SITEQUAL V2.0—A FORTRAN PROGRAM TO DETERMINE BOTTOMLAND HARDWOOD SITE QUALITY

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Abstract.—SITEQUAL is a computerized expert system that uses a number of easily determined soil conditions associated with physical structure, available moisture, available nutrients, and aeration to estimate site index for 14 southern hardwood species. The original program was written in the Basic language by Harrington and Casson (1986) based on the field methods for site evaluation developed by Baker and Broadfoot (1979). Unfortunately, this version of SITEQUAL does not operate as a stand-alone application, but rather requires a compiler that no longer works with modern operating systems. I have reprogrammed SITEQUAL (now version 2.0) in Fortran with a more user-friendly interface and a number of other minor improvements. To demonstrate SITEQUAL2.0's utility, I present two examples of output from bottomland hardwood sites in southeastern Arkansas. Further improvements to SITEQUAL2.0 are being considered, including the development of a graphical user interface and the addition of more species and environmental conditions.

INTRODUCTION

Bottomland hardwoods represent a significant forest resource in the eastern United States, including the Central Hardwoods region. While these low, seasonally flooded forests are generally considered to be some of the most productive, numerous factors influence the productivity of any given bottomland site, resulting in a dramatic range in species performance and possibilities.

In the 1970s, James B. Baker and Walter M. Broadfoot developed an expert system to predict bottomland hardwood site index using conventionally available (or easily derivable) topoedaphic attributes. As a soil scientist, Broadfoot had spent years developing the foundations of this system (Broadfoot 1964, 1969, 1976); Baker later contributed his experience in both soils and silviculture. Their first approximation included eight species (Baker and Broadfoot 1977) followed shortly thereafter by an update that included an additional six species (Baker and Broadfoot 1979). The Baker and Broadfoot system operates under the fundamental assumption that four factors are the primary determinants of hardwood growth performance in bottomlands: soil physical condition, growing season moisture availability, nutrient availability, and aeration (Baker and Broadfoot 1979).

Since the 1979 publication, others have refined certain aspects of this system, including an adaptation for loblolly pine (*Pinus taeda* L.) in southern Arkansas (Guldin et al. 1989) and a computerized version (SITEQUAL). The original SITEQUAL program was written by Harrington and Casson (1986) in the Basic language following the field methods and taxa of Baker and Broadfoot (1979). Unfortunately, because of how SITEQUAL was coded, it did not operate as a stand-alone application, but rather required an old Basic compiler which no longer runs on modern operating systems.

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To address this shortcoming, I have reprogrammed SITEQUAL (now version 2.0) in a simple, user-friendly interface with a number of minor processing and output improvements. To demonstrate SITEQUAL's utility, in this paper I present two examples of output from a range of bottomland hardwood sites in southeastern Arkansas and discuss plans for future improvements to SITEQUAL. These upgrades may include a graphical user interface, the addition of more species, and a broader range of environmental conditions.

METHODS

The Program

SITEQUAL version 2.0 (hereafter referred to as SITEQUAL2.0 to distinguish it from the original of Harrington and Casson) is currently available by request. SITEQUAL2.0 was written as a stand-alone Fortran[2] program that operates in a MS-DOS® shell available in the Windows® operating system (up to at least Windows 7). Since I did not have a working copy of the original SITEQUAL and only have the flow diagram from Harrington and Casson (1986) to work from, SITEQUAL2.0 represents an approximation of their program.

In addition to the new stand-alone interface, the ability to run multiple scenarios without exiting the program has been added to SITEQUAL2.0, as has a limited capacity to make some default adjustments. For example, the user can change the values of species-based input parameters by editing SPP_ATTRIBUTES.CSV in a spreadsheet or text editor. However, caution is advised in making these changes, as the default values were calibrated by the original authors and any departures from these may significantly impact the results (or cause the program to crash).

Program Operation

When executed, SITEQUAL2.0 opens to an introductory screen describing the current version of the program, including a quotation from Harrington and Casson's (1986) user guide (Fig. 1). Once the user has confirmed their intent to run the program, SITEQUAL2.0 reads a species attributes file to upload the default model settings and species parameters. This species attributes file (a comma-delimited ASCII data file called SPP_ATTRIBUTES.CSV, with a fixed data structure) must be located in the same directory as the SITEQUAL2.0 executable file (SITEQUAL.EXE).

In this example, the filename hungerrun.out has been assigned. The next screen in SITEQUAL2.0 continues the data input process (Fig. 2). This stage includes a new feature, the ability to process multiple datasets without restarting the program. Each dataset can be given a specific identifier code (up to 25 characters long) that can be any alphanumeric character or symbol/mathematical operator available on the keyboard (CHERRYBARK_OAK is used in this example). After this dataset is named, SITEQUAL2.0 proceeds through a list of inquiries regarding site conditions. In the current command-line version of this program, the user must choose one of the provided options, with the exception of pH where the actual pH value is entered. Typing something other than the choices provided will invoke an error message, and

[2] SITEQUAL2.0 was developed using Absoft Pro Fortran® v13.0.4, which is a Fortran 95 compiler that fully supports FORTRAN 77 and F2003 and F2008 features. Hence, as written, SITEQUAL2.0 should be portable to other standard versions of Fortran 95, including those Linux-based systems following this standard. However, it has not been compiled in any other environment and has only been run in a Windows 7 DOS® shell to date. Some elements may not be backward-compatible with older versions (for example, FORTRAN 77) of this programming language.

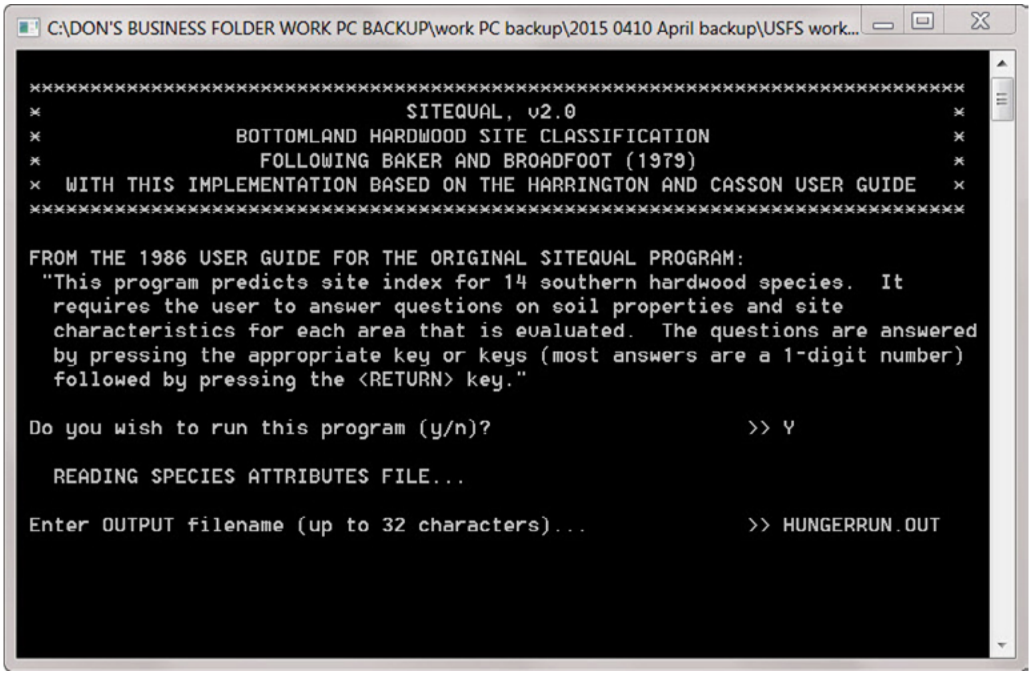

Figure 1.—Introductory screen of SITEQUAL2.0, including the initiating steps (reading the species attribute table from a file) and user entry of the output filename.

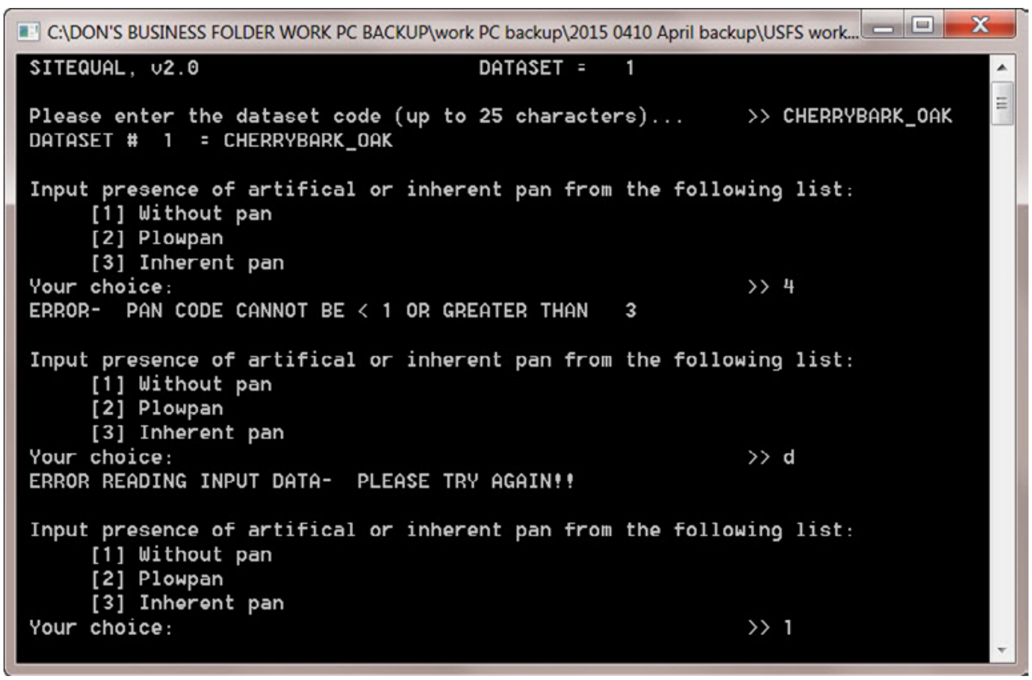

Figure 2.—The second data entry screen of SITEQUAL2.0, with examples of how incorrect data entries prompt the user to make corrections prior to advancing.

the user will be asked to enter an acceptable value. Figure 2 provides a couple of examples of incorrect entries and their resultant error messages. In the first instance, the value "4" has been entered, which is not one of the acceptable options for this particular question. The error message reiterates the acceptable range of values. In the second instance, the character "d" has been entered, which is not an integer at all. In the third instance, the valid entry "1" has been chosen and SITEQUAL2.0 then proceeds to the next question.

The user continues, answering all of the questions that appear until SITEQUAL2.0 has sufficient information to begin processing. After a final confirmation from the user that they are satisfied with their answers, SITEQUAL2.0 determines the site index estimates for all 14 species and writes to the file created by the user at the beginning of this process. The output of SITEQUAL2.0 is in the form of an ASCII text file that can be uploaded into any program (e.g., text editors, word processors, spreadsheets) capable of reading such files.

RESULTS AND DISCUSSION

More detailed examinations of the Baker and Broadfoot system are warranted. While the preliminary analyses of this system have been promising (Aust and Hodges 1988, Belli et al. 1998, Blackmon 1979), consideration of a wider range of species is still needed (Lockhart 2013). Such an evaluation is beyond the scope of this paper, however, and this effort focuses on demonstrating the capabilities of SITEQUAL2.0. The following examples of SITEQUAL2.0 represent output files generated from two different stands in southeastern Arkansas.

Example 1: Hunger Run Creek

Table 1 is an output of the CHERRYBARK_OAK dataset for the hungerrun.out file based on a site along Hunger Run Creek in Drew County (data adapted from Lockhart et al. [1999]). This productive site yielded high site index values for all species; however, some species obviously fared better under the conditions provided. While the aeration-based factors were maximized (100 percent) and greater than 92 percent of the physical condition points were achieved for all 14 species (Table 1), cottonwood (*Populus deltoides*) had less than half of the nutrient availability and not quite three-quarters of the moisture availability possible for that species. Yellow-poplar (*Liriodendron tulipifera*) had the highest value for the Hunger Run Creek location; however, this species is very uncommon in southern Arkansas. Cherrybark oak (*Quercus pagoda*) is considerably more prevalent and was predicted to have a site index of 112 feet in 50 years (Table 1). This value is slightly less than predicted by Lockhart et al. (1999), who gave a value of 114 feet for cherrybark. This modest difference arose because Lockhart et al. (1999) interpolated some of the default values of the Baker and Broadfoot system in the analog, tabular format (a paper datasheet) based on their own experience. SITEQUAL2.0 currently does not allow for that sort of modification.

Example 2: Nuttall Oak

Table 2 gives the output of a run of SITEQUAL2.0 using information adapted from Lockhart (2013). This site near Dermott in Drew County, Arkansas, is located on the Mississippi River Alluvial Plain and consists of an old-field stand that had been originally cleared in the 1970s, farmed for some years, and then replanted under the Wetlands Reserve Program (more details on the specific site can be found in Lockhart [2013]). According to SITEQUAL2.0, Nuttall oak (*Quercus nuttallii*), given the input parameters shown at the top of Table 2, would have a 50-year site index of 81 feet on this site. As noted in the previous example, the Nuttall oak site index in Table 2 is slightly different than the value (80 feet) given by Lockhart (2013). Again, this modest discrepancy arose because Lockhart interpolated between scoring categories as he evaluated the site conditions.

Table 1.—Cherrybark oak data set and output from the hungerrun.out file, based on data from a site along Hunger Run Creek in Drew County, Arkansas (adapted from Lockhart et al. [1999])

```
SITEQUAL, v2.0--Site evaluation for 14 southern hardwoods
OUTPUT FILE NAME   >>         hungerrun.out       DATE & TIME FINISHED: FEB 18, 2015  13:38:18:964

==================================================================================================
Input values for each soil site property:                 DATASET #  1  = cherrybarkoak
--------------------------------------------------------------------------------------------------
          Presence of pan:              1                 Soil depth:                  1
          Stratification:               2                 Annual fertilization:        0
          Soil structure:               1                 Soil texture:                2
          Compaction:                   1                 Present cover:               1
          Water table depth:            4                 Topographic position:        1
          Microsite:                    3                 Flooding times:              2
          Geologic source:              3                 Organic matter:              1
          Topsoil depth:                1                 Soil age:                    1
          pH:                           5.25              Swampiness:                  1
          Mottling:                     1                 Soil color:                  1
--------------------------------------------------------------------------------------------------
                           Number of points and percentage of total possible by factor
                        ----------------------------------------------------------------    Total
                         Physical          Moisture           Nutrient                        site
Species                 condition        availability       availability        Aeration     index
--------------------------------------------------------------------------------------------------
Cottonwood              44 ( 95.7%)       33 ( 71.7%)        12 ( 46.2%)        12 (100.0%)     101
Green ash               20 ( 95.2%)       34 ( 72.3%)        17 ( 65.4%)        10 (100.0%)      81
Hackberry, sugarberry   24 ( 96.0%)       18 ( 72.0%)        19 ( 76.0%)        25 (100.0%)      86
Cherrybark oak          29 ( 93.5%)       30 ( 78.9%)        22 ( 88.0%)        31 (100.0%)     112
Nuttall oak             23 ( 95.8%)       32 ( 76.2%)        26 ( 86.7%)        24 (100.0%)     105
Shumard oak             29 ( 93.5%)       24 ( 75.0%)        26 ( 89.7%)        30 (100.0%)     109
Swamp chestnut oak      26 ( 92.9%)       27 ( 87.1%)        21 ( 87.5%)        26 (100.0%)     100
Water oak, willow oak   27 ( 93.1%)       24 ( 70.6%)        21 ( 91.3%)        29 (100.0%)     101
Pecan                   26 ( 96.3%)       24 ( 80.0%)        27 ( 90.0%)        28 (100.0%)     105
Sweetgum                28 ( 93.3%)       27 ( 75.0%)        20 ( 83.3%)        30 (100.0%)     105
Sycamore                30 ( 93.8%)       11 ( 55.0%)        29 ( 74.4%)        39 (100.0%)     109
Yellow-poplar           38 ( 95.0%)       25 ( 83.3%)        23 ( 92.0%)        30 (100.0%)     116
==================================================================================================
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Table 2.—Nuttall oak data set and output from the nuttall.out file, based on data from a site near Dermott, Arkansas (adapted from Lockhart [2013])

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SITEQUAL, v2.0--Site evaluation for 14 southern hardwoods
 OUTPUT FILE NAME   >>         nuttall.out        DATE & TIME FINISHED: FEB 10, 2015   8:40:41:158

 ==================================================================================================
 Input values for each soil site property:                DATASET #  1  = nuttall
 --------------------------------------------------------------------------------------------------
          Presence of pan:              1                 Soil depth:                  1
          Stratification:               2                 Annual fertilization:        2
          Soil structure:               7                 Soil texture:                1
          Compaction:                   2                 Present cover:               3
          Water table depth:            4                 Topographic position:        1
          Microsite:                    2                 Flooding times:              1
          Geologic source:              1                 Organic matter:              3
          Topsoil depth:                2                 Soil age:                    1
          pH:                           5.25              Swampiness:                  1
          Mottling:                     3                 Soil color:                  1
 --------------------------------------------------------------------------------------------------
                           Number of points and percentage of total possible by factor
                        ----------------------------------------------------------------    Total
                         Physical          Moisture           Nutrient                        site
 Species                condition        availability       availability        Aeration     index
 --------------------------------------------------------------------------------------------------
 Cottonwood             31 ( 67.4%)       34 ( 73.9%)         9 ( 34.6%)         6 ( 50.0%)      80
 Green ash              14 ( 66.7%)       36 ( 76.6%)        11 ( 42.3%)         7 ( 70.0%)      68
 Hackberry, sugarberry  15 ( 60.0%)       18 ( 72.0%)        13 ( 52.0%)        18 ( 72.0%)      64
 Cherrybark oak         18 ( 58.1%)       28 ( 73.7%)        13 ( 52.0%)        17 ( 54.8%)      76
 Nuttall oak            15 ( 62.5%)       33 ( 78.6%)        15 ( 50.0%)        18 ( 75.0%)      81
 Shumard oak            18 ( 58.1%)       22 ( 68.8%)        17 ( 58.6%)        17 ( 56.7%)      74
 Swamp chestnut oak     16 ( 57.1%)       21 ( 67.7%)        13 ( 54.2%)        17 ( 65.4%)      67
 Water oak, willow oak  17 ( 58.6%)       26 ( 76.5%)        12 ( 52.2%)        18 ( 62.1%)      73
 Pecan                  17 ( 63.0%)       21 ( 70.0%)        18 ( 60.0%)        16 ( 57.1%)      72
 Sweetgum               18 ( 60.0%)       25 ( 69.4%)        10 ( 41.7%)        17 ( 56.7%)      70
 Sycamore               19 ( 59.4%)       12 ( 60.0%)        20 ( 51.3%)        19 ( 48.7%)      70
 Yellow-poplar          23 ( 57.5%)       22 ( 73.3%)        13 ( 52.0%)        15 ( 50.0%)      73
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SUMMARY AND FUTURE PLANS

As currently implemented, SITEQUAL2.0 is a basic tool to evaluate site conditions for a handful of species in a limited geographic region. Previous versions of this program have been used in research and management. For example, the Baker and Broadfoot approach has been shown to be one of the better tools for site index prediction in bottomland hardwood and pine-hardwood sites in Arkansas and Mississippi (Aust and Hodges 1988, Belli et al. 1998, Guldin et al. 1989). More recently, Lockhart (2013) demonstrated the utility of this system for site quality assessments. Although not presented in this paper, it is also possible to use SITEQUAL2.0 to conduct a type of sensitivity analysis for a given site by adjusting one or more factors and examining how the predicted outcomes differ. SITEQUAL2.0's simple design based on an expert system also lends itself to helping students learn about the relationship between site conditions and tree performance.

The addition of more features to SITEQUAL2.0 is being contemplated, including a version that gives the user the option to export more details on how individual species scores were determined. As suggested by both examples presented, allowing the user some flexibility to modify the default scoring system for species is also being contemplated. Although achieving some limited capacity to modify default settings may be possible with only some minor code revisions, this particular change may require a considerably more sophisticated user interface than currently possible. Once sufficiently developed, future versions of SITEQUAL may also be created for portable devices (e.g., smart phones, tablets, or field computers).

The addition of more species and a wider range of site conditions presents a different suite of challenges. There are dozens of other possible species and many other potential site conditions that could be incorporated, if sufficient knowledge behind the relationships between species and site exists. Expanding the number of species and breadth of site conditions may be possible if spatially registered data on individual trees (including accurate species identifications as well as age relationships) can be linked to detailed and compatible site information. For example, it may be feasible to get species and age information for site trees used by the U.S. Forest Service, Forest Inventory and Analysis (FIA) program mapped to sufficiently described soil polygons. Such an effort would require the close cooperation of the FIA program, which carefully guards the exact locations of its sample trees. Likewise, it may also be possible to develop the necessary background data from existing studies or other inventory plots; however, such information may be restricted to a limited geographic area.

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