Mississippi's Forest Inventory Pilot Program

Use of Computer and Spatial Technologies in Large Area Inventories

By
Robert C. Parker, Patrick A. Glass, H. Alexis Londo, David L. Evans,
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Forest and Wildlife Research Center
Mississippi State University

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Abstract

The objectives of the Mississippi Forest Inventory Pilot Program were: 1) to develop a forest inventory and information distribution system based on remote sensing, GIS, and GPS technologies in concert with widely accepted field data collection and computation techniques that can be extended to a statewide system and provide county-level timber inventory information at a sampling error of +/-10%, and 2) to utilize computer technology to make original and derived data products available with on-line technologies that will allow users to estimate timber supplies and monitor forest resource change. Assessment of LandSat™ satellite imagery over successive time periods facilitated the stratification of forest areas by age class and forest cover type. Other remote sensing technologies permitted the allocation of truly random plots using stratified random sampling criteria. Allocation of sample plots was designed to achieve a 10% sampling error at a county level for total cubic volume at the 95% confidence level within the Pilot Program area involving 4 counties of east-central Mississippi. GPS units coupled to a geostationary satellite were used to navigate on a real-time basis to plot locations with sub-meter accuracy. Inventory data were recorded on field computers containing specialized software. The satellite image estimates of forest acreage by age classes of conifers, hardwoods, and mixed conifer-hardwoods were combined with the inventory data to obtain post-stratified area and volume estimates by tree species, forest cover types, ownership class, and/or forest origin for user-defined areas with user-accessible Web site software. Procedures developed in this pilot project can be used in larger land base applications and for integration with and supplementation of existing inventory programs to meet user-defined precision criteria.

Introduction

Forestry is a leading industry in Mississippi (Munn and Bullard 1997). Data exist for systematic inventory plots and county summaries (Hartsell and London 1995), but there is no accurate representation of the spatial distribution of timber volume resources. Shifts in timber availability have dramatic impacts on the State's economy and environment. Forest change and resource location impact Mississippi's forest based industries and activities they support. There is no current system in place to track changes in the spatial distribution of harvesting (resource depletion) and successful regeneration (future availability; environmental recovery).

The United States Forest Service (USFS) currently conducts Forest Inventory and Analysis (FIA) surveys (Reams and Van Deusen 1999), which are designed to inventory forest resources nationwide. Historically, these inventories have been scheduled every 6 to 15 years with a mode of 10 years (Van Deusen 1997). Inventory plots are distributed systematically throughout a given region. Information computed from these inventories is designed for large areas (Schreuder and Thomas 1991) and is accurate for assessing the forest resources of a region or state. The last inventory data available for Mississippi were collected in 1993 and 1994 and included 3190 plots (Reams and Van Deusen 1999). The existing federal data collected were not designed to be statistically precise at the county level. Current inventories also do not describe the distribution of the forests in the state.

The objectives of the Mississippi Forest Inventory Pilot Program were:

1. To develop a forest inventory and information distribution system based on remote sensing, GIS, and GPS technologies in concert with widely accepted field data collection and computation techniques that can be extended to a statewide system and provide county-level timber inventory information at a sampling error of +/-10% at the 95% level of confidence.

2. To make original and derived data products available with on-line technologies that will allow users to estimate timber supplies and monitor forest resource change.

Experimental Design

This research was conducted on a contiguous four-county region in the east-central part of Mississippi and involved the counties of Choctaw, Clay, Oktibbeha, and Winston (Figure 1).

The pilot study was accomplished through use of LandSat™ (satellite) imagery in conjunction with a field inventory of forest resources for a multi-county area. Digital classifications of satellite data were used to allocate field sample locations for sampling by project crews and cooperators from the Mississippi Forestry Commission. All data were incorporated into an Internet World Wide Web site. The primary methods included:

1. Building a current forest type map for the four-county area of the state.

2. Augmenting the forest type map with ground inventory photo plots to generate a geospatial database that can be used to determine volume and distribution by timber type and ownership.

3. Making the information developed from objectives one and two available to the public on an Internet site.

4. Designing a knowledge-based expert system for estimating the growth of the mapped forest types from existing growth and yield data and other sources.

5. Designing a system that would combine spatial and resource data components into a visual online system that would allow the public to assess forest productivity for any user-defined land area.

Figure 1. Four county region for the Forest Inventory Pilot Program.

Project Implementation

Spatial Technologies

Veridian ERIM-International, a contract partner, geo-corrected the LandSat™ data, identified forested areas, and assessed the age and composition of the areas (Roller 2000). Forest area mapping was based on spectral categorization of the leaf-on 1998 Thematic Mapper (TM) data. Forest age was assessed using a first and last date forest stratified, hybrid change detection procedure developed by Veridian ERIM-International. This procedure yielded six forest age classes based on the available LandSat™ Multispectral Scanner (MSS) and TM data. Forest composition assessments were based on 1999 leaf-off TM data. The assessment was performed using a forest and age stratified spectral based procedure. Forest composition was assessed with respect to the relative amount of evergreen and deciduous forest present within a pixel.

Inventory and Plot Allocation

Sample Size Estimation

The initial estimate of sample size for each of the four counties in the pilot project was determined from information provided by the 1992 FIA inventory of these counties. The variability calculated for total cubic foot volume within a county was used to estimate the number of plots needed to meet an allowable sampling error of ± 10% at the 95% confidence level. The sample size formula for simple random sampling, rather than the formula for stratified sampling, was used. The former provided a more conservative estimate given some doubts about applicability of the information gleaned from the FIA database.

The resulting estimates of sample size varied from a high of 98 plots for Choctaw County to a low of 79 plots for Oktibbeha County. Again, based on the conservative approach regarding the preliminary database, it was decided that 100 plots would be allocated to each county. Plans were also made to follow this initial allocation with the establishment of additional plots, as necessary, once each county's volume data were analyzed. The final plot allocation was 695 plots in the four counties.

Plots were allocated proportionally, based upon area in each cover type, by county. ERDAS Imagine software was utilized to randomly choose each plot location. In an effort to allow for image geometric correctional errors and the known capabilities of the Differential Global Positioning Systems (DGPS), the criterior for choosing these plots was that each must be centered in a homogeneous 180 by 180 m area. Geographic coordinates projected in Mississippi Transverse Mercator (MSTM) for the center of each area served as plot centers. These coordinates were re-projected into latitude/longitude and formatted for the DGPS field units.

Field Equipment

GPS Systems

The Corvallis Microtechnology Incorporated (CMT) PC5L GPS™ and the Juniper Systems Landmark GPS™ were utilized to navigate to 695 random plot locations across the four county area (Figure 2). Equipment failure, either from physical damage to cabling or malfunction, accounted for the largest percentage of reduction in field productivity. Selective Availability, GPS satellite geometry and canopy coverage had minimal effect on productivity. Field recorder power requirements were comparable providing 10 hours of intermittent usage without failure. External power supplies for the DGPS decoding system proved to be bulky and cumbersome. The CMT field delivery system, consisting of a rigid frame backpack, proved more efficient for transporting the additional inventory equipment than did the flexible backpack of the Juniper system.

Prior to deactivation of Selective Availability, the rapidity of change in the pseudorange broadcast caused position fixes calculated by the CMT unit to fluctuate a known point by one to five meters in horizontal position. When Selective Availability was turned off, the CMT position fixes became more stable, at less than two meters in horizontal offset. The Juniper system, which displays the position computed within the Trimble AG 132 receiver, consistently reported positions around a known point within one meter regardless of Selective Availability influence.

When used under tree canopy conditions, both the CMT and Juniper GPS systems performed best with the large Trimble dome antenna.

Field Computers

The CMT-PC5L and Juniper Pro4000 field computers (Figure 2) were used with speciality software (MSINVEN) to record the tree and plot data and transfer the data to a desktop computer (INVENCOM). The software was written and compiled with Quick Basic 4.5 and contained assembler routines for screen handling.

Figure 2. Juniper Pro4000 (left) and CMT-PC5L Field computers with CMT GPS antenna.

DME Devices

The Haglof Forester DME 201 (Figure 3) was used to measure plot radii and horizontal distances for tree height measurement. Haglof developed the DME 201 for use as a distance measuring device in areas where terrain is uniform. It is a one-handed receiving device that utilizes a transponder located at plot center that resonates at 25 kHz with a 360˚ broadcast area.

Figure 3. Forestor DME 201 (bottom) with 360° transponders.

Height Measuring Devices

The Haglof Vertex and Vertex III hypsometers were used for tree height measurement (Figure 4). They are one-handed receiving devices that utilize a transponder located on the tree at some predetermined height, typically breast height, and resonate at 25 kHz with a 60˚ broadcast area to establish baseline distances. Using the receiver - transponder combination eliminates the need to measure baselines and the 60˚ broadcast angle for the transponder allows a wide range of motion for obtaining a clear line of sight. The ultrasonic equipment demonstrated a high degree of precision operating through a wide range of environmental conditions.

Measurement errors were obvious to operators and could be attributed to either a depleted power supply or multiple transponder interference.

DGPS and Navigation Procedures

DGPS allowed the use of stratified random sampling procedures. After the satellite imagery was classified and the required number of plots within each stratum was allocated, the coordinates for the plots were organized into navigation files for the DGPS receivers. Two separate DGPS systems were used for navigation (Figure 5); thus, requiring translation of the coordinate information from a standard text format into proprietary formats that the receivers would accept.

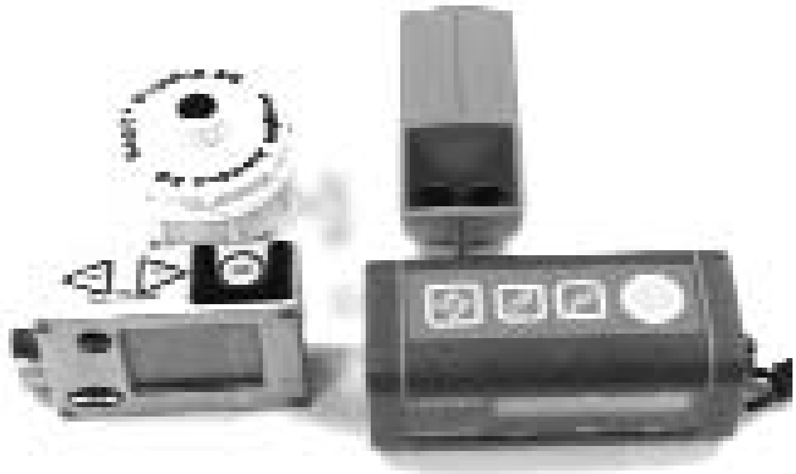

Figure 4. Vertex III (left) and Vertex (right) hypsometers.

Figure 5. CMT and Juniper (left) DGPS field delivery systems.

Inventory crews utilized image maps generated from the satellite data and standard topographic maps for navigation to the approximate plot location. Within a range of one mile from the plot location the crews switched on the DGPS units and utilized the navigational aids provided by the interface to locate the plot.

Field and Tree Data Collection

To assure consistent and uniform data collection across all encountered conditions, a procedures manual was developed (Appendix A). Inventory information was collected in two phases to allow for a complete description of the forested area. The first phase observations included the general characteristics of the site (i.e. slope, stand type, etc.) to ensure the data represented a homogenous sampling unit. Mensuration data were collected during the second phase. Measurements were collected for the computation of tree volume, inside and outside bark. In addition to stem length being measured to an absolute upper stem diameter limit, stem length was also measured to a usable limit typifying local mill harvesting practices. Five-and ten-year diameter growth rates were measured to allow projection for equivalent periods. Site index measurements were recorded to quantify productivity potential.

Portable field computers were used to collect data in an electronic format. This increased the efficiency of the inventory by eliminating the need for key-punching of the data and the possibility of transcription errors. Data collection software was developed to accommodate all the information collected and validate the data entries in real-time (Figure 6). As data were entered into the recorder, they were checked against a set of values appropriate for that measurement and the user was prompted to verify the entry if the input value was outside the expected range.

Ultrasonic measuring equipment was employed for distance and height measurements to decrease time spent on the plot. Tree heights were measured with Vertex hypsometers which eliminated the need to establish the baseline distance required by clinometers. Distance measuring devices, DME 201s, were used to establish plot radii and to check border trees without pulling a logger's tape through brush and around obstacles.

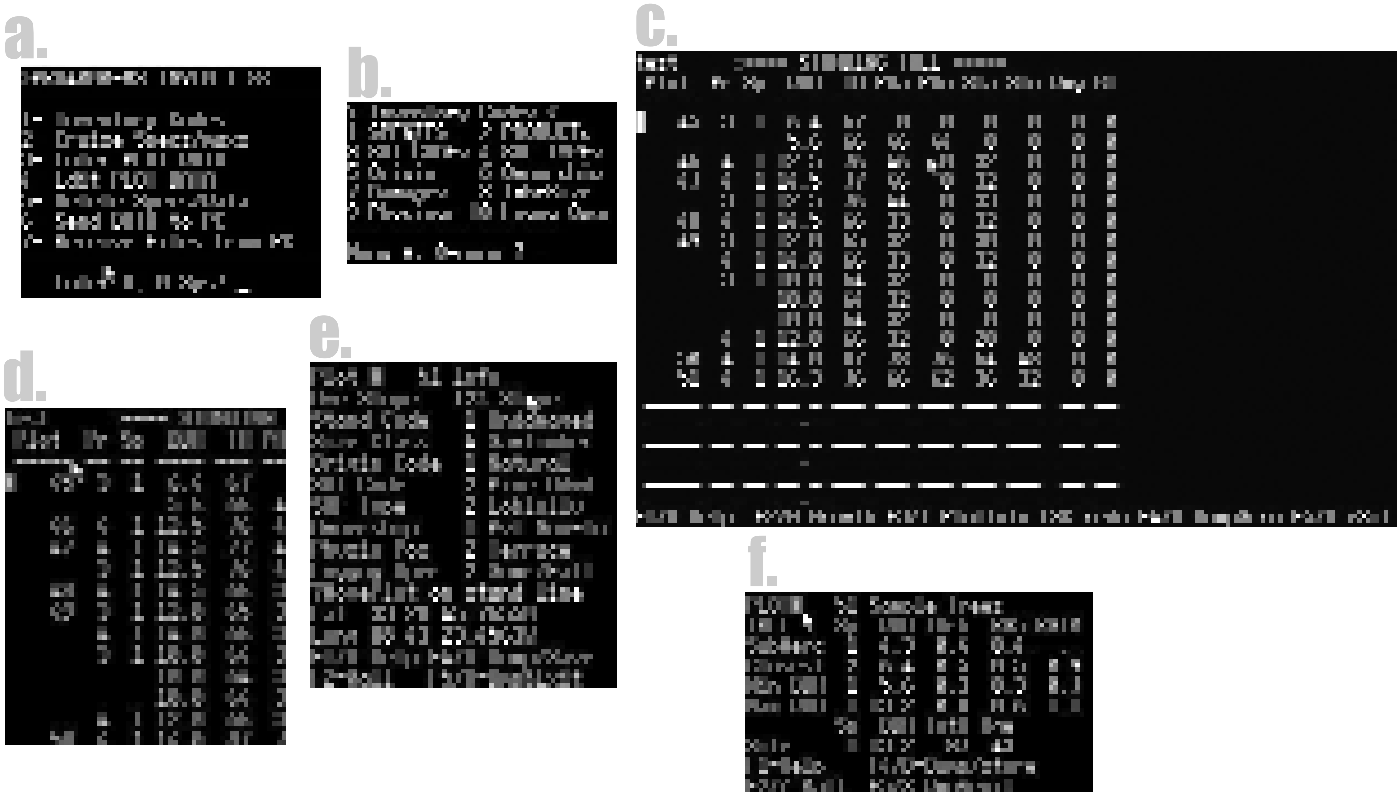

Figure 6. Screens from the Pro4000 field computer: a. main menu, b. enter/edit screen for inventory codes, c. full screen view of tree tally screen, d. window view of tree tally screen, e. plot information screen, and f. sample tree screen.

Field Training

Training and certification plots were established to represent the possible plot conditions encountered by field crews conducting the inventory. Training plots demonstrated various conditions that required a qualitative measurement or a subjective decision to be made.

The Mississippi Forestry Commission assigned 13 people to assist with data collection. Junior and senior level undergraduates from the College of Forest Resources were also employed to collect the field data. Two-person inventory crews were trained on the certification plots for four consecutive days in order to be certified competent with the equipment and inventory procedures.

Certification procedures required that an inventory crew navigate to and establish an inventory control plot within specified data collection criteria of time and precision. The inventory data were then printed and the crew and field supervisor returned to the plot. If there were no errors associated with qualitative or subjective criteria detected, the crew was certified.

Verification

Once data collection began, the integrity of the inventory data became the primary priority. Inventory data were downloaded and screened after each day of collection. It was discovered that the Corvallis Micro-Technology PC5L field computer ram disks were subject to radio frequency interference generated by the radio units in the Mississippi Forestry Commission vehicles. The impact of this interference ranged from scrambling some of the data fields to complete erasure of the file allocation table. This necessitated that these field computers be turned off or located outside a radius of 30 feet during radio transmissions.

Validity of the data was corroborated by check-cruising at a 20% intensity. Specially trained field crews were assigned check-plots and collected data from these plots as specified by the procedure manual. The two sets of inventory data were then compared and the original data were considered valid, if discrepancies were within pre-established limits.

To reduce the total amount of time spent collecting data on a plot, stem lengths were ocularly estimated. To detect and compensate for any bias in these estimations, the first two trees encountered on a plot were measured using hypsometers after the ocularly estimated field tally was completed. The corresponding trees were then paired by individual cruiser and correction curves were developed and applied to the estimated lengths of all trees on the plot.

Data Format

After collection and verification of the inventory data was completed, the information was organized for the database. Three separate data files were formed for the database: general stand description information, plot mensuration data, and growth and site data. These three files were in ASCII format and readily available for import into a database structure.

An expert system computer algorithm was used to screen the data collected by the field crews and create the database. The algorithm examined the field data, applied error checking rules set to detect and correct errors, wrote the corrected data to the database, and printed the original and corrected record for manual correction of the field data files. This expert system utilized the same external files and settings as did the report generator for complete system compatibility and portability of the error checking facility to any region or scale.

Data Delivery Tools

An interactive dynamic report generator called Mississippi Forest Monitoring and Inventory (MsFMIS) dynamic report generator was developed to synthesize and deliver information to system users. The software can derive reports from an inventory database stored on a public server, or optionally on a locally stored inventory database. It allows the user to select a reporting area on either a county group basis (Figure 7), or as an irregular polygon (Figure 8). After a report type is selected, the interface presents to the user changes to match the selected report type. The user can then select the desired stand and tree selection criteria appropriate for the report (species groups, forest types, land ownerships, size classes, products, and others). A beta version of the program can be downloaded from the Web site www.cfr.msstate.edu. To maintain compatibility with previous FIA databases, and have an interface that is familiar to potential clients, the FIA codes and names were adopted for the study.

Currently, the MsFMIS produces stand and stock tables, acreage tables, regeneration acreage, and productive potential stand and stock tabular reports by the selected criteria. Other dynamic link library (dll) report modules will be added as needed.

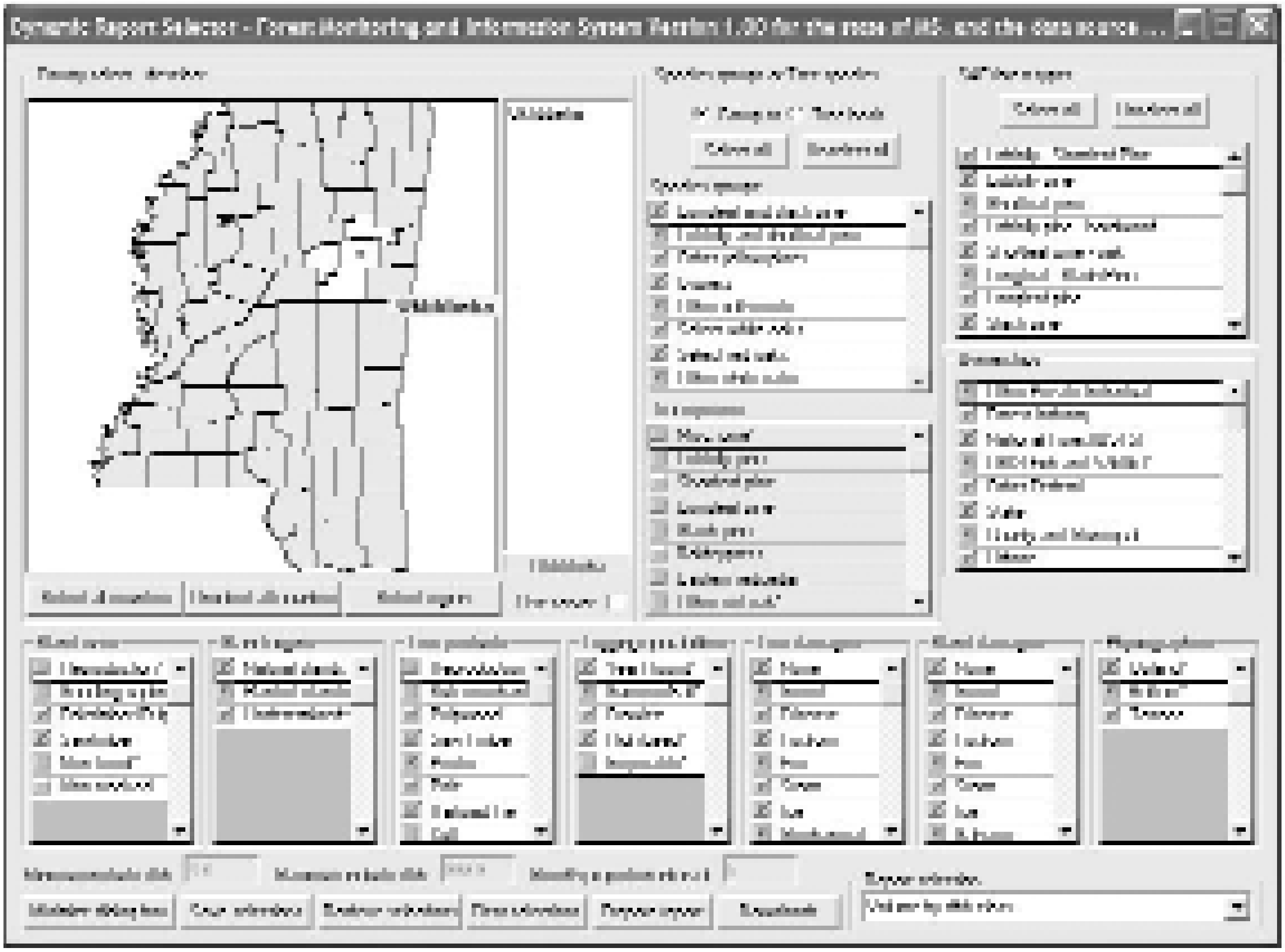

Figure 7. Example screen from MsFMIS depicting region selection such as county boundaries (upper left) to define an area from which to generate inventory information based on other criteria indicated by check boxes.

While the beta version MsFMIS software applies only to the small pilot study area, the program code was designed to be transportable to any scale or region. All the inventory codes, user interface settings, GIS files, file locations, and other locale specific settings reside in external files or the system registry. This externalization of locale specific settings allows the program to be adapted to another region by simply modifying the external settings. No changes in the source code of the program are required.

An interactive Web-based data delivery system was created using the FIA data standards. Developed in Microsoft Windows® interface format, the data delivery system is designed to provide forest resource data on a county or regional level (Figures 7 and 8). All information from the field plots is entered into a database and summarized depending on the user's needs. Irregular polygons or county boundaries can be used to define an interest area. Embedded in this system are routines that generate stand and stock tables (per acre values and totals are given) with the associated precision statistics for the area and volume estimates.

The four report dynamic link libraries to be included with the release version of MsFMIS will allow the client to derive virtually any volume, acreage, reproduction, or growth estimates showing point and reliability statistics. For report types that are needed on a continuing basis, custom programming will be added to make the report generation a one-step process. The report generation and database application interfaces (APIs) will be published so clients can customize the generated reports to suit their needs.

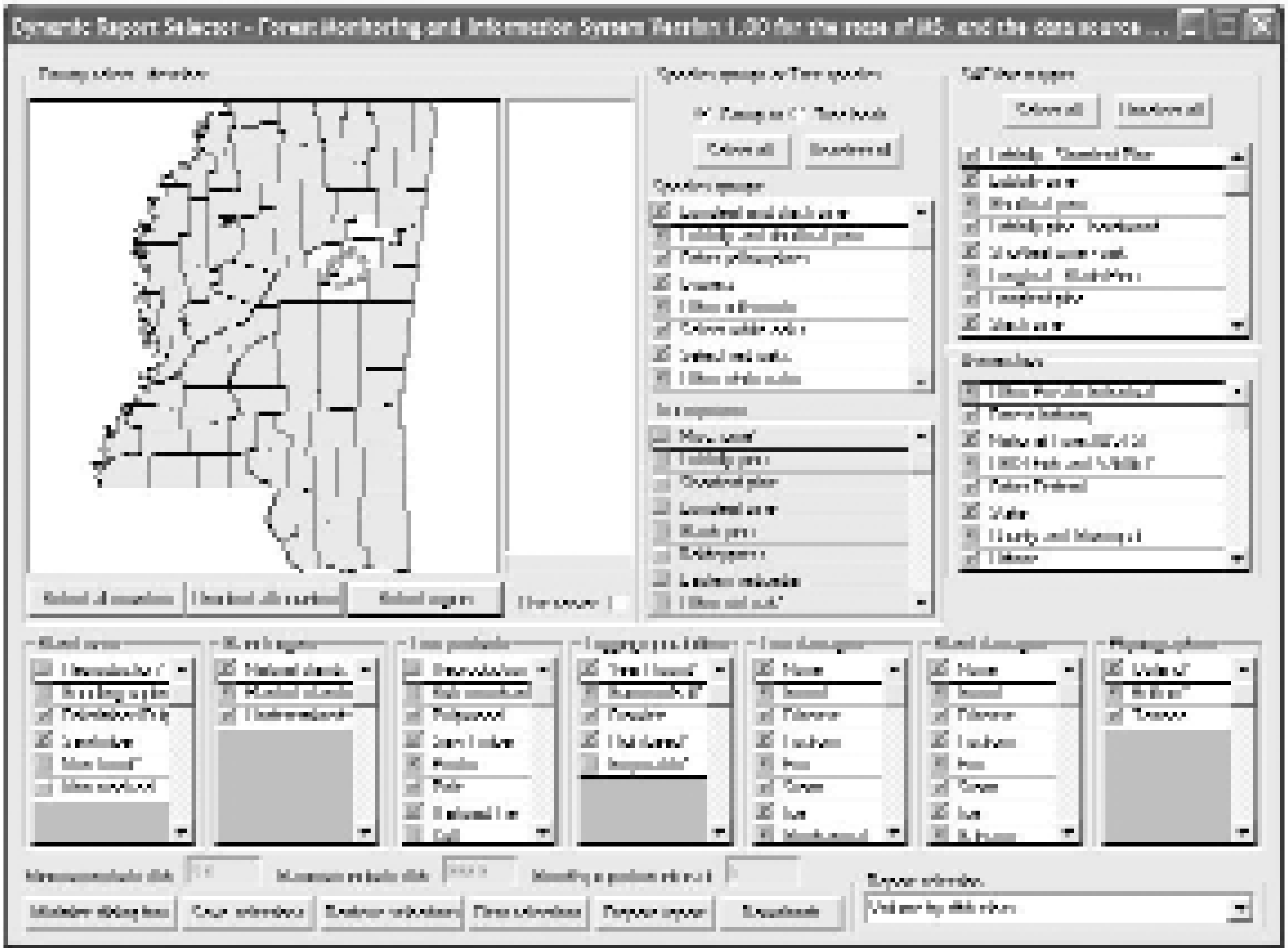

Figure 8. Example screen from MsFMIS depicting the selection of an irregular polygon to define an area from which to generate inventory information based on other criteria indicated by check boxes.

Based on Veridian-ERIM International products, clients can view the spatial distribution of forest age and composition within the study area (Figure 9). The spatial distributions can be viewed using ESRI's ArcExplorer software. ArcExplorer is freeware, and it can be downloaded from www.esri.com.

Results

Inventory analysis with MsFMIS was accomplished through an interface that allows the user to define several criteria for compiling results. The user has the ability to select from several inventory databases. Currently the USDA-USFS 1992 Southeastern FIA database and the Mississippi Pilot Inventory database are available for inventory calculations. A unique feature of MsFMIS is the versatility in selecting the area for analysis. An interactive map is provided that allows the selection of a single county or multiple counties, or the selection of a geographic region by outlining the area of interest with a polygon. The only restriction placed on the regional selection method is the total area within the polygon must be larger than 200 square miles. This insures that an adequate number of sample plots are included in the computations. After the region under consideration has been defined, the user can then expand or restrict the analysis based on the attributes of interest. Four separate reports will be available with the commercial version (Area, Regeneration, Growth and Volume), however, the current version only reports timber volumes with standard stand and stock tables.

A typical application scenario for forest industry would be to determine whether an area would be capable of supporting an additional milling facility. Their analysis objective would be to determine the total volume available that is capable of meeting milling specifications. Utilizing MsFMIS, the region of interest would be identified and the generalized criteria: Species, Forest Type, Ownership, Stand Size, Origin, Tree Product, Logging Operability, Tree and Stand Level Damages and Physiographics would be designated. These selection criteria would then be used to extract and process the inventory information from the database to produce standardized volume reports. Additionally, MsFMIS computes the associated statistics and sampling errors for each density and volume category. Particular attention should be paid to the sampling errors associated with the various density and volume estimates. The sampling error presented represents the combined variance structure from the acreage estimate and the volume estimate.

Imagery-based Products

Forest Cover Mapping – Forest cover maps were produced for the first and last date imagery. Forest cover mapping was developed using all spectral bands from the MSS and TM imagery. Spectral signatures of forest cover from the imagery were derived using unsupervised clustering. Maximum likelihood categorization was used to label the clusters which were based upon phenological image changes and ancillary photogrammetric information.

Forest Age – Forest age was determined using the time sequence of images from initial to most recent dates. Determination of forest age was performed in two parts: 1) aging of forested land that was detected in the first year in the sequence of the imagery, and 2) aging of land that had become forested after the first year in the sequence. Land that was forested in the first year in the sequence and never detected to be harvested while still being forested in the most recent image was determined to be in the oldest class. Subsequent classes were aged from the last observed harvest or pre-forested date determined from the intermediate image dates.

Forest Composition – Forest composition was determined using the two most recent satellite image acquisi-

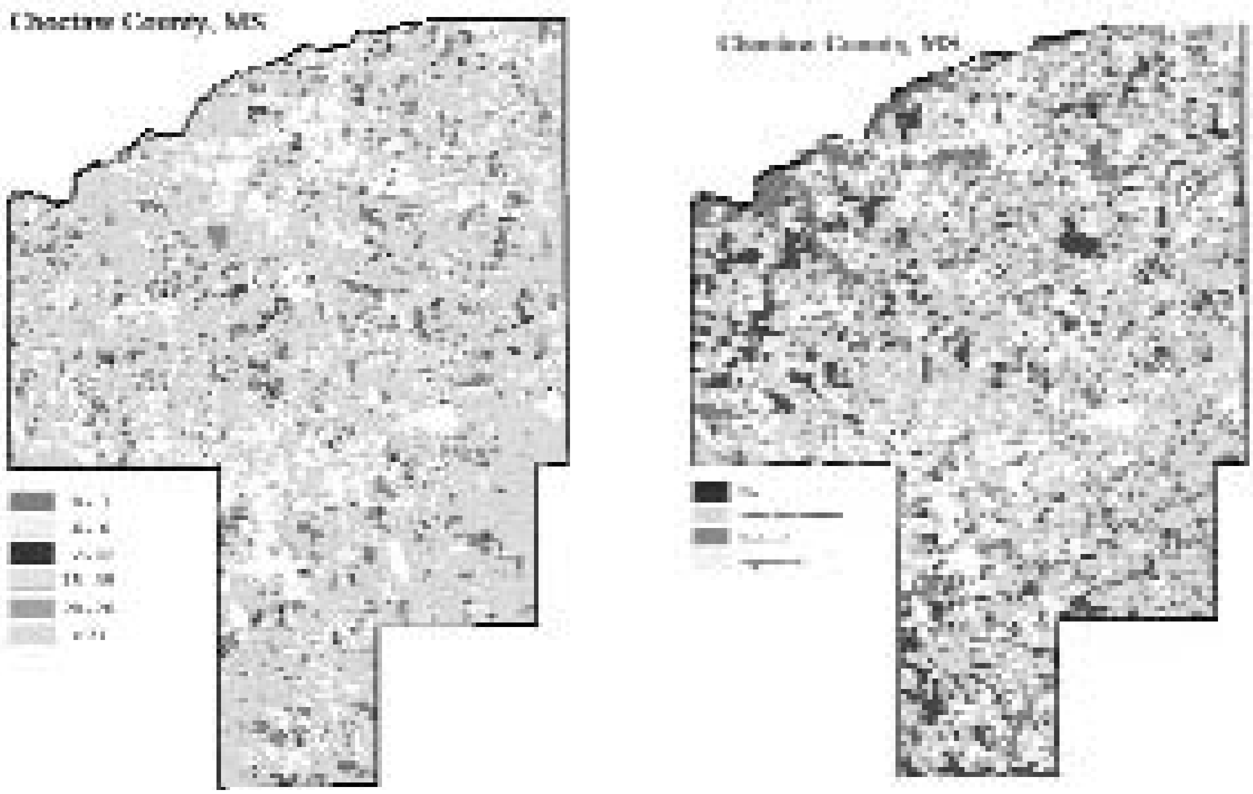

Figure 9. Examples of forest age and composition derived for Choctaw County, Mississippi.

tions. Using the standard normalized difference vegetation index (NDVI) to detect the amount of evergreen versus deciduous trees in a forested pixel, a continuous variable for all forested pixels was assessed. Using ancillary photogrametric information and knowledge of the vegetation growth patterns in Mississippi, it was possible to group the forested areas as pine, mixed, or hardwood forest.

Age and Composition Integration – Integrating forest age and forest composition information resulted in relating age to composition for any particular forested area. This information was used in assessing the sustainability of the forested resources in the study area.

Results of Harvesting Sustainability

The average annualized rate of forested harvesting is summarized in Table 1. An increase in forest harvesting in the early 1980's and the last half of the 1990's was evident. This information was based upon: 1) the forested area at the beginning of the study period, 2) the amount of harvested area detected throughout the study, and 3) an assumed harvest rotation of 40 years (standard at the beginning of the study). Based upon this information, the forest harvesting is occurring at a sustainable rate (2.5% per year) in the study area. This is an average annualized rate of forest harvesting by area of 0.54%. These observations relate to clear-tell harvest systems and do not reflect intermediate thinning during the full rotation of a timber stand.

Table 1.

The average annualized rate of forest harvesting by observed time interval.

Time Interval	Percent Forest Area Harvested Per Year
1972-1979	0.32
1979-1986	0.83
1986-1992	0.17
1992-1995	0.13
1995-1998	0.88

Knowledge-based prototype for estimating growth and yield

A prototype for a knowledge-based growth and yield (KBGY) prediction system was developed to supply managed stand growth projections and planning and decision support tools for industry, private landowners and public agencies. The prediction system was constructed in five component modules: 1) MS Windows® user interface that will be linked to the main MsFMIS interface, 2) a database update facility, 3) the database, 4) search engines and predictive algorithms, and 5) a report writer.

The knowledge-based growth and yield user interface (Figure 10) was implemented in a Visual C++ programming environment. The interface includes both required and optional user inputs. The user selects forest type, stand origin, current and future age, and report type for which growth and yield predictions will be made. Either current basal area per acre or current trees per acre must also be entered. Site index is an optional input that, when known, can further refine yield projections. The system assumes, depending on the type of user, varying degrees of current stand information may be available for input. The more inputs that are supplied, the more specific the predictions that can be made. For example, if site index is not entered, predictions will be broadly based across a range of site indices. If site index is supplied, predictions will be based only on growth and yield plots possessing that site index.

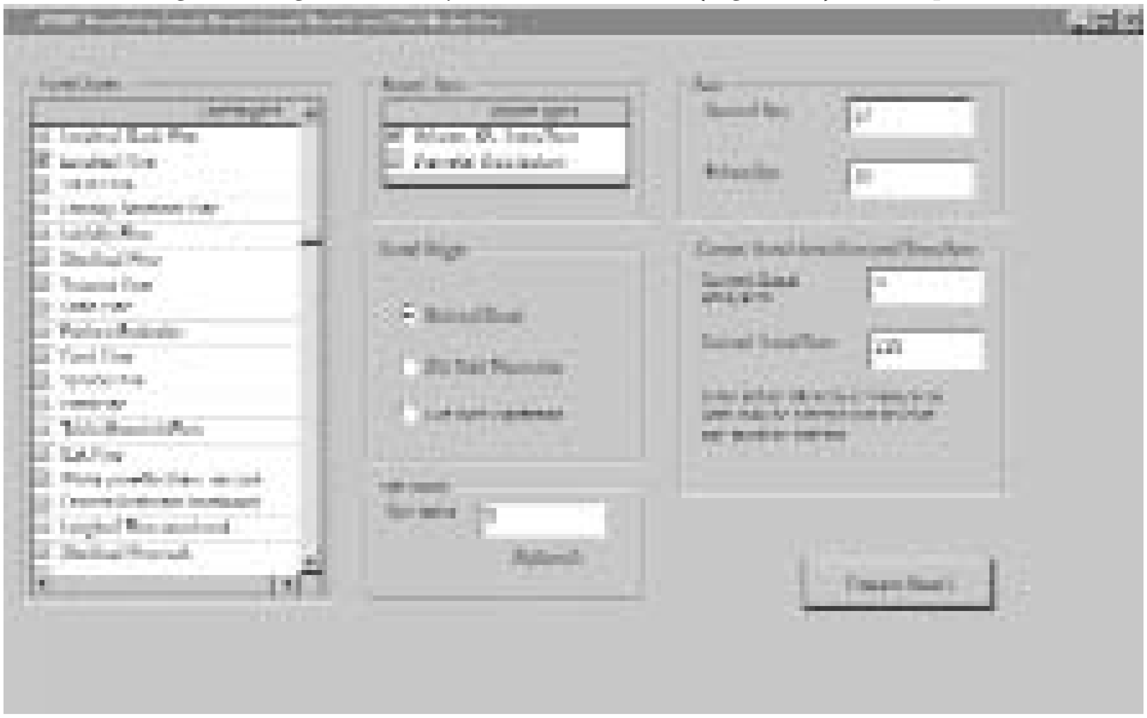

Figure 10. Example screen from MsFMIS depicting the knowledge-based growth and yield user interface.

The database update facility was developed as a WIN32 program in Visual C++. This module facilitates the addition of growth and yield data sets to the database component of the knowledge-based system. As the database grows, predictions can be made for an increasing number of forest types and management conditions with greater confidence. An ISAM (indexed sequential access method) database structure was utilized because of its superior access and retrieval speed as compared to relational database structures. It is anticipated that the database component of the full implementation will be extremely large and retrieval time will be an important issue. Microsoft's Open Database Connectivity (ODBC) standard for client-side database access and a standard Structured Query Language (SQL) embedded in Visual C++ code were employed for writing the database access code necessary to construct the search engine and predictive algorithms.

The report writer for the growth and yield system (Figure 11) was designed to display volume information in a format as similar as possible to the main MsFMIS interface, so as to appear as a seamless link. Volumes are reported on a per acre basis for inside and outside bark estimates in cubic feet of pulpwood and sawtimber and for three different board-foot log rules. Depending upon the user selected forest type, volumes are reported by the associated species group. The current USDA, Forest Service definitions of forest type-species group associations were utilized. A full implementation of the prototype is expected to be completed within the next two years. Tasks include the addition of a large number of growth and yield databases, further refinement of predictive algorithms, and formulation of reliability estimates and their comparison to traditional modeling techniques.

Accuracy Assessment

The accuracy assessment of the remote sensing products supplied by Veridian-ERIM International were completed using the field plot data, historical aerial photographs and current high resolution imagery. The field plot data and high resolution imagery were used to evaluate the forest cover type products. Historical aerial photographs were used to assess the age class products. This accuracy assessment was performed by the Spatial Information Technologies Laboratory of Mississippi State University.

Cover Type Assessments

Overall accuracy, based on the high-resolution aerial imagery, was estimated to be 93.54% (Table 2) while the accuracy estimated from the field plot evaluations was 64.87% (Table 3). The differences in these figures can be attributed to how each evaluation was taken. In the field, the assessment is made from under the canopy, looking up. Assessments from the high resolution imagery are made from above the canopy, looking down. Another cause for error could be the registration errors between the remote sensing product and the DGPS. Finally, the errors between the cover types may be a result of the compilation of the five field plot cover type categories into the three cover type categories produced in the remote sensing products.

Mississippi Knowledge-Based G&Y Reporter

Forest Type : Longleaf
Stand Origin : Natural Stand
Current Trees/Acre : 120

Current Age : 67
Future Age : 87

Future Basal Area/Acre : 129.50
Future Trees/Acre : 110

Predicted Volumes Per Acre By Species Group

Species Group	PW (o.b.)	PW (i.b.)	ST (o.b.)	ST (i.b.)	Total (o.b.)	Total (i.b.)	Doyle	Scrib	Int-1/4
LL/SL	227.1	184.3	219.1	178.1	228.1	185.0	659	889	1058

- Basal area/acre is in square feet.
- PW - pulpwood volume is per acre cubic feet from stump to 3-inch top.
- ST - sawtimber volume is per acre cubic feet from stump to 6-inch top.
- Total - total volume is cubic feet per acre from stump to a 0-inch top.
- Doyle, Scribner, and International 1/4 are board feet per acre.
- Sawlog trees are defined as 8.6 inches or greater DBH.
- Pulpwood tree are defined as 4.6 inches or greater DBH.
- Species group codes:

ASH	= Ash	BEE	= Beech
BSW	= Basswood	BLW	= Black Walnut
CTW	= Cottonwood	CYP	= Cypress
EX	= Exotic	HIC	= Hickory
LB/SH	= Loblolly-Shortleaf Pine	LL/SL	= Longleaf-Slash Pine
NC	= Non-commercial	OT-HH	= Other Hard Hardwoods
OT-RO	= Other Red Oaks	OT-SH	= Other Soft Hardwoods
OT-SW	= Other Softwoods	OT-WO	= Other White Oaks
OT-YP	= Other Yellow Pines	SEL-RO	= Select Red Oaks
SEL-WO	= Select White Oaks	SO-MP	= Soft Maple
SWG	= Sweetgum	TP/BG	= Tupelo-Black Gum
YPOP	= Yellow Poplar		

Figure 11. Example of report generated by MsFMIS from the knowledge based growth and yield user interface.

Table 2.

Error matrix assessing LandSat™-derived cover types using high resolution aerial imagery.

Classified Data	Reference Data: Non-Forest	Hardwood	Mixed	Pine	Regeneration	Total	Product Accuracy (%)	User's Accuracy (%)
Non-Forest	56	0	1	0	0	57	83.58	93.33
Hardwood	4	55	0	0	0	59	100.00	93.22
Mixed	0	0	54	0	0	54	98.18	96.49
Pine	0	0	0	58	0	58	100.00	100.00
Regeneration	8	0	0	0	58	66	89.66	86.67
Total	68	55	55	58	58	294	N/A	N/A

Kappa Statistic 0.9193

Table 3.

Error matrix assessing LandSat™-derived cover types using field plot

Classified Data	Reference Data: Non-Forest	Hardwood	Mixed	Pine	Regeneration	Total	Product Accuracy (%)	User's Accuracy (%)
Non-Forest	86	4	18	1	0	109	90.53	78.90
Hardwood	1	95	6	3	1	106	49.48	79.62
Mixed	6	81	173	73	0	333	77.58	51.95
Pine	1	3	12	107	0	123	46.52	86.99
Regeneration	1	9	14	46	56	126	98.25	44.44
Total	95	192	223	230	57	797	N/A	N/A

Kappa Statistic 0.5490

Age Class Assessments

Age class accuracy was assessed using historical aerial photographs. The only available statistic for this assessment was the overall accuracy for each age class (Table 4). These accuracies range from 90% to 94%. Again, these were assessed from above the canopy, looking down. Because of the temporal discrepancies between LandSat™ and the photographs, judgments about stand age were assessed from the original imagery. For example, if a stand was harvested in the middle of the age class, the photographs would show a mature stand of timber; however, by comparing the two satellite images from the beginning and end of an age class, a determination could be made.

Table 4.

Accuracies for age classes assessed using historical aerial photographs.

Age Class (Years)	Years Included	Year of Photography	Accuracy (%)
0-3	1996-1999	1996	90
4-6	1995-1993	1992	92
7-12	1992-1987	1985	92
13-9	1986-1980	1980	94
20-26	1979-1973	1969	94
+27	Prior to 1973	1969	96

Overall Accuracy

Overall the accuracy of the remote sensing products was within acceptable limits. The difference between classification techniques using aerial imagery and field data techniques generally show up as differences in the comparative statistics. As image processing capabilities and the resolution of satellite imagery increase, these products will be more reliable.

Conclusions and Future Directions

Integration of remote sensing data with GPS technologies is valuable for increasing inventory efficiency and level of precision. The benefits of this approach are two-fold: first, no effort was expended on sampling non-forested areas and secondly, sampling intensity was matched with the variability of the target resource. This coupling allowed for a true random sample of forest area by type over a large landscape. Based on the remote sensing forest typing, precision goals were attained.

Future directions for this product include validation, expansion, and integration with other programs. Expansion goals are aimed at applications in other states and regions. Finally, the integration of FIA data will further increase sampling efficiency (Cochran 2002).

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Appendix A

Field Procedures Manual

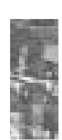
Pilot Program for a Forest Monitoring and Information System

Field Procedures Manual

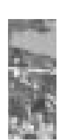
Volume 1

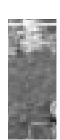
written by:
Patrick A. Glass

Revised October 21, 1999



Pilot Program for a Forest Monitoring and Information System





Measurement Plot Specifications and Procedures

This document supplies definitions, methodologies and standards for the inventory implementation of a pilot program for a forest monitoring and information system. The objective of this document is to describe field procedures that will assure consistent and uniform data collection over all expected conditions in the study area. It is expected that all plot data can be measured by a two-person crew in approximately two hours, on average, including time spent traversing to and from the plot.

Field Crews:

Each field crew will consist of two individuals. Each individual will be assigned a file designator. The file designator identifies, within the data structure, which person conducted the height estimations.

To reduce bias of ocular estimations, the same individual will perform estimations throughout the day. Prior to leaving the office, determine which crew member will perform height estimations. **Upon commencement of plot measurements, the same individual will complete all height estimations for that plot.**

Field Equipment:

Each field crew will be assigned a complete set of field equipment. In addition to equipment, a backup system (compass, clipboard, field data sheets and note pads) will be accessible to prevent loss of time due to equipment failure.

A G.P.S. receiver will be used to navigate to plot locations, and a field recorder will be utilized to record inventory data.

Tree heights will be measured with a Vertex hypsometer. The data will be used to obtain local volume tables and site index estimations on a subsample of trees on each plot. Hypsometers will also be used to obtain a measurement of slope for each plot.

DME 201 units will be used to check radial distances for boundary trees. Because of the nested plot design and diameter limited plot radii, each tree's radial distance will be verified.

Two increment borers (12 inch and 18 inch) will be issued to each crew. The 18 inch borer will be held in reserve for large trees. The borers will be used to obtain 5 and 10 year radial growth and age at breast height for site index. A bark gauge will be used to determine single bark thickness.

Logger's tapes will be supplied for diameter at breast height (d.b.h.) measurements. They will also be used to measure distances in the event the DME 201's or the hypsometers fail.

Clinometers will be carried as a precaution against equipment failure. Spare batteries for the hypsometer and the DME 201 will be carried to prevent delays caused by depleted power sources.

It is the responsibility of each field crew to maintain the equipment. In the event equipment is lost or becomes non-serviceable, the field coordinator should be notified as soon as possible.

Land Navigation:

Each plot location has been randomly selected from remote sensing information to fulfill accuracy requirements for the strata it represents. Latitude and longitude coordinates are used to identify plot centers. Gross navigation to each plot is achieved using available maps depicting vehicular access routes. It is extremely unlikely that plot access will be available to motor vehicles. If permission from the landowner can be obtained prior to site visitation it may be possible to minimize the amount of time spent traversing to the plot location.

At no time will a field crew be authorized to tamper with, vandalize or destroy fencing or gates defining property boundaries to facilitate access. Damage or destruction of property with the intent to aid navigation is not permitted. In the event of long traverses trail marking to assist with egress is restricted to flagging the line of travel, provided flagging is biodegradable and not used excessively.

Equipment Calibration:

The Vertex hypsometer and the DME 201 require calibration with ambient environmental conditions to compute distances accurately. Calibration will be conducted each time a field crew exits the vehicle in route to a new plot location. The procedures for calibrating each instrument are included in Appendix 5. Because both instruments can utilize either transponder it is more efficient to calibrate both instruments together. The stipulation with calibration is that the unit has time to adjust to ambient temperature and humidity conditions before calibrating. This is pertinent whenever the unit is initialized at the beginning of the day or has been in a vehicle for extended periods of time. Allow the units to adjust to environmental conditions for 10 minutes before calibration.

Plot Establishment:

The first determination to be made upon arrival at plot center is whether the plot will encompass a homogenous sampling unit. If there is no significant variation in type, size or age class, then plot center is established at the point navigated to with the GPS unit. If significant variation is encountered the plot center must be moved 1 chain from the original plot center, perpendicular to the stand line, into the stand occupying a majority of the plot. Micro-pockets (less than 10 acres) within a contiguous stand are considered to be part of the surrounding stand.

Examples where plot locations should be moved:

1) A plot overlaps the type boundary of a plantation and natural pine stand. The plot should be moved into the natural stand.
2) A plot overlaps the boundary of a thinned and unthinned stand. The plot should be moved into the unthinned stand.
3) A plot overlaps the boundary of a seed-tree and clear cut stand. The plot should be moved into the seed-tree stand.
4) A plot overlaps the boundary of a pine and mixed pine-hardwood stand. The plot should be moved into the mixed pine-hardwood stand.
5) A plot includes area converted to a non-forestry application (e.g. agriculture, roads, etc.).

Inaccessibility of plot center is not a reason for re-positioning. Plot locations may fall within or include watercourses or natural catchments. If the plot cannot be established without jeopardizing the safety of the crew, then a notation must be made and the field supervisor notified.

Plot Description:

Each plot sampled will be identified with a unique number. The plot number will index all data entered into the field recorder. In addition to plot number, descriptive information for each plot will be entered. Slope, Size Class, Origin, SAF Type, Ownership, Physiographic Position, Logging Operability and Stand Condition will be catalogued within each plot.

Slope - Identifies the average slope for the plot.
Slope observations are made with the hypsometer on a line parallel to the slope. Procedures for obtaining slope measurements are detailed in Appendix 7.

Stand Condition - Describes the current condition of the stand with respect to damage and harvesting activities. Explicit codes are defined in table 1.

Table 1.

Stand level damage categories, descriptions and data code.

Damage Type	Description	Code
Undamaged	There is no apparent damage within the stand.	1
Insect	Infestation of the stand as evidenced by pitch tubes, bore holes, webbed foliage, etc.	2
Disease	Infection of the stand as evidenced by brooming, cankers, conks, etc.	3
Fusiform	Infection of the stand by *Cronartium fusiforme*.	4
Fire	Damage to the boles and/or lower canopy from heat (excluding typical damage from prescribed burns).	5
Storm	Damage by excessive winds from hurricanes or tornadoes is prevalent (blowdown / windthrow).	6
Ice	Damage to the upper stems and crowns caused by ice accumulation (breakage in upper crown).	7
Salvage	Focused harvesting operations have occurred within the stand.	8
Thinning	Generalized harvesting has occurred throughout the stand.	9
Clear-cut	The stand has recently been harvested and no routinely used method of regeneration is apparent.	10
Seed Tree	The stand has recently been harvested and seed trees for regeneration are present.	11

Size Class - Classifies the merchantability class for the plot based on overall size composition. The predominate size class encountered on the plot defines the size class. Table 2 lists acceptable size class designations.

Table 2.

Plot merchantability classes, class description and data code for plot size class.

Size Class	Class Description	Code
Reproduction	No commercial tree species greater than 1 inch in d.b.h. are encountered within the radius of a 1/5th acre plot (excludes seed tree stands).	1
Sub-Merchantable	No commercial tree species greater than 4.5 inches in d.b.h. are encountered within the radius of a 1/5th acre plot.	2
Pulpwood	The majority of commercial tree species occupying the 1/5th acre plot are 4.6 to 10.6 inches in d.b.h.	3
Saw timber	The majority of commercial tree species occupying the 1/5th acre plot are greater than 10.6 inches in d.b.h.	4
Non Timber	The site has been converted to a non-forestry application.	5

Origin - Identifies the origin of the stand. Table 3 identifies acceptable origin codes.

Table 3.

Origin (regeneration method) categories, category description and data codes.

Origin	Description	Code
Natural	Regeneration occurred from natural processes.	1
Planted	Regeneration occurred from planted stock.	2
Undetermined	Regeneration method is not readily apparent.	3

SAT Code - Identifies the canopy coverage in a broader perspective than the SAF cover type. Table 4 provides guidelines for defining SAT codes.

Table 4.

SAT categories, category description and data codes.

SAT Codes	Description	Code
Pine	Canopy composition is greater than 80% coniferous.	1
Pine Hdwd	Canopy composition is between 60% and 80% coniferous.	2
Mixed	Canopy composition is between 40% and 60% coniferous.	3
Hdwd Pine	Canopy composition is between 20% and 40% coniferous.	4
Hdwd	Canopy composition is less than 20% coniferous.	5

SAF Cover-Type - Identifies the canopy species composition using SAF accepted cover types. There are 35 separate cover types that can be encountered. For the inventory, the definitive guide is "Forest Cover Types of the United States and Canada" published by the SAF (1980). Abbreviated descriptions are included with the code designations in Appendix 2.

Ownership - Identifies the primary ownership entity. Identification of ownership is not paramount to performance of the inventory. Minimal time should be spent discerning this variable. If ownership is obvious then identification should be made. Table 5 depicts the 10 categories that will describe all ownership possibilities.

Table 5.

Land ownership categories, category description and data codes.

Ownership	Description	Code
Private Non-Industrial	Acreage that does not appear to be intensively managed for forestry.	1
Industrial	Acreage that has the appearance of intensive management for forestry.	2
USFS	Acreage that is owned or operated by the USDA Forest Service.	3
USFWS	Acreage that is owned or operated by the USDI Fish and Wildlife Service.	4
Other Fed	Acreage that is owned or operated by any other federal entity including BLM, National Park Service, etc.	5
State Gov	Acreage that is owned or operated by the State, including state parks, 16th section land, etc.	6
Municipal	Acreage that is owned or operated by municipalities including city parks, public golf courses, etc.	7
Urban	Acreage that is owned or dwelled upon for residential purposes including subdivisions, private golf courses, etc.	8
Tribal	Acreage that is owned or operated by federally recognized Native American tribes including Choctaw, Chickasaw, etc.	9
Unknown	Acreage that ownership cannot be readily identified.	10

Physiographic Position - Classifies the geographic position of the plot. Table 6 supplies descriptions that will define relative position. Strict definitions are not applicable to identify physiographic position because of the variability experienced state wide.

Table 6.

Topographic position categories, category description and data codes.

Physiography	Description	Code
Upland	Drier, xeric sites found on top of ridges and side slopes.	1
Bottom	Wet, hydric sites found along rivers and streams.	2
Terrace	Mesic sites that by default are not upland or bottom.	3

Logging Operability - Classifies the terrain for season and equipment accessibility. Table 7 lists the applicable designators for logging operability.

Table 7.

Logging operability categories, category description and data code.

Logging Operability	Description	Code
Year Round	Accessible to logging equipment throughout the calendar year.	1
Summer/Fall	Accessible to logging equipment during these seasons only.	2
Crawler	Soil or slope precludes the use of rubber tired skidders.	3
High Lead	Cable harvesting systems are required.	4
Inoperable	Cannot be harvested economically or efficiently.	5

Latitude / Longitude - Identifies the plot center location in the event that location was moved from the preset.Before exiting the GPS software make a notation of the new corrected Latitude/Longitude of plot center. The new coordinates must be entered into these fields, if the plot center was moved from the preset navigation point.

Plot Measurements:

Three concentric overlapping plot sizes are incorporated within each plot. A 1/5th (0.20) acre plot with a radius of 52.7 feet is utilized to sample merchantable timber (4.6 inches in d.b.h. and larger). A 1/20th (0.05) acre plot with a radius of 26.3 feet is used to inventory sub-merchantable trees between 1 and 4.5 inches in d.b.h. A 1/100th (0.01) acre plot with a radius of 11.8 feet is used to record regeneration 0.0 to 1 inch in d.b.h. Refer to figure 1 for a representation of the plot design. Two sweeps will be made around the plot. One sweep is made for merchantable and sub-merchantable stems. The other sweep is made within the regeneration plot. Regeneration plots are only established on locations where the "Size Class" is designated "Reproduction." Sweeps will start on the radial line with a north azimuth to ensure there are no duplicate tallies.

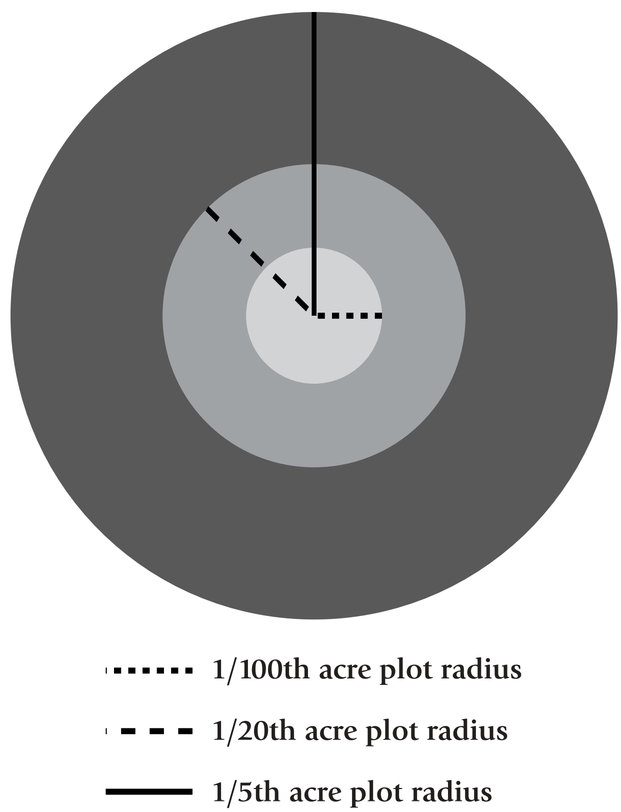


Figure 1. *Plot layout depicting effective radii.*

Individual Tree Tally:

Each live tree will have the following observations recorded. Product, species, d.b.h., total height, pulpwood height to an absolute top, usable pulpwood height, saw timber height to an absolute top, usable saw timber height, apparent damage and broken top diameter$_{ob}$ if present.

Plot: The unique number assigned to this particular set of Latitude / Longitude coordinates.

Product: A numeric code that describes the primary merchantability of the stem. Table 8 defines the specifications for the product classes.

Table 8.

Product merchantability categories, category description and data code.

Product Category	Description	Code
Reproduction	All commercial species that are less than 1.0 inch d.b.h. These trees are tallied according to height class.	1
Class 1	Commercial species less than 1 foot in height.	
Class 2	Commercial species between 1 and 3 feet in height.	
Class 3	Commercial species greater than 3 feet in height.	
Sub-merchantable	All commercial species that are between 1 and 4.5 inches d.b.h. Total height for these trees is estimated to the nearest foot.	2
Pulpwood	All commercial species that are 4.6 inches d.b.h. or greater that do not meet the qualifications for a product of greater value.	3
Saw Timber	Pine species that are 7.6 inches d.b.h. or greater and broadleaf species that are 11.6 inches d.b.h. or greater and of sufficient quality to be utilized as saw timber.	4
Peeler	Trees that are 15.6 inches d.b.h. or greater and have 16 feet of clear butt log.	5
Pole	Trees that are 11.6 inches d.b.h. or greater free of defect and sweep. Restricted to pine species (longleaf and slash) predominately found in southern coastal plain.	6
Railroad Tie	Hardwood species (red and white oaks) that are not suitable for saw timber but higher quality than pulpwood.	7
Cull	Any tree that has obvious defects that preclude its inclusion in any of the other product classifications (i.e. large areas of decay, very poor form, etc.)	8
Height Sample	The first two non-cull trees (merchantable and/or sub-merchantable) tallied on each plot are carefully measured for all pertinent heights. This sample is taken after the reproduction plot information is recorded. Heights are measured by the same individual that estimated heights.	9

Species: A numeric code from 1 - 60 that identifies the species of the tree. The predominant commercial species are assigned a code to be input. Additionally, genus codes are supplied in the event that species identification is not possible. Appendix 1 supplies the code, common name and species name.

Diameter: The diameter of the stem, at breast height, in tenths of an inch. Diameter is measured at 4.5 feet above ground level on the uphill side of the stem. If there is a deformity at d.b.h. then diameter is preferably measured 1 foot above the point where the stem resumes normal growth. If this point is inaccessible then the diameter is measured 1 foot below the point where the abnormality occurs. If the stem forks (visible separation) below d.b.h. then each of the multiple stems are treated as separate trees and measurements are taken at d.b.h. If the stem (visible separation) forks at or above d.b.h. then the stem is treated as a single tree and the diameter is taken at the base of the fissure scar. If the tree exhibits excessive butt swell as usually encountered with cypress and gum species then the diameter is measured 1 foot above the point where the stem resumes normal form. Parasitic vegetation (clinging vines, etc.) should be removed to assure that only the tree diameter is measured.

Total Height: The height of the tree (nearest foot) to meristematic tip or uppermost leader. Most conifers will exhibit one stem terminating with an apical meristem. If the main stem is intact, then height is measured to the apical tip of the tree. If the main stem has been damaged, then height is measured to the point where the breakage occurs. Broadleaf trees typically do not possess a single upper stem. They will however usually have a dominant leader. If a dominant leader can be identified then height is measured to its tip. If the top has been broken out then height is measured to the point of breakage on the largest diameter limb.

Pulpwood Height to Absolute Top: For conifer species, the height where the main stem is 3 inches DOB; for broadleaf species, the height where the main stem or largest diameter limb is 4 inches DOB (nearest foot). This height is recorded for both pulpwood and saw timber trees

Pulpwood Usable Height: The height at which the stem becomes un-usable in typical industry applications. This height will always be less than or equal to the height to an absolute top (nearest foot). This height is also recorded for both pulpwood and saw timber trees. Examples of usability limits are given below.

1) The stem forks at 5 inches DOB.
2) The stem forks and none of the multiple stems are 5 inches DOB.
3) The stem is broken.
4) The stem has crook and there is not 5.5 feet of stem pulpwood above the crook.

Saw timber Height to Absolute Top: For conifer species, the height where the main stem is 6 inches DOB; for broadleaf species, the height where the main stem is 10 inches DOB (nearest foot).

Saw timber Usable Height: The height at which the stem becomes un-usable in typical industry application. This height will always be less than or equal to height to an absolute top (nearest foot). Examples of usability limits are given below.

1) The stem forks and none of the multiple stems meet minimum saw timber diameter.
2) The stem incurs crook.
3) The stem is broken.
4) There is a branch whorl of 3 or more branches.
5) A branch is less than 45 degrees off vertical and is one-third the stem diameter where it branches.
6) A branch is equal to one-half the stem diameter.

Damage: Table 9 provides damage categories that will be used to relate tree level damage assessments.

Table 9.

Tree level damage categories, descriptions and data code.

Damage Type	Description	Code
Undamaged	The tree displays no apparent damage.	1
Insect	Infestation of the tree as evidenced by pitch tubes, bore holes, webbed foliage, etc.	2
Disease	Infection of the tree as evidenced by brooming, cankers, conks, etc.	3
Fusiform	Infection of the tree by Cronartium Fusiforme.	4
Fire	Damage to the bole and/or lower canopy from heat (excluding typical damage from prescribed burns).	5
Storm	Damage by excessive winds from hurricanes or tornadoes is prevalent (blowdown / windthrow).	6
Ice	Damage to the upper stem and crown caused by ice accumulation (breakage in upper crown).	7
Mechanical	Damage caused by human activity.	12
Decay	Decay of portions of the tree due to exposure.	13
Lightning	Direct strikes evidenced by spiraling scars on the stem.	14
Erosion	Exposure of root system by flowing water or wind removal of soil.	15

Broken Top: The stem diameter_{ob} where the break occurs. For broadleaf species this is defined where the largest diameter stem has been broken.

Field Procedures:

Upon exiting the vehicle turn the G.P.S. unit on, enter G.P.S. software if not resident, by typing "**GPS**" at the prompt. Select **Navigation** from the main menu and allow the unit to initialize. During the time of initialization the hypsometer and DME 201's will be calibrated. After initialization, the primary navigation screen will appear. Select the route containing the plot locations, then select the way point (plot) to be sampled. The unit will then show the azimuth and range to the plot location from your current position.

A directional aid is displayed on the navigation screen in the form of an arrow inside a circle, next to a fixed arrow orientated with the top of the screen. When the two arrows are parallel the unit is oriented in the direction of the plot. Proceed in the direction indicated; the unit is set to sound a proximity alarm and display a message when within 10 feet of plot center. Utilizing the range indicator, minimize the distance to the plot center.

Temporarily mark the plot center and assess for homogeneity of forest characteristics. If the plot can be established at that point then exit the G.P.S. software by pressing **esc** until questioned for confirmation of exit. Press **F5** to confirm exit.

If the plot has to be moved, make the necessary determination for direction and move the plot. When the plot center is established to contain homogenous stand conditions, escape (**esc**) to the main menu in the G.P.S. software. Scroll to the Collect Data menu item and press **enter**. Press **F3** to access the base data and when prompted for a file name press **return**. After a few seconds the base location data screen will appear. From this screen **note the latitude and longitude** for the new plot center. It will be input during the plot inventory. Press **esc** until returned to the main menu and then exit the G.P.S. software.

Start the field recording software by typing "**PLOT**" at the prompt and pressing the **enter** key. Select menu item **3** to start recording inventory data. When asked for job name enter your file designator (**FML01**). When asked about previous specs press '**y**' followed by enter. Enter the plot number and press enter. Press the **F3** key to access the "PLOT INFORMATION" screen. Press '**N**' followed with **enter**. Input the appropriate data into the various fields as required. **Remember to record new plot location coordinates, if plot center was moved.** When all data have been entered for plot description then press **F4** to return to the individual tree tally screen.

Starting from the radial line with a north azimuth, proceed in a clockwise direction, to record merchantable and sub-merchantable tree data. The first two trees tallied are to be nondestructively marked for subsequent height measurements. Borderline trees are to be tallied if the distance from the center of the stem to plot center is less than or equal to plot limiting distance. Classify the tree into the highest product category for which it qualifies. Identify the species of the tree if possible. If species identification is not possible, or the species is not included in the species list, then use the general codes (**1, 8, 16, 58, 59**) to identify the tree. If genus identification is not possible then classify the species as unknown. Measure the diameter of the tree to the nearest tenth of an inch. If the tree qualifies as pulpwood, then estimate the total height, absolute merchantable pulpwood height and usable pulpwood height. If a tree qualifies as saw timber (Peelers, Poles and Railroad Ties are considered saw timber for height measurements), then estimate total height, absolute merchantable pulpwood height, usable pulpwood height, absolute merchantable saw timber height and usable saw timber height. If the tree is sub-merchantable, measure diameter and estimate total height. If the tree is a cull, then measure diameter only.

Perform an inventory of reproductive material only on plots for which the size class is designated as reproduction, after all merchantable and sub-merchantable stems have been tallied. Reproduction size classes are entered into the TH field and the number of trees for that species/size class combination are entered into the PHa field. If there are more than 20 individuals encountered for any species/size class combination then enter 20 and proceed with the next combination.

Height Sub-Sample:

The first two trees that were tallied and marked are measured with the hypsometer for total, absolute and usable heights. **The measurements are to made by the same individual that estimated the heights.** Deactivate the DME 201 transponder by removing it from the range pole. Activate the hypsometer transponder by swiveling the pins outward from the casing. After measuring d.b.h. attach the transponder to the tree at d.b.h. Move away from the tree in a direction that will allow the clearest line of sight for as much of the tree as possible. Distance from the tree should allow for less than a 45˚ angle from the horizontal when sighting the top of the tree (i.e. distance equal to the height of the tree). Sight the transponder with the hypsometer until the targeting dot disappears. Then sight the top of the tree until the targeting dot disappears. Continue to sight additional heights as necessary until all height measurements obtainable from that tree are complete. Repeat the process for the second tree. **Under no circumstances are height subsample measurements performed prior to height estimations for the plot tally.**

Growth Projection Measurements:

Three merchantable and one sub-merchantable tree will be sampled for growth at each plot. The dominant species occupying the plot will determine the species of the sample trees. The largest merchantable diameter tree, smallest merchantable diameter tree and the merchantable tree closest to plot center (excluding the largest and smallest diameter trees) will be sampled. A sub-merchantable tree of the dominant species capable of supplying a 5 year radial growth increment will also be sampled. To access the plot growth entry screen press **F2**. Verify that the plot number is correct. For each tree record the species, d.b.h., single bark thickness, and 5 and 10 year radial growth increment.

Site Index Measurements:

On pine sites a dominant or co-dominant pine tree is sampled. On hardwood sites, if oak is present, then a dominant or co-dominant oak tree is sampled. If oak is not present, then a dominant or co-dominant tree from the predominant commercial species is sampled. Record the species, d.b.h., age at breast height and, utilizing the hypsometer, total height. If the tree that was selected for largest diameter is either a dominant or co-dominant, and representative of the predominate species then the growth and site index increment can be combined. After all measurements are recorded press **F4** to return to the tree tally screen.

Plot Exit:

All plot information should be collected at this time. Press **F4** to save the plot data, press **F5** to exit the plot tally entry routine and press **enter** to return to the main menu. Press **enter** again to return to the prompt. At the > prompt type "**GPS**" to activate the G.P.S. software, if the next point is to be navigated to a plot or turn the unit off if returning to the vehicle.

Appendix 1.

Common Name - Species Reference

Common Name	Species Name	Code
Misc. Pine	*Pinus spp.*	1
Loblolly	*Pinus taeda*	2
Shortleaf	*Pinus echinata*	3
Longleaf	*Pinus palustris*	4
Slash	*Pinus elliotii*	5
Cypress	*Taxodium spp.*	6
E. Red Cedar	*Juniperus virginiana*	7
Other Red Oak	*Quercus spp. erythrobalanus*	8
Cherrybark Oak	*Quercus pagodifolia*	9
Shumard Oak	*Quercus shumardii*	10
Black Oak	*Quercus velutina*	11
Nuttall Oak	*Quercus nuttallii*	12
Red Oak	*Quercus falcata*	13
Blackjack Oak	*Quercus marilandica*	14
Turkey Oak	*Quercus laevis*	15
Other White Oak	*Quercus spp. leucobalanos*	16
White Oak	*Quercus alba*	17
Post Oak	*Quercus stellata*	18
Swamp Chestnut/Cow Oak	*Quercus prinus*	19
Overcup Oak	*Quercus lyrata*	20
Durand Oak	*Quercus durandii*	21
Water Oak	*Quercus nigra*	22
Willow Oak	*Quercus phellos*	23
Laurel Oak	*Quercus laurifolia*	24
Chinkapin Oak	*Quercus muehlenbergii*	25
Live Oak	*Quercus virginiana*	26
Sweetgum	*Liquidambar styraciflua*	27
Ash	*Fraxinus spp.*	28
Sycamore	*Platanus occidentallis*	29
Yellow/Tulip Poplar	*Liriodendron tulipifera*	30
Tupelo	*Nyssa aquatica*	31
Blackgum	*Nyssa sylvatica*	32
Sugarberry / Hackberry	*Celtis spp.*	33
Hickory	*Carya spp.*	34
Pecan	*Carya illinoensis*	35
Walnut	*Juglans spp.*	36
Cottonwood	*Populus deltoides*	37
Basswood	*Tilia spp.*	38
Black	*Cherry Prunus serotina*	39

Appendix 2.

SAF Cover Type Definitions:

Cover Type	Description	Code
Lob-Short	Loblolly and shortleaf pine together comprise a majority of the stocking, although the proportion of each varies, loblolly is usually dominant.	1
Loblolly	Comprised of either pure stands of loblolly pine or mixtures in which loblolly makes up the majority.	2
Shortleaf	Shortleaf provides the majority of stocking but is rare except in young stands or on very dry sites.	3
Lob-Hdwd	Loblolly is not dominant but provides 20 percent or more of the stocking in mixture with hardwoods.	4
Short-Oak	Shortleaf is not dominant but provides 20 percent or more of the stocking in mixture with oaks.	5
Long-Slash	Longleaf and slash pine make up a majority of the stocking with slash being subordinate to longleaf.	6
Longleaf	Longleaf pine is pure or comprises a majority of the trees in the overstory.	7
Slash	Slash pine is pure or comprises a majority of the stocking.	8
Long-Scrub	Longleaf pine and scrub oaks comprise this typically younger type.	9
Slash-Hdwd	Slash pine and a variable mixture of hardwoods comprise the majority of the stocking.	10
ERC-Hdwd	Eastern redcedar and mixed hardwoods comprise the majority of stocking with varying proportions.	11
ERC	Eastern redcedar is pure or comprises the majority of the stocking.	12
S. Scruboak	Type consists of a mixture of scrub oaks where fire has been excluded not allowing longleaf regeneration.	13
Oak-Pine	Various oaks dominate the stocking with pine comprising less than 20 percent.	14
Oak-Hick	Oaks and hickories are prevalent throughout the stocking.	15
PO-Blkjck	Post oak and blackjack oak comprise the majority of the stocking.	16
White Oak	White oak dominates the stocking with other components less than 20 percent.	17
WO-RO-Hick	White and red oaks dominate the canopy with stocking levels varying among the species.	18
YP-WO-RO	Yellow poplar, white oak and red oak together comprise the majority of the stocking.	19
SG-YP	Sweetgum and yellow poplar comprise the majority of the overstory and the stocking.	20
O-G-C	Oaks, gums and cypress comprise the majority of the stocking with varying percentages of composition.	21
SCO-Chrybk	Swamp chestnut oak and cherrybark oak constitute a majority of the stocking.	22
SG-WiO	Sweetgum and willow oak comprise a majority of the stocking with sweetgum being dominant to willow oak.	23
SB-AE-GA	Sugarberry, elm and ash constitute a majority of the stocking. Sugarberry is replaced by hackberry in the northern part of the range.	24

Cover Type	Description	Code
OvO-Hick	Overcup oak and hickory make up a majority of the stocking.	25
Cyp-Tup	Cypress and tupelo together comprise the majority of the stocking.	26
Swb-STu-Rb	Combinations of sweetbay, tupelo and redbay, with sweetbay dominant, make up the majority of stocking.	27
WiO-WaO-LO	Willow oak, water oak and laurel oak in varying proportions comprise a majority of the stocking.	28
Live Oak	Live oak is pure or the majority of stocking.	29
Cyp	Cypress is pure or comprises a majority of the stocking.	30
Tup	Tupelo is pure or constitutes a majority of the stocking.	31
CotWood	Cottonwood is pure or comprises a majority of the stocking.	32
Syc-SG-AE:	Sycamore, sweetgum and elm together comprise a majority of the stocking with varying proportions.	33
Willow	Willow species comprise a majority of the stocking.	34
NonStock	Naturally occurring land areas excluding agricultural lands and pastures that are devoid of tree species.	35

Appendix 3.

Power Supply:

G.P.S.

The system consists of three separately powered integrated components. The field recorder has an internal power supply, the GPS receiver utilizes an external battery physically attached to the field recorder, the external antenna utilizes a battery and signal decoder carried in the backpack frame. The signal decoder attaches to the GPS receiver with a DB-9 connector on the COM 2 port. It is expected that the equipment will operate for 10 hours on a single charge. To insure maximum battery life, turn off the satellite decoder after establishing plot center. Turn all other equipment off when not in use. Therefore it is necessary that the equipment be recharged every evening. Procedure cards will be supplied to explain the necessary connections for recharging.

Hypsometer

The 60˚ transponder for the hypsometer has a 9 volt battery for its power source. The hypsometer uses two 1.5 volt AA batteries to power the unit. To replace the battery in the transponder, slide the battery cover out of the chamber, replace the battery with the proper polarity and slide the cover back into place. To replace the batteries in the receiver, unscrew the large silver battery cover with a coin, replace the batteries with the proper polarity and screw the battery cover back into place.

DME 201

Both the transponder and the handheld unit use a 9 volt battery for their power supplies. To change the battery for the transponder, unscrew the top of the unit, disconnect the 9 volt battery and replace, screw the unit back together. To replace the battery in the receiver, slide the battery cover completely off the unit, replace the battery with the proper polarity, replace the battery cover.

Appendix 4.

Transponder Activation:

The transponder for the DME 201 is an orange cylinder that sits on top of a telescoping range pole with an activation mount. To activate the transponder, firmly seat it onto the range pole. There is no visual indication that the transponder is activated.

The transponder for the hypsometer is a blue rectangular box. To activate the transponder swivel the mounting pins located in recesses on the back outward fully. There is a small red LED on the right side that blinks when the unit is active.

Both instruments utilize ultrasonic frequencies. Only one transponder can be in operation at any given time. If both transponders are in operation measurements will be invalid.

Appendix 5.

Calibration:

Hypsometer:
Activate the transponder and tape off a distance of 33 feet. Press and hold the On/Off button. After the unit activates the display will show Auto Distance. Press and hold the Undo button until the display shows the distance. The distance will replace a series of question marks ????.?. When the calibration distance is shown the unit is calibrated.

DME 201:
Activate the transponder and tape off a distance of 33 feet. Repeatedly press the red dot until the number 9 appears in the display. The unit will display 4 dashes [- - - -] followed by 2 dashes [- -]. When the calibration distance appears in the display the unit is calibrated.

Appendix 6.

Auxiliary CMT Operations:

Screen Contrast:
Screen contrast can be adjusted any time the unit is in operation. Press the **SH1** key then press the **Enter** key to access the unit setup screen. Scroll to the contrast setting and press **Enter**. Adjust the contrast with the left and right arrow keys until visibility is appropriate for current light conditions. Press **F3** to confirm the setting, then press **F5** to return to normal operation.

Power Supply:
Remaining battery power can be checked any time the unit is in operation. Press the **SH1** key then press the **Enter** key to access the unit setup screen. Scroll to the Powermeter setting and press **Enter**. A bar graphic and the estimated charge percentage are displayed. Press **F3** to confirm the setting, then press **F5** to return to normal operation.

Appendix 7.

Slope Determination:

Activate the transponder on the plot center stake. Move parallel with the slope to a point on the circumference of the 1/5th acre plot. Activate the hypsometer, and verify the radial distance to plot center. Then 'shoot' a height on the top of the transponder. The slope will show up on the screen directly under the angle label. If the slope is less than 100% there will be a percent (%) designator with the reading. If the slope is greater than 100% there will not be a percent (%) designator with the reading.

Appendix 8

Data Recording Sheets

Individual Tree Data

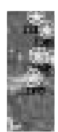
Crew Designator: Date: Lat: Long:

Plot	PR	SP	DBH	TH	PHa	PHu	STa	STu	DMG	BT

Crew Designator	
Date	
Plot	
Ave. Slope	
Stand Code	
Size Class	
Origin Code	
Sat. Code	
SAF Type	
Ownership	
Physio. Pos.	
Logging Oper.	
Latitude	
Longitude	

Growth Data

Plot					
Tree	SP	DBH	1 Brk	RG5	RG10
SubMerc					
Closest					
Min DBH					
Max DBH					
	SP	DBH	TOTH	AGE	
Site					



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