Internet Software for Forest Stand Carbon Sequestration

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ABSTRACT

The amount of carbon sequestered during growth of a forest stand is estimated based upon a Stand Growth model. The software will run on an individual's web browser and consists of a Three-Tier Client/Server System. Java Servlets are used to interact with the user via the web and comprises the middle tier. The Server tier runs the models and sends results back to the user. Total Carbon stocks are determined by using volume amounts from the Stand-Growth model output and converting to per-acre Carbon. The forest growth model (Stand-Damage Model with Java) is a gap model based on JABOWA and simulates volume and basal area increase over time. This information can be used to help identify cost-effective sequestration technologies and will allow researchers, policy planners, and individuals to rapidly estimate the amount of carbon that is being sequestered by forest stands.

Introduction

The Framework Convention on Climate Change (United Nations 1992) commits 192 signatory nations to monitor carbon stocks in vegetation. Consequently carbon inventory systems will need to be accurate, consistent, and accessible to the public. The Forest Stand Carbon Simulator allows an individual to quickly estimate the amount of carbon sequestered by their particular stand. Although this simulation tool was designed for a Northeastern U.S. climate, relative comparisons can be made for different size class distributions in other forest types to clarify the implications of forest management decisions. If and when carbon tax credits become available, this website could become an important resource for small landowners.

The amount of carbon that is sequestered during growth of a forest stand is estimated using a Stand Growth model. The software runs on an individual's web browser and consists of a Three-Tier Client/Server System. Java Servlets are used to interact with the user via the web and comprise the middle tier. The Server tier runs the models and returns results to the user. The programming language Java was chosen because it is object-oriented, architecturally neutral, network capable, web accessible, and multi-threaded.

Total Carbon stocks are determined by using the basal-area amounts from the Stand-Growth model output and converting these dimensions into per-acre Carbon. The forest growth model (Stand-Damage Model with Java or SDM) is based on JABOWA. SDM can model 72 tree species but the web interface was simplified by considering two options for simulation: stands dominated by either deciduous or evergreen trees.

Growth Model

The Stand-Damage Model with Java[1] (SDM) was used as the growth model. SDM is a gap model based on JABOWA and is used to estimate tree diameter growth, volume, height, and mortality for each simulated year. The model is a distance-independent tree growth simulator based on the work of Botkin (1993) and Shugart (1984). Each year, the model calculates the diameter growth of trees as a function of relative stocking, shading, heat, and defoliation. Tree-growth simulation is driven by weather. An accumulative heat unit measure (day-degrees above a single threshold of 40° F) is used to determine diameter growth. The user can modify several input parameters related to the forest and its environment, such as the location of the forest, its weather and soil, and the number of trees at the beginning of the simulation. The user can also apply different logging practices and consider different climate change scenarios.

SDM does not contain a component to estimate soil carbon. To estimate carbon storage on a small forest stand, it was assumed that stand growth had minimal effects on soil carbon and so only tree biomass carbon was considered (Hoover et. al. 2000).

[1]The use of trade, firm, or corporation names in this document is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

The “Stand-Damage Model with Java: Version 3.0” (Racin and Colbert 2004) describes the Windows version of the model. The “Description of the Stand-Damage Model” (Colbert and Sheehan 1995) provides the biological basis and the algorithms used. Model information and software downloads are available at **www.fs.fed.us/ne/morgantown/4557/gypsymth**

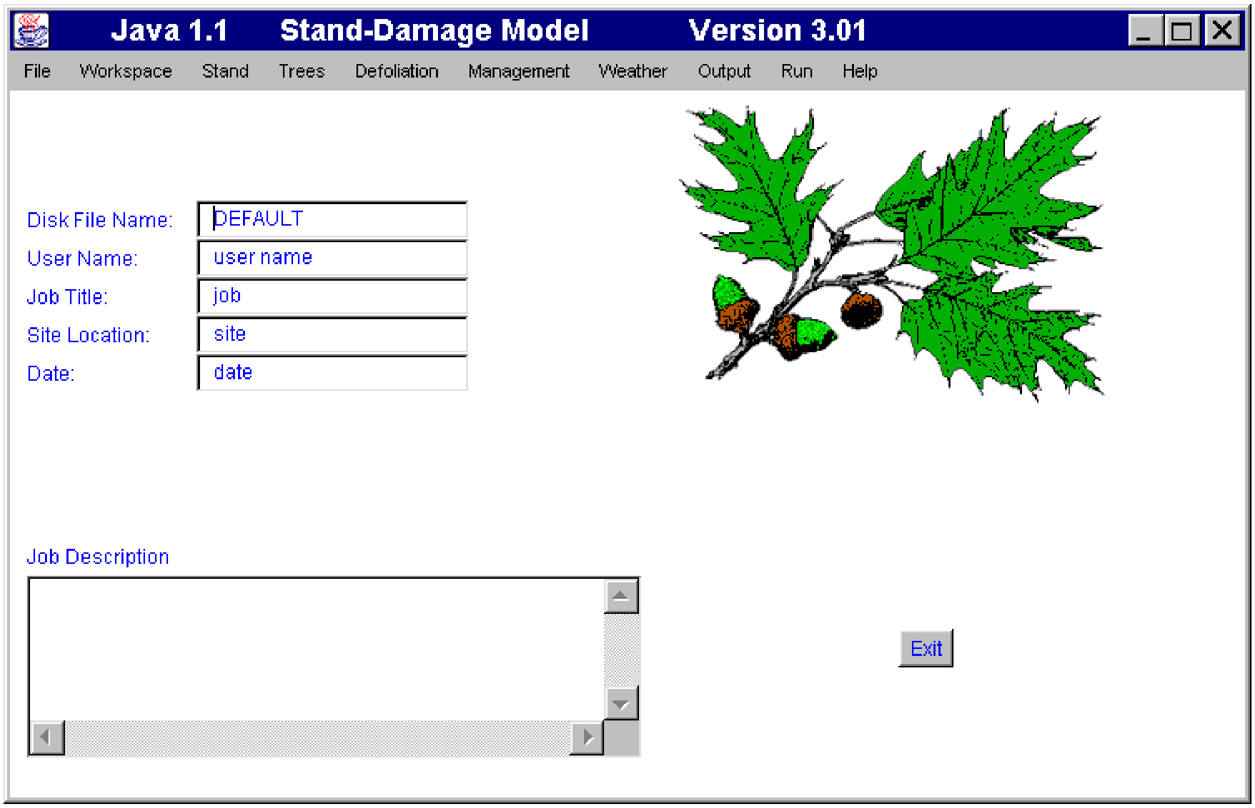

Figure 1: Main Interface for the Stand-Damage Model.

When the Stand-Damage Model is started from within Windows as an individual software package, the Main Interface is displayed (Fig. 1). Each menu item activates a pulldown submenu. Under the Main Menu **Trees** pulldown, items related to individual species can be edited. By selecting the **Trees** pulldown, one can edit the stem counts for up to 72 species. In this example, we choose northern red oak, *Quercus rubra*, and a screen showing where stem counts can be edited by diameter class is presented in Figure 2.

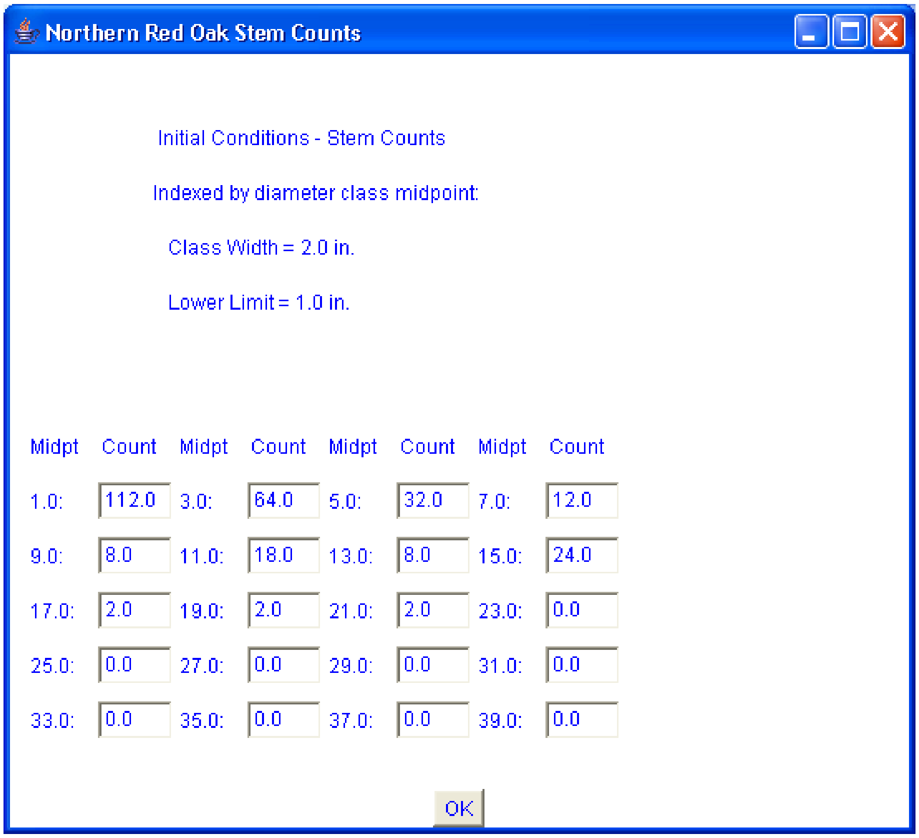

Figure 2: Stem Counts for Northern Red Oak

There are 20 diameter classes for each tree species. In the example presented in Figure 2, 112 stems have been entered in the 1 inch diameter class, 64 stems in the 3 inch diameter class, etc. After the Stem Count data have been entered and other parameters such as simulation length have been set, the simulation can proceed. When the simulation has been completed, the user can select **View** from the **Output** pulldown menu to view various outputs, including a Summary Table (Fig. 3).

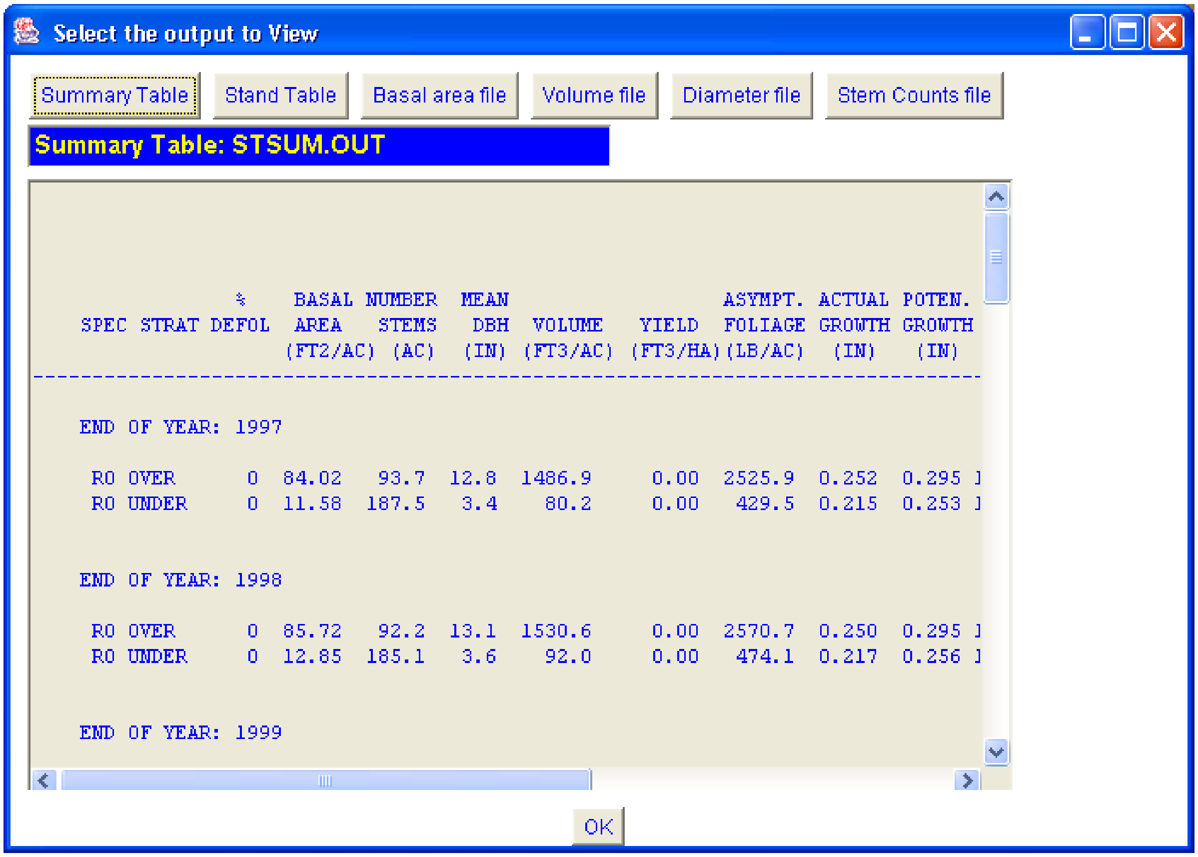

Figure 3: Summary Table

After the growth simulation is complete, the user can also view the results graphically by selecting **Graph** from the **Output** pulldown menu. An example when selecting the **Volume** button is presented in Figure 4. This shows the increase in volume for northern red oak.

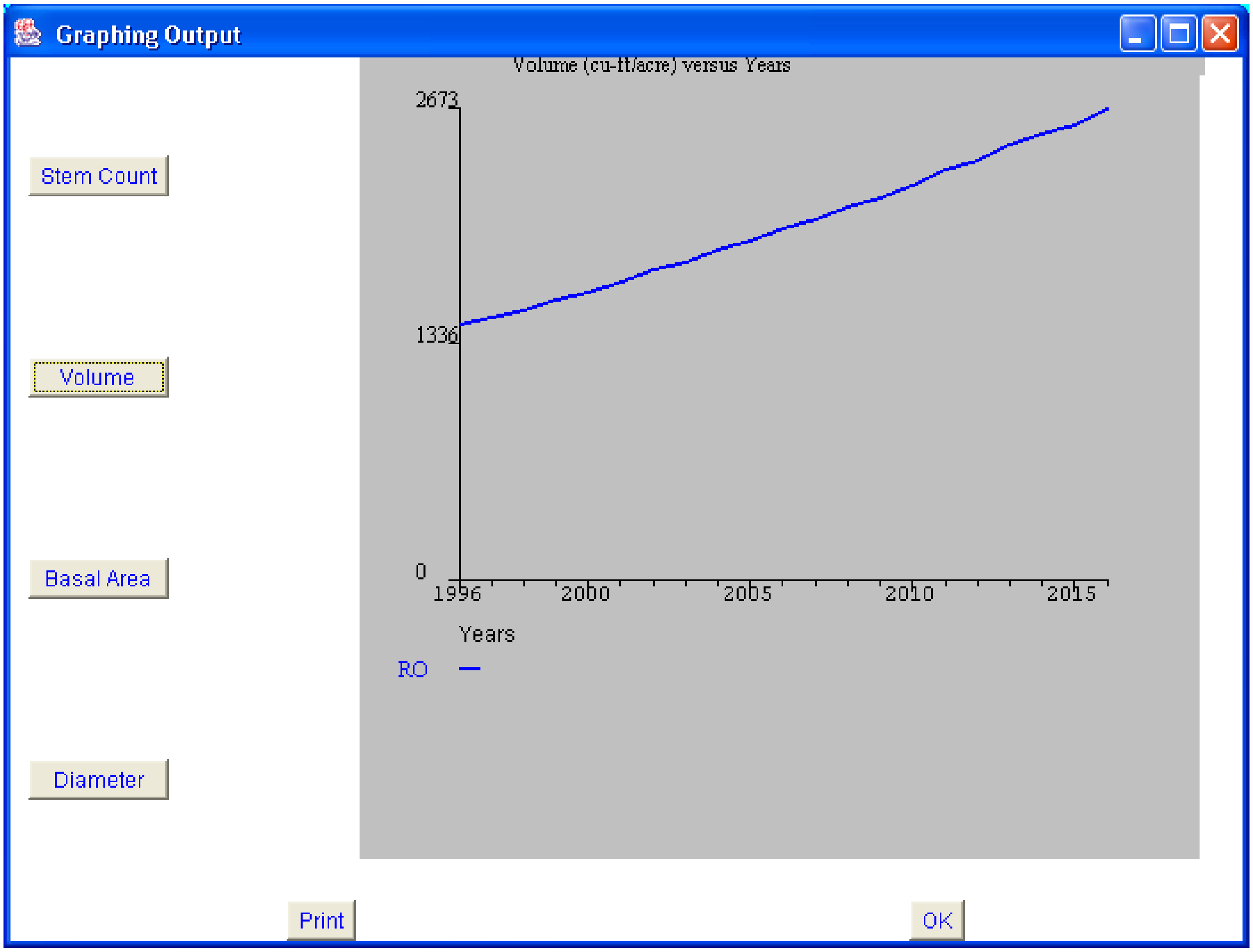

Figure 4.—Volume Graphical Output

Web Interface for Data Entry

The model described above (Stand-Damage Model or SDM) is a stand-alone software package that requires time and effort to be installed and used effectively. The new web approach takes the essential Carbon portions of SDM and makes it accessible to anyone with Internet access. The Web interface parallels the Stand-Damage Model interface. Since the web site is aimed at the average user and not the seasoned forester, the complexity was reduced. The initial data entry screen is shown in Figure 5. HTML Forms were used to input data. Each form item contains a pull-down selection list for each variable. The use of Forms eliminated the need to check each data entry for proper data type.

The first variable on the web page in Figure 5 is **Forest Type**. The user can choose between deciduous or evergreen. If deciduous is chosen, the parameters associated with northern red oak, *Quercus rubra,* are used. If evergreen is chosen, the parameters associated with eastern white pine, *Pinus strobus*, are used.

In the Stand-Damage Model (SDM), stem counts are entered by diameter class, and the default class width is the 2 inch class (Fig. 2). For the web page in Figure 5, the user enters the **Number of Trees per acre** within different class widths (5"-10", 10"-15", 15"-20", and above 20").

The next variable is **Stand Area**, for which the user enters in units of acres. **Simulation Length** in years is entered next. The user then has the option of entering their **2-Letter State Code**. The state is used to associate the region to the model since wood volume to carbon conversions can vary by geographic regions (Hoover et. al. 2000). The user can also enter their email address so that the entire stand table results can be emailed to the user.

When the user has finished entering data, the **Simulate** button is selected. This passes the information to the Server, which processes the data with the models. To return the page back to the initial parameters, the user selects the **Reset** button.

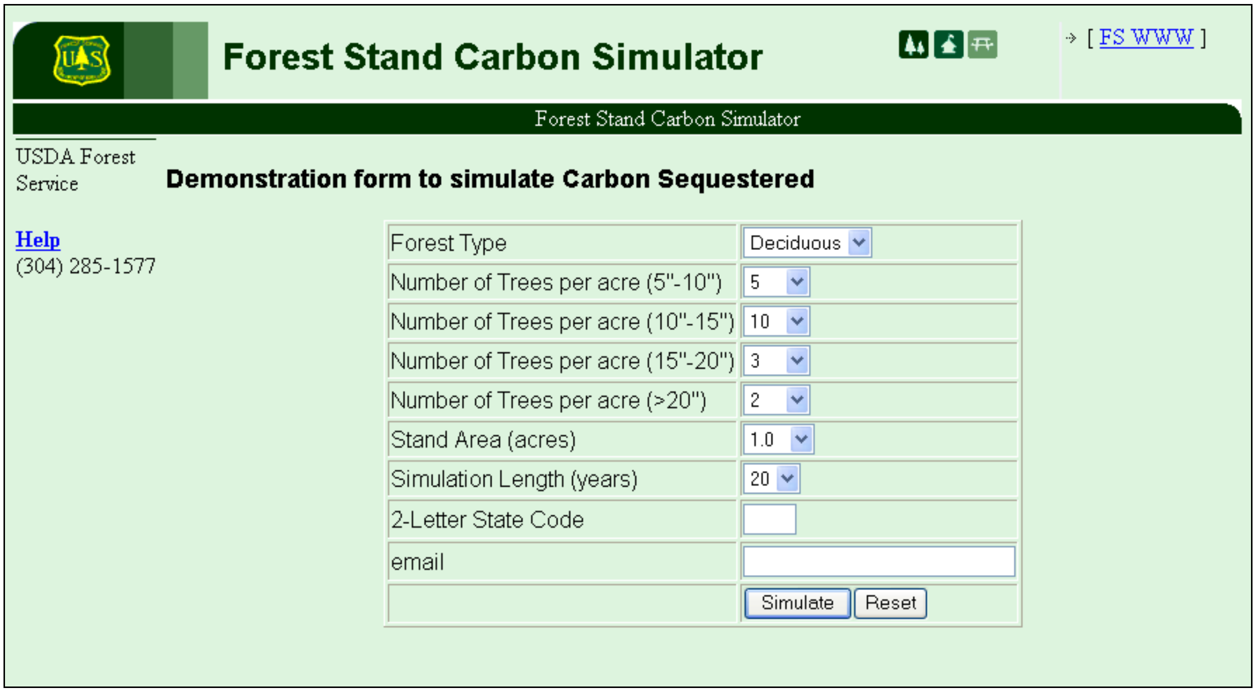

Figure 5: Web Page Input Form

Carbon Conversion

The volume generated by the Stand-Damage Model is converted to Carbon. If the user enters their state on the web page entry form (Fig. 5), carbon conversion takes account of regional differences (Hoover et. al. 2000). Otherwise, carbon is calculated using standard amounts for deciduous (northern red oak) or evergreen (eastern white pine).

Results Web Page

After the simulation is completed on the Server, the results are passed back to the user via the Results page (Figure 6). **Volume Generated** (cubic feet) is the first output on the page. If the stand has produced volume during the simulation period, volume will be a positive number. Volume is then converted to pounds and displayed as **Carbon Sequestered**. Carbon is then converted to Carbon Sequestration Units[2] (**CSU**) and displayed next. One Carbon Sequestration Units (**CSU**) is equal to 1,000 kg of Carbon Dioxide. The Carbon Dioxide amount is also shown in units of kilograms of Carbon Dioxide. Using financial information provided by the Chicago Climate Exchange[3], the **Carbon-Footprint Offset Price** is shown next and is calculated based on a dollar amount for each **CSU.**

The **Stand Input** parameters (Fig. 5) used to arrive at **CSU** are shown on the lower half of the web page. The user can print this web page to keep a record of their simulation.

[2] A Carbon Sequestration Unit (CSU) is defined as 1 metric ton (2204 lbs.) of carbon dioxide sequestered in soil or woody biomass. See National Carbon Offset Coalition (NCOC) at www.ncoc.us.
[3] The Chicago Climate Exchange (CCX) is a North American cap and trade system for greenhouse gases. www.chicagoclimatex.com

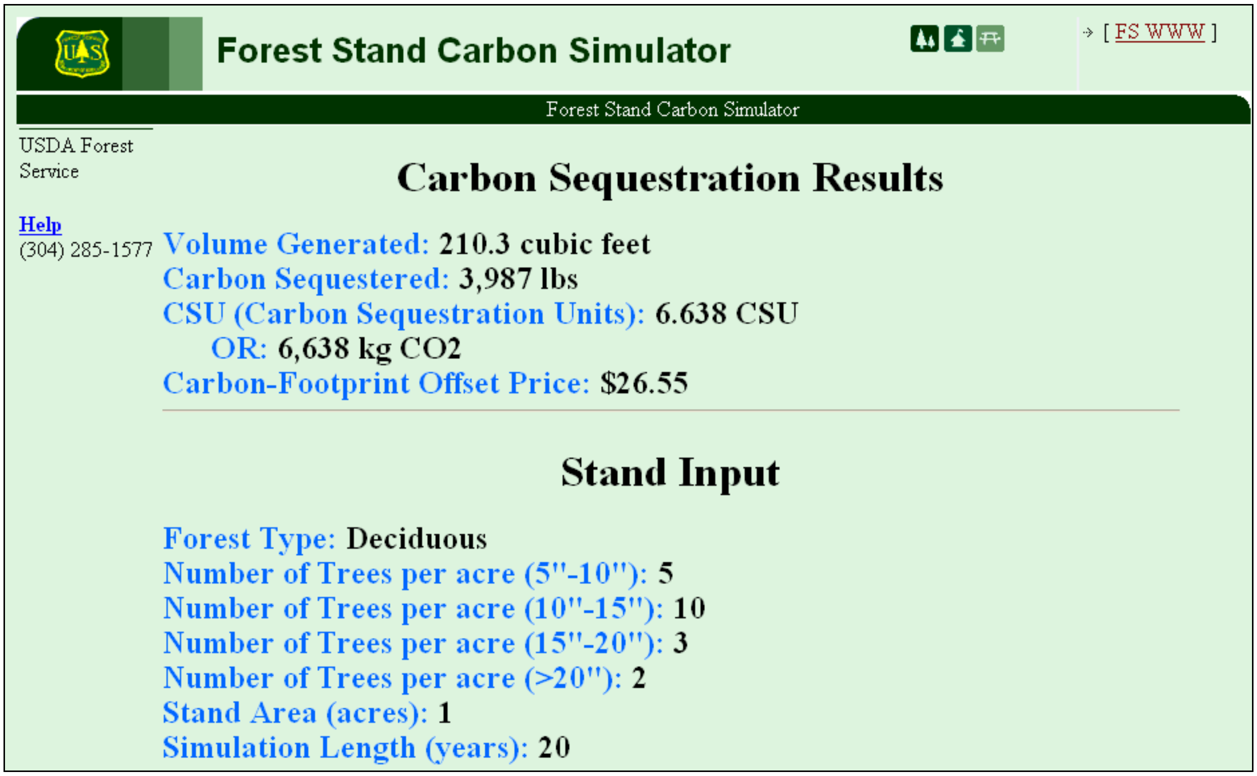

Figure 6: Web Page Results

Software Architecture

The software architecture consists of a Three-Tier Client/Server system (Fig. 7). The software has a user interface (the Presentation Tier), the tools to access and manipulate the data (the Application Tier), and the means to store data (the Data Tier or schema). By separating the software application in this way, each tier can be developed and maintained as independent modules. This type of software architectural design provides flexibility in defining the components and separates the functionality into distinct layers.

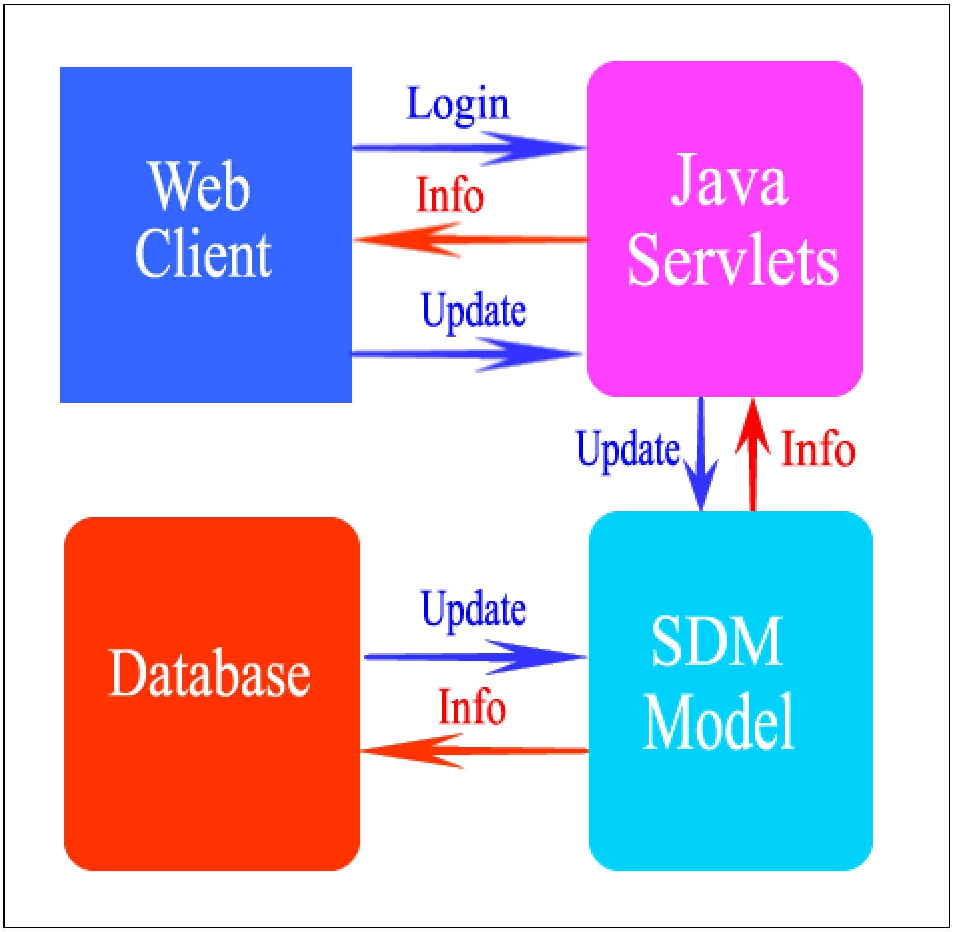

Figure 7: Software Architecture for Web Carbon Software

The Presentation Tier is the topmost level of the application (Web Client in Figure 7). This is the tier with which the web user interacts. The web page Input Form (Fig. 5) and the web page Results (Fig. 6) are the two primary pieces of the Presentation Tier. The Presentation Tier communicates with the other tiers by outputting results to the Application Tier. This is a *thin client* system, in that the Presentation Tier is given a minimum amount of responsibility.

The Application Tier (also referred to as the Business logic tier) contains the Tomcat Servlet engine, the Java Servlets, the Growth Model (SDM), and the Carbon conversion Servlet. This tier controls the application's functionality by performing detailed processing. The Servlets retrieve web page information and passes it to the Growth Model. Once the model has finished processing, the results are passed back by Servlets to the results web page (Fig. 6).

Tomcat was chosen as the Servlet engine because it is open source and freely available. Java Serlvets were used because they are more efficient than CGI scripts, have built-in security, and are highly portable.

The Data Tier consists of a database server. The information that is generated is stored on this tier. This tier keeps data neutral and independent from the Application Tier. Giving data its own tier improves scalability and performance. The relational database used is Oracle.

Summary

The global biosphere absorbs roughly one third of all global carbon emissions from human activity (Umadevi 2007). The Department of Energy is investigating the use of trees of the genus *Populus* for removing carbon dioxide from the atmosphere and storing the carbon in long-lived and safe forms (Pregitzer et. al. 2000). Degraded or marginal lands could also become a source of a significant carbon sink by using them to grow forest stands.

Updates to future versions of this software may include information gleaned from measurements of trees on permanent plots arranged in grids (Coomes et. al. 2002). A version for the more sophisticated user could also include more forest growth model parameters.

Providing Carbon-Sequestration software through the Internet allows researchers, policy planners, and landowners to rapidly estimate the amount of carbon that is being sequestered by forest stands. A web-accessible Carbon Simulator can be used by groups and/or individuals to plan their land use to maximize Carbon-Sequestration potential. The software can be run at http://apps.fs.fed.us/fscs/index.html

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