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# SOIL REQUIREMENTS AND SITE SELECTION FOR AIGEIROS POPLAR PLANTATIONS

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Abstract.--Information about soil requirements and site selection for Aigeiros poplars is reviewed, and a new technique for evaluating potential sites for planting eastern cottonwood (Populus deltoides Bartr.) in the United States is proposed. This method should serve as a practical field aid in site evaluation for cottonwood. If modified for geographic areas and species, the technique may be applicable to Aigeiros poplars throughout the world.

Additional keywords: Populus deltoides, black poplars, Euramericana poplars, site evaluation, site index, soil properties.

Because Aigeiros poplars require specific soil conditions for prolonged rapid growth, proper site selection is critical in plantation establishment. This paper summarizes information concerning soil requirements and site selection for Aigeiros poplars and proposes a new technique for evaluating sites for eastern cottonwood (Populus deltoides Bartr.) in the United States.

## SOIL REQUIREMENTS

Black poplar growth depends on four major soil factors (Broadfoot 1969; Broadfoot, Blackmon, and Baker 1972; Kaszkurewicz 1973; Schreiner 1959; Waring 1961; FAO 1958):

(1) Soil physical condition
(2) Moisture availability during the growing season
(3) Nutrient availability
(4) Aeration

Most of the literature dealing with soil requirements or growth of poplars emphasizes the need for deep, medium-textured, alluvial soils that are fertile and moist, yet well drained and well aerated. If forest managers could recognize soils with these characteristics, site selection would present no problem. However, since many interacting soil-site properties influence the major soil factors, site evaluation and selection for black poplars is usually difficult. This paper discusses soil requirements and methods of

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site selection for Aigeiros poplars. Because soil-species and soil-clone interactions often exist, the specific soil requirements of a particular species or clone may differ from those discussed here.

## Factor 1--Physical Condition of the Soil

Some of the soil-site properties that influence the physical condition of soil and thus tree growth include soil depth, presence of artificial or inherent pans, soil texture and structure, compaction, and past use of the site (Broadfoot, Blackmon, and Baker 1972). These properties (Table 1) illustrate the relationship of various soil-site conditions to site quality for one poplar species--eastern cottonwood. Poor soil physical properties limit tree growth directly by restricting the potential rooting volume (Garbaye 1974). Poor soil physical condition also affects growth indirectly by interacting with soil moisture, nutrient availability, and aeration. Brendemuehl (1957), for example, reported that of the soil physical factors studied in Iowa, those correlated with growth of eastern cottonwood were in some way associated with available soil moisture. Broadfoot and Bonner (1966) showed that compacted medium-textured soils had poor aeration and poor movement of moisture and nutrients.

Soil physical condition is often altered by past land use (Baker and Blackmon 1973). Some practices such as intensive agricultural cropping or grazing usually result in compacted surface soils and impaired structure (Broadfoot and Bonner 1966, McKnight 1963). Excessive or continuous tillage of medium-textured soils also causes the formation of artificial or mechanical hardpans, which reduces the effective soil rooting volume and retards movement of moisture and nutrients. Effective rooting depth of some soils is restricted by heavy clays, inherent pans, rock, or a high stagnant water table. Poplars generally make best growth on soils having at least 4 feet of unrestricted rooting depth (Broadfoot, Blackmon, and Baker 1972; Schreiner 1959; Tingle 1966; Waring 1961).

## Factor 2--Moisture Availability

Adequate soil moisture during the growing season is essential to good poplar growth. Since most of the water supplied to the rooting zone of the soil is from rainfall, flooding, and subsurface recharge, certain soil-site properties influence the quantity and quality of water available to trees. These properties include artificial or inherent pans, topographic position, microsite, depth to water table, soil texture and structure, frequency and duration of flooding, and past use of the site (Broadfoot, Blackmon, and Baker 1972) (Table 1).

For soils on floodplains of rivers or streams, water tables are usually at a depth that provides good subsurface recharge (Broadfoot 1960a, Broadfoot 1969, McKnight 1970). A well aerated water table should be periodically high enough to recharge the rooting volume of the soil but should not be so high or poorly aerated as to impede root development (Broadfoot 1973a, Broadfoot 1973b, Schreiner 1959, Waring 1961). A concave microsite such as a depression or trough affords the best moisture relationships during the growing season because it catches and holds runoff from surrounding areas.

Table 1.--Soil-site properties influencing the four major soil factors and thus cottonwood growth

| Soil-site property | Soil-site condition and relative quality | | |
|---|---|---|---|
| | Best | Medium | Poorest |
| **Factor 1. Physical condition** | | | |
| Soil depth and presence of artificial or inherent pan | Deep soil (> 4 feet); without pan [16][a/] | Medium depth (2-4 feet), or weak inherent pan, or plowpan [11] | Shallow soil (< 2 feet), or strong inherent pan [-11] |
| Texture (in rooting zone) | Medium-textured; silty or loamy [11] | Coarse-textured; sandy [8] | Fine-textured; clayey [-4] |
| Compaction (in surface foot) | No compaction; loose, porous, friable, bulk density < 1.4 g/cc [9] | Moderately compacted; firm, moderately tight, bulk density 1.4-1.7 g/cc [6] | Strongly compacted; tight, bulk density > 1.7 g/cc [-3] |
| Structure (in rooting zone) | Granular; single-grained; massive (if sandy, loamy, or silty) [5] | Prismatic; blocky [3] | Massive (if clayey); platy [-3] |
| Past use and present cover | Undisturbed; near-virgin, forest cover [5] | Moderate cultivation; cultivated < 20 years, or open with grass [2] | Intensive cultivation; cultivated > 20 years, or open and bare [-2] |
| **Factor 2. Moisture availability during growing season** | | | |
| Water table depth | 2-6' [10] | 1-2'; 7-10' [7] | < 1'; > 10' [Unsuitable];[0][b/] |

Continued

Table 1.--Soil-site properties influencing the four major soil factors and thus cottonwood growth (continued)

| Soil-site property | Soil-site condition and relative quality | | |
|---|---|---|---|
| | Best | Medium | Poorest |
| **Factor 2. Moisture availability during growing season (cont'd)** | | | |
| Artificial or inherent pans | No pans [9] | Weak inherent pan or plowpan [6] | Strong inherent pan [-6] |
| Topographic position | Floodplain or stream bottom [7] | Stream terraces or lower slopes [5] | Upland [-5] |
| Microsite | Concave; depression, pocket, trough [7] | Level; flat [5] | Convex; ridge, mound [-2] |
| Structure (in rooting zone) | Granular; massive (if silty, loamy, or clayey); stratified [5] | Prismatic; blocky [3] | Massive (if sandy); platy; single-grained [-3] |
| Texture (in rooting zone) | Silty or loamy [4] | Clayey [2] | Sandy [-2] |
| Flooding | Winter through spring [2] | Winter only [1] | None; continuous [-1];[Unsuitable] |
| Past use and present cover | Undisturbed; near-virgin, forest cover [2] | Moderate cultivation; cultivated < 10 years [1] | Intensive cultivation; cultivated > 10 years [-1] |
| **Factor 3. Nutrient availability** | | | |
| Geologic source | Mississippi River Loess, Blackland [8] | Mixed Coastal Plain and other [5] | Coastal Plain [-5] |

Continued

Table 1.--Soil-site properties influencing the four major soil factors and thus cottonwood growth (continued)

| Soil-site property | Soil-site condition and relative quality | | |
|---|---|---|---|
| | Best | Medium | Poorest |
| | **Factor 3. Nutrient availability (cont'd)** | | |
| Past use and present cover | Undisturbed; near-virgin, forest cover, cultivated < 5 years [5] | Moderate cultivation; cultivated 5-10 years, or open with grass [3] | Intensive cultivation; cultivated > 10 years, or open and bare [-3] |
| Organic matter (A-horizon) | > 2% [4] | 1-2% [3] | < 1% [-3] |
| Depth of topsoil (A-horizon) | > 6" [3] | 3-6" [2] | < 3" [-2] |
| Soil age | Young; no profile development; Entisols [3] | Medium; moderate profile development; Inceptisols [2] | Old; well-developed profile, leached; Alfisols [-2] |
| pH (in rooting zone) | 5.5-7.5 [3] | 4.5-5.5 7.6-8.5 [2] | < 4.5 > 8.5 [-2] |
| | **Factor 4. Aeration** | | |
| Soil structure (in rooting zone) | Granular, porous; single-grained; or massive (if sandy, loamy, or silty) [3] | Prismatic; blocky [2] | Massive (if clayey); platy [-2] |
| Swampiness | Wet in winter only [3] | Wet January-July [2] | Waterlogged all year [Unsuitable] |

Continued

Table 1.--Soil-site properties influencing the four major soil factors and thus cottonwood growth (continued)

| Soil-site property | Soil-site condition and relative quality | | |
|---|---|---|---|
| | Best | Medium | Poorest |
| | Factor 4. Aeration (cont'd) | | |
| Mottling | None to 18" depth [3] | None to 8" depth [2] | Mottled to surface [-2] |
| Soil color (A-horizon) | Black, brown, red [3] | Yellow, brownish-gray [2] | Gray [-2] |

a/ Each bracketed number indicates the site quality rating (SQR) of a particular soil-site condition (Section headed "A new approach to site selection: a subjective-objective method")

b/ If the soil is a sand or loamy sand, then (-20).

Soil structure and texture are the most important determinants of water infiltration, percolation, and retention. Movement of water into and through the soil profile occurs readily if there is a favorable balance of large and small pores. Medium-textured soils having a strong, granular structure permit rapid infiltration and movement of water in the soil and have a large water-holding capacity. Flooding during the winter and early spring provides complete water recharge of the soil and ample moisture during most of the growing season (Broadfoot 1967, Broadfoot and Williston 1973). Areas with compaction, artificial pans, and poor soil structure--usually associated with intensive agronomic cropping or grazing--frequently have inadequate growing season moisture (Baker and Blackmon 1973).

Factor 3--Nutrient Availability

Because of rapid growth and relatively high nutrient concentrations in their tissue, Aigeiros poplars not only require high levels of soil nitrogen, phosphorus, and potassium, but also require soils with high base status and ample micronutrients.

Fertilization can often provide supplementary nutrients; however, some of the soil-site properties that influence the native fertility and nutrient availability include soil age, geologic source and mineralogy, depth of topsoil, organic matter, pH, and past use (Broadfoot, Blackmon, and Baker 1972) (Table 1).

Geologic source and mineralogy strongly influence inherent fertility. Soils derived from parent material with high nutrient content are obviously more fertile than those formed from material low in nutrients. Likewise, soils with relatively high proportions of clay minerals that contribute to good cation exchange usually have good fertility.

Organic matter is a potential source of soil nutrients and also serves as part of the soil-nutrient exchange complex. Intensive agronomic tillage and cropping often reduce the amount of organic matter in the soil and deplete the nutrient reserve (Baker and Blackmon 1973, Blackmon and White 1972).

A soil's nutrient content declines with age because of the leaching of soluble elements from the surface layers. Profile development indicates leaching and thus aging. Young soils developing in floodplains are usually fertile because of the deposition of recent alluvium.

Soil pH is important for nutrient availability in that many elements are fixed in the soil and unavailable for plant absorption within certain pH ranges. Most nutrients are available to poplars when the pH is near neutral. Many researchers agree that black poplars grow best when pH ranges from 5.5 to 7.5 (Brendemuehl 1957, Capel and Coffman 1966, Carter and White 1971, McKnight 1970, Schreiner 1959).

Factor 4--Aeration

Some of the soil-site properties that influence or indicate soil aeration and site quality of cottonwood (Broadfoot, Blackmon, and Baker 1972) are presented in Table 1. Since air competes with water for the same soil pore spaces, there is a close relationship between moisture availability and aeration. Therefore, a good moisture-air balance in the soil is essential for optimum tree growth. Aigeiros poplars will not grow well on saturated soils, which do not allow sufficient soil air. When a shortage of available oxygen or an excess of $CO_2$ occurs in the soil, root respiration is restricted and nutrients cannot be absorbed and utilized.

A soil that is well aerated but still contains ample available moisture must have a proper ratio of large and small pores. Under ordinary conditions in humid temperate zones, the ratio between the volume of large to small pores should be about 1:1 (Kohnke 1962). The large pores tend to drain rapidly and are thus aerated, while the small capillary pores hold water. If a soil has either all large or all small pores, a proper moisture-air balance is difficult to maintain.

A good indication of poor soil aeration is the presence of mottling at or near the soil surface or a dull, gray color. Soils that are well aerated are usually bright and have a dominant color of black, brown, or red.

## SITE SELECTION

Because of the exacting edaphic requirements of black poplars, selecting sites that provide near optimum growing conditions is complex. Several systematic techniques of site selection or classification have been developed to provide estimates of soil suitability and productivity for poplars. Some are objective in that they attempt to quantify soil factors and correlate them with tree growth. Others are subjective, being based on an observer's evaluation of such criteria as physiographic area and topographic position, soil characteristics, frequency of occurrence and observed growth on particular series of soils, and site-indicator plants.

### Objective Approaches

Site classification systems based on measurable soil variables include those of Brendemuehl (1957), Broadfoot (1969), and White and Carter (1970). Brendemuehl found that eastern cottonwood growth on some Iowa soils was most highly correlated with available water and nitrifiable nitrogen in the 4-foot soil profile. Brendemuehl's prediction equation was:

$$\text{Site Index @ 50 years} = 79.984 + 1.238(AW) + 0.138(N);\ R = 0.70$$

Broadfoot found that cottonwood growth was most related to the percentage of clay and of silt + clay, pH, and extractable soil phosphorus in the 2- to 3-foot soil layer. His equation was:

$$\text{Site Index @ 30 years} = 62.9 - 0.363(\%\ \text{clay}) + 0.281(\%\ \text{silt + clay}) + 5.54(\text{pH}) - 0.033(\text{extr. P});\ R = 0.67$$

White and Carter reported that of the chemical and physical properties measured on some alluvial soils in Alabama, extractable soil potassium in the surface foot was best correlated with cottonwood growth. Their equation was:

$$\text{Site Index @ 6 years} = -0.50 + 0.48(\text{ppm soil K});\ R = 0.97$$

Results from these objective approaches obviously vary. There was no common soil variable correlated with growth. Broadfoot even emphasized that his equation failed to predict site index with sufficient precision to allow for investment planning. He attributed this failure to the inability to measure the true causes of productivity—soil moisture and nutrient availability during the growing season, soil physical condition, and aeration.

### Subjective Approaches

Partially because of the difficulty of objectively relating soil properties to tree growth, several subjective techniques of site classification for poplars have been developed.

Physio-topographic technique.--Some researchers believe that poplar sites can be selected on the basis of physiography and topography. In the United States, Broadfoot (1964) classified various soils as being suitable for eastern cottonwood management if they occurred: (1) on recent and old natural levees and slackwater areas of the Mississippi River floodplain, (2) on middle and lower slopes and stream bottoms within the Mississippi Valley Silty Uplands, and (3) in stream bottoms of the southern Coastal Plain and Blacklands areas. Soils found unsuitable for cottonwood generally occurred on upper slopes and ridges of the Mississippi Valley Silty Uplands, southern Coastal Plain and Blacklands areas, and on Coastal Plain terraces.

Maisenhelder (1960) considered moist, well drained, medium-textured soils in the batture of the Mississippi River floodplain as the best sites for cottonwood. He observed that heavier-textured soils on gentle slopes bordering swamps or sloughs may support satisfactory growth, while poorly drained clays in slackwater areas are less favorable, and low swampy sites and dry ridges are unsuitable.

In Czechoslovakia, Vincent (1948) delineated four major sites for growing poplars, based on physio-topographic position: (1) swampy ground, (2) forest meadows, (3) coarse-textured terraces, and (4) rolling uplands. He lists the most suitable poplar species for each of the sites.

Soil characteristics technique.--Broadfoot (1960b) and Broadfoot, Blackmon and Baker (1972) report subjective methods for evaluating eastern cottonwood sites in the United States based on such soil characteristics as texture, internal drainage, and inherent moisture conditions. The inherently moist, medium-textured soils with good internal drainage were classified as the best sites for cottonwood (S.I. = 120' @ age 30), and the inherently dry soils of fine texture with poor internal drainage as the poorest sites (S.I. = 90' @ age 30).

Frequency-of-occurrence technique.--Broadfoot (1964) has also formulated a subjective system of classifying soil suitability for hardwoods. The theory is based on frequency of occurrence and observed growth of cottonwood on a particular soil series. This system lists by physiographic area and topographic position over 50 series of soils favorable for cottonwood in the southern United States and over 40 unfavorable ones.

McKnight (1970) arranged Broadfoot's list of soil series according to their productivity into three groups--those providing "best growth," "good growth," and "mediocre growth."

Broadfoot (1976) has recently updated and expanded his 1964 soil suitability classification to include for each soil: (1) average and expected range in site index values, (2) a suitability classification comprised of four groups ranging from "unsuited" to "best," (3) information concerning the soil's suitability for planting, and (4) pertinent soil physical and chemical data.

Site-indicator plant technique.--The use of ground vegetation types as indicators of site suitability and quality for poplars has been studied in Germany (Hesmer 1951), Canada (Smith 1957), and South Africa (Tingle 1966). Most of these authors point out that the occurrence of indicator plants is related to such soil-site factors as moisture and nutrient availability, depth to ground water, wetness, and aeration. This technique has potential as a means of site selection, particularly on areas such as abandoned agricultural lands that do not presently support a stand of trees. Also, as Smith (1957) pointed out, the abundance and vigor of the indicator plants may be more important than their occurrence, especially where a species appears across a range of site productivity classes.

## Limitations of Existing Soil-Site Evaluation Techniques

The techniques now available to aid in site selection and classification for black poplars have inherent shortcomings that limit either their utility or accuracy. The problems associated with objectively selecting and quantifying measurable soil variables that consistently reflect the growth potential of hardwoods over wide geographic areas appear to be insurmountable (Broadfoot 1969). On the other hand, the use of such subjective factors as local topography, land forms, soil characteristics, or site-indicator plants provides only broad classes of soil suitability or productivity for poplars. An exception is Broadfoot's (1976) recent paper, which gives fairly narrow site index ranges for cottonwood on a variety of soils in the southern United States. However, use of these estimates is restricted to the soils he classified and requires identification of the soil by series name; also, his productivity values are applicable only for soils in a relatively undisturbed, near virgin condition.

## A NEW APPROACH TO SITE SELECTION: A SUBJECTIVE-OBJECTIVE METHOD

Recognizing the need for a quantitative approach that incorporates the qualitative features of a particular soil-site situation, we propose a new technique of site selection and evaluation of eastern cottonwood. This technique, which is based on our experience, assesses the relative importance of the four major soil factors on cottonwood growth and evaluates the soil-site properties that influence these factors.

Assuming maximum height growth of 130 feet in 30 years for cottonwood on an ideal site, we assigned site quality ratings (SQR) to each existing or specified soil-site condition of each property of the major soil factors (see numbers in brackets, Table 1). We derived these ratings by deciding what percentage of the 130 feet was contributed by each of the four major soil factors (Figure 1). We believe, for example, that physical condition is responsible for about 35 percent (46 of 130 feet) of cottonwood growth, that moisture availability also explains about 35 percent, that nutrient availability accounts for about 20 percent (26 of 130 feet), and that aeration explains about 10 percent (12 of 130 feet). Next, we assessed the influence of soil-site properties on each of the four major soil factors. For example, of the five soil-site properties that influence soil physical conditions, soil depth is responsible for about 35 percent (16 of 46 feet) of the total effect of these properties on soil physical condition (Figure 1). Texture, compaction, structure, and past use contribute 25 percent (11 of 46 feet), 20 percent (9 of 46 feet), 10 percent (5 of 46 feet), and 10 percent respectively. Similar appraisals were made of soil-site properties for each of the other three major soil factors. Therefore, the sum of the SQR's for each major soil factor corresponds to a site index of 130 feet at 30 years.

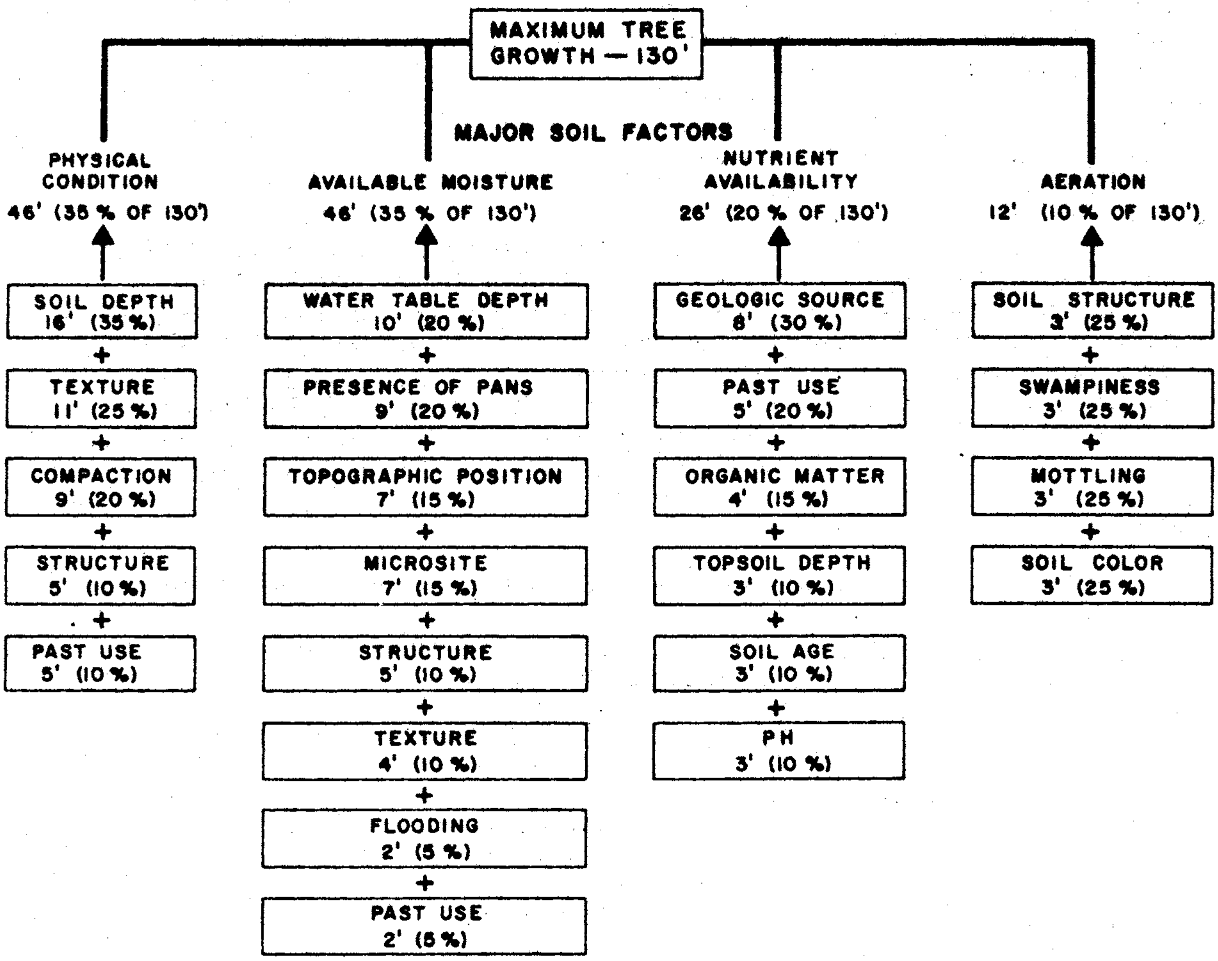


Figure 1.--Contribution of various soil-site properties to the four major soil factors and to cottonwood growth (maximum growth expected on an ideal site at age 30.)

We derived SQR values for medium and poor sites by estimating height reductions caused by less than optimal soil-site conditions. For example, we believe that soils of medium depth (2-4 feet) or those having a weak inherent pan or a plowpan would result in 5 feet less height growth (under factor 1) than would a deep soil (Table 1).

After evaluating the soil-site conditions for a specific location, a forest manager would refer to Table 1 in order to assign an appropriate SQR value to each soil-site condition for his area. He would then add the SQR values to obtain an estimated site index for cottonwood at that location. In obtaining SQR's, he would match the soil-site conditions on his area as closely as possible to the range of conditions listed for each soil-site property. When the manager is unable to match his soil-site condition to one described in the table, he should not hesitate to make an "educated guess," since a major advantage of the proposed technique is the importance of subjective evaluation. A few poor estimations would probably not cause serious errors in the final site quality rating.

The following example demonstrates how the system is applied: Let us assume that the hypothetical location to be evaluated is a recently abandoned old field in the Mississippi River floodplain that had been under intensive agronomic cropping for the previous 25 years. The area is level and not subject to flooding. The soil is a loam with no profile development; it is granular in structure but is moderately compacted and has a plowpan at 10 inches. It is brown and mottled at 36 inches. A water table occurs at 5 feet during the growing season; pH is 6.5, and there is less than 1 percent organic matter in the A-horizon.

The soil-site characteristics of the hypothetical area produced the following site evaluation:

| MAJOR SOIL FACTORS | | | | | | | |
|---|---|---|---|---|---|---|---|
| (1) Physical condition | | (2) Moisture availability | | (3) Nutrient availability | | (4) Aeration | |
| | | Water table . | 10 | | | | |
| | | Pans . . . . | 6 | Geologic source . | 8 | | |
| | | Position . . | 7 | | | | |
| Soil depth . and pans . | 11 [a] | Microsite . . | 5 | Past use . | -3 | | |
| Texture . . | 11 | Texture . . . | 4 | % organic matter . | -3 | Structure . | 3 |
| Structure . | 6 | Structure . . | 5 | Topsoil . | 3 | Swampiness. | 3 |
| Compaction . | 5 | Flooding. . . | -1 | Soil age . | 3 | Mottling. . | 3 |
| Past use . . | -2 | Past use. . . | -1 | pH . . . . | 3 | Color . . . | 3 |
| Total | 32 ft. | | 35 ft. | | 11 ft. | | 12 ft. |
| (Total possible) | (46 ft.) | | (46 ft.) | | (26 ft.) | | (12 ft.) |
| | | | | TOTAL SQR OR SITE INDEX = 90 ft. | | | |

[a] Values refer to bracketed numbers (Table 1); each number indicates the site quality rating (SQR) of a particular soil-site condition.

By summing the contribution of each major soil factor, one obtains a total site quality rating of 90, which corresponds to a site index of 90 feet at age 30. By comparing the values obtained for each major factor with the maximum values possible for an ideal site, a manager can determine which major factor is limiting growth. In this case, physical condition received 32 out of 46 (70 percent) of the points possible; moisture availability and aeration received 76 and 100 percent, respectively, of the total possible points. In contrast, nutrient availability received only 42 percent of its total possible points. Thus it appears that a lack of sufficient nutrients would limit growth on this site. This judgment might form a basis for soil ameliorative treatments, in this case fertilization, to improve the site quality for cottonwood. If a total SQR obtained for any site does not exceed 80 feet, the site should be considered unsuitable for cottonwood unless soil amelioration is performed to alleviate adverse soil-site conditions.

The advantages of the technique are: (1) it provides good estimates of productivity in terms of site index, based on numerous soil-site properties that act independently or together to govern growth; (2) it can be applied over a wide geographic area under any existing soil or site condition; (3) it does not require identification of soil series; (4) it provides guidelines for soil ameliorative treatments; and (5) it might possibly be modified to include *Aigeiros* poplars throughout the world.

Because the method requires minimum experience and laboratory testing and only cursory field scrutiny, a few hours of instruction from a soil scientist would probably enable a land manager to become familiar enough with soil-site conditions to make accurate estimates.

## SUMMARY AND CONCLUSIONS

*Aigeiros* poplars require specific soil properties that provide good soil physical condition, abundant moisture during the growing season, adequate nutrient availability, and good aeration. However, since many soil-site properties interacting with each other influence tree growth, site evaluation and selection for black poplars is often difficult.

Both objective and subjective approaches of site evaluation presently used for *Aigeiros* poplars have inherent shortcomings that limit utility and accuracy. The site index equations developed to predict site quality objectively over large geographic areas fail primarily because they are unable to account for the interaction of the many variables of productivity. The subjective approaches are only moderately accurate; they can be used over wide areas and provide a broad estimate of soil suitability, but do not offer precise estimates of site quality.

Our technique of site evaluation for eastern cottonwood provides good estimates of productivity, can be applied over wide geographic areas, and provides guidelines for soil ameliorative treatments. This system should serve as a practical field aid in site evaluation for cottonwood.

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