DEVELOPMENT OF A SILVICULTURAL DATABASE MANAGEMENT SYSTEM

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ABSTRACT

Data exchange among natural resource managers is inadequately addressed in today’s computer oriented society. There are great quantities of data being collected, but the speed and accuracy at which the data is summarized for end users is in question. The information that natural resource managers do receive is often not suitable for their planned objectives.

The purpose of this research is to create a system that will conveniently store, manage, manipulate and summarize natural resource data. This research has a two-fold objective. The initial objective is to create a silvicultural database management system to conveniently organize available stand information. A secondary objective is to test various user groups by assigning tasks to be performed via the system, and then, after each user answers a descriptive questionnaire, to evaluate their feelings towards the system.

This study is the initial effort in developing a larger, more integrated system. The ultimate system developed is envisioned to contain additional components that were not incorporated in this study (i.e., statistical package, landscape visualization tool, etc.). Components used in this initial portion of the system were chosen based on past experience of individuals involved in the research.
Funding for the research has come from the Missouri Department of Conservation (MDC). All data utilized in system construction has come from the Missouri Ozark Forest Ecosystem Project (MOFEP).

Results indicate that a lack of familiarity is the principal aversion towards the silvicultural database management system. However, favorable data manipulation and management assistance, along with relative ease of use, often relieved the apprehension created by lack of familiarity with the system. Ultimately, opinions towards the silvicultural database management system do not differ between individuals with varying degrees of natural resource management experience.
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CHAPTER 1

INTRODUCTION

Ecosystem management has become a major directive of national, state, and local agencies. Interest in ecosystem management can be illustrated by a recent issue of The Journal of Forestry (August 1994) entirely dedicated to addressing the topic. The issue's cover title was "Ecosystem Management: Will It Work?".

With the increased awareness of ecosystems, and their subsequent management, has come an increased need for additional information about these ecosystems. Powell, et al. (1994) contend, "How can one conserve or manage forests without knowledge of their land area, standing crop of timber, rates of mortality and harvesting, diversity of habitats, and health trends." A well-designed database management system (DBMS) would help facilitate these issues regarding the knowledge of one's resources.

The Missouri Department of Conservation (MDC) is one state agency committed to the development of a silvicultural database management system. The system will manage data collected by MDC from the Missouri Ozark Forest Ecosystem Project (MOFEP). MOFEP is a project to study the effects of forest management on the ecosystem.

The Missouri Ozark Forest Ecosystem Project is a long-term, cooperative research effort by MDC and the University of Missouri-Columbia (UMC) which is designed to provide resource managers with applied information on the effects of large-tract forest management in selected Missouri Ozark forests on certain plant and animal species. The project is proposed to include 50 years of forest management
and plot remeasurement to establish consistent trends and to allow for the natural
development of new forest stands following tree harvests.

**Problem Identification**

To successfully conduct a project as large as MOFEP an improved method of
data management is needed. The silvicultural database management system is needed
to coordinate the immense quantities of data obtained from the nine MOFEP
management compartments. This data will be monitored from year-to-year, decade-
to-decade, and conceivably longer to effectively understand the results of land
management practices.

Design and development of the silvicultural database management system was
the first step in this research. Following system completion usability became a
principal issue. Conceptually the system was well defined, but the operational
capabilities of the system for natural resource management needed to be identified.
Additionally, computer hardware constraints that may limit system capabilities needed
to be identified.

**Purpose**

The purpose of this project was to develop a silvicultural database management
system and to measure the users' perception of usefulness for the system.
Objectives

This research has a two-fold objective:

1) Operational objective - Determine, and then develop, a database structure with a format allowing for easy transferring of data to and from application programs (e.g., growth models and data viewers).

2) Research objective - Analyze user feedback and determine the degree of acceptance of the system for organizing and manipulating natural resource data.

A two-fold objective was necessary because development of a silvicultural database management system did not constitute investigative research, it was considered functional research only. Investigation of user feedback, to determine degree of system acceptance by users, was needed to satisfy the investigative research component of the study.

Hypothesis

Many task specific hypotheses have been used during system testing, but the overall research hypothesis follows:

\( H_0: \) Opinions towards the system, regarding natural resource management, does not differ between undergraduate students, graduate students, and professionals in the natural resource discipline.

\( H_1: \) Opinions towards the system, regarding natural resource management, does differ between undergraduate students, graduate students, and professionals in the natural resource discipline.

As stated in the research hypothesis, it is unclear how useful the system will be for various user groups with differing levels of experience. Since the system is untested no recommendation will be made for a specific user group or experience level.
System testing will determine if the system's functionality transcends all levels of educational and training experience.

Summary

A silvicultural database management system that can be developed to manage large quantities of data over long periods of time is needed. This thesis will cover the process involved in the development of this system and its subsequent testing. The structure of the system is designed to manage MOFEP data and all similar data.
CHAPTER 2

REVIEW OF LITERATURE

In this chapter appropriate literature was reviewed that related to the development and testing of a silvicultural database management system. This review has been organized into three principal sections: (1) research justification, (2) screening techniques, procedures, etc., and (3) documentation of significant works.

Justification of Research Importance

Ecosystem management as a catalyst

Ecosystem management can not be accomplished without a consensus, among agencies, on what defines an ecosystem. A conventional definition of the term "ecosystem" is an ecological unit consisting of both the living (biotic) communities and the nonliving (abiotic) environment, which interact to produce a stable system (Hickman, et. al. 1988). Subsequently, Joyce and Knight (1992) contend that delineating ecosystem management units is a rather subjective assignment. As a result, effective ecosystem management will require intradepartmental and interdepartmental coordination. An effective silvicultural database management system is essential to achieve this level of coordination.

Current conditions warranting research

As Powell, et al. (1994) expressed, the need for land managers to catalog their resources has become necessary in today's fast-paced, computer oriented society. However, there are few established methods or systems to adequately store and
manipulate the large quantities of data being collected from these ecosystems. It is not uncommon for forest managers to be accountable for databases containing 500,000 records with 100 tree attributes (McWilliams and Kelly 1986). For example, the 1992 MOFEP data collection season alone resulted in a database containing 54,501 records of forestry data. This number does not include the vast amounts of data collected on wildlife, soils, mammals, etc. This example illustrates how it does not take long to generate an imposing, almost inoperative, database.

The alarming fact is innovative techniques for collecting natural resource data are being constructed, with expanded capabilities, resulting in the collection of even larger quantities of data. Before 1974, most field crews tallied less than 60 timber variables on each plot. By 1990, more than 150 items were being collected at various locations (Powell, et al. 1994).

A DBMS that can keep-up with the fast-paced advances of modern data collection techniques needs to be constructed. To date, many ideas of acceptable database management systems to be used for natural resource management have been proposed, but few have been developed. Do not be mislead, there are systems available that can assemble an abundance of raw data and generate findings, but often the findings are meaningless to system users. Typical system users can handle only so much information before becoming inundated. The ideal management system needs to easily, but adequately, communicate its findings to natural resource managers. If the findings generated are vague or produce illogical results natural resource managers will ignore the findings in the decision making process and fall
back on using intuition (Baskerville and Moore 1988, Bishop and Hull 1991).

Advantages of using a DBMS are well documented (Chang and Sharraray 1986, Date 1975, van Roessel 1986). Below is a compiled list of potential advantages that can be obtained from using a DBMS (advantages are listed in order of most commonly mentioned).

1. Centralized control of the database, which is necessary for efficient data administration.
2. Ability to make available an integrated collection of data to a wide variety of users (shareability).
3. Data integrity maintained (accurate data).
4. Non-redundancy of shared data.
5. Retention of privacy through security measures within the system.
6. Data independence.
7. Reliability.
10. Avoid inconsistency in data storage.
11. Make application software independent of data.

These advantages make it possible to bring together a variety of data and interrelate it for a variety of users, not just for a limited few (Chang and Sharraray 1986).

Users of a DBMS consider the advantages listed above as significant reasons to use these types of systems. However, these advantages do not create automatic acceptance. Along with these advantages the DBMS must be easy to use. Arney (1986) states it well, "A more simplistic microcomputer-based inventory will serve the forest manager well at this time and will also place him/her in position to use other newly evolving technologies as they become fully functional in the next few years." Making technology invisible, and allowing users to focus on the job at hand rather than on the tool they're using will improve user efficiency (Appleton 1993).
Arney’s comment encompasses the focus of this study, which is to create such a system which allows natural resource managers to obtain results without becoming distracted by computer wizardry.

With such notable advantages and the advent of user-friendliness, interest in database management systems is high, but how do we choose the correct DBMS? In the 1970s there were no more than two dozen widely marketed DBMS product lines; today there are hundreds to choose from (Chang and Shararay 1986). Below is a checklist provided by Collier (1986) to aid in choosing a DBMS.

1. Identify what your needs are from the system.
2. Select the type of system that is "best" suited to your needs.
3. Identify specific products within chosen product category as "candidates".
4. Eliminate systems based on compatibility requirements.
5. Eliminate candidates based upon processing requirements.
6. Eliminate systems bases upon functional requirements.
7. Rank the remaining systems.
8. Investigate the top ranked systems and pick the "best".

By systematically following Collier’s checklist the most appropriate DBMS can be selected for the task at hand.

Research to develop a DBMS that can efficiently store and manipulate the large amounts of natural resource data being collected seems timely. With the recent developments in database management systems, and a method for choosing a system, the need for this research appears clear. However, everyone needs to realize a DBMS, no matter how easily constructed and manipulated, is only as reliable as the elements which comprise it (Smith and Blackwell 1980).
Evaluating Research Techniques and Procedures

System development

Cyclical or spiral development was the first attempt to develop a large, integrated, silvicultural database management system. It was anticipated that this research would result in a system that could be modified, based on user feedback, to incorporate improvements (Dumas and Redish 1993, Rettig 1991). Cyclical development involves (1) planning, (2) designing, (3) coding, (4) testing and (5) integrating. Each stage is systematically conducted and then repeated through a continuous improvement process.

Cyclical development helps alleviate the dilemma that design comes 'first' and use 'last', because many developers do not realize that the effectiveness of a working system depends on many criteria that cannot be anticipated at the early stages of development (Harrison and Thimbely 1990). With repetition at each stage it allows developers to consider suggestions for incorporation into the final design.

System testing

Testing is a significant component of system development. Testing of a newly developed database management system will generate suggestions which can be integrated into the system. Two forms of testing can be conducted: (1) functional testing; and (2) usability testing.

Functional testing is used to find discrepancies between the actual behavior of the implemented system's functions and the desired behavior as described in the system's functional specifications. To accomplish this goal requires first, that tests be
executed for all of the system’s functions, and second, that the tests be designed to maximize the chances of finding errors in the software (Ostrand and Balcer 1988).

During functional testing trial users are instructed to document problems in four areas (Perry 1986). Problem areas in which trial users were instructed to document are listed below.

1. Differences between what is and what should be.
2. Unclear or incorrect operating instructions.
3. Incorrectly prepared input.
4. Hardware or mechanical failure and/or operating system failure.

Usability testing is utilized to verify that people who use the system do so quickly, and easily to accomplish their tasks. Dumas and Redish (1993) believe that usability is an attribute of the entire package - hardware, software, menus, icons, messages, manual, quick references, and training. They also present the following five goals of usability testing.

1. Primary goal is to improve usability of a product.
2. Participants testing system should do real tasks.
3. Participants testing system should represent real users.
4. Test supervisors should observe and record what participants say and do.
5. Analyze data, diagnose real problems and recommend changes.

Usability testing is designed to assist system developers assemble the most efficient system possible. All system developers endeavor to do a good job. System developers understand that their goal is to produce effective software, not software that merely passes tests (Gelperin and Hetzel 1988).
Questionnaire development

A questionnaire is a set of questions compiled for response by a number of people independently. This statement implies three components. First, the design of the question, second who should be included in the sample group, and how many people should be included in the sample group.

Questionnaire design draws from a very wide range of disciplines, including statistics, psychology, sociology, anthropology, economics, and computer science (Hoinville and Jowell 1978). No one can be expected to master such a wide diversity of disciplines, however, Hoinville and Jowell (1978) furnish a list of details to consider prior to designing a questionnaire.

1. The questions must be designed so that they are easy for respondents to understand and to answer accurately and clearly.
2. The questionnaire must be easy for the interviewer to administer.
3. The questionnaire should be constructed so that the recorded answers can easily be edited, coded and transferred onto a computer file for statistical analysis.
4. The flow, structure and length of the questionnaire should encourage and keep the respondent’s interest.

Hoinville and Jowell explain that questionnaires can come in many shapes and sizes, however, the above design rules apply to all of them. All questionnaires must be designed specifically to suit the studies’ aims and the nature of the respondents. Notwithstanding, the design rules listed above should assist in engaging their interest, encouraging their cooperation, and invoking answers as close as possible to the truth.

Questionnaires are meant to be a two-way conversation between the researcher and the respondent. By first identifying the respondents, the types of questions you can realistically ask, concepts which can be explored, and methodology to use will be
defined (Labaw 1980).

Questionnaire respondents must be determined prior to questionnaire development. Dumas and Redish (1993) reveal five factors to consider in developing a profile of a system’s potential trial users.

1. Consider users work experience (e.g., experience with particular tasks that the system handles).
2. Consider users general computer experience (e.g., length of experience working with computers).
3. Consider specific computer experience (e.g., experience with relevant hardware and software).
4. Experience with this particular system.
5. Experience with similar products.

It must be determined how many potential users fit the test criteria. Those who fit the test criteria will be asked to respond to the questionnaire. Dumas and Redish (1993) conducted a study to determine how many respondents are needed to sufficiently locate problems in a product. They found that 80% of the usability problems in a product were detected with between four and five participants and 90% were detected with 10 participants. Additional participants were less and less likely to reveal new problems. They concluded that a reliable test could include 6-12 participants in 2-3 subgroups.

Once respondents have been chosen appropriate questions can be formed for inclusion on the questionnaire. The questions can be either open-ended or closed. Open-ended questions, or free-response questions, allow the respondents to fully explain their answers in their own words. Closed questions force the respondents to choose between a set of predetermined answers.

Open-ended questions have a slight advantage over closed questions when
trying to obtain respondents attitudes towards a given subject. Labaw (1980) advocates open-ended questions because she feels that they are the only way she can allow her respondents to "have their way". She also states that open-ended questions allow the respondent to indicate the depth of their feelings on controversial issues. Closed questions may not provide suitable options, and the options provided may influence the respondents answers.

Open-ended questions have many attitudinal measuring advantages, however, most questionnaires would not be complete without including a number of closed questions. Closed questions serve to keep the respondents "on track". Closed questions keep the respondents mind on the issue at hand and prevents them from digressing. Open-ended questions and closed questions work well collectively. As Labaw (1980) expresses, closed-ended questions often provide the statistical count and the open-ended questions usually provide the meaning of the statistical count.

Following questionnaire completion a pre-test of a small group, not included in the sample population, is desirable to verify effectiveness of questionnaire. It takes only a small number of pre-testers to adequately test the questionnaire. Research completed by Woods (1980) involved mailing questionnaires to 240 respondents, but sufficient pre-testing was accomplished by five pre-testers. Recommendations made by pre-testers should be assessed, and those enhancing the questionnaire should be accepted. Accepting recommendations of the pre-testers is appropriate. Schuman and Presser (1981) point out, "Even the masters of survey research sometimes write questions that in retrospect seem questionable."
Literature Documentation of Meaningful Research

The idea of an integrated silvicultural database management system is highly innovative. Literature documenting similar systems actively being utilized in the natural resources discipline is very limited. One similar system that is being utilized is the RAISON system that was developed by Lam and Swayne (1991). They have developed and successfully applied a microcomputer support system that uses database, spreadsheet, graphics, GIS, statistics, models and expert system. As they explain, the linkages, both within the system and to external software packages, greatly facilitate the transfer of information. The RAISON system was developed to assess the water resources impacted by acid rain in Eastern Canada.

There is also the Harvest Schedule Generator (HSG) developed by Moore and Lockwood (1993). This system is a tool to assist forest managers and others in the design and evaluation of forest management strategies. The Harvest Schedule Generator is a menu-driven system that contains a suite of programs designed to assist the user in preparing inputs, running simulations and generating queries that graphically display and map simulation results.

While literature documenting integrated database management systems being actively used in natural resources is limited, literature documenting research relating to the development of silvicultural database management systems is slightly more abundant. One of the more prominent, on-going studies is being conducted at University of Washington. Chad Oliver (1994) is the principal investigator and the study involves developing a Landscape Management System (LMS). The LMS
integrates large amounts of diverse information and scientific knowledge allowing management to be understood, planned, and implemented across large spatial and temporal scales for diverse objectives. LMS uses a modular, flexible systems approach allowing new information and knowledge to be incorporated into the system without the need to redesign the entire system. LMS is based on forest inventory data at the individual tree level to allow a rapid response to new demands of forest management.

Another recent study was conducted using the Oregon Transect Ecosystem Research (OTTER) Project and the National Aeronautics and Space Administration's (NASA) Pilot Land Data System (PLDS) (Skiles and Angelici 1993). As stated in the research documentation, "In essence, the hypothesis tested was that an existing data management system, PLDS, could support an active ecosystem project." Skiles indicates the main task for the PLDS was to effectively manage and store the extensive set of OTTER data collected during the course of the project for use by project scientists and their collaborators. The hypothesis was accepted, but a major failing of the OTTER/PLDS database on-line system was the lack of an attractive, easy-to-use software system (i.e., manuals and menus were confusing).

Another common style of literature documents abstract ideas only. Many natural resource professionals feel the development of a silvicultural database management system is essential for the continuing evolution of natural resource management. However, few have pursued the issue past the conceptual stage. Arney (1986) presents a comprehensive outline for the design, structure and budget of a
microcomputer inventory system, but no further information was made available. The operational objective of this thesis is to take the conceptual stage one step further and actually develop a silvicultural database management system.
CHAPTER 3

DEVELOPMENT OF THE SILVICULTURAL DATABASE MANAGEMENT SYSTEM

The initial section of this chapter discusses the hardware, application software, and methodology used for system development. A second section then presents system functions in a very detailed and descriptive manner. Ultimately, this section will allow a conceptualization of the completed silvicultural database management system.

Software Packages and Programming Techniques Used For System Development

Hardware and application software used for system development

The system was developed on a 486DX/33 MHz personal computer with 4 megabytes of memory. The application software used for system development was Microsoft FoxPro 2.5® Relational Database Management System for MS-DOS®. FoxPro 2.5 was chosen because of its ability to read data of DBASE III PLUS® and DBASE IV®. This was an influential feature because MDC was currently using DBASE III PLUS and DBASE IV in their district headquarters to manage all field data.

FoxPro 2.5 for MS-DOS has two versions available to run - Standard and Extended. The Extended version was chosen for system development because of its faster execution speed. The Extended version requires a 386SX or higher processor, 3 megabytes of RAM, MS-DOS version 3.1 or higher, and a mouse is recommended. A major advantage of FoxPro 2.5 is it improves on dBASE by offering a highly
regarded compiler for the dBASE software command language. With this compiler, FoxPro 2.5 can create custom, stand-alone database applications, which is the ultimate objective of this study.

The growth-and-yield model chosen for inclusion in the system was TWIGS version 3.0 (Miner et al. 1988). This version of TWIGS was developed for use on IBM personal computers. This model contains management and economic components for use in forests in the North Central United States. It was developed and validated at the North Central Forest Experiment Station, U.S. Department of Agriculture, Forest Service. The software is a Government-produced program and is in the public domain, except for the economic subroutine which is copyrighted by the Department of Forest Resources, University of Minnesota (UMFR) and the Forest Resources Systems Institute (FORS). For a detailed description of TWIGS capabilities refer to the TWIGS reference guide.

Method behind system development

For ease of programming and added flexibility the system was developed using modular programming. Modular programming is a programming style that breaks down program functions into modules, each of which accomplishes one function and contains all the codes and variables needed to accomplish that function.

Modular programming made system development less complicated because through this technique the system consisted of many small, easily debugged and easily maintained programs rather than a few very large programs. The silvicultural database management system was developed when the many small programs were
united into a single application program. In addition to making system development less complicated, modular programming also added flexibility to the silvicultural database management system. End-users have the ability to remove unneeded components of the system or replace them with alternative components. For example, the system was developed using TWIGS as the growth model, however, it may not be preferred by some end-users. Modular programming gives these users the ability to remove TWIGS and insert the growth model of their preference without an excessive amount of new programming needed.

Development of the database structures utilized in the system

A report detailing MOFEP plot construction and data collection procedures was provided by MDC. This report illustrated permanent plot construction and gave a detailed description of all data collected from these plots. Along with the report, MDC included two sample databases that contained actual field data collected during the 1992 field season. The sample databases included data collected from 0.5-acre sample plots and 0.05 acre sample plots. Examination of all materials provided by MDC allowed for development of the database structures included in the silvicultural database management system. The database structures utilized in the system are illustrated in Appendix A.
System Description

The silvicultural database management system has been developed to conveniently store, manage, manipulate, and summarize natural resource data in a user-friendly environment. During initial stages of system development attention was given to potential uses of the system. Many perspectives were considered, from the highest administrative point of view to the recommendations of the indispensable field worker. By incorporating these perspectives the system not only attempts to accommodate the experienced administrator, but also the inexperienced employee.

During all stages of system development every recommendation was thoroughly assessed. Ultimately, the completed system conveniently documents management activities and allows easy access to data and information pertaining to these management activities. It’s design incorporates previously available procedures and programs into one collective application. It exhibits a practical way to use the selected growth model TWIGS. In addition, it’s modular design allows for adaptability with expanding technology.

System operations

Primary interest was to create a system with the ability to integrate analysis of database files allowing natural resource managers greater flexibility with their data. The system is not only efficient in using database files to perform all system operations, but it is also an easily understood, menu-driven application.

To assure the system is easily understood it has been developed with context-sensitive help incorporated. Context-sensitive help is a user-assistance mode that
displays on-screen documentation relevant to the command, mode, or action the user is currently performing. This design feature is intended to reduce the time and keystroke counts needed to get on-screen help. Without context-sensitive help, the user must locate the desired information manually from an index or menu.

All system operations originated from a main menu that enabled users to do a host of calculations and data manipulations. Figure 3-1 is a diagram of the system configuration. The circular symbols represent system modification options. These options allow users to input new data and alter how data is displayed or used in data manipulation options. All box symbols are data manipulation options. These options allow users to perform calculations on data, produce growth projections, and creates reports of data. The two box symbols that are dashed indicate options that allow for creation of new databases which can be used with all other system options. Refer to Appendix B for a layout of the main menu. The following descriptions refer to each specific option presented on the main menu of the silvicultural database management system.

Alter site(s) in use - Option presented in the main menu of the system that allows users to setup a filter for all calculations and data manipulations to be performed within the system. When specific sites are specified the system will only use data from those sites to produce results. Site specifications will remain active until manually changed or system is exited.
Figure 3-1. Flowchart of system operations.
Change plot(s) in use - Option allowing users to setup a filter, based on specific plot specification, for all calculations and data manipulations to be performed within the system. As with site specification, only data from the specified plots will be utilized to produce results. Plot specifications also remains active until manually changed or system is exited.

Input new data - Allows users to enter new data to the end of a specified database, one record at a time, or alter records already in the specified database. This option is currently set-up to only enter new data into or alter existing data in database files used with MOFEP data structures.

Treatment documentation - This option provides a relatively unique capability of putting past silvicultural treatments and treatments prescribed for future implementation into archives (i.e., the treatments are recorded and saved). These records can then be queried and cross-referenced to create reports. These reports have great potential uses for individuals responsible for administering land management activities.

Develop stand table - This system option produces a stand table using any designated database and only specified sites and plots. During stand table development the system also presents options for using species specific site indices or a single stand site index to calculate results presented in the table. All stand tables display trees per acre, average diameter, basal area, and volume (cubic ft. and board ft.) in 2.0 inch size class intervals.
NOTE: The coefficients used for volume calculations are those for saw-log size diameter classes. Volume results are only displayed for those diameter classes. This includes a diameter at breast height (d.b.h.) equal to or greater than 9" (softwood) or with a d.b.h. equal to or greater than 11" (hardwood). Minimum top saw-log diameters are 7" (softwood) or 9" (hardwood).

Generate stocking tables - This option generates stocking tables in the same manner as the system develops stand tables. The difference results in the break down by tree species, not size classes.

Produce basic statistics - An option allowing users to produce 4 basic statistical results (Mean, Variance, Minimum, and Maximum). These results are calculated using all data contained in numeric fields within the designated database and presented in a concise table. If certain fields produce illogical statistical results users may designate specific fields within the designated database from which to generate results.

Run TWIGS - This option allows TWIGS to be run using any database of users choice, assuming it contains the needed database structure from which to create a TWIGS readable file. Under normal use TWIGS data must be converted to a TWIGS readable file using a separate program called TREEGEN. Once created, the TWIGS readable file has no other use but for TWIGS. This option, offered in the system's main menu, creates a TWIGS readable file from tree data stored in files with a database format. The process is quick and allows the original data, in the database file, to be manipulated in many additional manners. Once the TWIGS readable file
has been created and TWIGS is invoked no assistance is given (i.e., an understanding of TWIGS is needed). Additionally, all TWIGS projected files can be converted back into database files and used for other calculations in the system.

Query treatment databases - The final option presented leads to seven additional options in which to query databases containing information on future and past forest treatments. These options will allow users to create reports using information from specific site and plots. Examples of reports include comparisons of actual treatments implemented vs planned treatments, query of all past treatments implemented, query of all future treatments planned and query of past/present treatments by date or specific type of treatment. Additional options are presented allowing users to print the reports, see only a summary of the reports, or use the information obtained from the query for additional calculations (i.e., use the information to create tables, etc.).
CHAPTER 4

MATERIALS AND METHODS

The following chapter has been broken into two sections that coincide with the research objective of this study. Section one presents the materials and methods employed to test the system. Section two then reviews the methods used to analyze the degree of acceptance of the system.

System Testing

Data utilized for system testing

Data utilized for calculations and manipulations during system testing was selected from two separate sources. All stand and plot based data came from the sample databases received from MDC. These sample databases contained actual field data collected during the 1992 field season. All silvicultural treatments were simulated by the researcher and were based on silvicultural treatments the researcher had encountered or studied during many years as a forester.

Selection of individuals to test system

As identified in the study hypothesis, the sample population had to be comprised of individuals from three different levels of experience within the forestry discipline. These three levels of experience included forestry undergraduate students, forestry graduates students, and professional foresters. All undergraduate and graduate students were enrolled at the University of Missouri - Columbia. All professional foresters were employees of the Missouri Department of Conservation.
Due to the questionnaire requiring approximately three hours to complete, the sample sizes for each group is relatively small. Twelve (12) individuals were selected from each of the three groups. This sample size was established by the undergraduate group. It was determined that undergraduate students needed enough forest management background to justify their use as system testers (from here on referred to as testers or respondents). The obvious choice was to select undergraduate students currently enrolled in the Forest Resource Management course offered at UMC. During the semester of system testing there were 12 students enrolled in the class. Twelve individuals were then chosen from each of the other two groups.

Graduate students were selected based on their emphasis of study. Every attempt was made to include graduate students who were pursuing a degree emphasizing forest management. Resource foresters were selected from a list supplied by MDC. Listed were all MDC resource foresters and the location of their district headquarters. Four district headquarters, widely distributed throughout Missouri, were chosen and from each headquarters three resource foresters were asked to participate in system testing.

Locations of system testing

Locations of system testing included one UMC office site and several MDC office sites. Undergraduate and graduate students tested the system on the UMC campus. All students tested the system, independent of one another, using the same computer located in the office at 313 Gentry Hall. Professional personnel tested the system at four different locations around Missouri.
Locations included:

1) MDC district headquarters in Piedmont, MO;
2) MDC district headquarters in Columbia, MO;
3) 1995 Forest, Fisheries, and Wildlife (FFW) Conference;
4) MDC district headquarters in Lebanon, MO.

Professional personnel in Piedmont, Columbia, and Lebanon tested the system using two computers supplied by the researcher and one computer already located on the premises. Those professionals that tested the system at the 1995 FFW Conference used three computers supplied by the researcher.

Questionnaire construction

The questionnaire consisted of five sets of questions. The first four question sets had tasks associated with them. The tasks had to be completed prior to responding to the related set of questions. The last question set had no associated task.

The tasks were designed to entail many of the options incorporated in the system. By performing the tasks all individuals testing the system received a complete demonstration of system capabilities. Only those options that allowed direct manipulation of key databases exclusively developed for system testing were avoided.

Task one was designed to have respondents query the future treatment database to determine treatments planned for 1998. They were then instructed to use current data to generate a stocking table for all sites and plots planned for treatment in 1998. Task two required respondents to query the past treatment database and determine sites and plots that were treated in 1989. They were then instructed to use current
data to generate a stand table for these sites and plots. Those same sites and plots were then used to create a TWIGS readable file which was projected 10 years into the future. The projected data was then used to generate another stand table. Task three simply had respondents query treatments planned for 1997 and 1998 and then compare person hours between the two years. Finally, task four had respondents query treatment databases to determine how the silvicultural treatment actually conducted on site 1, plot 44 compared to the planned prescription for site 1, plot 44.

Each of the question sets, except for question set five, was comprised of two closed-ended questions and one open-ended question. Question set five differed by the addition of one closed-ended question. It was comprised of three closed-ended questions and one open-ended question.

Closed-ended questions contained in question sets 1-4 were analogous to one another. They were worded differently, but secured responses from similar topics of interest. Topics of interest included:

1. whether the tasks were accomplished;
2. whether the options encountered during completion of each task were effective;
3. whether the options encountered were understandable;
4. users’ familiarity with programs used in system.

Comparable to the closed-ended questions, the open-ended questions contained in question sets 1-4 were designed to capture the users attitudes of the system based on their knowledge of the system gained during completion of each task. Open-ended questions allowed users to list potential advantages and/or disadvantages of the system pertaining to the task they had just completed.
Question set five was more comprehensive than the first four question sets. It was formulated to determine the users' overall attitudes of the system, not merely the attitudes based on each individual task. The complete questionnaire is contained in Appendix C.

Pre-testing

Prior to administering the questionnaire to the actual system testers two individuals were chosen as pre-testers. Pre-testers included one forestry graduate student and one forestry undergraduate student enrolled at UMC. A professional was not included because it was concluded that the first two pre-testers had sufficiently fulfilled pre-testing requirements. Pre-testers were not involved in testing the system's usability, but rather how well the questionnaire tested the desired attributes.

During actual system testing the researcher left the testing area, however, during pretesting the researcher remained in the testing area with both pre-testers. While both pre-testers systematically conducted each task included in the questionnaire the researcher observed their reactions. When problems were encountered they were instructed to stop and explain why they were having difficulties. A list of encountered problems, suggestions, and information obtained from pretesters are listed below.

1) Determined that testing of system would require 3 hours per tester.
2) Revised demonstration given prior to allowing system testers to begin.
3) Located spelling and grammar mistakes in questionnaire and menu options.
4) Suggested wording tasks as closely as possible to the way the options would appear on screen.
5) Noticed many mistakes occurred due to reading questionnaire and menu options to quickly.
6) Did not know how to position cursor in the question they needed to answer.
7) Species codes, in HELP text, needed to be alphabetized.
8) Did not understand what to do once TWIGS was invoked.

By considering all items listed above many weak points in the questionnaire and system testing were located and corrected.

Administering the questionnaire to system testers

The questionnaire was administered via the computer. An option was added to the main menu of the system that gave system testers access to the questionnaire. This option was designed to only allow access to one question set and associated task at a time. Once they were finished with a question set they were allowed to move on to the next question set and associated task. Only when they had finished all five question sets were they allowed to proceed back through previous question sets. This design guided all respondents through the questionnaire in identical sequences.

In addition to the on-screen questionnaire, system testers were also given a hardcopy of the questionnaire for reference purposes only. They were not allowed to answer any questions on the hardcopy. They were required to answers all questions via the computer. When they responded to a question their answers were stored directly into a database for later use by the researcher.
Analysis

Closed-ended questions

All closed-ended questions were analyzed and displayed using two of the simplest, but most useful statistical tools available: (1) histograms; and (2) boxplots. Histograms were used to represent the frequency distribution of most of the true/false questions and ranking questions contained in the questionnaire. These methods of analyzation and display were chosen because they were simpler to comprehend, yet conveyed very valuable information.

Boxplots were used to illustrate whether prior experience with a database management system affected proficiency of system testers. Boxplots provided a visual display of five components of the data. The five components included: (1) the median, (2) the lower (Q₁) and upper (Q₃) quartiles, and (3) the extremes. Boxplots included a central box from Q₁ to Q₃ with the median marked by a horizontal line. Added to the central box were two vertical lines which extended to the extremes. If the medians of the two different groups being analyzed were located between the upper and lower quartiles of the other group the results were not considered significant.

Open-ended questions

The main statistical technique used to analyze open-ended questions was nonparametrical, or distribution-free, statistics. This analysis technique makes no assumption about the underlying distribution function other than that of continuity. The major advantage of nonparametrical analysis is that data not available as exact
measurements but only in qualitative or relative classifications can be analyzed. Parametric techniques were not utilized because they contain more assumptions and require larger sample populations than were practical to obtain during this study. Formulas and explanations for all nonparametrical analyzes employed are located in Appendix D.

The main method of open-ended analysis was Kendall's Coefficient of Concordance (W) (Siegel 1956). The open-ended questions, contained in the questionnaire, furnished respondents with an avenue to freely express their feelings or attitudes towards the system. Kendall's coefficient of concordance was useful for measuring the level of agreement, between the three groups testing the system, on whether the system was suitable for natural resource management or not.

The size of the coefficient (W) illustrates the level of agreement; perfect agreement would be indicated by a W = 1, and a lack of agreement would be indicated by a W = 0. If an observed W was equal to or greater than the tabled value at the 0.05 level, the null hypothesis was rejected at that level. Here, the null hypothesis predicts that there is no agreement among system testers on whether the system was advantageous to use or not, or they completely agree on whether the system was advantageous to use or not. On the other hand, if the null hypothesis can be rejected, the conclusion is that system testers agree on at least one reason why the system was advantageous to use or disadvantageous to use, or both.
Proficiency of system testers

Undisclosed to system testers, as not to effect testers use of system, keystrokes were recorded in a database for analysis. This unbiased method of data collection allowed for an analysis of the total keystroke counts needed for each individual tester to complete their assigned tasks. The method used to analyze the keystroke counts was the Kruskal-Wallis One-Way Analysis Of Variance By Ranks (H).

Kruskal-Wallis One-Way Analysis Of Variance By Ranks is a nonparametrical statistical technique useful for deciding if \( k \) independent samples are from different populations. This statistical technique was used to analyze whether the system testers, who were ranked according to their total keystroke counts needed to complete the questionnaire, could be observed to "bunch-up" or coincide between user groups. The null hypothesis tested was that there was no difference in the keystroke counts needed to complete the survey among the different user groups. If the null hypothesis was rejected, the alternative hypothesis states that there was a difference in keystroke counts needed among the different user groups.

As a follow-up to the Kruskal-Wallis One-Way Analysis Of Variance By Ranks the Mann-Whitney U Test was run. The Mann-Whitney U Test systematically searches pairs of groups for significant differences. This statistical technique was used to determine if the Kruskal-Wallis test had masked any significant differences between pairs of user groups. Specifically, the Mann-Whitney U Test was used to test the hypothesis that there were differences between pairs of user groups.

An error of observation was then calculated, per task for each tester, to
establish a proficiency trend from task one through task four. In statistics, an error of
observation is the difference between an observation (testers keystroke counts) and the
expected value (minimum keystroke counts required) due to uncontrollable factors in
the method of observation. The resulting values were averaged, by task, for each
independent group to obtain an average error of observation for task one through task
four. The resulting values were expressed in percentages.

Effect of Prior Database Use On Proficiency of System Testers

Acceptance of any computer application is based on users' opinions, and most
opinions are based on past computer experience. Past experiences provide users with
a basis for their current opinions and suggestions. With past experiences being quite
influential, it seemed only appropriate to investigate past experiences of system testers.

Analysis began by determining the number of testers having prior experience
with a database management system (Table 5-1). Approximately 2/3 of all testers had
prior experience with a database management system. This meant that they had a
basis for their responses to the questionnaire. Those with no prior experience
contributed an enlightened view of how acceptable the system was for inexperienced
testers.

Boxplots were then used to cross-reference prior database use with total
keystroke counts needed to complete the questionnaire. This analysis was an effort.
establish a proficiency trend from task one through task four. In statistics, an error of observation is the difference between an observation (testers' keystroke counts) and the expected value (minimum keystroke counts required) due to uncontrollable factors in the method of observation. The resulting values were averaged, by task, for each potential user to learn how to use the system, and attitudes towards the system are analyzed to determine the degree of acceptance for the system. Qualitative data is presented in a descriptive manner and quantitative data is presented in both graphical and tabular formats.

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CHAPTER 5

RESULTS AND DISCUSSION

In this section, (1) analyses are used to determine if prior database experience had an effect on users proficiency, (2) analyses are presented illustrating the ability of potential users to learn how to use the system, and (3) attitudes towards the system are analyzed to determine the degree of acceptance for the system. Qualitative data is presented in a descriptive manner and quantitative data is presented in both graphical and tabular formats.

Effect of Prior Database Use On Proficiency of System Testers

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Boxplots were then used to cross-reference prior database use with total keystroke counts needed to complete the questionnaires. This analysis was an effort
Table 5-1. Number of system testers with and without prior experience using a database management system.

<table>
<thead>
<tr>
<th>Group</th>
<th>Number</th>
<th>Percent</th>
<th>Group</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prior Experience</td>
<td></td>
<td>No Prior Experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professionals</td>
<td>10</td>
<td>83.3</td>
<td>Professionals</td>
<td>2</td>
<td>16.7</td>
</tr>
<tr>
<td>Graduates</td>
<td>6</td>
<td>50.0</td>
<td>Graduates</td>
<td>6</td>
<td>50.0</td>
</tr>
<tr>
<td>Undergraduates</td>
<td>7</td>
<td>58.3</td>
<td>Undergraduates</td>
<td>5</td>
<td>41.7</td>
</tr>
<tr>
<td>Total:</td>
<td>23</td>
<td>63.8</td>
<td></td>
<td>13</td>
<td>36.1</td>
</tr>
</tbody>
</table>
to determine if prior database experience influenced the proficiency of system testers. Initially, groups were combined to determine if there was a difference between users with prior database experience and users without prior database experience. The combined groups showed no difference between users with prior database experience and users without prior database experience (Figure 5-1).

Then, to determine if the combining of groups masked any difference within each independent group, the groups were graphed separately. No significant difference was found for professionals (Figure 5-2) or graduate students (Figure 5-3), but undergraduate students did express a slightly significant difference between testers with prior database experience and those without prior experience (Figure 5-4). The significant difference is indicated by the median line of keystroke counts for undergraduate students without prior database experience being located adjacent to the upper quartile of the undergraduate students with prior database experience. This figure illustrates that undergraduate students without prior database experience required more keystrokes, on average, to finish the questionnaire than undergraduate students with prior database experience.

The boxplots were an excellent visual representation of the data, however, they were quite indistinct when analyzing all groups collectively. So a more definite Kruskal-Wallis One-Way Analysis Of Variance By Ranks was used to observe the total keystroke counts required among all three groups simultaneously (Table 5-2). Results depicted no significant difference among the three groups regarding total keystrokes needed to complete the questionnaire. This meant that no group required
Figure 5-1. Difference in total keystroke counts for combined groups between system testers with and without prior database experience.
Figure 5-2. Difference in total keystroke counts between professionals with and without prior database experience.
Figure 5-3. Difference in total keystroke counts between graduate students with and without prior database experience.
Figure 5-4. Difference in total keystroke counts between undergraduate students with and without prior database experience.
Table 5-2. Summary of Kruskal-Wallis One-Way ANOVA by Ranks of Total Keystrokes Required To Complete the Entire Questionnaire.

<table>
<thead>
<tr>
<th>Mean Rank</th>
<th>df</th>
<th>H</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professionals = 210.5 (NS)</td>
<td>2</td>
<td>0.13</td>
<td>0.90 &lt; p &lt; 0.95</td>
</tr>
<tr>
<td>Graduates = 220.0 (NS)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undergraduates = 235.5 (NS)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level, (NS) is not significant.

significantly more or less keystroke counts than another. They all seemed to be distributed quite evenly.

As a follow-up to the Kruskal-Wallis One-Way Analysis Of Variance By Ranks, the Mann-Whitney U test was administered to analyze pairs of groups for significant differences (Table 5-3). This analysis was performed to determine if the simultaneous analysis of all three groups masked any significant difference between pairs of groups.

The follow-up analysis revealed no significant differences. The critical value for the Mann-Whitney U analysis was 37.0. The \( U \) value comparing professionals and graduate students, graduates and undergraduate students, and professionals and undergraduate students was 70.0, 68.0, and 62.5, respectively. All of these \( U \) values were greater than 37.0 resulting in none of them being significant at the 0.05 level.
Table 5-3. Summary of the Mann-Whitney U Test Conducting A Pair-wise Analysis of Keystrokes Required To Complete the Entire Questionnaire.

<table>
<thead>
<tr>
<th>Pairs</th>
<th>Mean Rank</th>
<th>U</th>
<th>Critical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professionals-Graduates</td>
<td>148.0 (NS)</td>
<td>70.0</td>
<td>37</td>
</tr>
<tr>
<td>Graduates-Undergraduates</td>
<td>146.0 (NS)</td>
<td>68.0</td>
<td></td>
</tr>
<tr>
<td>Professionals-Undergraduates</td>
<td>140.5 (NS)</td>
<td>62.5</td>
<td></td>
</tr>
<tr>
<td>Graduates-Undergraduates</td>
<td>154.0 (NS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professionals-Undergraduates</td>
<td>159.5 (NS)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level, (NS) is not significant.

Mastery of the System

It was unclear, at the onset of the study, how proficiently the various groups would be able to use the system, but regardless of their initial proficiency it was believed they could quickly become proficient. To foster this belief the system was developed with context-sensitive help incorporated. However, the usefulness of the context-sensitive help was not certain at the onset of the study.

Utilization of context-sensitive help

Determination of the usefulness of context-sensitive help was achieved through a relatively simple, yet informative, scatter plot (Figure 5-5). It plotted keystroke counts needed to complete the entire questionnaire against the number of times context-sensitive help was utilized. It was an attempt to determine if increased use of context-sensitive help resulted in fewer keystroke counts required to complete the questionnaire, thus demonstrating the potential ability to increase user proficiency.
Figure 5-5. Total keystroke counts, per system tester, needed to complete questionnaire compared to the number of times HELP was utilized while completing the questionnaire.
Illustrated in Figure 5-5 is a slight, yet discernable pattern between undergraduate students and the other two groups. Undergraduate students exhibit an affinity to using help more often than the other two groups. This affinity may be due to undergraduate students having an increased willingness to accept help, or a result of graduate students and professionals having a greater resolve to figure things out on their own. Regardless of the reason, undergraduate students used help an average of 5.08 times, compared to only 2.58 for professionals and 2.00 for graduate students.

An additional analysis was performed regarding the use of context-sensitive help. Following completion of task four, all testers were asked whether they had viewed the help text prior to task 4 and, if so, had it been useful. Surprisingly, only 7 out of 12 (58%) testers from both the professional and graduate student groups used help prior to task 4 (Figure 5-6). This was surprising because task 2 had required testers to enter United States Forest Service (USFS) species codes, and the codes were only available through the context-sensitive help. Apparently they had memorized the USFS species codes prior to testing the system. Favorably, all professionals and graduate students that had used the context sensitive help did believe it was useful.

As illustrated in Figure 5-6, many more undergraduate students used context-sensitive help than did professionals and graduate students. A total 11 out of 12 (92%) undergraduate students admitted to having used context-sensitive help prior to task 4. Out of those 11 undergraduate students, 10 (83%) of them concluded the context-sensitive help had been useful.
Figure 5-6. Context-sensitive help used prior to task 4 and, if used, an indication of the usefulness of the help.
In conjunction with the original question regarding use of context-sensitive help prior to task four, all testers were asked if they had not used the help text prior to task 4 had they used it to complete task 4 and, if so, had it been useful. Results indicated 33 of the total 36 (92%) system testers had not used the context-sensitive help to accomplish task 4. As a favorable sidenote, all 3 testers that had used the context-sensitive help found it useful. This result illustrates that most of the context-sensitive help that had been used during system testing had been used prior to task 4.

Duration of introductory period required for increased proficiency

All computer applications, regardless of user-friendliness, require a learning period for new users. It was hypothesized that proficiency of system testers would increase by simply using the system. To verify this hypothesis a histogram plotting the average error of observation for each task was constructed (Figure 5-7). In statistics, an error of observation is the difference between an observation (testers keystroke counts) and the expected value (minimum keystroke counts required) due to uncontrollable factors in the method of observation.

In Figure 5-7 a definite pattern developed for all three groups. Proficiency increased from task one through task four, respectively, with the only exception occurring in tasks three and four. The increase in proficiency is illustrated by the downward slope of each line contained in Figure 5-7. A stratified pattern also developed between the three groups. This stratification occurred in each task with professionals, graduate students, and undergraduate students each requiring greater
Figure 5-7. Average error of observation for tasks 1-4 (expressed as a percent).
keystrokes than the other, respectively. Again, an exception occurred in tasks three and four.

Both exceptions that occurred in tasks three and four were due to a large fluctuation in the proficiency of graduate students. In task three graduate students did an exceptional job in conducting the task within the minimum keystroke counts possible. However, in task four their average skyrocketed as a result of two students having error of observation percentages of 360 percent and 420 percent. The graduate student with the error of observation of 360 percent chose to "PRINT OUT" the report they were asked to view in task four. This resulted in an excessive keystroke count due to errors generated by choosing the print option when no printer was available. The other graduate student, with an error of observation of 420 percent, had an excessive keystroke count due to generating a stocking table. The stocking table was generated correctly, but task four did not require the generation of a stocking table.

A Kruskal-Wallis One-Way Analysis of Variance by Ranks was then used to simultaneously compare the average error of observation between each group (detailed information on individual testers can be found in Appendix E). This particular analysis tested the hypothesis that there was a difference in the average error of observation among the three user groups (Table 5-4). In other words, it was attempting to discover if one group illustrated an increase or decrease in proficiency significantly different from the other two groups. No significant difference was discovered through using the Kruskal-Wallis analysis.
Table 5-4. Kruskal-Wallis One-Way ANOVA by Ranks of Average Error of Observation (AEO) for Each Task.

<table>
<thead>
<tr>
<th>Professionals</th>
<th>Graduates</th>
<th>Undergraduates</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEO</td>
<td>Rank</td>
<td>AEO</td>
</tr>
<tr>
<td>Task 1</td>
<td>90.25</td>
<td>6</td>
</tr>
<tr>
<td>Task 2</td>
<td>69.11</td>
<td>3</td>
</tr>
<tr>
<td>Task 3</td>
<td>68.17</td>
<td>2</td>
</tr>
<tr>
<td>Task 4</td>
<td>71.67</td>
<td>4</td>
</tr>
<tr>
<td>Mean Rank</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

H = 3.72 (NS)  
df = 2  
0.10 < p < 0.20

*Significant at the 0.05 level, (NS) is not significant.

Basis of proficiency testing

Analyses scrutinizing proficiency of system testers were all based on the correct completion of all tasks. Without correct completion of all tasks it was difficult to determine if testers were improving their proficiency in using the system. Two questions were devised to determine if system testers believed they had correctly completed tasks. Initially, all testers were asked whether they had accomplished task one. Summing responses from all groups, 34 of the 36 (94%) system testers believed they had correctly completed task one. However, upon reviewing the steps they had used to complete task one it was determined only 32 of the 36 (89%) actually completed task one. This meant that five percent of system testers, even though they truly felt they had completed task one, could not be used in the proficiency analysis.
because their keystroke counts would bias the results. Their keystroke counts were exceptionally low due to incompletion of task one.

In question set four system testers were asked if a planned treatment had actually occurred as scheduled. Favorably, 33 of the 36 (92%) testers answered correctly. The correct response was no, the planned treatment had not occurred as scheduled. Surprisingly, all three incorrect answers happened in the same group. Three professionals incorrectly stated that the treatment had occurred as scheduled. An exact reason why they answered incorrectly was not determined, but it was possible they simply misread the treatment information.

Based on these two questions, 89% of all testers correctly completed task one and 92% had correctly completed task four. This not only indicated that a sufficient amount of system testers completed each task to support the proficiency analyses, but it also illustrated another interesting fact. Many testers increased their ability to correctly complete tasks. A greater percentage of system testers were able to correctly complete task four than were able to correctly complete task one.

Attitudes of Testers Towards System

The research objective of this study was to determine the degree of acceptance of the system, and the only way to accomplish this objective was to elicit attitudinal responses. These responses needed to encompass all significant features of the system. To assure all notable features were addressed several closed-ended questions were utilized to elicit responses.
Also, as not to restrict testers, all question sets allowed them to comment openly on reasons the system was an advantage or a disadvantage to use for natural resource management. Kendall's Coefficient of Concordance (W) was used to measure the level of agreement, between the three groups testing the system, on whether the system was suitable for natural resource management or not. Responses from each open-ended question contained in question sets 1-5 were analyzed separately.

Summary of attitudes elicited from closed-ended questions

One of the main goals of development involved creation of a menu driven system. It was anticipated that these menus would be understandable enough to simplify use of the system. To determine if this goal was attained question set one requested a response on whether the menu options enhanced the management system. Results of this question are displayed in Figure 5-8. It illustrates that 83% of the professionals, 100% of the graduate students, and 100% of the undergraduate students believed the menus did enhance the system. However, within the same question set system testers had been asked whether they felt the menu options were clear (without the use of context-sensitive help). As depicted in Figure 5-9, 66% of the professionals, 83% of the graduate students, and 92% of the undergraduate students concluded that the menu options were clear (understandable). The lower percentages of system testers indicating that the menu options were clear, as compared to the higher percentages indicating that the menu options enhance the system, indicate to the researcher that system testers believe that menus, even though
Figure 5-8. Number of system testers that felt system menus enhanced the system.
Figure 5-9. Number of system testers that felt system menus were clear.
they do enhance the system, could be made more clear.

System testers were also asked to comment on the system’s improvement on TWIGS. Comments were similar between all three groups. Approximately, 83% of system testers from each user group considered the system and its use of TWIGS as being a important improvement of TWIGS. However, no one elaborated on reasons why the system was an improvement of TWIGS. The reason no one elaborated was revealed by the system testers’ personal rankings of their TWIGS knowledge. System testers were asked to rank their knowledge of TWIGS (1-HIGH, 2-MODERATE, 3-LOW). The results of this questions are illustrated in Figure 5-10. As illustrated, 5 out of 12 undergraduate students (42%), 7 out of 12 graduate students (58%) and 11 out of 12 professionals (92%) regarded their knowledge of TWIGS as low. While 7 out of 12 (58%) undergraduate students, 5 out of 12 (42%) and 1 out of 12 professionals (8%) stated their knowledge of TWIGS was moderate.

A final concern of the researcher, regarding significant features of the system that needed addressed, was the time needed for system testers to accomplish each task and whether that time was acceptable. So in task three inquiry was made on the time it took each tester to complete the task. Results illustrated that it took no one longer than 10 minutes to accomplish task three. Approvingly, 35 of the 36 (97%) system testers felt this amount of time was satisfactory.
Figure 5-10. Ranking of TWIGS knowledge.
Summary of attitudes elicited from open-ended questions

Attitudes about the system were either considered advantageous or disadvantageous and fell into one of eight categories. Categories included (1) data manipulation, (2) design, (3) familiarity, (4) management, (5) time/speed, (6) usability, (7) no comment, and (8) no response. Refer to Appendix F for a definition of each category.

In Table 5-5 is a summary of Kendall’s coefficient of concordance (W) statistics which illustrates whether system testers had similar or dissimilar reasons why the system was an advantage or disadvantage to use. The null hypothesis predicts that there is no agreement among system testers on whether the system was advantageous to use or not, or they completely agree on whether the system was advantageous to use or not. On the other hand, if the null hypothesis can be rejected, the conclusion is that system testers agree on at least one reason why the system was advantageous to use or disadvantageous to use, or both. In the following discussion, \( W = 1 \) represents perfect agreement between system testers and \( W = 0 \) represents total disagreement between system testers.

In question set one Kendall’s coefficient of concordance (W) was 0.68 for advantages and 0.66 for disadvantage, resulting in only reasons for advantages being significant at the 0.05 level. System testers predominately agreed the system’s ability to manipulate data was its most advantageous function. However, they infrequently agreed on why the system was a disadvantage.
Table 5-5. Summary of Kendall’s Coefficient of Concordance (W) For Comments Concerning System.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$W^*$</td>
<td></td>
</tr>
<tr>
<td>Set 1</td>
<td>0.68</td>
<td>p &lt; 0.05**</td>
</tr>
<tr>
<td>Set 2</td>
<td>0.83</td>
<td>p &lt; 0.02**</td>
</tr>
<tr>
<td>Set 3</td>
<td>0.78</td>
<td>p &lt; 0.05**</td>
</tr>
<tr>
<td>Set 4</td>
<td>0.85</td>
<td>p &lt; 0.02**</td>
</tr>
<tr>
<td>Set 5</td>
<td>0.57 (NS)</td>
<td>p &lt; 0.20</td>
</tr>
</tbody>
</table>

*Corrected for ties.
**Significant at the 0.05 level, (NS) is not significant.

Although in task one the greatest level of agreement was for the system’s ability to manipulate data, professionals were more inclined to believe the system’s ability to aid management decisions was its greatest asset. Whereas, graduate students and undergraduate students were more inclined to believe its greatest asset was in the data manipulation capabilities. When looking more closely at reasons for disadvantages no group focused on a particular reason. All groups were widely dispersed on their reasons for the system being a disadvantage. The researcher believed that system testers were not yet familiar with the system and were unclear on what their purpose was in the research. Their uneasiness may have caused them to be apprehensive about being specific when making unfavorable comments.
In question set two Kendall’s coefficient of concordance (W) was 0.83 for advantages and 0.78 for disadvantage, both were significant. Focusing on the W-values it can be observed that system testers agreed strongly on reasons the system was an advantage, but not as strongly on reasons it was a disadvantage. As with task one, professionals still maintained the system’s most advantageous feature was its ability to assist in management decisions. Notwithstanding professional attitudes, the highest level of agreement was again for the system’s favorable manner of data manipulation. All three groups had agreed that the system’s design was its second most advantageous feature. All three groups agreed the greatest disadvantage was simply a lack of familiarity with the system. Not understanding the system made it difficult to use.

In question set three Kendall’s coefficient of concordance (W) was 0.78 for advantages and 0.72 for disadvantage, again indicating that both were significant. Graduate students and undergraduate students agreed with professionals this time by acknowledging management assistance as the system’s most beneficial feature. Albeit the highest level of agreement was for management assistance, graduate students and undergraduate students were widely dispersed on other reasons why the system was an advantage. System design was designated as being the system’s most prominent disadvantage. Groups agreed mostly that the lack of additional query options detracted from system design.

In question set four Kendall’s coefficient of concordance (W) was 0.85 for advantages and 0.63 for disadvantage, indicating the agreement for advantages was
significant at the 0.05 level. All groups agreed quite strongly on the system’s ability for aiding management decision as being its greatest advantage. All groups agreed that data manipulation capabilities was the second most advantageous benefit. No pattern of agreement was established for the disadvantages of the system.

In question set five Kendall’s coefficient of concordance (W) was 0.57 for advantages and 0.69 for disadvantage, which indicates that only disadvantages of the system were significant. Professionals mainly had no comments on advantages, graduate students stated management reasons as the best advantage, and undergraduates felt the time saved, or speed of the system, was the foremost advantage. With regards to disadvantages, most groups decided to make no comments.

Overall attitudes towards the system

Following analysis of attitudes for individual tasks all responses were combined and subsequently analyzed. All advantageous and disadvantageous comments were summed and analyzed using the Mann-Whitney U test (Table 5-6). This analysis was used to test the hypothesis that system testers made more comments of one nature than another. In other words, the test was determining if the system testers made more advantageous comments or more disadvantageous comments. The p-value obtained was highly significant (p = 0.008). This result indicated significantly more advantageous comments were made than disadvantageous comments.
Table 5-6. Summary of the Mann-Whitney U Test Conducting A Pair-wise Analysis of Total Counts of Advantageous Comments and Disadvantageous Comments From All Open-Ended Questions.

<table>
<thead>
<tr>
<th>Pairs</th>
<th>Mean Rank</th>
<th>U</th>
<th>2-tailed P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advantages-Disadvantages</td>
<td>40.0</td>
<td>0</td>
<td>0.008*</td>
</tr>
<tr>
<td></td>
<td>15.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level.

A more direct method was also used to get an understanding of the overall feeling for the system. A Likert Scale was used to rank the system from 1-5, with 1 indicating that system testers strongly agreed that the system was suitable for managing and manipulating natural resource data, and a value of 5 indicating strong disagreement. In Figure 5-11 it is illustrated that no one disagreed with the system's suitability to manage and manipulate natural resource data. The lowest ranking was undecided by 33% of the graduate students and 17% of the professionals, and no undergraduate students were undecided. Most system testers either strongly agreed or agreed the system was suitable for managing and manipulating natural resource data.
Figure 5-11. Ranking of system's suitability to manage and manipulate natural resource data.
CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

Stirring interests in ecosystem management have influenced many agencies to take a closer look at all lands under their supervision. To facilitate this objective an improved monitoring system is being considered in conjunction with the Missouri Ozark Forest Ecosystem Project (MOFEP). This system simplifies management of large quantities of data over long periods of time. In order to define its practical usefulness 36 individuals with forestry backgrounds were asked to use the system and respond to its usefulness for forest management.

Capabilities of manipulating data maintained in a database format fulfilled the operational objective of this study. Data, directly from database files, can be used in all system operations. Most notable is its capability to convert database files into a format that TWIGS can read. Responses from all 36 individuals that tested the system, and the subsequent analysis of those responses, accomplished the research objective established for this study.

Breakdown of Findings from System Analysis

Effects of prior database experience

Prior database system experience, or the lack thereof, did not seem to affect the abilities of system testers to use the system. There were only slight differences between those with prior database experience and those without prior database experience. One undergraduate student, with no prior database experience,
commented, "It (the system) is very user-friendly and different options can be easily accessed any time throughout the system. The help screen is very helpful when and if needed."

The reason for such comments by system testers and the ease of system use, even without prior database experience, is primarily due to incorporation of self-explanatory menus and context-sensitive help. A total of 94% of the testers stated that system menus enhanced the overall performance of the system.

Learning curve required for system testers

Results indicate an increase in proficient use of the system can occur within the time span required to complete all tasks and answer all questions associated with the administered questionnaire. System testers required approximately 1.5 to 3 hours to complete the questionnaire. In this amount of time they illustrated less need to use the context-sensitive help, displayed an improved ability to perform tasks using the fewest amount of keystrokes required, and exhibited greater adeptness in using the system to obtain correct answers to questions contained in the questionnaire. One undergraduate student made the comment, "I finished the task (3) in 2 minutes and by now I am feeling comfortable with the system."

Proficiency levels between all three groups were not significantly different, however, there was an identifiable difference between the three groups. Professionals represented the most proficient group, followed by graduate students, and succeeded by undergraduate students representing the least proficient group. Although there was
an identifiable difference between all three groups, no group illustrated a superior
ability to become more proficient, more quickly than another group.

TWIGS improvement

The operational objective of this study was accomplished when system
development incorporated the capability of transferring data contained in database files
to TWIGS. However, analysis of this system function was difficult as a result of
system testers lacking knowledge of TWIGS. Over half of all testers (63%) stated
their knowledge of TWIGS was low. Nonetheless, 83% of the them believed the
system improved on the use of TWIGS. One graduate student commented, "Although
my TWIGS knowledge is somewhat limited I feel that anytime you are not committed
to a format, such as in previous years when TREEGEN was the only TWIGS
readable file maker, the entire utility and ease of task completion is less restricted."

Attitudes Towards System’s Usability for Natural Resource Management

System testers found significant advantages to the system in four out of five
survey questions. They concurred three times out of five on reasons the system was a
disadvantage to use.

Out of the four times system testers agreed on reasons the system was an
advantage, two times were in acknowledgment of data manipulation capabilities as
being the most favorable attribute and the other two times they recognized assistance
with management decisions as its greatest asset. Agreement on disadvantages were
different all three times. Reasons for disadvantages included lack of familiarity with
the system, system design, and they agreed to make no comment on disadvantages in question set five. For all five question sets system testers made 307 advantageous comments and only 189 disadvantageous comments.

A Likert Scale was used to attain a more direct response on approval or disapproval of the system's suitability for natural resource management. Support was decisively in favor of the system for natural resource management. No one disagreed with the system being suitable for natural resource management.

After all analyses were completed and attitudes of system testers were assessed it was concluded that the null hypothesis of the study should be accepted. Opinions towards the system, regarding natural resource management, does not differ between undergraduate students, graduate students, and professionals in the natural resource discipline. No notable difference was located between system testers.

In general, most testers recognized the system's potential usefulness from both administrative and management perspectives. A professional responded, "A product such as this would be of tremendous benefit from both an administrative and management viewpoint. From an administrative viewpoint, it would be much easier to develop work plans and budgets. It would also give us a much better way of documenting management activities. In addition, it provides us with a practical way in which we can use TWIGS. In the past, use of TWIGS has been impractical because each individual tree had to be entered separately." Along the same thought one undergraduate student remarked, "This system helps to bring together all of the resources that are there to help us (Resource managers) manage land. What makes it
nice is that they are in one format and user friendly. I believe that this could easily
be used not just in areas that are managing the forest, but in areas that are also
managing for wildlife or even recreation. It makes a good system because it forces
people to put down on the computer what they plan on doing on the land and makes it
accessible for others both now and in the future."

Recommendations

The completed silvicultural database management system was well accepted by
system testers as being an initial effort in developing a larger, more integrated
system. They realized that the system had many advantages, but they also had many
ideas on how improvements could be made to make the next version of the system
superior. Refer to Appendix G for a complete list of suggestions made by system
testers.

An overview of recommendations made by system testers

Upon careful examination of all responses made by system testers it was
concluded that more specific selection capabilities for querying treatment databases is
the most prominent feature that needs to be added to the system. Many examples
were given on selection capabilities that need to be added. One example was to allow
queries to be made by specific or ranges of months, not just years. Many testers
believed a display of databases and years from which to choose to perform queries
would be extremely beneficial.
Besides improvements to specific selection capabilities for queries many testers expressed a need for improvements in the contents of the queries. The most common remark was the need for a revenue section within treatment documentation databases. This would allow natural resource managers not only to forecast what future treatments were going to cost, but what kind of return they could expect from implemented treatments.

An interesting idea suggested by a couple testers was to have the system flag treatments that had not yet occurred, but were assumed to have occurred. If a treatment had been planned to occur, but had not occurred by the date of the query it would be displayed as a notice to the manager. This option would prevent managers from falling behind on planned treatments.

Qualitative observations

Following testing sessions many system testers made unsolicited remarks regarding the system. Many of these comments warranted mentioning. It became evident, over the many months of testing, that younger personnel were more willing to accept the new system than were the older personnel. The majority of the testers that accepted the new system were very excited about the system and hoped to see it accepted by state agencies.

One issue alluded to by many testers was that computer systems, while beneficial and very promising, will not replace old-fashioned timber cruises. It was also noted that resource foresters for MDC collect different data than do the research foresters for MDC. This requires the system to be flexible in order to
accommodate both forms of data. It was also well noted that resource foresters seldom use projections generated by forestry growth models.

Suggestion for Further Research

At the completion of this study the project coordinator had already secured another researcher to carry on the study. Logically, the next step is to develop a revised version of the system incorporating all suggestion given by system testers. However, it is anticipated that with the rate of improved technology the new system will also incorporate new ideas, possibly even utilize totally different application software for system development which contains expanded capabilities.

What ever the direction this study follows, it is important that end-users have their input into how the final product functions. Following completion of this research the researcher feels that it would be very beneficial for the individual taking-over the project to meet with potential users and hear from them first-hand what they desire in the upgraded system. In addition to their suggestions, the researcher feels it is important that the upgraded version of the system incorporate a more flexible data query. System users need to be able to query data by methods they select, not by a few predetermined methods.
LITERATURE CITED


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Oliver, Chad, et. al. 1994. Landscape Management System (LMS) founding principles. A Cooperative project of: University of Washington, College of Forest Resources, Silviculture-Engineering Cooperative, Olympic Natural Resources Center; USDA, Forest Service, Pacific Northwest Research Station; Washington State Department of Natural Resources. Computer program available at HTTP://SILVAE.CFR.WASHINGTON.EDU/LMS.HTML


UNCITED LITERATURE


APPENDICES
APPENDIX A

Database Structures
### Database Structure for OVER.DBF

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Field Type</th>
<th>Field Width</th>
<th>Decimal Places</th>
</tr>
</thead>
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<td>0</td>
</tr>
<tr>
<td>PLOT</td>
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</tr>
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### Database Structure for SUB.DBF

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<th>Field Width</th>
<th>Decimal Places</th>
</tr>
</thead>
<tbody>
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<tr>
<td>PLOT</td>
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<tr>
<td>SUBPLOT</td>
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</tr>
<tr>
<td>DBH</td>
<td>NUMERIC</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>
APPENDIX B

Main Menu of Silvicultural Database Management System
CURRENT DATABASE FILE IN USE =

CURRENT SITE(S) =
CURRENT PLOT(S) =

SYSTEM MODIFICATION OPTIONS

Alter site(s) in use
Change plot(s) in use
Exit to DOS
Input new data

Treatment documentation
  * Future
  * Past/Present

Survey reply

DATA MANIPULATION OPTIONS

Develop stand table
Generate stocking table
Produce basic statistics
  * Mean, Variance
  * Min, Max

Run TWIGS
Query treatment database
APPENDIX C

Silvicultural Database Management System Questionnaire
SURVEY OUTLINE

You will be presented with 5 sets of questions. The first 4 sets will have tasks to perform prior to answering the questions. The last question set has no associated task. The survey has been designed to have you answer all 5 sets of questions before you will be allowed to return to any previous questions. If you return to change one of your previous answers after all questions have been answered you will once again be required to proceed through each question in succession.

Return as often as needed to read each task and the questions associated with that task (this is possible until you press the "COMPLETELY FINISHED" option on the question screen). Doing this will allow you to perform the task more accurately the first time.

NOTE: At any time while conducting a task you feel confused do not hesitate to view the HELP text associated with the system (press F1 for HELP).
TASK #1

Objectives:
* Determine treatments planned for 1998
* Generate stocking table for sites and plots to be treated in 1998

Important information needed to conduct task #1:

Database to be used in conducting task 1 is OVER.DBF. OVER.DBF is in the same directory as the system itself (i.e., it is in the current directory). Data contained in OVER.DBF was collected from 1/2 acre sample plots. All measurements on these sample plots were conducted in 1993. The site indices were averaged for the following species:

white oak = 55     scarlet oak = 45     black oak = 45
shortleaf pine = 75 black hickory = 50  mockernut hickory = 40
red maple = 65     swamp tupelo = 40    post oak = 60

Task 1:

* Query treatment databases and determine silvicultural treatments to be implemented in 1998. View both the summary and detailed reports (no need to print report). Use site and plot numbers on which the silvicultural treatments are to be implemented in 1998 to generate a stock table.

* When generating stocking table specify species specific site indices when generating the stock table. Use OVER.DBF and above information to conduct task. When finished conducting task return to answer questionnaire by once again pressing the "SURVEY REPLY" option.

Question 1: (If task has been conducted answer questions)

A) Was the task accomplished? (T/F)

B) Were the menu options clear (without HELP text)? (T/F)

   Do you feel the menus enhanced this management system? (T/F)

C) As pertains to task #1:
   Can you envision any advantages of such a capability?

   Can you envision any disadvantages of such a capability?
TASK #2

Objectives:
* Determine treatments implemented in 1989
* Generate stand table for site and plot treated in 1989
* Use the same site and plot numbers to create a TWIGS readable file
* Save the newly created TWIGS readable file
* Use the new file to conduct a TWIGS projection
* Use TWIGS projected data to create another stand table

Important information needed to conduct task #2:

Database to be used in conducting task 2 is SUB.DBF. SUB.DBF is in the same directory as the system itself (i.e., it is in the current directory). Data contained in SUB.DBF was collected from 1/20 acre sample plots. All measurements on these sample plots were collected during a regeneration survey conducted in 1994 (5 years after the initial treatment in 1989).

Task 2:

* Query treatment databases and determine the silvicultural treatment(s) implemented in 1989. View the detailed report and focus your attention on the summary of the treatment implemented in 1989 (this description contains information needed for the TWIGS projection to be conducted in this task). Use the site and plot numbers on which the silvicultural treatment was implemented in 1989 to generate a stand table. Use SUB.DBF and specify a single site index of 55 to develop both stand tables in this task.

* Using the "RUN TWIGS" option create a TWIGS readable file using the site and plot numbers on which the treatment was implemented in 1989. Commit the site and plot numbers to memory because the "RUN TWIGS" option requires you to reenter each when creating a TWIGS readable file. Use SUB.DBF to create the file. When entering "HEADER INFORMATION" use the USES species code for white oak and 55 as the stand site index (no species specific site indices).

* Save the newly created TWIGS readable file, under any name preferred, to the current directory (no need to specify full path). Then use TWIGS to project forest growth (no management needed). Use TWIGS to project growth to the next year in which treatment is planned for the same site and plot on which treatment occurred in 1989 (this information should have been obtained from the treatment description in the detailed report). Write the tree list created by TWIGS to another file. Save the tree list under any name you prefer. No need to specify full path when saving the file (simply type new file name).
* Now exit TWIGS and use the new TWIGS projected data file to create another stand table (Hint: You will need to create a new data base file). You will also need to be sure ALL sites and ALL plots are in use when creating the stand table. (REASON: The newly created database file was created using the TWIGS projected data file and does NOT contain the fields SITE or PLOT.)

**Question 2:** (If task has been conducted answer question)

A) How would you rank your knowledge of TWIGS (high being a great deal of knowledge, low being a lack of knowledge)?

1) HIGH    2) MODERATE    3) LOW

B) Based on your knowledge of TWIGS do you feel this system makes it easier for you to create a TWIGS readable file? (T/F)

Please explain answer.

C) As pertains to task #2:
List potential uses or short-comings of this system.
TASK #3

Objectives:
* Determine treatments to be conducted in 1997 & 1998
* Compare person hours needed between 1997 & 1998

Task 3:

* Query treatment databases and compare silvicultural treatments planned for 1997 and 1998 (2 queries needed). Examine both summary reports. Make note of the total person hours needed in each indicated year. Return to the survey and answer the questions based on what you viewed in each report.

Question 3: (If task has been conducted answer questions)

A) Approximately how long did it take you to accomplish task #3?

1) < 5 min. 2) < 10 min. 3) < 15 min. 4) < 30 min. 5) > 30 min.

B) Was the time required to conduct task #3 satisfactory? (T/F):

C) As pertains to task #3:
   Please list potential benefits from this system.

   Please list potential inadequacies of this system.
TASK #4

Objective:
* Compare treatment actually implemented on a given site and plot to the treatment that was planned for that site and plot

Task 4:
* Query treatment databases and determine how the silvicultural treatment actually conducted on site 1, plot 44 compared to the planned prescription for site 1, plot 44. Study the detailed report and return to survey to answer questions.

Question 4: (If task has been conducted answer questions)

A) Did the treatment planned for site 1, plot 44 occur as scheduled? (T/F)

B) Was the HELP text utilized during task #4? (T/F)
   If yes, was it helpful? (T/F)
   If no, had you viewed the HELP text prior to task #4? (T/F)
   If yes, was it helpful then? (T/F)

C) As pertains to task #4:
   Can you envision any advantages of such a capability?
   Can you envision any disadvantages of such a capability?
There is no task associated with the last set of questions.

NOTE: After you answer this set of questions you may return to previous tasks and questions to redo them. However, you will once again have to proceed through each one in succession.

Question 5: (If task has been conducted answer questions)

A) With what group are you associated?
   1) Professional  2) Graduate  3) Undergraduate

B) Had you used a database management system prior to this one? (T/F)

C) The system you have participated in testing is suitable for organizing and manipulating natural resource data.
   1) strongly  2) agree  3) undecided  4) disagree  5) strongly agree  disagree

D) From an administrative or management viewpoint please comment on the systems adaptability to natural resource management.
APPENDIX D

Formulas Utilized For Analyzing User Feedback
Kendall's Coefficient of Concordance (W)

\[ w = \frac{S}{[(1/12)k^2(N^3 - N)]} \]

where: \( S = \) sum of squares of the observed deviations from the mean of \( R_j \), that is, \( S = \Sigma (R_j - \Sigma R_j/N)^2 \)

\( k = \) number of sets of rankings

\( N = \) number of entities (individuals) ranked

\( (1/12)k^2(N^3 - N) = \) max. possible sum of the squared deviations

This analysis required three steps: (1) the creation of categories, (2) the editing and coding of responses, and (3) the tabulation of the data. All responses were coded into one of the following eight categories.

1. data manipulation;
2. design;
3. familiarity;
4. management;
5. time/speed;
6. usability;
7. no comment;
8. no response.

Coding of the responses required the researcher to read all responses given by system testers and tally each response into a category in which it "best" fit. Categories were not predetermined by the researcher. Categories were established by actual comments included in users responses on the questionnaires. This method of creating categories is called contextual coding.

When tied observations occurred each observation was assigned the average rank they would have been assigned had no ties occurred. The effect of tied values is
to depress the value of $W$. When the proportion of ties was small, that effect was negligible. However, when the proportion of ties was large, a correction was introduced to increase slightly the value of $W$ over what it would have been if uncorrected. The correction factor was:

$$ T = \Sigma(t^3 - t) / 12 $$

where: $t =$ number of observations in a group tied for a given rank

With the correction of ties incorporated, the Kendall Coefficient of Concordance was

$$ w = \frac{S}{[(1/12)k^2(N^3 - N)] - k\Sigma T} $$
Kruskal-Wallis One-Way Analysis of Variance

\[ H = \frac{12}{N(N + 1)} \sum_{j=1}^{k} \left( \frac{R_j^2}{n_j} \right) - 3(N + 1) \]

where:
- \( k \) = number of samples
- \( n_j \) = number of cases in \( j \)th sample
- \( N = \sum n_j \), the number of cases in all samples combined
- \( R_j \) = sum of ranks in \( j \)th sample (column)
- \( \sum_{j=1}^{k} \) directs one to sum over the \( k \) samples (columns)
Mann-Whitney U Analysis

For independent sample populations between 9 and 20, significance test may be made with the Mann-Whitney U test by using a table which gives critical values of $U$ for the significance level of 0.05 for a two-tailed test. If the $U$ value yielded is equal to or less than that of tabled value, $H_0$ may be rejected at the level of significance indicated at the head of the table (significant at the 0.05 level).

The $U$ value is calculated using the following formula.

$$U = n_1 n_2 + \left[ n_1(n_1 + 1)/2 \right] - R_1$$

where:

- $n_1 =$ Number of cases in the smaller of two independent groups
- $n_2 =$ Number of cases in the larger of two independent groups
- $R_1 =$ Sum of the ranks assigned to group whose sample size is $n_1$
Average Error of Observation

The following equation was utilized to calculate the error of observation for each system tester. Each value was then multiplied by 100 to convert the value into a percentage. Also included is an example from a system tester that required 10 keystrokes to complete task four (task four required a minimum of 5 keystrokes to complete). Refer to table for minimum keystroke counts possible for tasks 1 - 4.

\[ K = \left| \frac{M - R}{M} \right| \times 100 \]

where:  
\( K \) = Error of observation (expressed in percent)  
\( M \) = Minimum keystroke counts possible  
\( R \) = Actual keystroke counts required by system tester

Minimum keystroke counts possible for tasks 1-4.

<table>
<thead>
<tr>
<th>Task</th>
<th>Minimum Keystrokes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31 or 19*</td>
</tr>
<tr>
<td>2</td>
<td>36</td>
</tr>
<tr>
<td>3</td>
<td>10 or 8*</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

*Tasks 1 & 3 had two possible methods of completion.  
**Task 5 had no associated task so required no minimum keystroke count.

Example:  
\[ K = \left| \frac{5 - 10}{5} \right| \times 100 \]

\[ K = \left| -1 \right| \times 100 \]

\[ K = 100\% \]
APPENDIX E

Table E-1. Kruskal-Wallis One-Way ANOVA by Ranks of Total Keystroke Counts Required To Complete the Entire Questionnaire.

Table E-2. Mann-Whitney U Test Conducting A Pair-wise Analysis of Keystroke Counts Required To Complete the Entire Questionnaire (Professionals vs Graduate Students).

Table E-3. Mann-Whitney U Test Conducting A Pair-wise Analysis of Keystroke Counts Required To Complete the Entire Questionnaire (Graduate Students vs Undergraduate Students).

Table E-4. Mann-Whitney U Test Conducting A Pair-wise Analysis of Keystroke Counts Required To Complete the Entire Questionnaire (Professionals vs Undergraduate Students).
Table E-1. Kruskal-Wallis One-Way ANOVA by Ranks of Total Keystroke Counts Required To Complete the Entire Questionnaire.

<table>
<thead>
<tr>
<th>Professionals</th>
<th>Graduates</th>
<th>Undergraduates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keystrokes</td>
<td>Rank</td>
<td>Keystrokes</td>
</tr>
<tr>
<td>216</td>
<td>30.0</td>
<td>199</td>
</tr>
<tr>
<td>164</td>
<td>16.0</td>
<td>244</td>
</tr>
<tr>
<td>160</td>
<td>12.0</td>
<td>134</td>
</tr>
<tr>
<td>286</td>
<td>35.0</td>
<td>129</td>
</tr>
<tr>
<td>228</td>
<td>32.0</td>
<td>163</td>
</tr>
<tr>
<td>133</td>
<td>4.0</td>
<td>212</td>
</tr>
<tr>
<td>169</td>
<td>19.0</td>
<td>219</td>
</tr>
<tr>
<td>169</td>
<td>19.0</td>
<td>105</td>
</tr>
<tr>
<td>158</td>
<td>11.0</td>
<td>172</td>
</tr>
<tr>
<td>161</td>
<td>13.5</td>
<td>181</td>
</tr>
<tr>
<td>155</td>
<td>9.0</td>
<td>211</td>
</tr>
<tr>
<td>157</td>
<td>10.0</td>
<td>139</td>
</tr>
<tr>
<td>Mean Rank</td>
<td>210.5</td>
<td>220.0</td>
</tr>
</tbody>
</table>


Table E-2.  Mann-Whitney U Test Conducting A Pair-wise Analysis of Keystroke Counts Required To Complete the Entire Questionnaire (Professionals vs Graduate Students).

<table>
<thead>
<tr>
<th>Professionals Keystrokes</th>
<th>Rank</th>
<th>Graduates Keystrokes</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>216</td>
<td>20.0</td>
<td>199</td>
<td>17.0</td>
</tr>
<tr>
<td>164</td>
<td>12.0</td>
<td>244</td>
<td>23.0</td>
</tr>
<tr>
<td>160</td>
<td>9.0</td>
<td>134</td>
<td>4.0</td>
</tr>
<tr>
<td>286</td>
<td>24.0</td>
<td>129</td>
<td>2.0</td>
</tr>
<tr>
<td>228</td>
<td>22.0</td>
<td>163</td>
<td>11.0</td>
</tr>
<tr>
<td>133</td>
<td>3.0</td>
<td>212</td>
<td>19.0</td>
</tr>
<tr>
<td>169</td>
<td>13.5</td>
<td>219</td>
<td>21.0</td>
</tr>
<tr>
<td>169</td>
<td>13.5</td>
<td>105</td>
<td>1.0</td>
</tr>
<tr>
<td>158</td>
<td>8.0</td>
<td>172</td>
<td>15.0</td>
</tr>
<tr>
<td>161</td>
<td>10.0</td>
<td>181</td>
<td>16.0</td>
</tr>
<tr>
<td>155</td>
<td>6.0</td>
<td>211</td>
<td>18.0</td>
</tr>
<tr>
<td>157</td>
<td>7.0</td>
<td>139</td>
<td>5.0</td>
</tr>
</tbody>
</table>

| Mean Rank | 148.0 | 152.0 |
Table E-3. Mann-Whitney U Test Conducting A Pair-wise Analysis of Keystroke Counts Required To Complete the Entire Questionnaire (Graduate Students vs Undergraduate Students).

<table>
<thead>
<tr>
<th>Graduates</th>
<th>Undergraduates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keystrokes</td>
<td>Keystrokes</td>
</tr>
<tr>
<td>199</td>
<td>16.0</td>
</tr>
<tr>
<td>244</td>
<td>22.0</td>
</tr>
<tr>
<td>134</td>
<td>4.0</td>
</tr>
<tr>
<td>129</td>
<td>2.0</td>
</tr>
<tr>
<td>163</td>
<td>9.0</td>
</tr>
<tr>
<td>212</td>
<td>20.0</td>
</tr>
<tr>
<td>219</td>
<td>21.0</td>
</tr>
<tr>
<td>105</td>
<td>1.0</td>
</tr>
<tr>
<td>172</td>
<td>13.0</td>
</tr>
<tr>
<td>181</td>
<td>14.0</td>
</tr>
<tr>
<td>211</td>
<td>19.0</td>
</tr>
<tr>
<td>139</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Mean Rank
Graduates: 146.0
Undergraduates: 154.0
Table E-4. Mann-Whitney U Test Conducting A Pair-wise Analysis of Keystroke Counts Required To Complete the Entire Questionnaire (Professionals vs Undergraduate Students).

<table>
<thead>
<tr>
<th>Professionals</th>
<th></th>
<th>Undergraduates</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Keystrokes</td>
<td>Rank</td>
<td>Keystrokes</td>
<td>Rank</td>
</tr>
<tr>
<td>216</td>
<td>20.0</td>
<td>315</td>
<td>24.0</td>
</tr>
<tr>
<td>164</td>
<td>11.0</td>
<td>245</td>
<td>22.0</td>
</tr>
<tr>
<td>160</td>
<td>8.0</td>
<td>161</td>
<td>9.5</td>
</tr>
<tr>
<td>286</td>
<td>23.0</td>
<td>151</td>
<td>4.0</td>
</tr>
<tr>
<td>228</td>
<td>21.0</td>
<td>131</td>
<td>1.0</td>
</tr>
<tr>
<td>133</td>
<td>2.0</td>
<td>189</td>
<td>17.0</td>
</tr>
<tr>
<td>169</td>
<td>14.0</td>
<td>171</td>
<td>16.0</td>
</tr>
<tr>
<td>169</td>
<td>14.0</td>
<td>169</td>
<td>14.0</td>
</tr>
<tr>
<td>158</td>
<td>7.0</td>
<td>209</td>
<td>19.0</td>
</tr>
<tr>
<td>161</td>
<td>9.5</td>
<td>201</td>
<td>18.0</td>
</tr>
<tr>
<td>155</td>
<td>5.0</td>
<td>143</td>
<td>3.0</td>
</tr>
<tr>
<td>157</td>
<td>6.0</td>
<td>168</td>
<td>12.0</td>
</tr>
</tbody>
</table>

Mean Rank 140.5 159.5
APPENDIX F

Complete Tables, Categories and Calculations for Kendall’s Coefficient of Concordance (W)
Categories:

Data Manipulation - Referring to the use of the fundamental database manipulation operations (data insertion, data modification, and data retrieval) to make changes to data records.

Design - Alluding to the arrangement of context-sensitive help, instructions, menus, etc.

Familiarity - Reference to the knowledge or acquaintance with system.

Management - Any comment regarding management decisions, organization of plans, or allotment of resources.

Time/Speed - Rate at which results are obtained using system or reference to the amount of time saved using this system.

Usability - Reference to system's functionality.

No Comment - If system testers actual answered "No comment."

No Response - If the question was left blank.
### TASK #1 (ADVANTAGES)

A = Data Manipulation  
B = Design  
C = Familiarity  
D = Management  
E = Time/Speed  
F = Usability  
G = No Comment  
H = No Response

<table>
<thead>
<tr>
<th>Group</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professionals</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>3</td>
<td>0</td>
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</tr>
<tr>
<td>Rank</td>
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<td>6.5</td>
<td>6.5</td>
<td>1</td>
<td>3</td>
<td>6.5</td>
<td>6.5</td>
<td>4</td>
</tr>
<tr>
<td>Graduates</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rank</td>
<td>1.5</td>
<td>3</td>
<td>7</td>
<td>4.5</td>
<td>1.5</td>
<td>4.5</td>
<td>7</td>
<td>7</td>
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<tr>
<td>Undergraduates</td>
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<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>6</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

**Sum of Ranks (Rj)**

\[
\begin{align*}
4.5 & \quad 11.5 & \quad 19.5 & \quad 11.5 & \quad 7.5 & \quad 17 & \quad 19.5 & \quad 17 \\
\end{align*}
\]

**Mean of Rj** = 13.5

\[
s = (4.5 - 13.5)^2 + (11.5 - 13.5)^2 + (19.5 - 13.5)^2 + (11.5 - 13.5)^2 + (7.5 - 13.5)^2 + (17 - 13.5)^2 + (19.5 - 13.5)^2 + (17 - 13.5)^2 = 221.5
\]

\[
w = 221.5 / (0.083)(3)^2(8^3 - 8) = 0.59
\]

Correct for ties:

**Correction value** = 60 + 36 + 120 / 12 = 18

\[
w = 221.5 / (0.083)(3)^2((8^3 - 8)) - 3(18) = 0.68
\]
**TASK #2 (ADVANTAGES)**

A = Data Manipulation  
B = Design  
C = Familiarity  
D = Management  
E = Time/Speed  
F = Usability  
G = No Comment  
H = No Response

<table>
<thead>
<tr>
<th>Group</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professionals</td>
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<td>3</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rank</td>
<td>2</td>
<td>3</td>
<td>6.5</td>
<td>1</td>
<td>6.5</td>
<td>4</td>
<td>6.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Graduates</td>
<td>7</td>
<td>5</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Rank</td>
<td>1</td>
<td>2</td>
<td>7.5</td>
<td>3</td>
<td>4</td>
<td>5.5</td>
<td>5.5</td>
<td>7.5</td>
</tr>
<tr>
<td>Undergraduates</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Rank</td>
<td>2</td>
<td>2</td>
<td>7.5</td>
<td>4</td>
<td>2</td>
<td>5.5</td>
<td>5.5</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Sum of Ranks (Rj)  
5  
7  
21.5  
8  
12.5  
15  
17.5  
21.5

Mean of Rj = 13.5

\[ s = (5 - 13.5)^2 + (7 - 13.5)^2 + (21.5 - 13.5)^2 + (8 - 13.5)^2 + (12.5 - 13.5)^2 + (15 - 13.5)^2 + (17.5 - 13.5)^2 + (21.5 - 13.5)^2 = 292 \]

\[ w = 292 / (0.083)(3)^2(8^3 - 8) = 0.77 \]

Correct for ties:
Correction value = 60 + 12 + 36 / 12 = 9
\[ w = 292 / (0.083)(3)^2[(8^3 - 8)] - 3(9) = 0.83 \]
### TASK #3 (ADVANTAGES)

A = Data Manipulation  
B = Design  
C = Familiarity  
D = Management  
E = Time/Speed  
F = Usability  
G = No Comment  
H = No Response

<table>
<thead>
<tr>
<th>Group</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professionals</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rank</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
<td>1</td>
<td>2</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Graduates</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rank</td>
<td>2</td>
<td>6.5</td>
<td>6.5</td>
<td>1</td>
<td>3.5</td>
<td>3.5</td>
<td>6.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Undergraduates</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rank</td>
<td>2.5</td>
<td>4</td>
<td>5.5</td>
<td>2.5</td>
<td>1</td>
<td>5.5</td>
<td>7.5</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Sum of Ranks (Rj)  
10  
16  
17.5  
4.5  
6.5  
14.5  
19.5  
19.5

Mean of Rj = 13.5

\[ s = (10 - 13.5)^2 + (16 - 13.5)^2 + (17.5 - 13.5)^2 + (4.5 - 13.5)^2 + (6.5 - 13.5)^2 \]
\[ + (14.5 - 13.5)^2 + (19.5 - 13.5)^2 + (19.5 - 13.5)^2 = 237.5 \]

\[ w = 237.5 / (0.083)(3)^2(8^3 - 8) = 0.63 \]

Correct for ties:
Correction value = 210 + 66 + 18 / 12 = 24.5
\[ w = 237.5 / (0.083)(3)^2[(8^3 - 8)] - 3(24.5) = 0.78 \]
**TASK #4 (ADVANTAGES)**

A = Data Manipulation  
B = Design  
C = Familiarity  
D = Management  
E = Time/Speed  
F = Usability  
G = No Comment  
H = No Response

<table>
<thead>
<tr>
<th>Group</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>D</td>
</tr>
<tr>
<td>Professionals</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Rank</td>
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<td>7</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Graduates</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Rank</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Undergraduates</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Rank</td>
<td>2.5</td>
<td>6</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Sum of Ranks (Rj)</td>
<td>6.5</td>
<td>19</td>
<td>19</td>
<td>3</td>
</tr>
</tbody>
</table>

Mean of Rj = 13.5

\[
s = (6.5 - 13.5)^2 + (19 - 13.5)^2 + (19 - 13.5)^2 + (3 - 13.5)^2 + (12.5 - 13.5)^2 + (13 - 13.5)^2 + (19 - 13.5)^2 + (16 - 13.5)^2 = 257.5
\]

\[
w = \frac{257.5}{(0.083)(3)(8^3 - 8)} = 0.68
\]

Correct for ties:
Correction value = 48 + 120 + 126 / 12 = 24.5
\[
w = \frac{257.5}{(0.083)(3)(8^3 - 8) - 3(24.5)} = 0.85
\]
## TASK #5 (ADVANTAGES)

A = Data Manipulation  E = Time/Speed  
B = Design  F = Usability  
C = Familiarity  G = No Comment  
D = Management  H = No Response  

<table>
<thead>
<tr>
<th>Group</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
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Mean of Rj = 13.5

\[
s = (10 - 13.5)^2 + (12.5 - 13.5)^2 + (21.5 - 13.5)^2 + (9 - 13.5)^2 + (13 - 13.5)^2 \\
+ (9.5 - 13.5)^2 + (10 - 13.5)^2 + (22.5 - 13.5)^2 = 207
\]

\[
w = \frac{207}{(0.083)(3)^2(8^3 - 8)} = 0.55
\]

Correct for ties:

Correction value = 30 + 24 + 12 / 12 = 5.5

\[
w = \frac{207}{(0.083)(3)^2[(8^3 - 8)] - 3(5.5)} = 0.57
\]
TASK #1 (DISADVANTAGES)

A = Data Manipulation  E = Time/Speed
B = Design  
C = Familiarity  F = Usability
D = Management  G = No Comment
H = No Response

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Sum of Ranks (Rj) 17 5 8 12 21.5 19.5 15 10

Mean of Rj = 13.5

\[ s = (17 - 13.5)^2 + (5 - 13.5)^2 + (8 - 13.5)^2 + (12 - 13.5)^2 + (21.5 - 13.5)^2 \]
\[ + (19.5 - 13.5)^2 + (15 - 13.5)^2 + (10 - 13.5)^2 = 231.5 \]

\[ w = 231.5 / (0.083)(3)^2(8^3 - 8) = 0.61 \]

Correct for ties:
Correction value = 36 + 30 + 36 / 12 = 8.5
\[ w = 231.5 / (0.083)(3)^2((8^3 - 8)) - 3(8.5) = 0.66 \]
**TASK #2 (DISADVANTAGES)**

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**Sum of Ranks (Rj)**

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**Mean of Rj = 13.5**

\[
s = (14 - 13.5)^2 + (10.5 - 13.5)^2 + (5.5 - 13.5)^2 + (16 - 13.5)^2 + (19 - 13.5)^2 + (19 - 13.5)^2 + (2.5 - 13.5)^2 + (5 - 13.5)^2 + (19 - 13.5)^2 = 242.5
\]

\[
w = \frac{242.5}{(0.083)(3)^2(8^3 - 8)} = 0.64
\]

Correct for ties:

**Correction value = 120 + 84 + 66 / 12 = 22.5**

\[
w = \frac{242.5}{(0.083)(3)^2[(8^3 - 8)] - 3(22.5)} = 0.78
\]
**TASK #3 (DISADVANTAGES)**

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</table>

**Sum of Ranks (Rj)**

|            | 19 | 4 | 14.5 | 12 | 18.5 | 21.5 | 10 | 8.5 |

Mean of Rj = 13.5

\[
s = (19 - 13.5)^2 + (4 - 13.5)^2 + (14.5 - 13.5)^2 + (12 - 13.5)^2 + (18.5 - 13.5)^2 + (21.5 - 13.5)^2 + (10 - 13.5)^2 + (8.5 - 13.5)^2 = 250
\]

\[
w = 250 / (0.083)(3)^2(8^3 - 8) = 0.66
\]

Correct for ties:
Correction value = 48 + 30 + 54 / 12 = 11

\[
w = 250 / (0.083)(3)^2[(8^3 - 8)] - 3(11) = 0.72
\]
### TASK #4 (DISADVANTAGES)

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**Sum of Ranks (Rj)**

|                | 11 | 8  | 18 | 16 | 18 | 18 | 15.5| 3.5 |

**Mean of Rj = 13.5**

\[
s = (11 - 13.5)^2 + (8 - 13.5)^2 + (18 - 13.5)^2 + (16 - 13.5)^2 + (18 - 13.5)^2
+ (18 - 13.5)^2 + (15.5 - 13.5)^2 + (3.5 - 13.5)^2 = 207.5
\]

\[
w = \frac{207.5}{(0.083)(3)^2(8^3 - 8)} = 0.55
\]

Correct for ties:

Correction value = 36 + 126 + 36 / 12 = 16.5

\[
w = \frac{207.5}{(0.083)(3)^2[(8^3 - 8)] - 3(16.5)} = 0.63
\]
**TASK #5 (DISADVANTAGES)**

A = Data Manipulation  
B = Design  
C = Familiarity  
D = Management  
E = Time/Speed  
F = Usability  
G = No Comment  
H = No Response

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</table>

Sum of Ranks (Rj)  
- 16  
- 14.5  
- 7.5  
- 18.5  
- 18.5  
- 14.5  
- 3  
- 15.5  

Mean of Rj = 13.5

\[ s = (16 - 13.5)^2 + (14.5 - 13.5)^2 + (7.5 - 13.5)^2 + (18.5 - 13.5)^2 + (18.5 - 13.5)^2 + (14.5 - 13.5)^2 + (3 - 13.5)^2 + (15.5 - 13.5)^2 = 208.5 \]

\[ w = 208.5 / (0.083)(3)^2(8^3 - 8) = 0.55 \]

Correct for ties:

Correction value = 66 + 120 + 120 / 12 = 25.5

\[ w = 208.5 / (0.083)(3)^2[(8^3 - 8)] - 3(25.5) = 0.69 \]
APPENDIX G

List of Suggestions Made By System Testers
List of Suggestions

1) Include a revenue option in treatment documentation.

2) Create a more specific selection capabilities for querying treatment databases.

3) Have system handle a nested sampling scheme.

4) Display a list of available database files which can be manipulated using system operations.

5) Allow users to define merchantability limits for timber.

6) Have system account for soundness of trees and acceptability of trees when calculating volumes.

7) Include a database building option within the system.

8) Add an identification field to treatment databases to allow for the use of data from more than one area (i.e., prevent the system from querying treatment information from all areas to produce reports). For example, without an identification code a query by a specific site number would result in a report containing information from every area with the specified site number.

9) Permit volume calculations using variable radius plot expansion factors.

10) Include a default values for site indices when entering species specific site indices.

11) Rearrange the menu for choosing site indices for volume calculations. Have the option for use a single site index for the entire stand be the first option on the menu.

12) Enable queries on treatment databases by calendar year, fiscal year or by month.

13) Set EXACT OFF when querying treatment databases so query will locate treatments that may have been misspelled when entered in system.


15) Search all planned treatments and if any treatment have not been conducted by the date scheduled flag them and display them in a report.
16) Include a security device to prevent data from being altered by unauthorized users.

17) Add additional projection/manipulation packages to the back end of the system such as the Cornell ecology programs.

18) Further explain menu options.

19) Eliminate the option of entering site indices for non-commercial species.

20) Add an index of confidence limitation to keep users from expecting volume predictions from being completely accurate.

21) Insert an option allowing for the comparison of two queries at the same time.

22) Include fields for terrain, debris and other problems associated with different stands within treatment databases.

23) Create an easy method to update predicted treatment costs each year.

24) Display a list of dates from which queries can be made.