremuloides* Michx. presents, in its extremely wide range, several different forms. Dr. N. L. Britton has segregated one of these as *Populus cercidiphylla* (North American Trees, 180, 1908). Mr. Ivar Tidestrom has also characterized one from Ohio as *P. tremuloides davisiana* (Notes on Populus, Plinius, 15, Pl. I, fig. 10, 1911) and another from Colorado and Utah as *P. aurea* (l. c., figs. 5, 6, 7). For the purpose of this bulletin, however, it is thought best to treat these segregates as forms of one widely variable species.

contrast. The difference is especially well-marked in young timber, and becomes less apparent as the bark loses its smoothness and becomes ridged. This difference is responsible for the lumberman's names for the two aspens of "yellow" (largetooth) and "white" (quaking aspen) popple. In certain situations, and apparently when growing among heavier-foliaged associates, the bark becomes ridged while the trees are still small—4 or 5 inches in diameter breast-high. The ridged bark appears somewhat earlier in largetooth than in quaking aspen.

The leaf buds of quaking aspen are sharp pointed and red in color, while those of large-tooth aspen are obtuse and of a grayish color. This feature and the color of the bark form the best means of identifying the species in the winter, when the leaves are off.

There are several other less marked differences between the species, but those already mentioned are sufficient to afford positive identification. One distinguishing peculiarity of largetooth aspen, noted in the vicinity of Katahdin Iron Works, Me., is a bright carmine stain on the peeled trunk immediately following the removal of the bark in spring logging.

THE WOOD.

The wood of both the aspens is light, soft, weak, compact, and very perishable in contact with soil. The broad sapwood is creamy white in color and the heartwood is light brown. The difference between heartwood and sapwood, however, is usually scarcely appreciable in green and freshly seasoned wood. A cubic foot of air-dried wood weighs from 25 to 30 pounds.

Aspen wood does not possess a long fiber, and consequently produces a weak paper unless mixed with longer fibers, such as those of spruce. The length of the fibers varies greatly in specimens taken from different trees and from different parts of the same tree. Two sets of measurements of a large number of fibers made by members of the Forest Service gave the following results:

	Length in millimeters.		
	Average.	Maximum.	Minimum.
Populus tremuloides	0.95–1.05	1.44–1.59	0.50–0.56
Populus grandidentata	.98– .99	1.37–1.63	.51– .64

Cellulose determinations made for sound sticks of from 8 to 10 inches in diameter gave about 62.8 per cent for both species.

Aspen lumber is easily worked and seasons rapidly, but warps and checks badly. The grain is often badly twisted, especially in the western part of its range.

USES.

MISCELLANEOUS.

The small size, lack of durability, softness, and weakness of aspen wood and its liability to warp render it poorly adapted for many important uses, such as lumber, ties, poles, and mine props. It can not, for example, compete with larger species, such as pine and spruce, for construction lumber, nor with more durable woods like oak, cedar, and chestnut for ties, poles, and mine props, but there are many uses in which size and durability are not important, and it is to a number of these that the many good qualities of aspen wood adapt it excellently. Its chief uses at present are for paper pulp, excelsior, and fuel. Although statistics are not available for other uses than that of paper, its consumption for excelsior and fuel is probably at least as large as for pulp. For fuel, corral poles, etc., it is principally cut in small quantities for local use in the regions in which aspen is the most available tree, and large quantities are used in this way every year. As fuel it makes a quick, hot fire, suitable for baking.

Aspen lumber is considered an excellent material for barn floors, stalls, and all parts of barns subject to kicking or gnawing by animals; though soft, it is tougher than pine, wears quite well, and does not splinter badly under heavy use. It is employed to some extent for box boards and for veneer. Aspen is already being used to a small extent for the manufacture of low-grade spools. It seasons more rapidly than birch, and its use as a substitute for the lower grades of birch in spool manufacture will probably extend its range of utility.

In Europe the closely related species, *Populus tremula* Linn., produces the best and whitest wood pulp, and is also widely used in match manufacture.[1] Charcoal from this tree is extensively employed in making gunpowder. It is used for box boards, furniture backing, and even mine props, and a coating for foundry molds is made of the ground wood, mixed with water, for separating sand from metal and facilitating the removal of the latter. Eventually American aspen will undoubtedly come into use for many of these purposes and for others where a soft, light wood, not necessarily of large size, is desired.

The fact that small sizes suffice for most of the uses to which aspen is put gives it two great advantages for silviculture over trees whose value depends upon size: (1) Utilization is practically complete, and there is little waste except in the stumps; and (2) salable wood can

[1] The cheap safety matches which are imported in large quantities into this country from Sweden, Germany, Russia, and other countries are made chiefly from aspen wood.

be obtained from thinning young or middle-aged stands which have reached merchantable size but which are too dense for rapid growth.

ASPEN PULP.

While spruce, fir, hemlock, and other coniferous woods supply the bulk of the pulp used in the manufacture of news paper, wrapping paper, wall paper, etc., aspen produces a paper that is peculiarly adapted for use in the manufacture of books and magazines, and it is at present the most important source of supply for these uses. Paper manufactured from aspen alone would be too weak for such uses, and manufacturers customarily add a certain amount (usually about 40 per cent) of sulphite spruce, because of the strength which the longer fibers give. The finished paper is tough, white, and easily sized, and though inferior to rag paper for the finer uses, it is much cheaper.

Among the advantages of aspen over other northern "hardwood," or broadleafed trees for pulp manufacture are the relatively low cost of logging it and the ease with which its pulp can be bleached. With the discovery of practicable bleaching methods for such woods as paper birch, white maple, etc., these also may come into extensive use for the manufacture of book and magazine paper, although the greater ease with which aspen can be peeled and logged will continue to give it the advantage.

Aspen pulp is manufactured by what is known as the "soda" process. Large mills, running to capacity, produce about a ton of paper per hour. About 1,000 to 1,200 pounds of air-dried, bleached pulp are produced per cord of aspen bolts. Theoretically a cord should yield over 1,400 pounds of air-dried, unbleached pulp, but there are always losses in pulping, bleaching, and washing; these losses are diminishing as the manufacturing processes become more thoroughly understood.

More aspen is used for paper making than any other wood except spruce and hemlock. In 1909, according to statistics obtained by the United States Census Bureau in cooperation with the Forest Service, approximately 328,500 cords of "poplar" wood were consumed in the United States. Of this amount it may be safely estimated that 75 per cent—246,375 cords, or more than 6 per cent of the total amount of wood pulp consumed in 1909—was of aspen alone, while the remaining 25 per cent, 82,125 cords, was of other species classed with aspen under the common trade name of "poplar." About 7.8 per cent, 25,622 cords, of the aspen used was imported from Canada. The total amount of domestic "poplar" used in 1909 was equal to about 18 per cent that of domestic spruce, 54 per cent that of domestic and imported hemlock, and 68 per cent that of all other species, domestic and imported.

EXCELSIOR.

Aspen produces a high-grade excelsior, and there are many mills operating throughout the New England States and New York that use annually about 40,000 cords of aspen, and have for many years supplied a large part of the excelsior used in this country. Basswood produces a quality of excelsior fully as good as that made from aspen, and the selling price is usually about the same, but since basswood is much more valuable for other uses, its use for excelsior is not economical, and it will probably not compete seriously with aspen in excelsior manufacture.

The scrub or "Jersey" pine, *Pinus virginiana* Mill., is a formidable competitor with aspen for the excelsior trade. Notwithstanding the better quality of aspen excelsior, the greater cheapness of the pine excelsior leads to the conclusion that it will eventually drive out aspen excelsior from some of its present markets.

PULPWOOD LOGGING.

Pulpwood logging is carried on in the spring because the trees peel much more readily at this season, when the "sap runs," than at any other. The woods work begins, therefore, about the middle of May. Toward the middle of July peeling becomes difficult and the felling ceases. In order to utilize fully the peeling season the work within this period is usually restricted to the felling and peeling of the trees. Climatic conditions determine the length of the peeling season as well as the ease with which the peeling can be done. The longer the spring period of moisture continues the greater the number of trees which can be peeled.

When the peeling season ceases the trees are either cut into 4-foot lengths and piled or hauled intact to the river in which they are to be driven. Aspen logs do not drive well, and even when seasoned by being left exposed to dry air many will sink if driven for a considerable distance. They are therefore frequently rafted with logs of spruce. Aspen is sometimes driven in 4-foot lengths, but when this is done the loss from sinkage is usually great. The greater portion of the aspen, however, is sawed up and hauled over snow roads to a railroad.

Stacked wood is scaled by measuring the length and height of the pile and dividing the area in square feet by 32, which is the number of square feet in the side area of a cord; or, if the piles are all 4 feet high, by dividing the total length of ranks by 8. When the tree is scaled as a whole the Fabyan cordwood caliper scale is used. By the former method 128 cubic feet of wood and air space between are considered a cord, while in the latter case 128 cubic feet of solid wood are taken as a cord. In checking up it is found that for large

timber the caliper scale overruns, while for small timber it will not hold out.

Both stumpage value and the cost of labor vary considerably. During the past five years stumpage values have ranged from 75 cents or $1 per cord in Maine, to $1 or $1.25 in New York, varying greatly with the accessibility of the timber. The cost of cutting, peeling, cutting into 4-foot lengths, and piling is usually from $1.35 to $1.60 per cord. Labor is paid either by the cord or by the month. It is usually cheaper and more satisfactory to pay by the cord.

The men commonly work in pairs, and two men can fall and peel about 50 average trees (about 12 cords) per day. Two men can saw up and pile only about 6 or 8 cords per day on an average, so that if the peeling season lasts two months nearly four months more will elapse before the logging operation is completed, unless the force is increased. Hauling over snow usually costs from $1 to $1.50 for a 5-mile haul.

From $3.50 to $5 per cord on board cars has ordinarily been paid by local buyers. Laid down at the mill the wood costs about $6 or $8.

GENERAL RANGE.

No other tree in America has so wide a distribution as quaking aspen, *Populus tremuloides*, and it is safe to say that in all the world the only tree which exceeds it in this respect is its near relative, the European aspen. Together these trees nearly encircle the land surface of the globe, the European species covering 140° and the American 112° of longitude. In latitudinal distribution the American aspen covers 41°, while the north and south range of the European species is about 35°. The large-tooth aspen is very much more restricted than the quaking aspen, but even this species compares favorably as to range with many trees of the eastern United States.

QUAKING ASPEN.

The northern limit of the range of quaking aspen extends from Labrador west to the southern shores of Hudson Bay, thence northwestward to the Arctic Ocean at McKenzie Bay and along the Porcupine and Yukon Valleys to Norton Sound, in Alaska. It grows north of the Arctic Circle, from the shores of Great Bear Lake, in the Northwest Territory, to Kotzebue Sound, an arm of Bering Strait. Southward it is abundant in most of the inland Alaskan forest, grows as far west as the inland slopes of the Coast Ranges in British Columbia, is found, though not so abundantly, throughout the States of Washington and Oregon, and extends through northern California and down both slopes of the Sierra Nevada to Kern River, in south central California. In Mexico it is found in a few

localities on the plateau of Mount San Pedro Martir in Lower California, and reaches its southern limit in the mountains of Sonora and Chihuahua.

The bulk of its western distribution is, however, in the Rocky Mountains, where it is common on burned slopes, especially in the central and south central ranges.

Quaking aspen is found only in isolated localities throughout the plains region from southeastern Alberta and southern Saskatchewan southward to Kansas. From much of this region it is absent altogether and is usually restricted everywhere to river valleys.

From Manitoba it extends southeastward through eastern North and South Dakota, Iowa, central Illinois, southern Indiana, and north central Kentucky, eastward through the Great Lake region to the Atlantic seaboard as far south as New Jersey. It extends south along the Appalachian Mountains to the southeast corner of Kentucky and into eastern Tennessee.

Aspen is essentially a cold-enduring and a moisture-needing tree, and just as in the North it grows close to the limit of tree growth, in the mountains it is found in the cool, moist climate of the upper or alpine zone of vegetation. Since this zone rises in altitude as it extends southward, the range of aspen is correspondingly elevated. In Alaska it grows between sea level and elevations in protected gulches varying from 2,000 to 3,500 feet; in Washington, Oregon, and the northern Rocky Mountain States usually between altitudes of 1,100 and 6,000 feet; in California between 5,000 and 10,000; and in Colorado, Utah, Arizona, and New Mexico between 6,000 and 11,000 feet. In the State of Washington it is found at sea level, while in Lower California it does not grow below 8,000 feet. These figures represent the approximate extremes of aspen growth; its best growth, in point of size and abundance, is found within much narrower limits.

In the East, owing to more favorable moisture conditions, aspen is not so dependent upon high altitudes in its southern extension. In Maine its best growth is between altitudes of 700 and 2,000 feet, though it grows to within 20 feet of tidewater. Near its southern limits in Kentucky it is found below 600 feet in the north central and between 1,000 and 2,000 in the southeastern part of the State.

LARGETOOTH ASPEN.

Largetooth aspen has not been recorded farther west than the Riding, Duck, and Turtle Mountains in Manitoba and north central North Dakota. Its distribution corresponds closely to the eastern part of that of quaking aspen, but it extends somewhat farther to the south, into North Carolina and central Tennessee. Owing to its similarity to quaking aspen and to the fact that it is often mistaken for that species, the northwestern limits of its botanical range are

still undetermined. Though not commonly so abundant as quaking aspen, there are localities, notably in Maine, Manitoba, and Minnesota, where the reverse is the case. Its altitudinal range is approximately that of quaking aspen in the East.

COMMERCIAL RANGE.

The economic utility of the aspens extends far beyond the region of their use for paper making, but since much the greater part of the recorded annual cut is consumed as pulp wood, this region may be considered as their present commercial range. However, some aspen as already being cut for pulp outside of this area. The vast stands of quaking aspen in Utah and western Colorado will in the future undoubtedly furnish abundant raw material for this industry. At present the principal mills using aspen pulp are located in eastern New York and southern Maine, although the logging operations, at first confined to the country adjacent to the mills, have now spread throughout the northeastern and Lake States and southeastern Canada.

The centers of aspen wood consumption in the United States are indicated in Table 1, prepared from the census of pulp wood consumption for 1908.

TABLE 1.—*Consumption of "poplar" pulp wood, 1908.*

	Domestic.	Imported.
	Cords.	*Cords.*
New England	114,343	5,649
New York	46,434	14,986
Pennsylvania	35,424	.....
Lake States	6,646	2,018
Total	202,847	22,653

The aspen in these regions, as in most of its range, chiefly occupies the sites of past fires, and the extent and date of the last fire can often be closely approximated from the age and extent of the aspen stand which followed it. Chief among the fires of recent times was the Miramichi fire of 1825, which burned for nearly 100 miles on both sides of the Miramichi River in New Brunswick. During the same year great fires also swept over large areas in northern Maine, and the total surface burned in that year amounted to at least 5,000,000 acres, comprising, in addition to the Miramichi region, a broad belt of country extending from the Rangely Lakes in Maine northeastward to beyond the Penobscot River. Thus it happens that throughout this region there exist numerous more or less extensive aspen stands about 85 years old, and it is this mature aspen which has supplied the bulk of the aspen pulp for the northeastern

United States. On an average, this area contained about two cords of aspen per acre. Of this not more than 4,000,000 cords have been cut or burned. The present stand in the drainage basin of the Miramichi River has been estimated to contain at least 3,000,000 cords. A large part of the area swept by these early fires has been subject to later burnings, so that even-aged stands of many different ages may be found within this region. Notable among these are the extensive 25-year-old stands in the Dead River region of Maine.

Aspen stands seldom cut over 35 cords to the acre, although small areas of pure aspen sometimes run higher. Twenty cords per acre is considered very good, though it is not unusual. A yield of less than 5 cords per acre for mature stands is very poor. Many large stands in northern Maine and New Brunswick will average from 5 to 20 or more cords per acre over quite extensive areas, and it is only in such places that operations are considered worth while at present.

THE TREE.

CLIMATIC REQUIREMENTS.

As has already been stated, the aspens are preeminently cold-enduring and moisture-loving trees. Quaking aspen, in particular, endures at its northern and upper altitudinal extremes very severe temperatures, while in the South it thrives in the cold climates of high altitudes, where it receives an abundance of moisture. In the southern Rocky Mountains and the Sierra Nevada it often endures long periods of drought, but only where its roots are well supplied with moisture, as along streams. In the plains region, also, where the precipitation would otherwise be insufficient, aspens grow along stream courses. In the eastern United States both species receive approximately from 30 to 40 inches of annual precipitation. The growing season is very short in the North, and killing frosts sometimes occur every month in the year. Farther south, however, it often exceeds five months in duration.

SOIL AND MOISTURE REQUIREMENTS.

For their best growth the aspens require deep, fresh or moist, but porous and well-drained soils. Sandy loams mixed with decayed vegetable matter are the best. In the Rocky Mountains thrifty stands of quaking aspen are often considered good indications of agricultural soil.

The aspens are not, however, absolutely restricted to fertile soil. They are often found in abundance on thin, fairly dry soil, as well as in poorly drained situations. In such places, though there are commonly more trees to the acre, they never grow so rapidly, so large, or to so perfect a form as in the better situations. Thus, in

northern Maine a 31-year-old aspen stand growing on deep, loose, sandy loam contained 672 trees per acre, about 60 feet high and from 6 to 8 inches in diameter, while on a dry, gravelly ridge within 10 rods of the other a stand of the same age contained 1,224 trees per acre, but averaging only about 25 feet in height and from 2 to 5 inches in diameter.

In the East the best stands of aspen are found on loamy soil, either adjoining lakes and streams or on little knolls or benches along the lower hills or in ravines or on benches far up the sides of mountains, but in all places where it thrives the soil has the same general characteristics. It is interesting to note that it is just such soils which produce the best growth of spruce and fir.

TOLERANCE OF SHADE.

The striking intolerance of shade exhibited by aspens and its effect upon the life history of aspen stands is perhaps the most important feature bearing upon the relation of these species with other trees which grow in company with them.

From the seedling stage to old age the aspens bear less shade than any of their associates. Even paper birch, the most constant companion of aspen in the northeastern and Lake States, though itself very intolerant, is less so than the aspens. Nearly all the other trees which grow with them are able to strike root and grow even better under the protection afforded by the thin foliage of the aspens and paper birch than without; but the aspens are unable even to survive for more than a very short time under the light shade of their parent trees. Unless their crowns are in full light from the very start, they fall early victims to the shade of their more aggressive neighbors. Thus, aspen stands which may be practically pure during youth gradually give way to longer-lived and more shade-enduring species, and only rarely succeed themselves.

Aspen root sprouts, or suckers, which spring up from the roots of recently felled or burned trees, are even less tolerant of shade than seedlings, and die within a few years unless they are practically free from shade. The precise amount of light necessary for the successful development of root sprouts has never been determined, but an estimate, based on the density of the crown cover, was made in the course of this study. The data are the results of counts made over many measured sample areas in different parts of Maine, and are given in Table 2.

TABLE 2.—*Effect of shade on the length of life of aspen root sprouts.*

Density of crown cover (1 is complete cover, crowns touching).	Quantity of sprouts.	Condition of sprouts in consecutive years following logging.[1]								
		First year.	Second year.	Third year.	Fourth year.	Fifth year.	Sixth year.	Seventh year.	Eighth year.	Ninth year.
0.8	Scattered....	B	B	C	D	E	.....	.....	.....	.....
.7	Few.....	B	B	B	C	D	E	.....	.....	.....
.6	Abundant..	A	A	B	C	D	D	E	.....	.....
.5	.....do.....	A	A	B	C	D	D	D	D	E
.4	.....do.....	A	A	B	B	C	D	D	D	D
.3	.....do.....	A	A	B	B	B	B	B	B	B
.2	.....do.....	A	A	B	B	B	B	B	B	B
.1	.....do.....	A	A	A	A	A	A	A	A	A
.0	.....do.....	A	A	A	A	A	A	A	A	A

[1] Legend:
A=Dominant sprouts thrifty; sufficient on the ground for a pure stand of aspen.
B=Dominant sprouts in good condition in open spaces.
C=Sprouts nearly all dying.
D=Sprouts nearly all dead.
E=Sprouts all dead.

From this table it is obvious that root sprouts resulting from the logging of aspen can not be depended upon to reach commercial size unless the area is cut practically clear.

As the trees in a stand increase in size, the struggle for light becomes more and more intense. In stands of root sprouts the vigorous trees, and those best situated as regards soil and light, become noticeable by their greater height as early as the tenth year. The trees which are left behind receive less and less light as their neighbors put on more foliage, and eventually die. This process is kept up throughout the life of the stand and makes possible the classification of all the trees as: (1) Dominant, those which are noticeably above the average height; (2) intermediate, those of average height, crowded by their neighbors; and (3) suppressed, those which are hopelessly outdistanced.

GROWTH.

The aspens are commonly considered among the most rapidly growing trees of the northeastern United States, and this is undoubtedly true of young trees in favorable situations. The rate of growth, however, is frequently very much overestimated, especially in the case of full-grown trees.

Since aspen stands become established within a very few years after burns and clearings, if they come in at all, the age of a stand can be closely approximated if the date when the area was last burned is known. The age may also be obtained with reasonable certainty directly from the tree itself by counting the rings of growth, since it is established beyond doubt that, except in rare cases, one ring is regularly added each year. Such counts show that while

aspen ordinarily exceeds in rapidity of growth spruce, fir, beech, sugar maple, and even paper birch during the first 20 or 30 years, its growth rate decreases thereafter, while many of the other species are still in their period of rapid development.

Since it is very difficult to distinguish between seedlings and suckers after the first 5 or 10 years, little is known of their relative growth rates after this period. At the beginning, suckers shoot up much more rapidly than seedlings, and this excess in rate of growth undoubtedly exists as late as the twentieth or thirtieth year. Among other trees which produce sprouts the sprouts are almost universally more rapid growing and at the same time shorter lived than seedlings, and this fact can safely be assumed to be true of the aspens.

The following table clearly illustrates the progress of the growth of aspen trees by 10-year periods. The data were obtained by counting the growth rings of 409 trees which grew in Franklin and Somerset Counties, Me. Since the rate of growth is directly dependent upon the quality of the soil, the moisture conditions, and other features of the locality, the trees have been separated into three classes, representing the maximum, average, and minimum rates for commercial aspen stands. Thus, for the best situations the figures given for Quality I are applicable, for second-grade situations the figures for Quality II, and for poor situations the figures for Quality III.

TABLE 3.—*Rate of growth based on quality of locality.*

Age.	Quality I.			Quality II.			Quality III.		
	Diameter breast-high outside bark.	Height.	Total volume, excluding bark.	Diameter breast-high oustide bark.	Height.	Total volume, excluding bark.	Diameter breast-high outside bark.	Height.	Total volume, excluding bark.
Years.	*Inches.*	*Feet.*	*Cu. ft.*	*Inches.*	*Feet.*	*Cu. ft.*	*Inches.*	*Feet.*	*Cu. ft.*
5	1.3	11	.....	0.6	7	.....	0.2	4	.....
10	2.7	21	.....	1.6	15	.....	1.0	8	.....
20	5.3	40	1.0	3.8	32	.....	2.4	17	.....
30	8.0	55	7.5	5.8	45	2.0	3.6	28	.....
40	10.4	66	16.5	7.8	56	7.0	4.7	39	0.5
50	12.7	75	27.5	9.4	65	13.0	5.8	50	2.5
60	14.8	81	42.5	10.9	71	19.0	7 0	57	5.5
70	17.0	85	62.0	12.3	74	25.0	8.2	61	8.5
80	19.2	87	82.5	13.4	75	31.5	9.3	64	12.5
90	21.3	88	104.0	14.3	77	37.0	10.5	66	16.5
100	23.3	89	126.0	15.1	78	42.5	11.7	66	20.5

SIZE AND LONGEVITY.

The aspens are the smallest of the poplars, and are among the smallest of the commercially important timber trees of the United States. Large trees, over 100 feet high and 3 feet in diameter, are nevertheless sometimes found, though such a size is exceptional and

is rarely attained even by the quaking aspen, which is the larger of the two species. The average maximum size attained by the aspens in the pulp district is from 60 to 90 feet in height and from 18 to 24 inches in diameter breasthigh. In the best situations this size indicates maturity; only a small portion of the trees in the original stand ever reach it, and of those that do many show signs of decay. By far the greater part of the aspen cut for pulpwood is under 14 inches in diameter. No fixed merchantable size can, however, be set for aspen, since this depends upon the local conditions which determine the yield per acre. Practically all of the cutting now practiced is carried on without regard to whether the stand is at its maximum yield or not; and so in many places quantities of small, thrifty trees are felled which if left to attain a larger size would increase the yield per acre.

The aspens are short lived, and perfectly sound trees over 100 years old are uncommon. Eighty-year-old stands are sometimes found which are practically free from decay, but these are rather the exception, and the average age of dominant aspen trees probably falls between 70 and 80 years. Of the thousands of sprouts and seedlings which commonly start up, an exceedingly small proportion have survived by the time the trees are 50 years old, so that the average length of life of aspen is extremely low. One of the chief causes of this great mortality is without doubt the insufficiency of light. There are many other agencies, however, which are directly or indirectly fatal.

SUSCEPTIBILITY TO INJURY.

The principal injurious factors are fire, fungi, wind, and insects. Frost, which is harmful to many tree species, does not appear to damage the aspens severely, as their extreme northerly range testifies. Young sprouts, however, are often killed back, owing to the unhardened condition of their wood at the time the first severe frosts occur.

Fire, though practically indispensable for the introduction of the characteristic commercial stands of aspen, is very destructive to young trees. The slow, humus-destroying ground fires are the most fatal, since they eat into the soil and completely destroy the roots, preventing the abundant sprouting which would take place if only the tops were killed. Even large trees may be killed and prevented from sprouting by such fires. Light surface fires do not always injure the older trees, but the younger ones have very thin bark, and are therefore sensitive to fire. It is seldom that a young aspen survives even a comparatively light burn. Fires indirectly injure aspen stands of all ages by reducing the vitality of the trees and by providing vulnerable points for the entrance of fungi and insects.

The most common fungous disease of the quaking aspen throughout a large part of its range is the white heart rot, caused by the false-tinder fungus, *Fomes igniarius* (L.) Gillet.[1] This disease in most of the species which it attacks is usually confined to the heartwood, but in aspen it encroaches upon the sapwood, and trees may be killed outright. If not killed directly by the fungus they fall easy victims to the wind, to which their weakened condition offers little resistance.

The false-tinder fungus always enters the tree through a wound and usually through a dead branch. Hence, it seldom attacks young trees. The aspens are attacked only after about the twentieth year. As they increase in age, however, and their branches begin to die the points of entrance for the fungus become numerous. Mature aspen trees are thus much more susceptible than those of other species, or even of younger trees of the same species. This disease is almost always present in aspen stands which are approaching maturity, and its presence is a warning to the timberland owner to cut at once or forfeit the value of his stand.

Another important fungous enemy of aspen is a brown heart-rot, *Fomes nigricans* Fr. This fungus closely resembles *Fomes igniarius* in every respect and has been considered a form of it. *Fomes nigricans* is known also to infest many of the trees which commonly associate with the aspens. Paper birch, yellow birch, and beech are susceptible to one or both of the diseases, and the presence of the fungi in any of these species is always a menace to any of the others which are found in company with it.

The aspens are frequently damaged by wind, either by breakage or by being uprooted. Their weak wood and slender form offer poor resistance to heavy gales, even after the trees have reached practically their full growth. Their root systems are not sufficiently well developed to hold the full-grown tree against the force of strong winds, especially when the trees are left isolated in logging. Decay in the wood or roots of course greatly increases the danger of windfall.

Insects rarely damage aspens seriously, yet there are a few insects which commonly cause some injury and are sometimes directly responsible for the death of the trees.

REPRODUCTION.

In their characteristics of reproduction the poplars differ in many important respects from most other trees, except the willows. Of the poplars, the aspens exhibit particularly striking points of con-

[1] See Bulletin 149, Bureau of Plant Industry, United States Department of Agriculture, "Diseases of Deciduous Forest Trees," by Hermann von Schrenk and Perley Spaulding.

trast in their enormous sprouting capacity and in the abundant production and low degree of fertility of the seed.

REPRODUCTION BY SEED.

Aspens begin to bear seed when comparatively young. Thrifty trees may begin to bear when only 20 years old. As among all the other poplars and the willows the staminate, or pollen-producing, and the pistillate, or seed-producing flowers, are borne, with rare exceptions, on separate trees. Blossoming and seed fall take place in the spring and early summer, earlier in the South and later in the North, and the time varies somewhat with the earliness or lateness of the season. The flower buds, which become conspicuous in the fall preceding, burst and quickly develop into catkins 10 days or more before the leaves appear, and the seeds begin to mature and fly at about the time that the leaves are unrolling. When ripe the catkins are about 4 inches long in quaking aspen and from 4 to 5 in largetooth aspen.

The amount of seed borne by aspens is so great that during the brief productive period in the spring the air, even at some distance from the stand, is often filled with the minute wind-blown seeds, only noticeable by the little tufts of cottony hairs which bear them up. Where concentrated on the still surface of streams "backed up" by dams or log jams they often collect in millions, forming a cottony layer over large areas. This marvelous abundance of aspen seed is all the more remarkable for the reason that not all the trees, probably not more than half, are seed producers.

Besides the fact that only a portion of the trees bear seed, three other factors interfere to limit the abundance of reproduction from seed: (1) A very large proportion of the seeds are abortive; (2) those which are vital lose their germinative capacity within a very short time—from two to three weeks; and (3) unless the seeds fall on mineral soil—on recently burned over or cleared land or on other open spots not covered with vegetation or undecomposed leaf litter—their chances for growth are very small. Typical aspen stands are in fact so closely confined to burned over soils that these may be considered practically essential for the successful reproduction of aspen. These factors would be fatal to the reproduction of a less prolific tree, and it is evident that the aspens owe their very existence to their abundant seed production and natural provisions for wide distribution. Seldom a year goes by without a heavy seed crop, although the individual trees do not bear every year.

REPRODUCTION BY SUCKERS.

It is natural that with such light and abundant seed aspen should be able to reproduce itself abundantly on clearings adjacent to quan-

tities of seed-bearing trees, and also less abundantly in localities at a considerable distance from the seed supply. It is less easy to understand why, as is frequently the case, great areas of burned land situated far from seed-bearing trees or in a direction from them contrary to the prevailing wind should spring up within a very few years to dense and extensive thickets of aspen, mixed, of course, to a greater or less extent with other small or short-lived species. It is to be expected that some seed would find its way to these places on account of the facility with which it flies through the air, but the great density of the young aspen isolated from seed trees is undoubtedly attributable largely to the prolific growth of suckers or root sprouts.

It is often exceedingly difficult to distinguish with certainty between seedlings and sprouts, even in their early years, since the sprouts, unlike those of birch, maple, etc., rarely or never start from the stump, but come up from the roots and are therefore practically identical in appearance with the seedlings. The distinction rapidly increases in difficulty with the age of the tree, since the early small root connections soon become hidden or almost completely obliterated in the accumulating mass of woody tissue.

Just what the proportion of suckers to seedlings is remains an unsolved problem. Undoubtedly it varies greatly in different regions and with soil, seed supply, and competing species. Where the root suckers meet with little competition they may be expected and have been found to exist in large numbers, and even to predominate in the stand. On an 11-year-old stand of aspen in northern Maine, which sprang up after a fire that destroyed the parent 69-year-old stand, over 100 of the young trees which looked the most like seedlings were pulled up and examined to determine their origin. When the base of the stems where the root systems begin were cut open the presence of the old roots proved all to be suckers. They ranged from 15 to 20 feet in height and from 1 to 3 inches in diameter.

The growth of suckers after lumbering may be even more prolific than after fire, since the sprouting capacity of the roots is never impaired by spring lumbering, as it is apt to be after burns. Usually, however, the trees of other species which were not removed with the aspen cause sufficient shade to kill most of the suckers within a few years.

Several conclusions can now be drawn which bear directly upon the management of aspen: (1) 70-year-old trees are not too old to produce root sprouts; (2) fires severe enough to kill full-grown trees may not destroy the sprout-producing capacity of the roots; and (3) the rate of early sprout growth is very rapid, and since the reproductive power is supplied by the live roots which are already present, no long period of time is required, as is usual in seed reproduction, for restocking the area. The suckers do not depend largely

upon the vitality and growth energy in the roots of the parent tree, as do stump sprouts, but soon develop independent root systems. Their vigor and the size which they ultimately attain is, therefore, not so closely dependent upon the age of the parent tree.

Sprouting often takes place from the roots of live, standing trees, though rarely so abundantly as after the trees are felled or burned. If this happens during the summer or early fall comparatively few sprouts will result. At other seasons the sprouting capacity remains vigorous. Thus it happens that aspen pulp-wood logging, since it is practiced in the spring when the bark peels easily, is usually followed by a prolific production of suckers, provided sufficient light is admitted and the soil conditions are favorable. Early spring fires may be expected to result in much better sprouting than summer fires.

Abundant sprouting is not confined to healthy trees. Badly decayed aspens are also capable of producing sprouts profusely. It is thus possible that diseases may be transmitted from diseased parent trees to the suckers by way of the roots.

On loose, fertile soil the sprouting capacity is much greater than on heavy, clayey soil. Experiments upon the closely related European aspen, results of which can in this case be accepted as applying also to the American species, show that suckers are not produced from roots covered with 6 inches or more of clay and sod, although they will develop abundantly if the soil above the roots is loose and only 2 inches thick. This shows that the access of air is a necessary condition for exciting the sprout-producing capacity of the roots.[1]

The European aspen occasionally produces stump sprouts from stumps not over 8 inches in diameter. The quaking aspen also has been reported from the Rocky Mountains as producing stump sprouts, but this kind of sprouting is uncommon, even for young trees.

As with sprouts in general, aspen suckers are undoubtedly shorter lived than seedlings. Their value is great, especially in good, fertile soil, on account of their more rapid growth. Trees which sprout repeatedly, however, tend to "run out" after a few generations, and it becomes necessary to infuse "new blood" by introducing seedlings. Although aspen seedlings require less light than suckers, the shade of dense, rapid-growing stands of young root sprouts is too heavy for them. Hence a dense growth of poor root sprouts may entirely prevent the regeneration of an area with more thrifty but slower-growing seedlings. Such a result may cause a sprout growth to become, instead of a benefit, a direct impediment to the future welfare of the stand.

[1] B. Kumitzky: Botanical and Silvical Characteristics of Aspen, with Notes Regarding its Uses. Yearbook, Imperial Forest Institute, St. Petersburg, 1888, pp. 57–171. (In Russian.)

THE STAND.

ORIGIN.

The great introducing agent of aspens is fire. Forest fires clear the ground of shade-giving vegetation, expose mineral soil by burning away the leaf litter,[1] and, except in deep-running ground fires, facilitate sprouting by killing the tree trunks without destroying the roots. The first two conditions are essential for the establishment of seedling aspen stands. The last makes possible the development of aspen stands from suckers, provided the previous stand contained aspen trees and provided also that sprouts from other species do not choke out the aspen. In the North the latter condition is not greatly to be feared, since aspen excels all other tree species in its capacity for sucker production.

When the way has thus been prepared for aspen seedlings they must come in at once or other trees and shrubs will seize the ground. The length of time after a fire during which the ground remains sufficiently free to receive aspen reproduction varies, of course, with the abundance, sprouting capacity, and seeding habits of other species in the vicinity, the prevalence of wind, birds, and other agents of seed distribution, the nature of the locality, etc. Thus, if the fire occurs during the summer preceding a heavy seed fall of some other species the latter will have every opportunity to monopolize the ground. This, without doubt, frequently happens, notably in the case of lodgepole pine in the Rocky Mountains, and red, white, and jack pine in the East. Furthermore, if a dense growth of hardwood sprouts, berry bushes, and weeds spring up immediately after a fire, aspen seedlings will be effectually excluded, except in chance openings. Where herbaceous weeds, such as fireweed, *Erechtites hieracifolia* (L.) Raf. and *Eupatorium* sp., form the first growth over burns aspen reproduction is not precluded, and such weeds, indeed, apparently precede aspen quite commonly.

The most common companions of aspen in restocking burned over lands in the Northeast are paper birch and pin or "fire" cherry; in fact, aspen is often greatly outnumbered by these species. Birch seeds, like those of aspen, ripen in the spring and are distributed by the wind. The seeds of cherry, on the other hand, are ripened in summer and are distributed almost entirely by birds. Thus, while paper birch seeds up burns at about the same time as the aspen and so rarely interferes with the development of aspen seedlings, fire cherry may entirely monopolize the ground if the fire takes place soon after the termination of the aspen seeding season. As a rule,

[1] It is also possible that fires cause chemical changes in the soil, such as the liberation of potash, which will promote germination and growth, though this is by no means certain.

however, aspen is able to cope successfully with the light-foliaged and short-lived fire cherry, which usually becomes suppressed and crowded out of the stand within 15 or 20 years.

Although fire is responsible for most of the large, even-aged, commercial stands of aspen, it is not absolutely essential for the introduction of aspen. The necessary conditions for germination and growth are supplied when, as after lumbering, clearings are made in the forest and moist mineral soil is exposed. In such places aspen seed finds a satisfactory seed bed; but since clearings made during logging usually disturb the humus soil cover only in spots, do not remove all the shade-producing vegetation, and are usually less extensive than forest fires, it is safe to say that seed reproduction of aspen on unburned land, except after cultivation, never results in more than a scattered growth of individual trees or small groups among other species.

The extensive even-aged stands of aspen are probably very often the result not of one but of two or more fires. A single fire in virgin forest allows the establishment of a scattered stand of aspen seedlings among other species. Then a subsequent fire in the spring clears the surface, and is immediately followed by an abundant appearance of aspen sprouts from the roots of the seedlings. While no observations exist to prove that this process is the common one, the characteristic occurrence of aspen in even-aged groups through the forest points very strongly to this conclusion.

TEMPORARY STANDS.

Just as fire cherry and other small or short-lived trees and shrubs form "temporary stands" over aspen, so the aspen, in most of its extensive stands, is itself merely temporary, and gives place, within a single generation, to relatively permanent stands of more shade-enduring and longer-lived species, from which aspen is permanently excluded. While the aspen stand is still young, scattered seedlings of spruce, beech, maple, and other shade-enduring trees begin to appear beneath it, and these gradually increase in numbers and size until a well-marked second growth of decidedly different appearance is established. The contrast between the aspen and its "understory" is greatest when the latter consists of conifers, such as spruce and fir. Among the important trees commonly noticed coming up under aspen shade may be mentioned the red and white spruces and balsam fir in northern New England, white pine in the Lake States, and Engelmann and blue spruces, Douglas fir, and various balsam firs in the Rocky Mountains. For a while the aspen is able by its rapid early growth to keep above its heavier-crowned neighbors, but as the aspen approaches maturity and begins to fall of in height growth this undergrowth pushes up through the crown cover of the aspens. The stand

thus changes from a pure stand of aspen to a mixed one of aspen and other species. When aspens are found in mixed stands they are almost always at least as old as any other species in the mixture. The final stage in the succession is the complete extinction of the aspen, either by the shade of its taller, heavier-crowned neighbors, or by other causes. The large numbers of dead aspen snags which are sometimes found in stands of spruce, balsam, or white pine plainly indicate the recent transformation of the forest from a practically pure stand of aspen to a stand of other species in which aspen is not even represented.

From these characteristics of aspen stands arises their greatest importance, apart from the actual commercial value of the wood. Their light foliage does not prevent, but rather encourages, by the protection which it affords from frost and wind, the development of valuable shade-enduring species beneath. The height growth of these is accelerated both by the protection and by the upward struggle for light. By the time the aspen has ceased its function as a "nurse," a tall well-formed forest of better species is in its place, showing by its good form and rapid growth the beneficial effects of the early protection.

The effect of aspen stands upon young trees of other species is not, however, invariably beneficial. When the stands are too dense, as is often the case in youth, the shade and the competition of roots may be so great as to cause a slender and weak development of the species underneath, especially if they are only moderately shade enduring. White and red pine in the East and various pines in the West frequently suffer in this way. In such cases aspen is, at least temporarily, a tree weed, though a judicious thinning would in many cases afford a sufficient remedy.

Another injurious effect of aspen upon associated species consists in its liability to harbor and disseminate tree diseases, such as *Fomes igniarius* and *nigricans*, which are also enemies of beech, paper and yellow birch and other associates. When such diseases become prevalent in aspen stands the aspen at once becomes a menace to the oncoming growth of other species and should be removed.

PERMANENT STANDS.

Toward the northern limit of its range and at high altitudes in the West aspen frequently forms permanent stands. In the Rocky Mountain regions the small aspen stands about springs or other moist spots are undoubtedly in many cases permanent, while in parts of Alaska and northern Canada aspen is often able to maintain itself practically indefinitely among the more shade-intolerant species of the far North. The factor chiefly responsible for permanency is the absence of aggressive competition from shade-enduring and shade-

giving trees. It is in these regions, where unfavorable climatic conditions exclude or greatly handicap many of its southern competitors, that aspen exhibits its superior endurance to the best advantage.

In the eastern United States the great variety and abundance of shade-enduring trees effectively preclude the permanency of aspen stands, except through the agency of fire or through the deliberate interference of man. Forest fires which kill not only the aspen, but all the other trees in the stand also, and are often followed by an abundant growth of aspen suckers and seedlings, may and frequently do bring about a recurrence of aspen on the same site. This may conceivably be repeated again and again, until the sprouting capacity of the aspen roots is exhausted. If, in the meantime, aspen seed falls on the burned oversoil and fresh stock for sprouting is thus added, the process may be repeated indefinitely. Aspen stands perpetuated in this way, however, can hardly be called permanent, since the absence of fire during a single life period of the stand would inevitably result in at least the partial exclusion of the aspen.

DEVELOPMENT AND DECADENCE OF ASPEN STANDS IN THE NORTHEAST.

DEVELOPMENT OF THE STAND.

The progress in the development of stands of aspen suckers in the northeast is illustrated in the quarter-acre sample plots shown in Tables 4, 5, and 6. These plots were taken at random in stands 15, 22, and 53 years old. The true history of an aspen stand can be determined only by observations of the same stand made at intervals of a few years from youth to old age, and several series of these observations would have to be conducted simultaneously in the different regions within the range of aspens in order to obtain a complete knowledge of the behavior of the trees under all conditions. In the absence of such prolonged investigations, however, these tables, which represent conditions believed to be typical, will serve to show about what the process of succession of aspens by other species is.

TABLE 4.—*Fifteen-year-old aspen suckers on a quarter-acre area, Sebec Lake, Me.*

Diameter breast-high.	Number of trees.					
	Aspen, living.	Maple.	Beech.	Paper birch.	Balsam fir.	White cedar.
Inches.						
1	190	.....	.....	.....	.....	.....
2	210	20	.....	8	20	11
3	180	18	8	4	11	13
4	70	10	2	10	4	14
5	10	10	8	8	1	10
6	.....	.....	2	.....	4	4
Total	660	58	20	30	40	52

TABLE 5.—*Twenty-two-year-old aspen suckers on a quarter-acre area, Maine.*

Diameter breast-high.	Number of trees.						
	Aspen.		Maple.	Beech.	Paper and yellow birch.	Balsam.	Spruce.
	Living.	Dead.					
Inches.							
1	.....	136	.....	.....	.....	.....	.....
2	50	112	68	6	.....	8	.....
3	84	4	16	.....	14	2	2
4	86	.....	8	.....	.....	.....	.....
5	42	.....	6	.....	.....	.....	.....
6	22	.....	2	4	.....	.....	.....
7	4	.....	.....	2	.....	.....	.....
Total	288	252	100	12	14	10	2

TABLE 6.—*Fifty-three-year-old aspen suckers on a quarter-acre area, Katahdin Iron Works, Me.*

Diameter breast-high.	Number of trees.					
	Aspen.		Maple.	Paper and yellow birch.	Iron-wood.	Balsam.
	Living.	Dead.				
Inches.						
2	.....	7	24	.....	30	.....
3	4	36	30	1	13	3
4	5	22	9	.....	1	4
5	14	10	5	1	.....	2
6	23	4	.....	3	.....	1
7	18	.....	.....	1	.....	2
8	14	.....	.....	.....	.....	2
9	7	.....	.....	1	.....	5
10	3	.....	.....	.....	.....	2
11	.....	.....	.....	.....	.....	.....
12	.....	.....	.....	.....	.....	1
Total	88	79	68	7	44	22

A comparison of these tables clearly indicates the marked decline in the quantity of living aspen suckers which is so characteristic of aspen stands. This decline is not due so much in this case to the competition of other species as to that between the aspen themselves. The small number of dead sprouts counted in Table 6 resulted from the early fall and decay of most of the suckers killed during the first few years, which render them indistinguishable from other forest litter after a short time. The smallness of the diameters of the aspen, as shown in Tables 5 and 6, is undoubtedly due to the crowding of the suckers in competition. With plenty of light, the diameters, especially of 53-year-old aspen, should be much greater. Of the trees in mixture, the shading effect of maple, beech, and the conifers will be much more harmful to the aspen than that of lighter-foliaged trees like the birches.

DECADENCE OF THE STAND.

The immense stands of aspen which followed the Miramichi fire and other extensive fires that swept away large areas of virgin forest

in Maine and New Brunswick about the year 1825 have already passed beyond the age at which the trees are at their best. Those which have not so far been removed by logging are fast deteriorating, so that not only is the quantity of merchantable material on this great area less per acre than it was 20 years ago, but much of the remaining stand is of inferior quality. Notwithstanding the fact that consumers are less exacting now in regard to white rot than they were a few years ago, the aspen from many of these 80 to 90 year old stands must now be culled by from 5 to 20 per cent. Ten years ago within this same region culling was almost unheard of. Decay is so rapid in aspen that many large trees which were practically sound 10 years ago are now unmerchantable. It is safe to say that within the next 20 years the remaining portion of the aspen which followed the Miramichi fire will become practically unmerchantable. Unless lumbered in the near future much of it will go to waste.

The rapid decadence of old aspen is graphically exhibited in the case of a logging operation near Katahdin Iron Works, Me., in which the aspen had been culled 20 per cent. The stand on this township was equal to the best in the State in size and quantity of trees, and the reason why it should be so much more affected with white rot than stands a little farther south was not apparent until the age of the trees was determined. It was found that the stands so badly affected with white rot were 95 years old, while the others farther south, from which only a 5 per cent cull was made, were only 80 years old. This difference of 15 years was undoubtedly responsible for the difference in the amount of cull. Table 7, representative of the 95-year-old stand above cited, shows clearly that a great loss resulted from too long postponing the cut.

TABLE 7.—*Loss from decay on 1 acre of standing 95-year-old aspen.*[1]

Diameter breast-high.	Living trees.				Dead trees.	
	Sound.		Unsound.[2]			
	Number.	Volume.	Number.	Volume.	Number.	Volume.
Inches.		*Cords.*		*Cords.*		*Cords.*
10	.....	.....	.....	.....	9	1.71
11	.....	.....	.....	.....	3	.65
12	7	2.03	.....	.....	15	4.36
13	1	.31	.....	.....	4	1.26
14	7	2.82	.....	.....	.....	.....
15	.....	.....	1	0.47	.....	.....
16	1	.52	1	.52	.....	.....
17	.....	.....	.....	.....	.....	.....
18	.....	.....	2	1.13	.....	.....
19	.....	.....	.....	.....	.....	.....
20	.....	.....	2	1.24	.....	.....
Total	16	5.68	6	3.36	31	7.98

[1] Besides aspen, the stand on the area contained yellow birch and hard maple.
[2] Unsound trees were detected through the presence of fungous fruiting bodies, shelves, or "punks." These always indicate that the tree has reached an advanced stage of decay.

The volume of sound live wood from this acre is thus 5.68 cords, that of unsound live wood 3.36 cords, while that of dead wood amounts to 7.98 cords. Dead aspen wood in such a stand is practically absolute waste, since decay must have reached an advanced stage to cause the death of the tree. To it must be added that portion of the wood from the unsound living trees which is too badly decayed to be merchantable. It is safe to assume that these trees, all of which bear fungous-fruiting bodies, will produce not more than half their volume, or 1.68 cords, of merchantable wood, the other half being waste. Thus the yield of merchantable wood amounts to 7.36 cords per acre, and the waste from decay 9.66 cords per acre.

The decay of dead aspen is very rapid. Consequently it is certain that very few of the dead trees in the stand were dead 20 years ago. On the other hand, the growth in volume of such old trees is not very rapid, and is not commensurate with the loss from decay. It is safe to say, therefore, that had this aspen been cut 20 years ago the yield would have been over twice as great as at present.

To corroborate the figures obtained in the sample area, and to determine the loss involved in allowing aspen stands to get too old, advantage was taken of a cutting operation in a near-by stand of the same age, covering a tract of 5 acres. The stand had been an excellent one, but had been left standing until overmature. The merchantable aspen trees had already been cut from this area at the time the examination was made, and had been felled, sawed up into 4-foot lengths, and piled.

Table 8 shows the amount and source of loss.

TABLE 8.—*Loss in cut and piled material from decay in 95-year-old aspen (5 acres), Katahdin Iron Works, Me.*

Diameter breast-high.	Living trees.	Dead trees.	Volume of living trees cut and piled.	Volume of dead trees left standing.
Inches.	*Number.*	*Number.*	*Cords.*	*Cords.*
6	.....	24	.....	.....
7	.....	19	.....	.....
8	9	24	.....	.....
9	13	40	.....	.....
10	26	45	.....	.....
11	28	40	.....	.....
12	67	58	.....	.....
13	52	26	.....	.....
14	47	17	.....	.....
15	31	9	.....	.....
16	24	3	.....	.....
17	10	.....	.....	.....
18	9	2	.....	.....
19	2	.....	.....	.....
20	6	.....	.....	.....
21	1	.....	.....	.....
22	1	.....	.....	.....
23	.....	.....	.....	.....
24	1	.....	.....	.....
Total	327	307	96.5	68
Less 20 per cent cull	.....	.....	77.2	.....

The piles amounted to 96½ cords (19.3 per acre), but the wood was so badly infested with white rot that it was culled 20 per cent by the purchaser. The actual merchantable yield of the 5 acres was thus only 77.2 cords, or 15.4 cords per acre. The dead trees on this area would have yielded, if sound, 68 cords, or 13.3 cords per acre. In view of the rapid decay of dead trees and the rapid spread of decay in living ones, it is probable that 20 years ago the present dead trees were alive, and that the proportion of decay in the living ones was much less. Assuming that all the trees were sound 20 years ago, and allowing the liberal discount of one-fifth for the growth of the trees since then, the yield at that time would have been 26.3 cords per acre. A still further discount of 20 per cent for possible decay at that time would leave 21.06 cords per acre, an excess of 36 per cent over the present merchantable yield. Further, had the stand been logged clean 20 years ago, the second growth of sprouts, which would undoubtedly have sprung up immediately, would now be well advanced toward merchantable size.

The fact can not, therefore, be too much emphasized that to leave aspen standing after the beginning of decay is to introduce a dead loss which increases, not gradually, but rapidly with every year that the stand is left uncut.

MANAGEMENT.[1]

All the aspen which has been cut, up to the present time, and all which will continue to be cut until the supply begins to run short, was introduced naturally and without the designed aid of man. By far the greater part of it followed burns, while a small portion came up after clear cuttings in virgin forest. Until its usefulness for paper was discovered it was considered a useless encumbrance of the ground. Now, as a valuable tree, its original stands are becoming exhausted, while, owing to the increasing control over forest fires and the encroachment of more shade-enduring trees, opportunities for the starting of new stands are yearly becoming less. If future supplies are desired, they must be secured through special efforts, based on a knowledge of the life habits of the tree.

Aspen management may follow one of two general directions, according to the ultimate use which it is desired to make of the land: (1) As a merely temporary crop, for a single rotation, preliminary to crops of other species already present as reproduction in the aspen stand; or (2) with the intention of devoting the land permanently to aspen.

[1] Paper birch is an abundant and valuable associate of aspen in the Northeast. Since in its rate of growth and other characteristics it greatly resembles aspen, while the methods of logging are very similar, the management to be employed for mixed stands of birch and aspen will not vary greatly from those given for aspen alone. For a full discussion of the management of paper birch stands the reader is referred to Forest Service Circular 163, Paper Birch in the Northeast, by S. T. Dana, forest assistant.

TREATMENT AS A TEMPORARY CROP.

By this is meant simply the tending of the stand through a single rotation, both for its own wood and to encourage the early development of other species in its shade. It is not strictly aspen management; it is more appropriately a preliminary step in the management of the succeeding stand. By it the uncertainty and lapse of time necessary for the establishment of an entirely new stand are avoided. This method gives a valuable intermediate yield of aspen, but anticipates no future stand of this species, since the shade of the second growth will kill out aspen reproduction, except in chance openings.

TREATMENT AS A PERMANENT CROP.

The advantages of aspen as a perpetual crop lie in: (1) Its adaptability to short rotations, resulting from its relatively quick growth and the small sizes which are merchantable; and (2) its usefulness in the stable industry of paper making. The short rotations of aspen make two cuttings possible during the time that one crop of spruce or other slow-growing species is maturing. Its utility for book and magazine paper is acknowledged, and the disposal of the future crop can be relied upon with practical certainty.

ROTATION.

One of the first considerations in the management of aspen is the rotation, or the period of years between the establishment and the final removal of the stand. For aspen in the Northeast the maximum age which the trees may be allowed to attain is fixed by the relatively early beginning of decay at approximately 80 years. In fully stocked healthy stands on the best soil this is the age at which dominant trees reach their maximum yield. Since, however, decay frequently sets in much earlier, necessitating the immediate removal of the trees while yet considerably under full size, the length of each rotation can not be made arbitrary, but must depend upon the condition of the stand.

In situations especially favorable to aspen growth, the rotation may be somewhat abbreviated; a rotation of 50 years may sometimes prove profitable. It should be remembered, however, that when healthy the dominant trees of this age are usually just beginning their most rapid growth in volume, as will be noticed on reference to Table 3, page 17. If left 20 or 30 years longer—at the risk, of course, of fire and decay—their volume would be more than doubled.

The maximum volume of the mature stand may be obtained with a considerably shorter rotation if the stand is judiciously thinned from time to time.

THINNINGS.

The fierce competition for light and growing space which goes on throughout the life of a fully stocked stand kills over 99 per cent of the trees and allows less than 1 per cent to reach the age of 80 years. Before the stand reaches merchantable size the trees killed in competition are, of course, a total loss. As soon as they pass the minimum limit for profitable cutting, however, they may all be utilized and the producing value of the stand thus greatly increased.

A heavy thinning at this time will not only save this material—amounting to from 20 to 40 per cent of the total volume—but if properly done will leave the best and most vigorous trees with a larger amount of light and growing space, thus enabling them to put forth more foliage and much increase their rate of growth. At the same time their root development will be stimulated and danger of future windfall greatly diminished. In this thinning all the conspicuously short trees, those which show signs of decay or other damage, and merchantable dead trees should be removed; enough of the more vigorous stand should also be cut as to leave the stand in a uniformly thinned condition. The tallest and best formed trees should, of course, be left standing. Around these the crown cover should be opened up by the removal of their neighbors only enough to give their crowns room to expand and meet within the ensuing 5 or 10 years. No large openings should be made in the crown cover. These endanger windfall, prevent the full utilization of the growing space, and interfere with rapid growth by drying out the soil.

A second severe thinning should be made after the crowns of the trees have again closed up, probably after the lapse of 10 or 15 years. The same procedure should be observed as for the first thinning. The trees will by this time have reached a size at which the thinning should yield a distinct profit. The largest trees, except those in which decay is present, should be left for the final cutting.

The great advantage of thinnings in aspen stands lies in the saving of a great amount of wood which would otherwise fall and rot in the forest. In addition to this, the trees which remain are benefited by the increased growing space which they receive and grow more rapidly in consequence. In the final cutting more and larger trees can undoubtedly be harvested than from unmanaged stands of the same age, or the same wood production can be obtained with a rotation 10 or 20 years shorter than in an unthinned stand.

CLEAN CUTTING AND REPRODUCTION.

Since aspen is practically unable to reproduce under its own shade, satisfactory reproduction can be secured only by clear cutting. This should remove not only the aspen, but all other merchantable trees

as well. Reproduction may be either from root suckers or from seed. Root suckers, owing to their very rapid growth, can usually succeed without special attention. Seed, however, must fall on mineral soil, and the seedlings must be freed from competition with shrubby and herbaceous vegetation, as well as with seedlings and sprouts of other tree species and with aspen sprouts.

Thorough surface burning is the most practicable means of exposing mineral soil and removing competing vegetation over large areas. If done during the late fall, winter, or early spring, it will accomplish this without injuring the sprout-producing capacity of the roots. Where it is wished to discourage sprouting it should be done in the summer. As a rule, the production of root sprouts is to be encouraged; when, however, sprout stands decrease in sprouting capacity, either through repeated cutting or decay, they can be rejuvenated only by the introduction of seedlings. In this case a light surface fire should be run over the area during the summer, after the appearance of the sprouts above ground.

Burning, however, is extremely hazardous to surrounding timber, and can only be recommended when done at seasons and on days when fire is unlikely to run beyond control, and when thoroughly supervised by a force of men large enough to prevent the fire from spreading. Large areas should be divided into easily guarded patches for burning, and the first burning should be done at the edges of the area and next to any valuable timber which might adjoin, so as to afford protection if the fire on the area subsequently burned should get beyond control. Furthermore, burning is not to be recommended unless there is strong probability of an abundant seeding from adjacent aspen stands. Where such stands do not exist, and over large areas, it will usually be advisable to leave small groups of trees standing to insure uniform seeding.

Natural reproduction, either from seed or suckers, would be best if the trees were cut in the winter or early spring, before the swelling of the buds and the flight of the seeds. Aspen logging, however, is usually done later in the spring, continuing as long as the trees peel easily, which is often as late as the beginning of summer. The stands of suckers which result from late spring logging, though possibly not quite so hardy as those resulting from winter cutting, are usually sufficiently vigorous fully to justify logging during the peeling season.

The felled trees should be peeled, sawed up, and piled as soon as possible, in order to avoid the damage to young sprouts which their later removal would inevitably cause. For the same reason, large piles placed along roads are preferable to small, scattered ones.

APPENDIX.

VOLUME TABLES.

Aspen stands are usually estimated either by a general guess, based on a knowledge of the yield of similar stands, or by estimating the number of trees per acre and dividing by the number of trees which it is thought will make a cord. The first of these methods is inexact and is subject to wide errors, even when practiced by an experienced estimator. The second is but little more accurate, since in it both the number of trees per acre and the number per cord are, as a rule, merely guessed at. Since the yield of a given area depends upon (1) the number and (2) the volume of the trees on it, it is evident that the more closely these are approximated the more accurate will be the estimate.

The following volume tables give the volumes in cubic feet and cords for aspen trees of all heights and diameters commonly found. They are based on measurements of 362 trees in Piscataquis, Franklin, and Somerset Counties, Me. To use them, the diameters of all trees on a representative sample area comprising a known proportion of the tract should be calipered or estimated at breastheight and the figures listed on a tally sheet. The approximate height of the trees of each diameter must then be determined, either by estimate or by felling and measuring a few representative trees. In the tables the volume for a given diameter will be found in the column which corresponds most closely with the height thus determined and in the row which corresponds with the diameter. The volume of all the trees of each diameter class can thus be found very easily, and their sum is the total volume of the sample area. The sample areas may be of any shape and size, so long as the size is accurately known. A convenient unit for measurement is a strip 80 rods long and 2 rods wide, containing 1 acre. Enough of these sample areas should be measured to include at least 10 per cent of the tract.

By "merchantable volume," in Tables 1 and 2, is meant that portion of the bole between a stump 1 foot high and a minimum upper diameter of 4 inches inside bark and all branches 4 inches and over inside bark. The volumes do not include bark.

TABLE 1.—*Merchantable volume in cubic feet by diameter and height.*

Diameter outside bark breast-high.	Height of tree.						
	30 feet.	40 feet.	50 feet.	60 feet.	70 feet.	80 feet.	90 feet.
	Volume.						
Inches.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
5	0.5	1.0	1.5	2.0	3.0	.....	.....
6	2.0	2.5	3.0	3.5	4.5	6.0	.....
7	3.5	4.0	4.5	5.5	7.0	8.5	.....
8	5.5	6.0	7.0	8.0	10.0	11.5	13.0
9	.....	8.0	9.5	11.0	12.5	14.5	16.5
10	.....	10.5	12.0	14.0	16.0	18.0	20.0
11	.....	.....	15.0	17.0	19.0	21.5	25.0
12	.....	.....	18.0	20.5	23.0	26.5	30.0
13	.....	.....	.....	24.0	27.0	31.5	36.0
14	.....	.....	.....	28.5	32.0	37.0	43.0
15	.....	.....	.....	32.0	37.0	43.0	51.0
16	.....	.....	.....	37.0	43.0	50.0	59.0
17	.....	.....	.....	43.0	49.5	57.0	68.0
18	.....	.....	.....	.....	57.0	66.0	76.0
19	.....	.....	.....	.....	65.0	75.0	85.0
20	.....	.....	.....	.....	74.0	84.0	95.0

TABLE 2.—*Merchantable volume in cords and number of trees per cord, by diameter and height.*

Diameter breast-high.	Height of tree.					
	30 feet.		40 feet.		50 feet.	
	Volume.	Trees per cord.	Volume.	Trees per cord.	Volume.	Trees per cord.
Inches.	*Cords.*	*Number.*	*Cords.*	*Number.*	*Cords.*	*Number.*
5	0.01	100.0	0.02	50.0	0.03	33.3
6	.03	33.3	.04	25.0	.05	20.0
7	.05	20.0	.06	16.7	.07	14.3
8	.08	12.5	.09	11.1	.10	10.0
9	.....	.....	.11	9.1	.12	8.3
10	.....	.....	.14	7.1	.15	6.7
11	.....	.....	.....	.....	.18	5.6
12	.....	.....	.....	.....	.21	4.8

Diameter breast-high.	Height of tree.							
	60 feet.		70 feet.		80 feet.		90 feet.	
	Volume.	Trees per cord.	Volume.	Trees per cord.	Volume.	Trees per cord.	Volume.	Trees per cord.
Inches.	*Cords.*	*Number.*	*Cords.*	*Number.*	*Cords.*	*Number.*	*Cords.*	*Number.*
5	0.03	33.3	.....	.....	.....	.....	.....	.....
6	.06	16.7	0.07	14.3	0.10	10.0	.....	.....
7	.08	12.5	.10	10.0	.13	7.7	.....	.....
8	.11	9.1	.14	7.1	.16	6.3	.....	.....
9	.14	7.1	.16	6.3	.19	5.3	.....	.....
10	.18	5.6	.20	5.0	.23	4.3	0.25	4.0
11	.20	5.0	.23	4.3	.26	3.8	.30	3.3
12	.24	4.2	.27	3.7	.31	3.2	.34	2.9
13	.27	3.7	.30	3.3	.35	2.9	.40	2.5
14	.31	3.2	.35	2.9	.40	2.5	.46	2.2
15	.....	.....	.39	2.6	.45	2.2	.53	1.9
16	.....	.....	.44	2.3	.52	1.9	.60	1.7
17	.....	.....	.....	.....	.57	1.8	.68	1.5
18	.....	.....	.....	.....	.65	1.5	.75	1.3
19	.....	.....	.....	.....	.....	.....	.82	1.2
20	.....	.....	.....	.....	.....	.....	.90	1.1