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A DECISION SUPPORT SYSTEM FOR FOREST HARVEST PLANNING IN NORTH CAROLINA

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ABSTRACT

Forest preharvest planning (FPP) can enhance recognition of environmentally-sensitive areas in advance of forest harvesting, including soil and water resources. While preharvest planning is often a standard component of many forest harvesting operations, either explicitly with paper-based checklists or implicitly with best professional judgment, Geographic Information System (GIS) technology is frequently underutilized by forest managers, consultants, landowners, and loggers (forestry users) during this forest management activity. According to the Final Report for the North Carolina Forestry Best Management Practices (BMP) Implementation Survey 2000-2003, preharvest planning resulted in higher implementation of BMPs for water quality. However, in general throughout North Carolina, information about the availability of state-of-the-art GIS technology, publically available GIS data, and Free and Open Source Software (FOSS) is often not well disseminated to forestry users. In order to address this gap in information transfer, a Forestry GIS Web Portal was created that includes a trial version of a web-based decision support system (DSS) for FPP (FPP-DSS) designed using FOSS. Based on feedback from forestry users, opportunities will be pursued to expand the trial version of the FPP-DSS to a statewide system available to natural resource managers and citizens throughout North Carolina. Through the use of current GIS technology and data, a DSS for forest harvest planning in North Carolina can offer additional information to support the protection of water quality and soil resources, and further support the implementation of forestry BMPs for water quality.

KEY TERMS: BMP, preharvest planning, decision support system, GIS, free and open source.

INTRODUCTION

Forest preharvest planning (FPP) is a common tool used in silvicultural operations to identify general site characteristics, potential hazards, and potential site rehabilitation needs associated with a proposed forest harvest (NCDFR, 2006). The primary objective of preharvest planning is often the prevention of non-point source pollution delivery to streams and other water bodies. To achieve this objective, the North Carolina (NC) forestry community commonly relies on traditional printed maps and resources (e.g., topographic maps, soil survey maps, etc.) during FPP to protect soil and water resources. According to the Final Report for the NC Forestry Best Management Practices (BMP) Implementation Survey 2000-2003, preharvest planning resulted in higher implementation of BMPs (85 percent), which resulted in a lower risk (5 percent) to water quality during harvesting activities (NCDFR, 2005). While preharvest planning is often a standard component of many forest harvesting operations, either explicitly with paper-based checklists or implicitly with best professional judgment, Geographic Information System (GIS) technology is frequently underutilized by forest managers, consultants, landowners, and loggers (forestry users) during this forest management activity. Most forestry users are familiar with hard copy topographic and soil survey maps, but where to access these and other more current electronic maps is often not well known. In addition, information about the availability of state-of-the-art GIS technology, publically available GIS data, and Free and Open Source Software (FOSS) is often not well disseminated to forestry users in NC.

Since the advent of GIS, natural resource managers have utilized the technology to better inform resource management decisions (Lang, 1998; Warnecke et al., 2002). However, as with all technology, the speed at which advancements are made is difficult to match in training, education, and information outreach. As a whole, the forestry profession in NC is rich with professionals whose silviculture knowledge surpasses the level of expertise in many other professions. However, a parallel knowledge of GIS technology and data is lacking. Several common misperceptions likely compound this issue: 1) GIS software is too expensive, 2) GIS software is too difficult to use, and/or 3) GIS data is not available. In order to address the described gap in information transfer and dispel these common misperceptions, a Forestry GIS Web Portal was created that includes the following core components: 1) basic information about GIS technology, 2) information about where to access

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GIS software and data, 3) information about using GIS to support forest management decisions, and 4) a user-friendly web-based GIS decision support system (DSS) designed to assist with FPP activities. This paper focuses primarily on describing the steps taken to develop the web-based DSS for FPP (FPP-DSS).

The primary goal of the FPP-DSS will be to generate a brief report with supporting mapping that identifies general site considerations, potential hazards, and potential site rehabilitation needs associated with site characteristics such as highly erosive soils, rocky soils, steep slopes, streams, wetlands, protected species, conserved lands, and historical and cultural sites. This information can assist with the identification of suitable locations for forest harvesting operational areas, including stream crossings, hauling roads, loading decks, and skid trails and will also highlight areas of special concern. Additional goals for the FPP-DSS include 1) easy access for forestry users; 2) a user-friendly interface; and 3) a framework that can be modified, built upon, and improved as needed enhancements are identified.

METHODS

A systematic workflow process was chosen to guide the development of the DSS that includes the following seven steps: 1) assess need; 2) review literature/technology; 3) select technology and develop trial version; 4) test trial version (alpha testing); 5) solicit forestry user feedback (beta testing); 6) finalize technology solution; and 7) maintain, improve, and upgrade technology solution as needed. This paper focuses on steps 1-3. Steps 4-7 are ongoing.

Step 1 was undertaken to define the specific goals for the DSS and to ensure that the tool developed sufficiently addressed a "real-world" need in the forestry community. To further evaluate the NC forestry community's interest and receptiveness for a FPP-DSS, a brief questionnaire was prepared using a free online survey utility (SurveyMonkey©) and forwarded to a representative sample of forestry users in the state. Only forestry users who have in the past conducted, are currently conducting, or are considering conducting FPP activities in the future were asked to complete the questionnaire. Table 1 illustrates the questions asked on the survey, including the answer choices.

Table 1. Forestry Community FPP-DSS Assessment of Need Questionnaire

Questionnaire Prompt	Answer Choices				
Pick the category that best describes your role in the forestry community.	Forest Land Management	Consulting Forestry	Timber Procurement	Logging	Forest Landowner
How often do you use hard copy maps (e.g., topomaps, soil survey maps, aerial photos, etc.) during preharvest planning?	Every Time	Sometimes	Never	No Experience with Preharvest Planning	
Rank your familiarity with using GIS technology.	Very Familiar	Somewhat Familiar	Unfamiliar		
How often do you use GIS software and data during preharvest planning?	Every Time	Sometimes	Never	No Experience with Preharvest Planning	
Rank how easy it is to locate, access, and use electronic maps (e.g., topographic maps, soil maps, etc.) and/or GIS data (e.g., streams, water bodies, soils, elevation/contours, watersheds, etc.) that could support preharvest planning in North Carolina.	Easy	Moderate	Difficult	Not Sure	
If GIS software was free and easier to use, and GIS data was easier to access, would you use GIS more often during preharvest planning?	Yes	No	Not Sure		
If an online map viewer pre-loaded with GIS data (e.g., river basins, streams, steep slopes, erodible soils, topomaps, aerial photography, etc.) existed in North Carolina, would you use it during preharvest planning?	Yes	No	Not Sure		

A review of existing literature/technology (step 2) was performed to ascertain the state of development of various FOSS applications and to identify any case studies documenting use, including recommendations and/or discussions about the pros/cons of using one application over another.

During step 3, the following questions were used to assist with narrowing the list of FOSS choices (Table 2), as recommended in Ramsey (2007).

Table 2. FOSS Screening Questions

Question
Is the project well documented?
Is the development team transparent?
Is the software modular (i.e., Is it flexible)?
How wide is the development community?
How wide is the user community?

Based on the literature review conducted and the answers to the questions above, the most suitable FOSS components were selected to meet the FPP-DSS goals. The trial version was then developed in association with a paired watershed study designed to evaluate the effectiveness of forestry BMPs in the Piedmont of NC. Specifically, the trial FPP-DSS was developed using GIS data from two counties, Durham and Granville. Available data layers that could support informed decisions during preharvest planning were identified, formatted, and loaded into the FPP-DSS trial version.

Alpha testing will be performed during step 4. FPP-DSS developers will evaluate the functionality of the tool and ensure that all design components operate as intended. Table 3 lists the alpha testing parameters (questions) to be used. Each question must be answered with a "Yes" before user feedback is solicited (beta testing).

Table 3. FPP-DSS Alpha Testing Parameters

Parameter/Question
Do all data layers draw in the map viewer?
Are all data layers symbolized in a logical and easy to interpret fashion?
Do all tools (zoom, identify attributes, measure, etc.) function correctly?
Do all hyperlinks function correctly, opening live links with no error messages?
Does the FPP-DSS maintain acceptable stability when used for extended periods?
Does the FPP-DSS maintain acceptable stability when multiple users are accessing?

Once alpha testing is complete, beta testing will be performed with the assistance of a sample group of forestry users (step 5). Feedback from the users will be reviewed, identified enhancements will be made, and the FPP-DSS trial version will be finalized (step 6). Into the future, the FPP-DSS will be maintained, improved, and upgraded based on technology improvements and forestry user-identified needs (step 7).

RESULTS

Assessment of Need Questionnaire Results

The assessment of need questionnaire yielded numerous responses from a variety of forestry community members. As a whole, significant support for the development of a web-based GIS tool to assist with preharvest planning in North Carolina exists. Table 4 illustrates the answers to each question presented as the percent (%) of the total questionnaire responses.

Table 4. Forestry Community FPP-DSS Assessment of Need Questionnaire Results

Questionnaire Prompt	Answer Choices				
Pick the category that best describes your role in the forestry community.	Forest Land Management *(46%)*	Consulting Forestry *(12%)*	Timber Procurement *(27%)*	Logging *(4%)*	Forest Landowner *(11%)*
How often do you use hard copy maps (e.g., topomaps, soil survey maps, aerial photos, etc.) during preharvest planning?	Every Time *(75%)*	Sometimes *(25%)*	Never *(0%)*	No Experience with Preharvest Planning *(0%)*	
Rank your familiarity with using GIS technology.	Very Familiar *(46%)*	Somewhat Familiar *(50%)*	Unfamiliar *(4%)*		
How often do you use GIS software and data during preharvest planning?	Every Time *(61%)*	Sometimes *(27%)*	Never *(12%)*	No Experience with Preharvest Planning *(0%)*	
Rank how easy it is to locate, access, and use electronic maps (e.g., topographic maps, soil maps, etc.) and/or GIS data (e.g., streams, water bodies, soils, elevation/contours, watersheds, etc.) that could support preharvest planning in North Carolina.	Easy *(16%)*	Moderate *(64%)*	Difficult *(16%)*	Not Sure *(4%)*	
If GIS software was free and easier to use, and GIS data was easier to access, would you use GIS more often during preharvest planning?	Yes *(90%)*	No *(5%)*	Not Sure *(5%)*		
If an online map viewer pre-loaded with GIS data (e.g., river basins, streams, steep slopes, erodible soils, topomaps, aerial photography, etc.) existed in North Carolina, would you use it during preharvest planning?	Yes *(87%)*	No *(2%)*	Not Sure *(11%)*		

n = 56; percentages rounded to nearest whole percent

Literature/Technology Review

During the literature/technology review, numerous resources were identified that assisted with the selection of the FOSS application(s) to be used. Table 5 includes a selection of the literature reviewed, presented as a matrix denoting the type of information presented in each publication.

Table 5. Literature Review Matrix

Literature	Provides Overview of FOSS GIS	Describes FOSS Desktop-GIS Applications	Describes FOSS Web-GIS Applications	Describes Web-GIS Architectures	Compares Different FOSS Applications	Compares FOSS Applications to Payware Applications
Alesheikh et al., 2002				✓[1]	✓[1]	✓[1]
Buchanan, 2006						✓[2]
Milosavljević et al., 2005				✓		
Ramsey, 2007	✓		✓	✓	✓	
Steiniger and Bocher, 2009	✓	✓			✓	
Steiniger and Hay, 2009	✓	✓	✓		✓	

[1]Map Servers only [2]Compares ArcGIS 9.0 to GRASS 6.0 only

Technology Selection and Trial Version Development

Figure 1 depicts the FOSS components selected to compose the FPP-DSS. Each of the FOSS components are well documented and supported by relatively transparent development teams, are flexible, have a modest-to-wide development community, and have a growing-to-wide user community. In addition, these FOSS applications align well with other North Carolina state agency initiatives and projects.

In order to streamline the development of the trial version, shapefiles were used as the spatial data store for the Map Rendering Engine (GeoServer), initially negating the need for a backend Database (PostgreSQL/PostGIS). The Map Viewer (OpenLayers) was customized and standard tools such as zoom, identify attributes, and measure were enabled. Once the user interface was formatted and designed to the desired specifications, the spatial data was loaded into the Database to improve scalability, speed, and to fully enable spatial query operability. A custom tool was developed to export map layer attributes at a user-specified location to a Hyper Text Markup Language (HTML)-based form.

Table 6 below lists the GIS data layers loaded into the FPP-DSS trial version. Within the FPP-DSS, each data layer is accompanied with metadata that describes the original source, intended use, and expected accuracy of the data. Data layers were grouped according to like categories (Table 6) and symbolized using logical, easy to interpret symbology. All data categories were assigned a scale dependency that dictates the scale at which the layer will turn on following startup; with the exception of Base Data, which was set to display automatically upon startup. All data layers can be turned on or off by the user during operation.

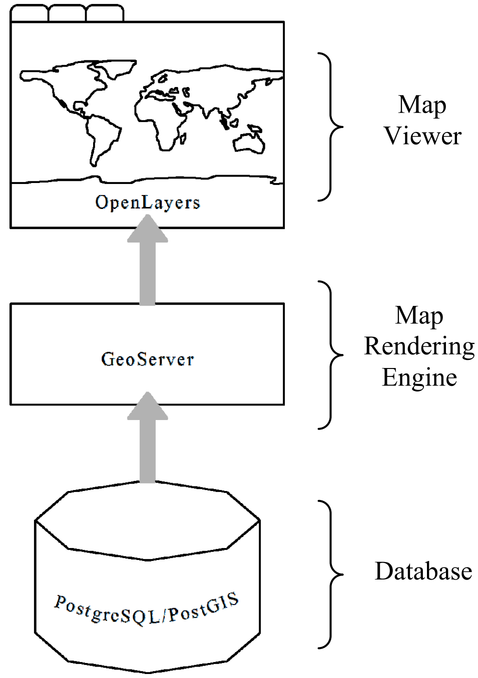

Figure 1. FPP-DSS FOSS Components

Table 6. FPP-DSS GIS Data Layers

Category	Data Layer
Base Data	Jurisdictional Boundaries – State, County, and Municipal Infrastructure – Roads, Posted Bridges, Railroads, and Utility Lines Publically Owned Lands – Federal Forests and Parks, State Forests and Parks, Wildlife Management Areas, County and Municipal Parks, and other Conserved Land Imagery – Aerial Photography
Physical Geography Data	Physical Geography Boundaries – Ecologic Provinces, Geologic Provinces, River Basins, and Local Watersheds Hypsography – Steep Slopes and Contours Hydrography – Streams, Open Water, and Wetlands Soils – Surface Soil Texture, Soil Erosion Class, and Hydric Soil Class
Ecological/Biological Data	Rare Species Occurrences Significant Natural Heritage Areas Non-native and Invasive Species – Quarantine Areas (e.g., fire ants, gypsy moth, etc.)
Social, Cultural, and Historical Data	Emergency Response Office Locations – Hospitals, Fire Stations, etc. Registered Historic Sites

SUMMARY

Forest preharvest planning is a critical step that can be taken to improve forestry BMP implementation and reduce risks to water quality prior to timber harvesting. Despite this, the full breadth of GIS resources available to the forestry community to support more informed decisions during FPP in NC is commonly not used. An assessment of need revealed that GIS technology use during FPP activities, as well as general knowledge about GIS technology, data, and use, is lacking among some forestry users. Providing basic information about GIS technology, information about where to access GIS software and data, and information about using GIS to support forest management decisions are some of the mechanisms to increase GIS use during FPP. However, by providing a free user-friendly web-based GIS application tailored to support FPP activities, the NC Division of Forest Resources can more directly influence the frequency at which well informed decisions are made before and during timber harvesting.

With the expansion of FOSS GIS applications and the growing availability of free GIS data, the development and use of inexpensive GIS-tools to support forest management decisions is a growing reality for the forestry community. Numerous FOSS resources exist; each with varying degrees of development, support, versatility, and functionality. Determining which FOSS applications best fit a desired purpose should depend on several factors including, but not limited to, whether the FOSS is well supported by a development team, the FOSS is well documented and frequently used by others, and the FOSS is flexible and can be integrated with other software applications. When evaluating these factors, one must review existing literature and software documentation to determine the best FOSS application(s) for the intended use.

Through the use of current GIS technology and data, a DSS for forest harvest planning in NC can offer additional information to support the protection of water quality and soil resources, and further support the implementation of forestry BMPs for water quality.

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