BLACK WALNUT SUITABILITY INDEX: A NATURAL RESOURCES CONSERVATION SERVICE NATIONAL SOIL INFORMATION SYSTEM BASED INTERPRETIVE MODEL

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Abstract.—Suitable site conditions are essential for productive growth of black walnut (*Juglans nigra* L.). Field officers at the Natural Resources Conservation Service (NRCS) in the Midwest are often asked, "What is a good walnut soil?" Current NRCS information available to most field offices rates soils only as "suitable" or "unsuitable" for black walnut. To refine the precision of this categorization and more effectively answer this question, we developed a quantified suitability model that uses 10 soil and site factors from the National Soil Information System database (NASIS). Our interpretive model generates a black walnut suitability index rating for each soil component within each soil survey map unit. Soil properties in the model are effective soil depth, available water capacity, water table depth, percent clay, percent sand, pH, and surface rock fragments. Site properties are flood frequency and duration, landform, and historic native vegetation. Linear and nonlinear functions are used to convert NASIS property values to numeric scores, which are then weighted according to relative importance in the model. Output ratings are on a continuous scale from 0.0 to 1.0, with higher values indicating better suitability. On the basis of these numeric values, the soils are grouped into the following six suitability classes: unsuited, poorly suited, somewhat suited, moderately suited, well suited, and very well suited. The final Black Walnut Suitability Index provides a rational, objective method of rating soils based on their inherent potential for black walnut growth.

INTRODUCTION

Black walnut (*Juglans nigra* L.) is a commercially valuable lumber, veneer, and nut species; provides important wildlife values; and has an extensive range across the entire Eastern United States. Black walnut displays wide ecological amplitude across many landscape positions and will grow under a variety of soil and site conditions (Williams 1990). Suitable soil and site conditions are essential for the productive, commercial growth of black walnut (Ponder 1982, Ditsch and others 1996).

A frequently asked question at the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) field office level in the Midwest is: "What is a good walnut soil?" Current NRCS Field Office Technical Guide rates soil series only as "suitable" or "unsuitable" for black walnut and is based on information from NRCS Conservation Tree and Shrub Groups. This guidance is too general for developing site-specific soil interpretations for black walnut areas that may include multiple map units and provides no scaled rating.

OBJECTIVES

To more effectively refine the precision of this categorization, we developed a quantified suitability model that uses 10 soil and site factors from the USDA National Soil Information System database (NASIS). The purpose of our paper is to describe an interpretive model that generates a black walnut suitability index rating for each soil component within each soil survey map unit.

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METHODS

Index Development

The focus of the black walnut suitability index (BWSI) was to identify critical rating criteria that would categorize a soil map unit's suitability for black walnut production. Black walnut is sensitive to a number of soil conditions and grows best on deep, well drained, nearly neutral, loamy, bottomland soils that experience periodic flooding of short duration (Losche 1973, Countryman and others 1997, Atchison 2005).

Based on black walnut growth criteria identified above and from research studies in the Midwest (Geyer and others 1980, Ditsch and others 1996, Ponder 1998, Geyer and Ponder 2004), the "ideal" black walnut soil for our model is a compilation of these factors and is defined as 1) very deep (>150 cm without a restrictive layer); 2) moderately well to well drained (water table >100 cm deep); 3) high available water capacity (AWC)(>35 cm of available water in 150 cm of soil depth); 4) slightly acid to slightly alkaline (pH 6.5 to 7.4) in the upper 60 cm; 5) medium textured (≤35 percent clay and ≤50 percent sand at 25-60 cm depth); 6) no rock fragments in the upper 60 cm; 7) a forest-derived soil; and 8) a floodplain site with no to brief duration (2 to <7 days) flooding.

In addition, inappropriate black walnut soil and site factors (Geyer and others 1980, Ponder 1982, and Parker and others 1992) are used to create unsuitable ratings for the model. These factors include: 1) shallow soil depth (<50 cm to a retarding layer); 2) wetness (water table <15 cm); 3) low available water capacity (<7.6 cm in 150 cm of soil depth); 4) very long-duration flooding (>30 days); and 5) >50 percent subsoil clay or >90 percent subsoil sand. All other combinations of soil and site factors between an ideal soil map unit component and an unsuited soil map unit component are rated as intermediate in suitability.

Based on these key growth criteria for black walnut, our quantified suitability model uses 10 soil and site factors from the NASIS database to generate soil ratings for black walnut. Soil properties in the model are as follows: 1) effective soil depth; 2) available water capacity; 3) water table depth; 4) texture (percent clay and percent sand); 5) pH (low and high); and 6) surface layer rock fragments. Site properties are: 1) flood frequency; 2) flood duration; 3) landform; and 4) historic native vegetation. Table 1 displays a summary of these factors, their generated membership values used in the index, and explanations of criteria.

Interpretation Structure

Structured Query Language is used to access and manipulate the NASIS database. Linear and nonlinear functions and assigned values are used to convert NASIS property values to numeric scores, which are then weighted according to relative importance in the model. Output ratings are on a continuous scale from 0.0 to 1.0, with higher values indicating enhanced suitability.

The BWSI model structure (Fig. 1) combines individual rules into two major groupings, an additive rule and a multiplicative rule. The multiplicative rule contains four subrules for soil properties that can restrict black walnut suitability, and is used as a multiplier in the model to strongly impact the final index. The soil properties rated in the multiplier subrules are: 1) depth to bedrock; 2) flood duration; 3) AWC; and 4) soil wetness. The multiplicative rule returns the lowest rating of its four subrules, and multiplies this rating with the output from the additive rule. This step has the effect of overriding other soil property values of lesser importance. For example, if depth to bedrock is less than 50 cm for a given soil map unit (one of the unsuited criteria), the other soil properties are now irrelevant. Such a map unit would be rated 0 on the depth to bedrock subrule, and the resulting multiplicative rule value of 0 would, when multiplied with the additive rule value, insure that the soil is rated as unsuited.

Table 1.—Black walnut suitability index multiplicative and additive factors with explanations and associated criteria values

Factors	Explanation	Criteria Value
	Multiplicative Factors	
Depth limit	Soil depth to bedrock or restrictive pan	• <50 cm = 0 • ≥50 cm = 1
Flood duration	Flooding duration in May	• None to brief (0 to <7 days) = 1 • Long (7 to 30 days) = 0.5 • Very long (>30 days) = 0
AWC limit	Available water capacity from 0 to 150 cm	• <7.6 cm = 0 • ≥7.6 cm = 1
Wetness	Water table depth in April	Piecewise linear function from 0 to 1 based on 4 datasets: • ≤15 cm = 0 • 30 cm = 0.5 • 60 cm = 0.75 • ≥100 cm = 1)
	Additive Factors	
Depth	Soil depth to restricting (e.g., bedrock, fragipan) and/or retarding (e.g., abrupt textural change, densic material) layer of any kind from 50 to 150 cm	Sigmoid curve scaled from 0 to 1. • 50 cm = 0 • 150 cm = 1
Texture	Percent of subsurface (25-60 cm) clay or sand	Piecewise linear function from 1 to 0 based on datasets: • Clay: ≤35 percent = 1; 40 percent = 0.5; >50 percent = 0 • Sand: ≤50 percent = 1; 60 percent = 0.9; 70 percent = 0.7; 80 percent = 0.2; >90 percent = 0
AWC	Total available water capacity from 0 to 150 cm (entire profile)	Sigmoid curve scaled from 0 to 1. • 0 cm = 0 • >35 cm = 1
pH	Soil pH (water) from 0 to 60 cm	Sigmoid curve scaled from 0 to 1. • Low pH: 4.0 = 0; ≥6.5 = 1 • High pH: 8.5 = 0; <7.4 = 1
Fragments	Percent of rock fragments greater than 5 cm in diameter in top 60 cm of soil profile	Sigmoid curve scaled from 1 to 0. • 0 percent = 1 • >35 percent = 0
Flood frequency	Flooding frequency in May	• None or rare (0 to 5 percent chance in any year) = 0 • Occasional (5 to 50 percent chance in any year) or frequent (more than 50 percent chance in any year) = 1
Landform	Landform designation	• Ridge/shoulder = 0 • Backslope = 0.33 • Footslope/terrace = 0.67 • Floodplain = 1
Historic vegetation	Historic vegetation with landscape position	• Upland prairie = 0 • Floodplain/terrace prairie = 0.33 • All mixed forest and prairie = 0.67 • All forest/woodland = 1

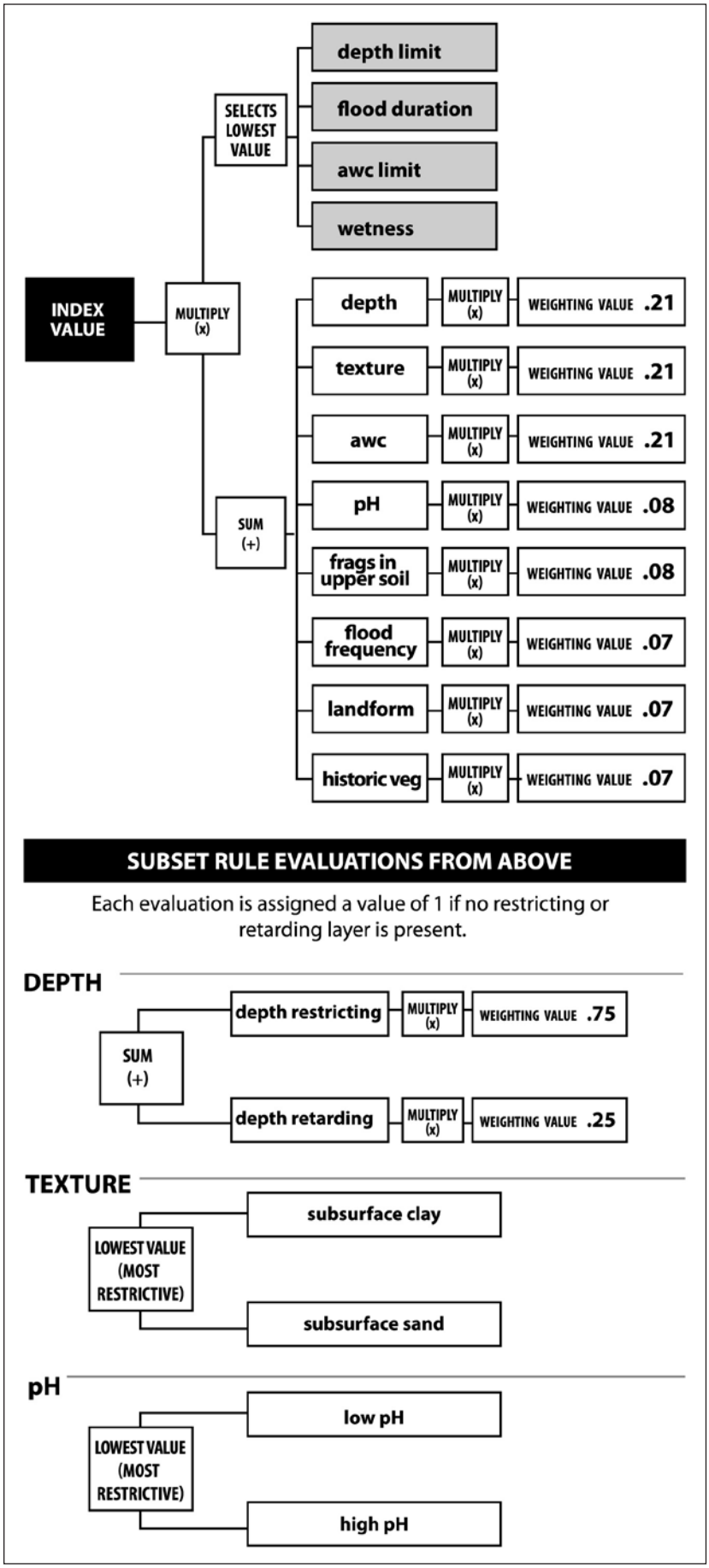

Figure 1.—The BWSI model structure showing individual rules. If one of the multiplicative factors (gray shading) is 0, the soil is rated 0 (unsuited). If all the multiplicative factors are 1, the sum of the additive factors will be the basis for rating the soil. If the lowest of the multiplicative factors is between 0 and 1, the sum of the additive factors will be multiplied by this value, thereby reducing the final suitability index. The final index is derived by multiplying the additive and multiplicative rules together.

Table 2.—Black walnut suitability qualitative rating index with corresponding calculated Index values based on eight additive and four multiplicative factors associated with black walnut growth

Black Walnut Suitability Index Rating	
Qualitative rating	Calculated value
Very well suited	0.976 - 1.000
Well suited	0.800 - 0.975
Moderately suited	0.600 - 0.799
Somewhat suited	0.400 - 0.599
Poorly suited	0.200 - 0.399
Unsuited	0.000 - 0.199

The additive rule creates gradations between fully and partially suited soil map units. The additive rule contains eight subrules: 1) soil depth; 2) texture; 3) AWC; 4) pH; 5) fragments in the upper soil; 6) flooding frequency; 7) landform; and 8) historic vegetation. Four of these additive subrules are compound: 1) pH (low and high); 2) soil depth (restricting and retarding layers); 3) historic vegetation (historic vegetation with landscape interaction); and 4) texture (sandy and clayey). Each subrule is weighted to reflect its relative importance. Weighted values for the additive subrules were assigned based on regression analysis results by Geyer and others (1980) and Geyer and Ponder (2004) and on the qualitative statements of other researchers (Losch 1973, Parker and others 1992, Ditsch and others 1996). Soil depth, texture, and available water capacity were consistently cited as major influencing factors relative to black walnut growth. Accordingly, these three subrules are weighted higher in the model. The weighted values of the eight subrules are then added to create the final additive rule value. If the multiplicative rule value is one (no restrictions) then the additive value will determine the final Index value. If the multiplicative rule value is greater than 0 but less than 1, (e.g., wetness or flooding is >0 or <1), the final index value will be a multiplicative factor of the additive rule summed values.

On the basis of these numeric values, the soils are grouped into six suitability classes (Table 2). These classes are identified as unsuited, poorly suited, somewhat suited, moderately suited, well suited, and very well suited. The qualitative rating breaks are arbitrary. The two highest rating categories, very well suited and well suited, are established with smaller numerical ranges to create a more limited rating class than the others. The remaining four qualitative rating classes are then evenly divided with numerical breaks.

RESULTS AND DISCUSSION

The BWSI is currently attached exclusively to Missouri data sets in the NRCS Soil Data Mart (SDM). Annually, Missouri NRCS refreshes its soils database by recalculating all soil interpretations in NASIS, including the BWSI, and exporting these refreshed data to the SDM. Any revisions to the soils database that have occurred over the year are captured in this process.

Other states may interface the BWSI on their state's soils. The state soils database administrator can then include the Index on the SDM and in the NRCS Web Soil Survey (WSS) but will be responsible for maintenance of their specific BWSI.

Table 3.–Black Walnut Suitability Index output table example from the Web Soil Survey for selected map units from Boone County, MO. This output table identifies up to the top five limiting rating reasons and their associated values. Values shown in parentheses under the "Rating reasons" column represent the rating values generated by each subrule in the model.

Map unit symbol	Map unit name	Rating	Rating reasons (rating values)
64008	Freeburg silt loam, 2 to 5 percent slopes	Somewhat suited	Flood Freq: None/Rare (0.00) pH limiting factor (0.26) Watertable: 30-60 cm (0.61) Landform: Footslope/ Terrace (0.75) Available water capacity: 20-30 cm (0.94)
66000	Moniteau silt loam, 0 to 2 percent slopes, occasionally flooded	Unsuited	Watertable: < 15 cm (0.00) pH limiting factor (0.08) Landform: Footslope/ Terrace (0.75) Available water capacity: 20-30 cm (0.93)
66014	Haymond silt loam, 0 to 3 percent slopes, frequently flooded	Very well suited	Available water capacity: 20-30 cm (0.94)

Running the BWSI can be accomplished through NASIS, the WSS, and the SDM. In WSS, the BWSI is under the Vegetative Productivity pull-down menu of the Suitability and Limitation for Use tab, under Soil Data Explorer. It is also located under the Soil Reports tab. In SDM, BWSI is one of the choices within the Selected Soil Interpretations report. NASIS web access is restricted to authorized USDA individuals and is controlled by individual state soil survey staffs. Access to WSS and SDM is open to anyone using the internet. Their respective URL's are http://websoilsurvey.nrcs.usda.gov/app/ and http://soildatamart.nrcs.usda.gov/ . Each of the open web sites has different multi-step procedures with multiple output display options. The WSS can generate site-specific black walnut suitability interpretive maps as well as associated tabular outputs by soil map unit. SDM outputs are limited to tabular outputs by soil map unit. Table 3 displays an example of the tabular output from the WSS.

No quantitative field testing of the BWSI has been conducted. However, field observations, along with examination of BWSI output for soil map units of known black walnut suitability, indicate that the Index displays an acceptable degree of accuracy. User comments have been positive. Whichever web site is used, the BWSI provides a new rational, objective method of rating soil map units based on their inherent potential soil properties for black walnut growth.

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