An Interactive Web Mapping Application for Alternative and Renewable Energies in North Carolina

By

Jessica Knight

Submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the Degree of
Master of Natural Resources

Raleigh, North Carolina

2011

Approved by advisory committee:

Dr. Dennis Hazel, Co-Chair
Dr. Bob Abt, Co-Chair
Heather Cheshire

March 29, 2011

Abstract

Knight, Jessica. Masters of Natural Resources – GIS Technical Option

Biomass is coming to the forefront of renewable energies, especially in the state of North Carolina. The Renewable Energy Portfolio Standard that was passed in 2007 sparked an interest in the state in this sector, along with increased pellet demands in Europe and a desire for clean and “home grown” fuels. Companies are seeking to build their businesses in North Carolina and want to know just what the state has to offer them. In a world of technology, everyone is looking for a way to solve problems quicker and easier, even in the renewable energy sector. There are several web mapping applications that are in use or are being developed that make use of spatial information relating to renewable energies and resources. Some of these applications are just used for basic data viewing, and others carry out basic analysis functions.

This interactive web application, or IMS, makes use of several spatial data layers, an algorithm, and a python script to create a map that is then put onto the web utilizing the ArcServer 10 environment. Several biomass-based commodities are utilized in the IMS: hardwoods, softwoods, cultivated crops, and hay. The IMS has a custom analysis tool that allows a user to enter two commodities of interest, the percentage of each commodity is required, and a distance in miles. The result of the analysis is a raster map displaying the total amount of the commodities, based on the requirements input by the user, throughout the analysis area. White areas of the map are desirable, as they are areas with high levels of the commodity and black areas are less desirable areas. This tool will be used as a way to get prospective companies interested in the state of North Carolina and involve them in the analysis process.

Currently, this application is not available to the public, but it will continue to be improved upon and more tools will be added. The user interface will be made more user-friendly, with more than two commodities able to be selected, with all but one being optional. Costs will also be added to the analysis tools to create more real-world analysis scenarios. After improvements are made, this application will be made public for prospective companies to make use of and explore the state for biomass-based renewable energy generation.

Acknowledgements

I would like to extend my deepest gratitude to my committee, Dr. Bob Abt, Dr. Dennis Hazel, and Dr. Heather Cheshire. To Dr. Cheshire, thank you for being a wonderful advisor for the past two years and pointing me in the direction of this project. To Dr. Hazel, thank you for working so closely with me on this project and for aiding me in obtaining funding by taking me on as a Fellow. To Dr. Abt, thank you for all of your insight on the economic side of the project. I was able to complete this project with a much better understanding of the bigger picture. Special thanks also to James Jeuck and Chris Hopkins. Without you, this project would not have come to fruition. Thanks also goes to Bill Slocumb for allowing me to utilize CEO server space to host my project, and for your instruction in creating a web application in GIS550.

I also want to thank my parents for always supporting me in my endeavors. Last, but not least, my deep thanks goes to my husband for always being there for me and encouraging me in life, my school work and on this project.

Table of Contents

An Interactive Web Mapping Application for Alternative and Renewable Energies in North Carolina

http://virginislands.cnr.ncsu.edu/jdkitzmi_MastersProject/default.aspx

Introduction

Renewable Energy in North Carolina

Alternative and renewable energies are becoming a major focus in the state of North Carolina, with woody biomass at the forefront. North Carolina passed the Renewable Energy Portfolio Standard in 2007 (REPS). The REPS requires that 12.5% of North Carolina's electricity be offset by 2021, with 7.5% of that required to be from renewable sources, the rest from energy-saving measures (Hazel and Hobbs). Until that time, there is a schedule for increasing the offset, starting at 3% in 2012, 6% in 2015 and 10% in 2018 (Session Law 2007-397, Senate Bill 3). The passage of this bill has only garnered more interest in alternative and renewable resources. This bill, combined with an increase in pellet demand in Europe for home heating (Figure 1) as well as a desire for more "home grown" biofuels in North Carolina have led to a desire for renewable energy production in the state. According to the North Carolina Strategic Plan for Biofuels Leadership from 2007 (Biofuels Center of North Carolina), nearly 5.6 billion gallons of petroleum-based liquid fuels are consumed by North Carolinians every year and each gallon is produced outside of the state. Strides are being taken to expand the visibility of North Carolina in the energy sector. The desire for more information about biomass-based renewable and alternative resources is growing in North Carolina and North Carolina State University's Extension Forestry program has been receiving many requests for resource and site analyses as a result. In response to these requests, Helene Cser (NCSU) is creating a geo-spatial database as a central resource for biomass-based renewable energies in the state including biopower generation, biofuels production, pellet production, and combined heat and power applications. It not only holds spatial data relevant for renewable energy, but related data such as current utility companies and their power generation source (coal, nuclear, etc.) and reference layers (county boundaries, etc.).

In a state with significant forestry and agriculture resources, woody biomass and agricultural crops are viable options for renewable energy, both to meet the new standards and to make North Carolina a "greener" state. A method for viewing these data that includes basic analytic tools would further promote North Carolina as a key state in the green energy sector for the future. The application created in this project is such a tool and is part of a larger project within NC State's Extension Forestry called FiberAnalytics that utilizes this application and the database to aid in promotion of the state for energy production.

Importance of the Application

As geographic information systems (GIS) technology continues to improve and become more user-friendly, interactive mapping services (IMS) have become mainstream for easy viewing of spatial data concerning a given state or region. With the increased desire for renewable resources for energy production, many companies and investors are searching for space and resources to develop or use renewable energy in the state of North Carolina. An interactive web interface can allow public and private users interested in developing renewable energy generation to quickly and easily examine current available resources and transportation networks, and related spatial data in the state. Cser's (NCSU) spatial database for North Carolina includes spatial data for animal waste resources, biofuels, current electricity generators, renewable energy programs, landfill methane, hydroelectric power, solar, and wind potential, as well as reference layers for infrastructure, boundaries, and population centers. The interface created for this project can make use of this database, or others like it, to quickly and easily display basic spatial data to the public.

Many current web applications are often limited in their capabilities for analysis. For example, the interface created by the National Renewable Energy Labs (NREL, http://maps.nrel.gov/biomass) simply displays data and allows a user to do a basic selection of resources within a given distance from a user-defined point. It summarizes the data and gives the user the total amount of resources in the area, but gives no information on the spatial distribution of the resources. It is also on a nationwide scale, so more localized data may be outdated. The Vermont Energy Atlas (www.vtenergyatlas.com) also allows selection of resources in a given location. However, the user can only select one resource at a time, which can make resource analysis cumbersome and time consuming. An application that is currently being developed that is most similar to the one created here is BioSAT (University of Tennessee, http://www.biosat.net/index.html). This system makes use of analysis tools focused on both forest and agricultural resources. Currently, it makes use of one biomass commodity at a time, combined with distance, type of transportation, and quantity desired of the requested commodity, among other factors. The analysis produces a table of values with a zip code and associated values of interest. This application differs greatly from my application, and these differences will be illustrated.

The application in my project makes extensive use of GIS data, showing resource dispersal and county boundaries, and information on major highway routes critical for planning an energy producing facility. Within this application I have incorporated an algorithm that has been developed to quickly allow for analysis of resource availability in a given area. This web application, created specifically for North Carolina, includes basic, easy to use geoprocessing tools to allow users to explore the state on a more in-depth level and make use of the algorithm by way of a Python script. The IMS can be utilized to encourage companies interested in the state to learn more about resource availability by allowing them to experiment with different scenarios on their own. Another benefit of the database, IMS, and associated analytical tools is to promote establishment of sustainable energy facilities by providing spatial-based information to guide site-location decisions. It also has the potential for future policy creation and analysis, as policy makers will be able to also view the resource distribution in the state.

Methods

Data

The primary data layers used for this example were generated utilizing an algorithm that will be explained in greater detail. These layers are centered on eight biomass commodities – hay, corn, hardwood logging residues, hardwood pulpwood, hardwood other removals, softwood logging residues, softwood pulpwood, and softwood other removals. To generate these layers, the 2006 National Land Cover Dataset (NLCD) were used along with Timber Product Output (USDA Forest Service TPO data) averaged over odd years from 1995 until 2007. The NLCD dataset is a 30m resolution dataset and was resampled to represent 40-acres per cell using the NEAREST resampling technique in ArcGIS Desktop 10. Hay and corn data were found using Quick Stats from the National Agricultural Statistics Service (USDA). Forest Inventory and Analysis data from 2006-2010 (USDA Forest Service FIA data) were used to compare and modify estimates obtained from the NLCD dataset. For reference layers, a North Carolina county boundary file of 27 counties was used, along with 2 counties in Virginia (ESRI). A layer showing North Carolina major highways was also used. Highways were clipped to the area of interest utilizing the clip tool in ArcGIS Desktop 10.

Algorithm

The algorithm (Algorithm 1) used for this IMS tool is a formula created by Chris Hopkins, Research Associate with Forest Biomaterials at NC State University to calculate resource availability for a given area. Parameters for the algorithm are designated as alpha and beta values and are specific to each commodity of interest. The alpha and beta parameters are used to calculate the amount of each resource specified for a circle with a radius expressed in miles. The algorithm processes resource data and creates a spatial distribution of the resource, with results given on a cell by cell basis.

In this algorithm, $T = \alpha D^{\beta}$, T is total tons of a resource for a given cell based on the criteria for the input (distance, commodity, and, if applicable, percent of the commodity required). D is distance in miles, the radius of a circle around a cell. The alpha and beta values for each commodity are derived using the TPO and NLCD data, along with neighborhood operations in ArcGIS Desktop 10. Alpha is the coefficient for the radius distance, and beta is the exponent. If multiple commodities are of interest, the equation can then be expanded to $T = (\text{Percent Commodity } 1 * \alpha D^{\beta}) + (\text{Percent Commodity } 2 * \alpha D^{\beta})\ldots$, with alpha and beta values varying, as they are associated with individual commodities. The equation can continue on for as many commodities as necessary. Distance can be different for each commodity but in this application, it is the same for both. Commodities are expressed as percentage of the commodity required for the given scenario. For example, a company may desire to have 35% of their feedstock come from hardwood pulpwood and 65% from hardwood logging residues. These percentages would then be put into the equation as a decimal to be multiplied by the associated commodity alpha, beta, and distance values, as represented above.

The alpha and beta values are calculated by first examining the TPO data. This dataset is county based for each commodity. For example, the total tons of hardwood logging residues for all of Wake County are given but the data do not specifically indicate the spatial distribution of the residues within the county. The NLCD dataset shows the land cover types throughout the state and was reclassified into hardwoods, softwoods, cultivated crops, and pasture, allowing the total acreage of cover types to be calculated for each county. From this information, the tons/acre of a commodity can be calculated per county by dividing the total tonnage for a commodity from the TPO data by the acreage of that commodity. The resulting value is placed in all cells that correspond to the associated land cover type, such as hardwood forest.

The next step uses geoprocessing in ArcGIS Desktop. A focal statistics operation that moves from cell to cell and puts a statistical value in each cell based on a defined area around it, is used to sum all tonnage values in a fixed distance around the cell. This focal sum is run on each cell for a radius of 10, 20, 30, 40, 50, and 60 miles. The result of each focal sum is stored for each cell for each distance, resulting in six raster maps for each commodity of hardwood logging residues, hardwood pulpwood, hardwood other removals, softwood logging residues, softwood pulpwood, softwood other removals, hay, and corn. The 40-acre resolution land cover map is converted to a point map, with centroids for each 40-acre cell. The values of all 48 focal sum operations are extracted to this point file. This table is then exported to an EXCEL table. For each commodity and each cell, the tonnages for all focal sums are regressed with distance of the focal sum as the independent variable and the associated tonnage value as the dependent variable. This linear regression is then log transformed, using natural logs, resulting in the equation $\ln(T) = \ln(\alpha) + \beta\ln(D)$. From this, the slope and the intercept are determined. The slope value from the linear model is the alpha value for each commodity and coefficient for distance,

D. The intercept from the linear model becomes the exponent in the algorithm equation, or the beta value for the commodity. The alpha and beta values vary from cell to cell and are linked to their associated point in the point file so they can be converted back to a raster. The end result is one raster for alpha and one raster for beta for each commodity. With a distance radius given, these alphas and betas can be used to determine the total tons available in that radius using the original algorithm.

Python Scripting

Python is a programming language that works directly with the ArcGIS environment. The scripts created with Python can be used in ArcGIS Desktop to create custom tools to be used on one's own computer, or to be a layer tool used in an online environment. There have been many changes to Python with the release of ArcGIS Desktop 10, making it easier to interact with ArcGIS and carry out geoprocessing operations. The creation of a Python script was essential for development of the customized user interface and tool. To create the tool, the new Arc Python module (*arcpy*) needed to be imported to Python. *Arcpy*, as defined by ESRI, is a site-package that allows one to perform geographic data analysis, data conversion, data management, and map automation with Python. This module allows the user to tap into all geoprocessing tools available in ArcGIS 10 and is much more streamlined than the module that was utilized in versions 9.2 and 9.3. Along with the *arcpy* module, the *sys* module that allows for argument variable definition was also imported. In the *arcpy* module, all Spatial Analyst tools were imported to the script so that all functions of Spatial Analyst could be utilized. The last piece of coding to set up the overall environment was to overwrite the output of each operation. This makes the output of geoprocessing tasks overwrite a previous file with the same name so that the output file name does not have to be changed every instance the tool is run.

The next step was to set the variables for all of the components of the algorithm. Each variable name was set to an argument variable with number n, with n being the number of the variable in the total list of variables. Variable names are described in the script comments (Appendix). In this script, only two commodities were being utilized but more can easily be added. The variables had to be set to specific data types. Raster variables were defined as raster and numeric variables were defined as float. Python cannot utilize the raster calculator tool from ArcGIS but raster calculations can be carried by just using ordinary operators (Appendix). The final step was simply saving the output of the raster calculation. This allows use of the output in other processes and display in the map application.

ArcServer10

ArcServer10 is the environment used to put map documents and custom tools onto the web, allowing public access and use. For the mapping application to be put online, a map must be created and it first must look and function as desired. For this to occur the python script needed to be added to ArcGIS and a layer tool had to be created.

A new toolbox was created and the script for the algorithm was imported to the new toolbox. From here, the script was configured with the correct input and output variables, including the labeling desired for the user graphical user interface (GUI). The script was then tested and put into model builder in ArcGIS. All user inputs were defined by creating parameters from the input and output variables. Default values were also selected for these parameters. The extract by mask tool was added so that the resultant raster would include only the counties of interest. The final output was then labeled as a model parameter and set to add to the display. Once the model was completed, it was validated to test for functionality and added to the Table of Contents in ArcGIS. This created a layer tool that would be recognized in ArcServer as a geoprocessing task. Finally, the symbology was changed and layers renamed so that the map document looked as desired for the web application. The map document was then uploaded to the ArcServer environment as a GIS resource.

The final step was to set up the IMS with the application for resource analysis in it. The map layers were selected to appear in the application with a background aerial image from Bing. The default and full extents were set to be the area of the 29 counties selected for this initial study. The custom tool was set up by adding the toolbox as a supporting service and adding a geoprocessing task that would reference the toolbox and the model. This task was configured with an easy to understand label, along with a help when the mouse pointer was hovered over the GUI window. A print task was also added so that results could be printed if desired. Map elements were selected for display, as well as a title and background color. Once all tasks were complete is was ready to be used for resource analysis.

Results

Functionality of the Application

The application makes use of a custom tool created using Python script, as well as other built in tasks and tools. The custom tool is accessed via a link in the upper left hand corner of the application window, titled “Calculate Resources”. When clicked, the user can enter a percentage as a decimal (ex. 0.5 for 50%) for the first commodity. Next, a distance, radius in miles, is entered. This distance reflects how far the prospective company would be willing to travel for a given commodity. The first commodity’s alpha value is selected from a drop down box. The commodities are identified as – corn, hay, HWLR (Hardwood logging residues), HWPLP (Hardwood pulpwood), HWOR (Hardwood other residues), SWLR (Softwood logging residues), SWPLP (Softwood pulpwood), and SWOR (Softwood other residues). The beta value matching that commodity is selected from the next drop down box. The percentage for the second commodity is then entered, and the alphas and betas selected. Once the submit button is pressed, the geoprocessing begins. In the 29 county test group, the result appears on screen in less than 10 seconds. A print task was also added next to this tool to allow users to print results from the analysis.

In addition to the custom tool, there are many other functions available to the user built into ArcServer10. Any layer in the “Table of Contents” can be turned on or off by checking or un-checking the box next to it. Users also have the ability to specify a scale, zoom or pan, measure distances, and obtain details about a particular location or object using the “Identify” tool.

User Interface

The interface is fairly simple and uncluttered and can be accessed from just one page (Figure 2). The custom tools and tasks are on the upper left hand side of the interface. The built-in functions of the map application are on the upper right hand side. There is a “Map Contents” window on the left that lists all layers in the map document. Groups of layers can be expanded or minimized and individual layers can be expanded to see symbology. Above this is the “Results” pane that displays results from any task that is carried out, such as from the “Calculate Resources” tool (Figure 3). This tool is clearly labeled and has text boxes for the numeric values to be entered and drop down menus for the existing alpha and beta layers in the “Map Contents” frame. Results from two different sets of parameters for the “Calculate Resources” tool can be seen in the Appendix (Figure 4, Figure 5). In the black to white gradient raster, darker areas have lower resource availability; white areas have the highest resource availability. Only results for the 29 test counties in are shown in Figure 4. For example, areas that have the highest combination (50%/50%) of hardwood and softwood logging residues within a 50 mile radius are shown in white. The areas with highest concentration are circled in red so that they can be easier to distinguish. The identify tool can be used to determine just how much of the given resource is available in that area.

Discussion

The current application is a working prototype and improvements and changes will be made in the future. Currently, the user defines the distance that they would be willing to travel for a given commodity, or combination of commodities. This allows a prospective company to decide on locations to examine further based on the largest amount of resources that could be acquired. We plan to develop a new tool that will allow the user to input how much of the commodity or commodities they require and in what combination. The output would then be the distance that would be required to meet their requirements. This would allow the same company to decide on locations to examine further based on the shortest distance to travel to obtain the required tonnage of the commodity. Once both of these tools are working properly, the goal is to incorporate the cost factors, including commodity and transportation costs, into the tools to allow more decision making power. The hope is that interested parties would be able to narrow their search to have fewer sites in mind for further examination. They can also manipulate the tools and attempt to optimize distance, cost, and resources based upon different criteria, giving the user more of a hand in the overall process.

Making these tools more user-friendly is also a future goal. With the release of ArcGIS Desktop 10, Visual Basic for Applications has been removed in favor of more Python functionality. VBA allowed for customization of GUIs based upon the Python scripts that were created for ArcGIS. Without VBA, it is difficult to create custom GUIs. A basic GUI can be easily created in ArcGIS from an imported script, complete with browsing buttons and drop down menus. However, to make this tool more user-friendly, having a GUI with simple check boxes for each commodity that would automatically pull the alphas and betas would be helpful, rather than requiring the user to choose each alpha and beta separately. More work needs to be conducted to determine what customization of the GUI needs to be done.

Another issue is that when the results are displayed, they are displayed on top of all other map layers. Conducting more research is also necessary on this topic, as having reference layers, such as transportation routes, visible under the result would allow easier interpretation and orientation. Research is being done into the ability to incorporate the Flex API module to allow more customization of the appearance of the application and streamlining of the tools and tasks.

One final issue encountered is the ability to make commodities the number of commodities optional. Currently, both commodities are required. More research will be done to resolve this issue. Once resolved, the number of commodities could easily be 2 or 3, with all but one being optional.

In the future, the entire state or North Carolina will be part of the IMS application with customized tools. The current test area does result in some problems with edge effect. Expanding to the entire state can help alleviate this problem, but it will still need to be addressed in the future. Once the expansion is successful, this application could even be applied to the entire Southeastern region. In addition, there are other data layers that would be beneficial to add to make this application more complete. Other reference layers such as renewable resource companies currently in operation may be useful in deciding on which sites to focus on. Adding information about resources such as solar may be helpful, as the user may want to utilize renewable or alternative energies to power their facility. Current utility companies may be useful as well, since the REPS allows these to either produce their own energy with renewable sources or purchase it from another location. Locating something such as a pellet production facility near an existing utility company may be something an outside investor is interested in focusing on. In addition to the highways already represented, adding major railways may also be beneficial, making transportation routes and costs easier to determine.

This application is the first step of many in creating an extensive and informative tool that will promote the potential of North Carolina's extensive renewable and alternative energy resources. It is anticipated that this will aid in meeting the REPS requirements and further educate others about renewable and alternative energies. This application has the potential to be used not only to site future energy generation facilities, but may also be useful for policy creation. The ability to visualize resources and current facilities may demonstrate the need for new and different policies. There is still much to be done to add to the functionality of this tool, but it can now be used to help educate those outside of the state about North Carolina's resources and allow companies to make more informed decisions before going to a consultant for a more detailed site analysis. The ability to explore different scenarios quickly and easily is a positive attribute of this application. Although we plan to expand this application, it is important to keep it simple and easy to use. Creating multiple applications may prove useful as capabilities expand, with each focusing on specific tasks. This application will continue to expand and improve in the future, as more information is gathered about real world scenarios that prospective companies wish to solve.

References

Biofuels Center of North Carolina. "Fueling North Carolina's Future". North Carolina's Strategic Plan for Biofuels Leadership. 1 April 2007. http://www.biofuelscenter.org/userfiles/File/NC_Strategic_Plan_for_Biofuels_Leadership.pdf

Cser, Helene. Extension Associate. North Carolina State University, Department of Forestry and Environmental Resources.

Esri StreetMap Premium. 2007. Esri. http://www.esri.com/data/streetmap/index.html

Forest Inventory and Analysis National Program. 2006-2010. United States Department of Agriculture, Forest Service. http://www.fia.fs.fed.us/tools-data/default.asp

General Assembly of North Carolina. *Renewable Energy and Energy Efficiency Portfolio Standard (REPS).* Session Law 2007-397. Senate Bill 3. http://www.ncga.state.nc.us/sessions/2007/bills/senate/pdf/s3v6.pdf

Hazel, Dennis and Alex Hobbs. "The North Carolina Renewable Energy Portfolio Standard and Its Significance for NC Forest Landowners". *NC Cooperative Extension.* http://www.ces.ncsu.edu/forestry/biomass/pubs/WB003.pdf

Hopkins, Christopher. Research Associate. North Carolina State University, Department of Forest Biomaterials.

National Agricultural Statistics Service, Quick Stats. 2010. United States Department of Agriculture. http://www.nass.usda.gov/

National Land Cover Database. 2001. Mutli-Resolution Land Characteristics Consortium. http://www.mrlc.gov/

National Renewable Energy Laboratory. Biomass [map]. "BioFuels Atlas" 2011 http://maps.nrel.gov/biomass

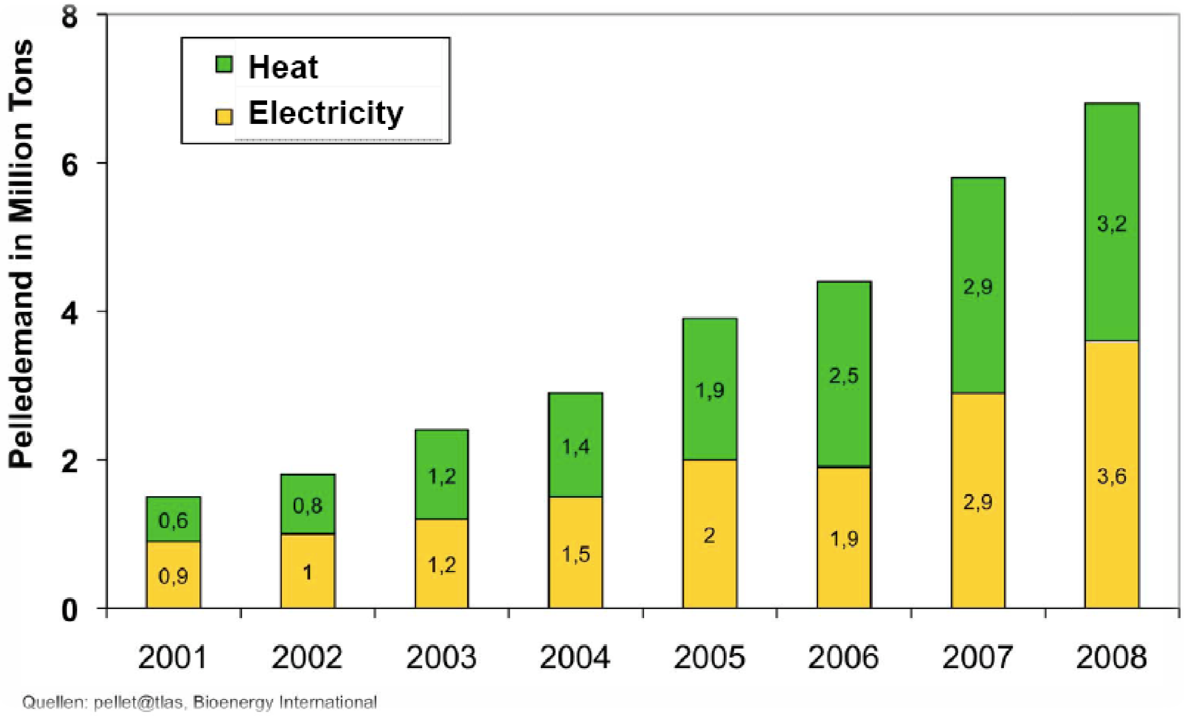
Timber Product Output. 1995-2007. United States Department of Agriculture, Forest Service. http://srsfia2.fs.fed.us/php/tpo2/tpo.php

University of Tennessee, et al. BioSAT [map]. "BioSAT Making Innovation Work". 2011. http://www.biosat.net/index.html

Vermont Sustainable Jobs Fund. Renewable Energy Atlas of Vermont [map]. "VT Energy Atlas". 2011. www.vtenergyatlas.com

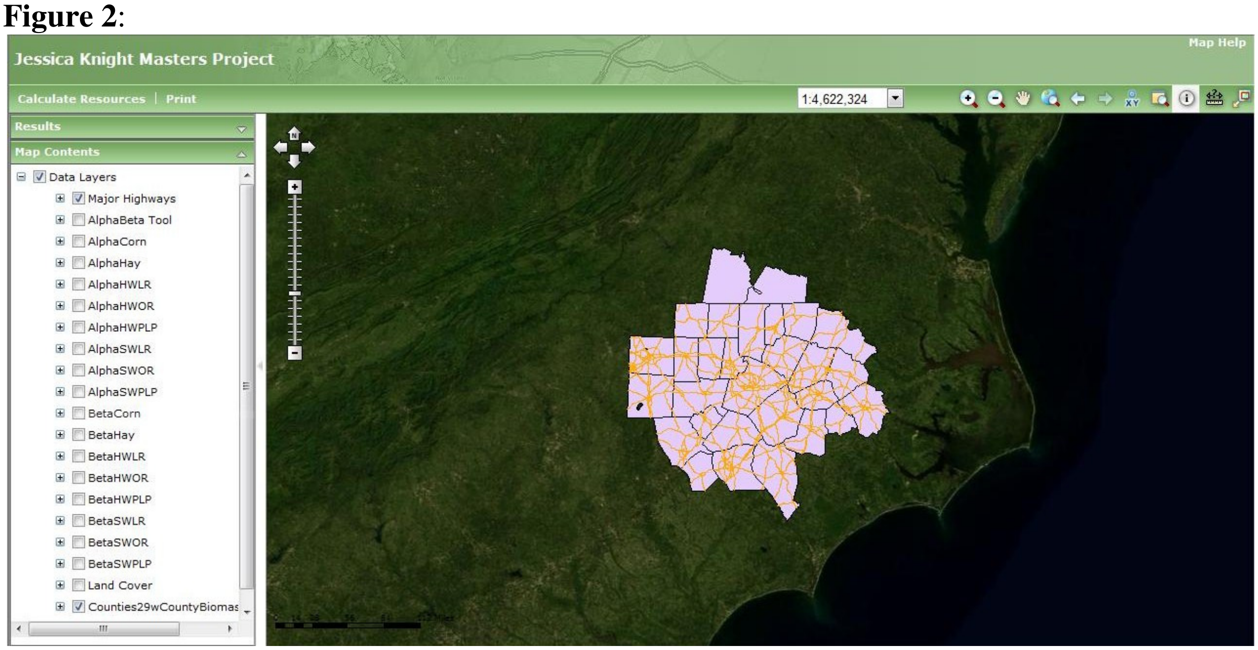
Figures

Figure 1:



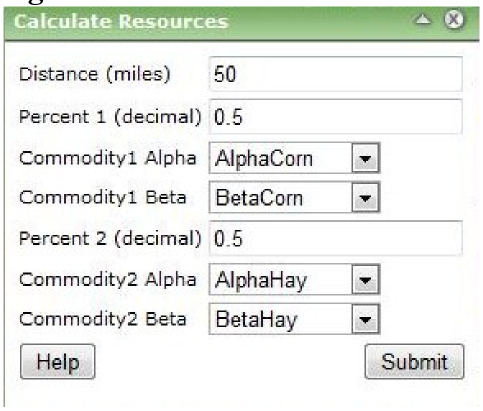
Pellet demand in Europe. Source: Bioenergy International

Figure 2:



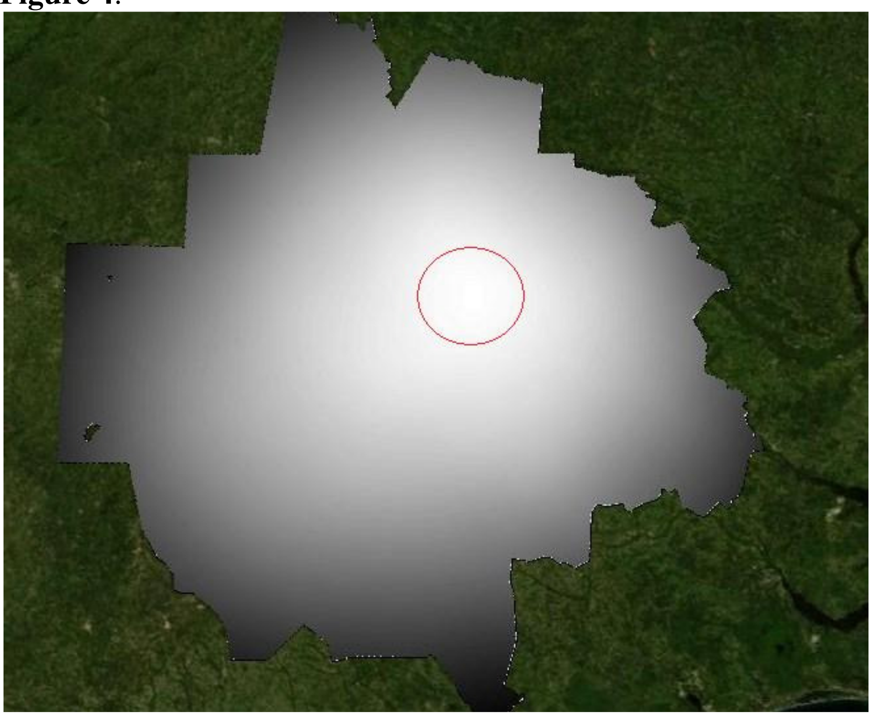
Full user interface. Base layers shown – NC county boundaries for test area and NC highways

Figure 3:



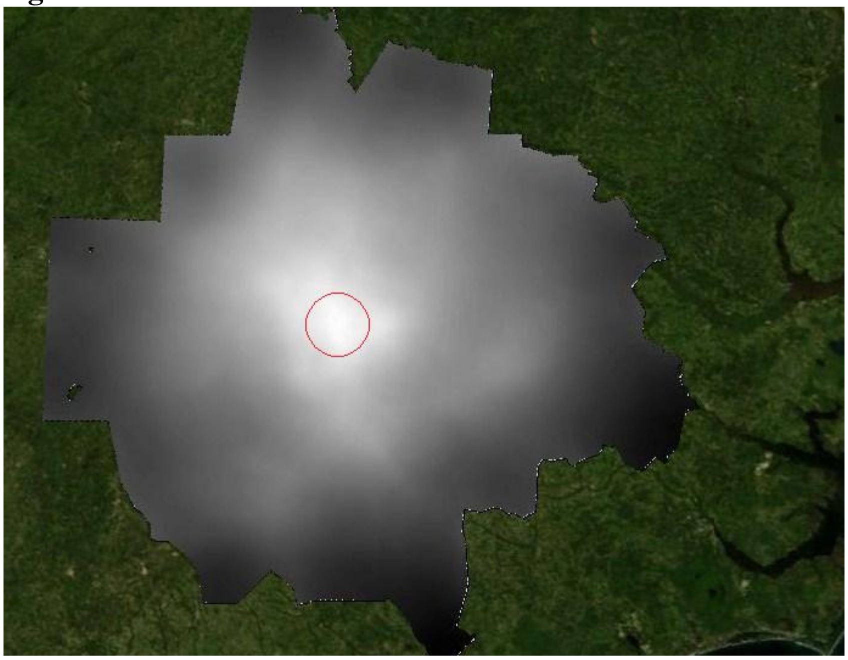
Custom geoprocessing tool interface

Figure 4:



First sample result image. Test parameters – 50% hardwood logging residues and 50% softwood logging residues at 50 miles.

Figure 5:



Second sample result image. Test parameters – 50% hardwood logging residues and 50% hardwood pulpwood at 100 miles.

Appendix

Algorithm:

$$T = \alpha D^{\beta}$$

T = Tons
D = Distance

Python script:

```
 #Name: rasterCalc.py
 #Purpose: code for raster calculations using alphas and betas
 # Author: Jessica Knight
 #Date Created: February 16, 2011
 #Last Updated: March 9, 2011

 #import modules
 import arcpy, sys
from arcpy.sa import *

#Overwrite Output
arcpy.gp.overwriteOutput = True

#Set variables
# perc = percent
#Comm = commodity; A = alpha; B= beta
# number associated with perc and Comm stands for respective commodity (1 and 2)
distance = sys.argv[1]
perc1 = sys.argv[2]
CommA1= sys.argv[3]
CommB1 = sys.argv[4]
perc2 = sys.argv[5]
CommA2 = sys.argv[6]
CommB2 = sys.argv[7]
OutPut = sys.argv[8]

#Cast to rasters
#CA = commodity alpha, CB = commodity beta
RastCA1 = Raster(CommA1)
RastCB1 = Raster(CommB1)
RastCA2 = Raster(CommA2)
RastCB2 = Raster(CommB2)

#Cast to float
#P = percent
DistFloat = float(distance)
P1Float = float(perc1)
P2Float = float(perc2)
```

```
#Calculate new raster
# ** = raise to power
OutRast = (P1Float*RastCA1 * DistFloat**RastCB1) + (P2Float*RastCA2 *
DistFloat**RastCB2)

#Save Output
OutRast.save(OutPut)
```

Project Link: http://virginislands.cnr.ncsu.edu/jdkitzmi_MastersProject/default.aspx