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YOUTH, MATURITY, AND OLD AGE

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ABSTRACT. — Aspen ecology is examined in mature, regenerating, and overmature stands. Investigations in mature stands indicate that aspen growth is controlled primarily by soil water-holding capacity (texture), water table depth, and exposure to wind. These same factors control the rate of aspen conversion but the availability of seed must also be considered. Aspen seedling and sampling densities may be influenced by competing vegetation, site treatment after harvesting, and drainage. Deteriorating (overmature) stands are becoming common, can be regenerated, and should now be considered in forest management planning.

The present aspen forest in northern Wisconsin began with the timber harvesting and extensive fires of the early 1900's, but it was not until the 1950's that aspen was recognized as an important tree species. Then with large areas of aspen forest nearing maturity and providing a supply of pulpwood, aspen suddenly became an economically desirable forest species. Most northern pulpmills now use aspen pulpwood to the near exclusion of other species. In addition, it is recognized as an important food for deer and grouse.

The end of the first aspen forest in Wisconsin is approaching as stands continue to be harvested. In the second aspen forest, which has already begun, there are substantial changes that will have a bearing on the economics and operation of the industries that depend on aspen. The present paper summarizes the author's investigations on the ecology of quaking aspen in north-central Wisconsin as it may affect future aspen silviculture, management and supply.

Because geographic conditions vary greatly and the ecological considerations may be applicable to other States and regions, a brief review of the climatic and soil conditions is necessary. Within the counties of Langlade, Lincoln, Oneida, Vilas, Sawyer and Price, a climatic gradient exists from southeast (Lincoln County) to northwest (Sawyer County); the average growing season temperature decreases from 68.6° F. to 66.6° F.; the growing season precipitation increases from 14.7 inches to 16.1 inches; and the growing season length decreases from 130 to 107 days (U.S. Department of Agriculture 1941).

Upland soils of the area are classes as Spodosols (weak Podzols intergrading to Gray Brown Podzolics) with an albic (A_2) horizon near the surface and an underlying spodic (B_{hir}) horizon. Soil textures range from coarse sand to fine silt loam depending on the initial material. Soils formed in glacial outwash (Crivitz, Hiawatha, and Vilas series) range from sand to light sandy loam, and from heavy sandy loam to loam for soils formed in glacial till (Elderon, Iron River, and Pence series). These soils are well to excessively drained but often have water tables in the lower part of the rooting zone. Soils formed in loess have silt loam textures; a mottled fragipan at a depth of 12 to 22 inches usually restricts root growth and slows the rate of percolation through the profile. These soils are moderately well and well-drained on slopes and ridge tops (Goodman, Lynne, and Stambaugh series), and somewhat poorly drained in depressional areas (Clifford series). In this paper, soils formed in glacial outwash, glacial till and loess will be referred to as coarse-, medium-, and fine-textured soils respectively.

MATURE STANDS

Growth

Past studies (Kittredge 1938, Stoeckeler 1948, 1960; Wilde and Pronin 1950; Voigt, Heinselman, and Zasada 1957; Meyer 1956; Strothmann 1960; Graham, Harrison, and Westell 1963) have frequently related aspen growth rates to some characteristic of soil (texture, horizon thickness, stoniness, pH, cation exchange capacity and organic matter and nutrient levels) or of site (slope, aspect and topographic position). In the northern Wisconsin study[1] aspen site index was related to some of the above soil and site factors as well as additional factors that proved to be quite important. The following paragraphs on aspen growth summarize the results of that study.

Aspen site index is strongly influenced by soil texture. As the percentage of silt increases from 5 to 90 percent, average site index (age 50) increases from 69 to 85 (fig. 1). A similar relationship exists with decreases in the percentage of sand from 95 to 5 percent. In general, stands on coarse-, medium-, and fine-textured soils have site indices that range from 66 to 72, 72 to 78 and 78 to 85 respectively; however, the influence of other site factors (e.g., water table depth) will cause considerable overlap between ranges. These relationships agree closely with those from other previously cited studies.

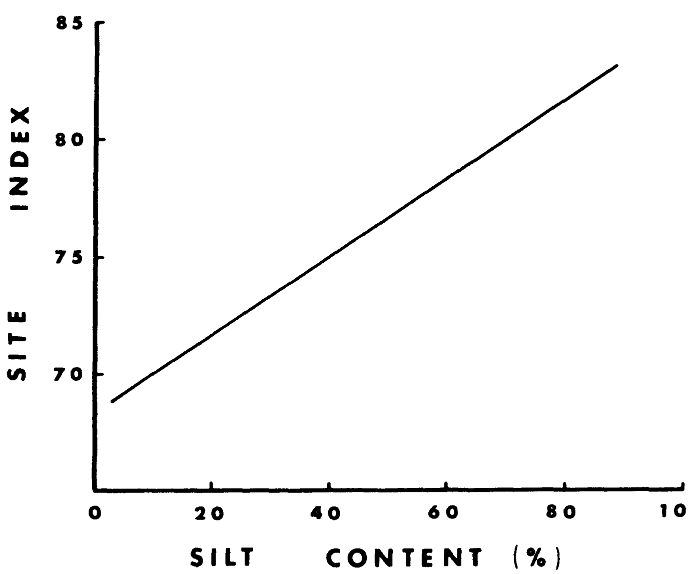

Figure 1. — *Relationship of aspen site index to silt content of the soil.*

[1] *Fralish, James S. 1969. Site indices and rate of conversion in northern Wisconsin quaking aspen. Ph.D. dissertation. Univ. of Wisconsin, Madison.*

Moreover, for growth to occur, a tree must utilize the primary substances obtained from soil — water and nutrients. Thus, using a formula developed by Auclair and Cottam (1971) the available water-holding capacity of the soil was calculated for each stand. The average water storage capacity in inches per foot of soil depth for coarse-, medium-, and fine-textured soils is approximately 1.50, 2.50 and 4.0 respectively. Statistically, the relationship between site index and available water-holding capacity is very strong (r. = 0.658) and indicates that growth is controlled by available soil water.

Because soil water is of major importance, it is relatively easy to understand how other soil factors affect aspen growth. The stoniness of the soil affects aspen growth by decreasing the water-holding capacity of the soil by decreasing the amount of space where water can be held. A soil that is 25 percent stone will have a site index that is at least five feet lower than for a nonstoney soil, other factors being equal.

A water table within the rooting zone will increase aspen growth by providing additional amounts of available water. However, the relationship between site index and water table depth is not linear (fig. 2). Water tables between 3 and 8 feet in depth will greatly increase aspen growth, particularly in the coarse- and medium-textured soils. Water tables deeper than 8 feet will have little effect on growth because few roots penetrate to that soil depth. Water

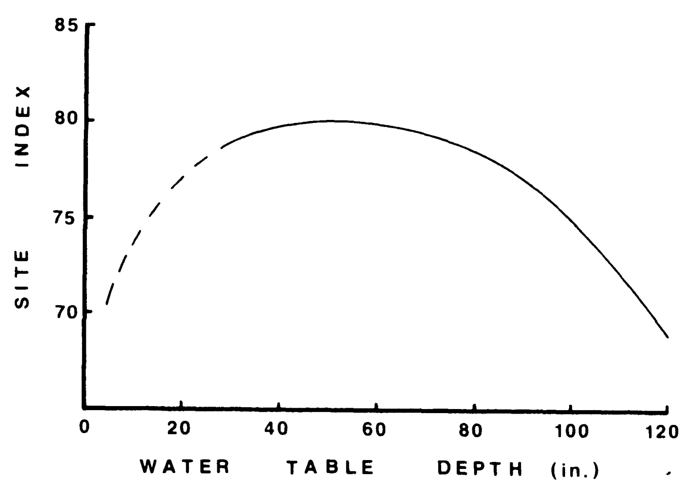

Figure 2. — *Relationship of aspen site index to water table depth.*

tables less than 2 feet in depth will decrease aspen growth because of decreased space and air that is necessary for roots to develop and support a large tree.

Subsurface horizons of substantially finer texture are particularly important on coarse-textured soils that seldom can retain enough water for maximum aspen growth. These horizons influence aspen growth in a manner similar to that of a water table. They prevent water from being lost from the rooting zone, and, if they are not restrictive to root growth, will substantially increase aspen site index.

The effect of the water table on aspen growth becomes less important on the fine-textured soils (fig. 3), because sufficient water for growth is already held by soil particles. In addition, the shallow fragipan slows the rate of water movement through the profile. However, when water accumulates on or near the surface, as in the poorly drained silt loam soils, site index may be very low (less than 40).

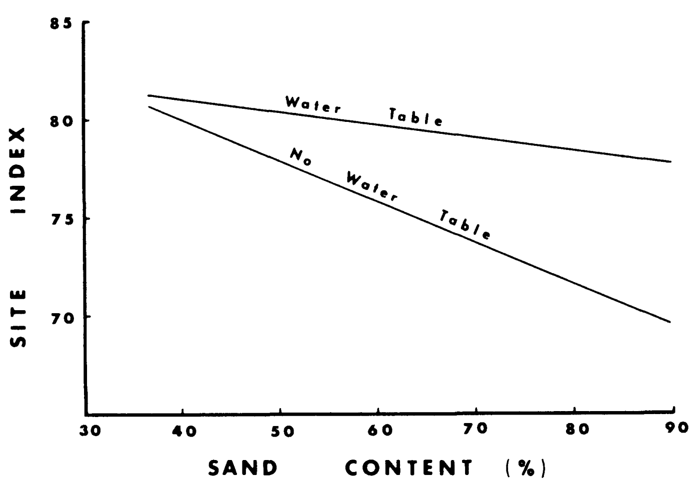

Figure 3. — *Relationship of aspen site index to water table depth and sand content of the soil.*

If aspen growth is primarily dependent on soil water, then will site factors that increase the rate of water loss from a site or tree (evaporation or transpiration) affect growth? The answer is an unqualified yes; because of more rapid soil water depletion, there will be more frequent periods of longer duration when water is unavailable to the tree. Most of the previous site studies on aspen have investigated aspect, slope, and topographic position. Stands located on south, southwest, and west aspects, on steep slopes, or on ridge tops tend to have lower site indices because of increased evapotranspiration or runoff rates.

Wind is an additional factor that has been usually overlooked in most aspen studies but it is important because wind also affects evapotranspiration rates. Exposure to wind is nearly as important in influencing aspen growth as soil water-holding capacity and water table depth. Isolated stands and stands located on ridge tops have lower site indices because of higher internal wind velocities than stands on middle slopes, or stands protected by forest on two or more sides, particularly the south, southwest, and west sides. In general, protected stands whether in valleys, between ridges, or surrounded by forest, have higher site indices than unprotected stands, other factors being equal.

Soil nutrient levels have very little effect on aspen growth in northern Wisconsin; similar results for Wisconsin aspen were obtained by Stoeckeler (1960). However, Voigt and others (1957) and Stoeckeler (1960) found that site indices increased as levels of phosphorus, potassium, calcium, and magnesium increased in Minnesota soils.

Compositional Changes

Shade intolerant species such as aspen eventually will be replaced by shade tolerant species that form a more stable forest community. In the northern Wisconsin study,[2] the environmental factors that control growth, soil water-holding capacity, water table depth, and exposure, also were found to control the species composition of stands replacing the present aspen stands. However, the presence or absence of a seed source may also have a significant effect. The following paragraphs on compositional changes in aspen stands summarize the results of the above study.

On coarse-textured soils (Crivitz, Hiawatha, and Vilas series), rapid aspen succession is not a problem. At present, 70 percent of the aspen stands do not have any or have very light understories. Hardwood species such as sugar maple, white ash, basswood, and American elm rarely grow on these soils because of their droughty nature. In 30 percent of the study stands there are up to 150 stems per acre of red maple, white birch, and red oak.

If mature white pine trees are present within a 10-chain radius of a stand generally there will be

[2] *Ibid.*

white pine in the understory. However, even with an adjacent white pine seed source, the present white pine understories are not dense, having an average of only 135 stems per acre.

After aspen stands are clearcut on coarse-textured soils at the end of the present rotation, aspen suckers sufficient to form another stand will grow through the low density pine and/or hardwood understory which averages less than 200 stems per acre for all stands investigated. A few mixed stands of aspen-hardwood or aspen-hardwood-pine may result but the problem of aspen conversion may be more serious in one or two rotations when the understories are better developed.

On medium-textured sandy loam and loam soils (Elderon, Iron River, and Pence series), white pine and northern hardwood species also may be found in mixture or separately in the understory. The proportion of pine and hardwood in the understory usually depends on the availability of seed from adjacent seed sources. In general, aspen stands on the medium-textured soils exhibit moderate conversion rates. Therefore, changes in the acreage and volume of aspen on these soils can be expected.

After a clearcut of stands on the medium-textured soils, approximately 25 percent of the sites will immediately convert to the northern hardwood or northern hardwood-white pine forest type, and another 45 percent of the new stands will be some combination of aspen, northern hardwood, and pine. Approximately 30 percent of the stands will regenerate to relatively pure stands of aspen.

Stands on the moderately well-drained and well-drained fine-textured silt loam soils (Goodman, Lynne, and Stambaugh series), are rapidly converting to the northern hardwood forest type. These soils have high water holding capacities and are rapidly invaded by sugar maple, red maple, yellow birch, white ash, green ash, American elm and red elm. White pine is usually not a component of the forest understory in many parts of north-central Wisconsin. White pine of any size is noticeably absent, particularly in the Newwood River area of Lincoln County and parts of Price and Sawyer Counties. Surveyor's records indicate that white pine was once a component of the forest in these areas, but apparently it was eliminated during the cutting and fires of the early 1900's.

After aspen stands are clearcut on the silt loam soils, 45 percent of the sites will immediately convert to the northern hardwood forest type and another 45 percent will convert to some combination of aspen and hardwood. Approximately 10 percent of the sites will remain in pure aspen. At the end of the next rotation, aspen will not be an important species on the fine-textured soils unless drastic methods are used to maintain it.

YOUTH

Foresters recently entered a new phase in aspen management when the vast areas of mature stands began to be replaced by young stands of aspen or northern hardwoods. Management problems and procedures for these young aspen stands are considerably different than those for mature stands and several questions need to be answered.

How does reproduction density vary with the soil texture, amount of overstory remaining, or understory density? How effective is site treatment in removing competing species and maintaining aspen? Do the results of site treatment vary with the soil texture and drainage?

In north-central Wisconsin, clearcut aspen stands on coarse-textured loamy sand and fine-textured silt loam soils were studied in an attempt to answer these questions (Fralish and Loucks 1968; Fralish 1971). Approximately one-half of the clearcut stands investigated had been subsequently treated (cleared) by a bulldozer and a K-G blade or disk. Generally the data for clearcut but untreated stands on silt loam soil are for stands that are slowly changing in composition; rapidly converting stands were more difficult to locate since, after cutting, these stands immediately converted to northern hardwood species.

In general, a few small trees remained after harvesting operations in clearcut stands; on a per acre basis only 51 and 44 trees ($\geq$ 3.5 inches) remained standing on loamy sand and silt loam soils respectively (table 1). Aspen reproduction did not appear to be affected by this low number of overstory trees, although larger numbers could increase competition and reduce the number and growth of suckers. Stands that were both clearcut and treated by bulldozing had no overstory trees and the brush and hardwood understory common to fine-textured soil was also absent.

Table 1. — *Density of residual trees in 3- and 4-year-old stands after clearcutting and in overmature stands on loamy sand and silt loam soils (stems/acre ≥ 3.5 in. d.b.h.)*

Species	3- and 4-year-old stands		Overmature stands	
	Loamy sand	Silt loam	Loamy sand	Silt loam
Aspen	15	38	115	138
Pine	8	0	3	1
Northern hardwoods	2	6	1	93
Red maple	10	0	7	1
White birch	14	0	7	11
Miscellaneous	2	0	2	10
Total	51	44	135	254

The average number of aspen seedling and sapling stems per acre for 3- and 4-year-old clearcut stands on loamy sand soils (Crivitz, Hiawatha, Vilas series) range between 12,700 and 13,700 on both treated and untreated sites (table 2). In 1-year-old stands, there are probably 16,000 to 18,000 stems per acre. The data indicate that lack of aspen reproduction is not a problem on sandy soils even where the former stand was mixed aspen and jack pine. In stands investigated disking had been employed to stimulate jack pine reproduction rather than aspen; at present aspen dominates these sites.

After stands were harvested on moderately well and well-drained silt loam soils (Goodman, Lynne, and Stambaugh series), aspen reproduction developed quickly and in high numbers (approximately 18,000 stems per acre in 1-year-old stands)if hazel and northern hardwoods were absent from the site. Very few of these stems were browsed by deer. In 3- and 4-year-old stands, aspen density decreased to 12,352 stems per acre (table 2) indicating a high mortality rate due to intense interspecific competition.

However, aspen suckers developed rather slowly and in lower numbers (approximately 5,600 stems per acre in 1-year-old stands) on fine-textured soil if heavy hazel was present on the site. Approximately 50 to 60 percent of these stems were browsed by deer. Moreover, suckers apparently continued to develop; at age 4 there were 8,162 stems per acre. Hazel definitely reduces aspen suckering but does not compete sufficiently to prevent a new stand from developing. Where hazel is very dense, prescribed burning can probably be used to reduce competition.

Table 2. — *Density of seedlings and saplings in 3- and 4-year-old stands after clearcutting and in overmature stands on loamy sand and silt loam soils (stems/acre < 3.5 in. d.b.h.)*

Species	3- and 4-year-old stands						Overmature stands	
	Clearcut			Clearcut and treated				
	Sand	Silt 1/	Silt 2/	Sand	Silt 3/	Silt 4/	Sand	Silt
Aspen	13,647	12,352	8,162	12,766	10,764	8,084	1,602	728
Pine	5/358	0	0	6/233**	0	0	5/116*	0
N. hardwoods	0	48	24	0	80	20	2	1,537
Red maple	80	812	266	542	40	20	245	309
Red oak	132	0	0	60	0	0	206	2
Willow	220	1,820	602	873	880	5,408	129	297
Miscellaneous	362	912	196	461	1,992	128	534	174
Total	14,799	15,944	9,250	14,935	13,752	13,660	2,834	2,045

1/ No understory competition.
2/ Heavy brush competition.
3/ Moderately well-drained soils.
4/ Somewhat poorly drained soils.
5/ White pine.
6/ Jack pine.

Dense advanced hardwood reproduction prevents aspen suckering. As previously mentioned, the clearcut but untreated stands on silt loam soils generally had low numbers of advanced hardwood reproduction and, therefore, had high numbers of aspen suckers. On sites where large numbers (500 or more per acre) of hardwood stems are present, the conversion rate is rapid and the site must be treated if aspen is to be maintained. The treated sites are now covered with well-stocked young aspen stands (table 2) but without treatment aspen would have been excluded as the sites were stocked with advanced hardwood reproduction after clearcutting but prior to treatment.

On somewhat poorly drained silt loam soils (Clifford series), the treated sites had approximately 18,000 stems per acre at age one, but at age four only 8,084 stems remained and most of these stems were located on small raised mounds. The surrounding lower and more poorly drained areas were nearly devoid of aspen reproduction. Therefore, it appears that sites with somewhat restricted drainage should not be treated but be allowed to convert to northern hardwoods.

Other species such as black cherry, red maple, white birch, juneberry, and pin cherry are found in nearly all stands. Only willow showed a relationship between density and soil texture or site treatment (table 2). Willow has a much higher density on the silt loam soil, especially on the treated sites. These higher densities reflect not only the more favorable moisture conditions but also the stimulating effect of site disturbance.

OLD AGE

The phenomenon of aspen stand deterioration (natural breakup) is a relatively new problem in forest management (Fralish and Loucks 1968; Fralish 1971). It should not be assumed to occur with the same frequency or at the same stand age throughout the geographic range of aspen. Some evidence indicates that natural breakup varies with climatic conditions.

In central Wisconsin maximum stand age ranges from 25 to 35 years (Portage County), while 75 miles to the north (Lincoln County) maximum stand age ranges from 45 to 50 years. In Sawyer County, 100 miles northwest of Lincoln County, maximum stand ages range from 55 to 60 years. Aspen stand ages in northern Minnesota may reach 100 years (Zehngraff 1947). Although other climatic factors may be influencing maximum stand age, there is some correspondence to summer temperatures. Mean July temperatures for these four geographic areas are 71° F., 69° F., 67° F., and 63° F. respectively (U.S. Department of Agriculture 1941).

Deterioration appears to follow a definite pattern in each stand. During the ages of rapid growth the even-aged condition of the stands creates severe competition for light and moisture. As less vigorous, slower growing individuals die, openings are created that are rapidly closed through radial crown growth of faster growing individuals. Because of the closely packed canopy and even-aged condition, the trees become dependent on a continuous canopy to prevent exposure and breakage by wind.

Growth slows as maturity is reached, thus when individual trees die, the canopy holes cannot be closed as during earlier periods of rapid growth. As the canopy becomes more open, the frequency of breakage increases. Moreover, the open canopy exposes the stand to the stresses of increased wind, sunlight, and evaporation. Aspen physiology is not designed to tolerate these sudden stresses and the tree usually dies, or becomes less vigorous and thus more susceptible to disease and insect attack which further increases the frequency of breakage. The entire process of deterioration may take no longer than three or four years.

In mature stands, aspen density may average from 300 to 400 trees per acre. In deteriorating stands, aspen density ranges from 115 to 138 trees per acre (table 1) and is decreasing. The stands are relatively open and the trees often, but not always, show evidence of heartrot.

Overmature stands on loamy sand soil have low numbers of aspen seedlings and saplings because suckering is inhibited by the remaining overstory (table 2). The stem densities of other species are also low so that these sites are converting to open, nonproductive forest and brush, primarily uneven-aged aspen, *Rubus*, and related species. However, as long as a few live aspen trees per acre remain, such stands can probably be regenerated through the removal of the overstory and disking to stimulate suckering. In some cases, it may be preferable to refrain from treating such areas in order to create a natural opening for wildlife.

Where aspen stands deteriorate on fine textured soils, generally hardwoods will occupy the site because an overstory remains to inhibit aspen suckering and there is severe competition from the hardwood understory. Site treatment to remove the overstory and hardwood understory will probably regenerate the aspen; however, more research needs to be done on deteriorating stands.

MANAGEMENT IMPLICATIONS

The ecological relationships between quaking aspen, soil and site characteristics, and associated vegetation have both long and short management implications to land managers. The relationship between site index and conversion rate, both of which increase on the fine-textured silt loam soils, is important. The best aspen sites are being lost to the northern hardwood types, thus as conversion continues the total volume and acreage of aspen will decline drastically. Average aspen growth and volume per acre can be expected to decrease because only the poorer sites will remain in aspen.

Perhaps management should consider the economics of using more hardwood pulp as opposed to the continued use of aspen pulp. Hardwood species are slower growing, but no effort is needed to maintain them on silt loam soil. Maintenance of aspen through site treatment methods results in increased costs, but aspen is faster growing and at present mills are equipped to handle aspen pulp. Because the greatest conversion to hardwood will occur at the end of the present rotation, these economic evaluations should be made immediately.

However, site treatment to regenerate aspen must be judiciously applied. Poor aspen sites that are converting to northern hardwoods on somewhat poorly drained fine-textured soil should be permitted to continue. On coarse-textured soils, site treatment should not even be considered. In areas where overmature stands are common, regenerating these stands may be necessary especially with the reduction in aspen acreages in the years ahead. In general, it appears that foresters will have to do some precise management planning.

Finally, foresters should not limit the types of site treatment methods that can be employed to regenerate aspen. At present, only mechanical methods have been attempted and found satisfactory. However, the present aspen forests were the result of cutting and fire, thus prescribed burning should be investigated as a possible management tool.

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