

OPERATIONAL CONSIDERATIONS FOR THE APPLICATION
OF REMOTELY SENSED FOREST DATA FROM LANDSAT
OR OTHER AIRBORNE PLATFORMS

A-10

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ABSTRACT

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The forest data base requirements necessary to efficiently manage a large timber based forest industry of the 1970's have transcended by a considerable margin those data required two decades ago. These data demands have grown both in quantitative terms and in the level of precision acceptable to successfully undertake the multiple decision making processes required.

From the traditional generation of area/volume and frequency tables used in immediate planning for harvest and cultural activity, data are now subjected to the rigors of long range planning manipulations, as these data represent the major input to such planning models. To be effective in such planning activity, the data must be provided in a timely manner. Concurrent with the increase in data demand and the speed of preparation, has been the ever increasing difficulty in securing and reducing these data within the timetables demanded.

Remote sensing techniques at all levels seemed to offer the most promising prospect in satisfying the data requirements, and in alleviating the difficult task of collecting the data. After a thorough review of the technology of remote sensing and the state of the art of interpretation, it was realized that the best hope for a practical, implementable scheme was to approach the problem in three phases, all interrelated, but independent enough to allow for the progressive modular development of a multi-level sampling system. At each stage, operational feasibility will be evaluated so necessary revisions can be integrated into the system as needed.

INTRODUCTION

St. Regis Paper Company, Southern Timberlands Division, has been involved since 1971 in investigating the possibility of utilizing remotely sensed data as a viable data source in establishing a practical forest information system. The collection of the data must be economically feasible and the results applicable to large non-contiguous forest land holdings in the Southeastern Coastal Plain provinces of the United States, with precision levels commensurate with a broad range of user requirements.

Statement of the Problem and Background

Nature of the Problem.- With the inception of active forest management practices in the United States at the turn of the century, and especially with the intensification of these practices in the post World War II years, specifically in the South, a significant part of forest management activity has been devoted to the definition of the forest complex in terms of:

- . quantitative standing timber values
- . patterns of stand structure and conditions
- . dynamic response of the forest over time.

Quantitative Timber Values: Quantitative timber values refers here to those measurable quantities of interest defining timber as a raw material in terms of commercial units of value (cubic feet, cubic meters, board feet, tons, frequency, etc.). These values are important not only in describing the gross raw material availability as a single value, but also in providing a quantitative measure for alternative uses available from the timber supply on hand.

Forest Stand Structure and Condition: Very seldom is a forest described as a whole, but rather a conglomerate of many forest cover type components, occurring as a result of natural forest progression or from conditions resulting from man's cultural activity. While quantitative timber values describe the sum of individual tree measurements, stand structure and conditions describes the timber stands as productive entities. Structurally, stands are evaluated as to species composition, age classes of significance and density of stocking. Stand condition reflects the environmental situation under which the timber is growing, and the productivity (growth) potential as indicated by topographic position and growing site. Growing site is here defined as an index value relative to productive potential.

Stands then, are vegetative associations with individual quantitative values and growth characteristics. Stands may also constitute non-vegetative entities undergoing cultural transition, but are still considered part of the overall forest.

Dynamic Response of the Forest Over Time: Dynamic response refers to the growth and net change occurring throughout the forest complex over periods of time. Such growth represents the aggregate growth and net change over the whole forest represented by its constituent stands.

Magnitude of the Problem.-Any large wood-using manufacturing facility such as a pulp and paper company requires many hectares (acres) of timberland to support the raw material demand of the mills^{1/}. St. Regis, as a typical, large forest products company, owns or controls over 2.3 million hectares (5.7 million acres) in Continental United States and Canada. From these lands raw material is supplied to seven pulp mills and at least five saw mills producing products from wood studs to finish veneers. The extent of St. Regis land holdings is summarized in Table I.

As an operating division of the Corporation, Southern Timberlands includes over 680 thousand hectares (1.7 million acres) of forest land owned or controlled. From these lands, three pulp manufacturing facilities draw approximately 30 percent of their raw materials. When the lands are under full production, it is anticipated that company produced raw material will approach 70 percent of the mill requirements.

Geographically the three mill regions within Southern Timberlands are illustrated in figure 1. The mill regions comprise the major administrative subdivisions within the Division and are identified as the Jacksonville, Pensacola and Mississippi

^{1/} Throughout this study, common units of measure were used in lieu of SI units; thus, area = acres, volume = cubic feet, length = feet, or chains (66 feet).

Regions. The administrative components of these subdivisions are illustrated in figure 2. Relative area values are included for comparison.

Districts are the largest administrative subdivision within a mill region, and are usually composed of fee lands, and several ownerships. These ownerships represent the more than 90 leases and timber purchase contracts making up the 380 thousand hectares (949 thousand acres) of controlled land in the South; Table II.

Ownerships and fee blocks are further subdivided into Administrative Units. As the name implies, these are units maintained for record keeping and locational convenience. The smallest and most vital land subdivision within the Southern Timberlands is the Operating Area. Far more than mere administrative subdivisions, Operating Areas are functional biological data units from which information at all levels is derived. The evolutionary history of the Operating Area is an interesting one and reflects at once the traditional approach to the data acquisition problem and the vector with which remote sensing technology might be integrated with established procedure, to provide a timely data base of quantity, and precision to meet the current and future needs of management.

Background.- From the beginning of forest management in the South, the problem of securing adequate data from the forest has existed, and various schemes for gathering this information have formed an integral part of most forest management activity. Whether such data were manifested as cryptic scribbings on the back of an envelope or a totally automated information system, the basic objective has been the same; to establish current quantitative timber values associated with a heterogeneous array of timbered and non-timbered stands, and to identify and measure those variables most significant in the prediction of future quantitative timber values and stand profiles.

In the early 1950's an elaborate management plan was developed for Southern Timberlands utilizing the best information available. The core of this plan was an extensive inventory carried out by a light ground sample and photo interpretation of modified infra-red black and white images flown in 1952. The objective of this plan was to achieve even-aged management within one or two rotations through a checkerboard cutting pattern.

During this same period of time, a new ground sampling concept was introduced to southern forest managers. Called Continuous Forest Inventory by its developers, this technique was later revised and renamed Permanent Growth Sample (PGS). This sampling scheme was based upon permanent plot locations established on a very wide grid. Periodically measured on a three to five year basis, PGS was designed to provide overall forest statistics, and to establish growth and net change patterns. With very precise measurements as a feature, the prime objective of PGS was to establish growth rates either empirically or through regression techniques for the forest as stratified by those parameters most contributory in growth prediction, i.e., site, age and density.

Results from PGS highlighted two important points:

1. The variables controlling the growth patterns of the forest were not adaptable to rectangular management units, but rather, were closely allied with the criteria as earlier defined for a stand.
2. PGS could not stand alone efficiently as a data source in providing

information on volume and stand composition, in addition to growth and net change.

From the above, it was determined a different forest sampling technique was necessary to properly define volume and stand composition, and that any such scheme must use the stand as a primary unit of inventory since this vegetative association would be projected through time.

Parallel development of computer technology, both in hardware and software, cast forest data acquisition in a new light. The tools of operations research; linear programming, forest simulation, and mathematical scheduling provided the means for the development of long range planning models. The scope of data required increased, the quality of the data became more stringent and the timeliness of the generated information became vital. Inventory results became the main input source to these upper echelon planning models. Since small errors magnify, given the ingredient of time, the precision of this input became critical.

Since projections are made on an annual basis, the projective unit must be operable; that is, harvested or regenerated, within a year's time. Some stands were just too large to meet this annual operability criterion, and had to be subdivided. The stand and/or its subdivision was redefined as an Operating Area, and became the primary inventory and projective unit. The inventory of these areas became Operating Area Inventory (OAI). Figure 3 is an illustration of the range of data collected on PGS and OAI. Operating Areas became not only the basic inventory and projective units, but also the primary units for management, replacing the rectangular man-made configuration with a biological association whose management was to be optimized with applicable economic standards. Administrative Unit maps are generated from current color photographs flown at a scale of 1:15,840. Figure 4 shows such a photo with delineated Operating Areas and the inventory sample points located as permanent records.

To augment OAI and to insure current data, the basic inventory information is annually updated to the first of the year. The updating file has become the major source of forest information used as input into the long range planning models, and other analyses as may be required within the Division.

Purpose

The data required to measure and establish those parameters of quantitative value, stand structure and composition, growth and net change are broad indeed. Traditional data acquisition procedures are inadequate to acquire the data at a level of precision and speed to meet the current and projected needs of management. Developing methods and techniques to augment the data acquisition activity without sacrificing the accuracy or precision of data collected constitutes the primary thrust of this research activity. As of this writing, no conclusive results have been reached. It is the objective of this report to outline the methods, and where established, the procedures taken in the approach to resolving this problem.

METHODS AND PROCEDURES

Approach

Feasibility Study.- In the early 1970's, remote sensing, as a concept beyond

that of conventional photography, materialized before the general public almost overnight. Replete with unfamiliar data renditions, hardware configurations, computational analysis procedures, and, of course, the associated vernacular, remote sensing developed an aura of mysticism, with a "Buck Rogers" overtone. To a potential user, the urge was to "ride off in all directions at once". St. Regis was no exception. The literature abounded with problems and their solution and it was easy to become enthusiastic over all this new technology and its potential. It soon became apparent that the solutions afforded were for problems we didn't have. For the most part, the resolution of these problems was of academic or local interest only. The question had to be: "Can this new technology, stripped of its shroud of mystery, contribute significantly to the solution of the data acquisition problem within Southern Timberlands?"

It was determined to approach this technology slowly and deliberately through a feasibility study. The objective was, through review of literature, conversing with those working in the area and the attendance of selected short courses, to determine what the real possibilities were, and what techniques held the most promise of success in solving the problem.

After a year and a half, certain conclusions were reached.

1. Operational remotely sensed data acquisition was not yet a reality for the private sector.
2. Digitizing of photographs, either single or multi-band involved so many uncontrolled variables as to render the data analysis questionable at best.
3. Given the data and the proper digitized format, the hardware/software analysis interface was a formidable one requiring high costs for questionable gain. While the hardware (computer capacity) was and had been available, existing software packages were rare, complicated and not tailored for general user applications.
4. The real potential of remote sensing, beyond photogrammetry, was as a tool to augment already ongoing systems, and at least for the present, should not be considered as a stand-alone technique for forest data acquisition.
5. The need for specific problem definition became apparent. Such a definition would include an identification of what was needed, a complete review of known techniques and methodology, and an assessment of what additional capability was necessary to fulfill the Divisional data requirements.

Scope.- The scope of the remote sensing research project, as proposed, is broad, exceeding by far the range of any one study plan. It was proposed to divide the research into three phases; to establish a photo/ground sample correlation, to investigate techniques of multi-spectral digital analysis, and to develop a semi-automated multi-level sampling system. Each phase is to be controlled by a work plan but will be related to the other phases, and in many cases, work will be carried out simultaneously. To properly verify results, research activity will be replicated at least three times throughout the Division. These areas are illustrated in figure 1 and are; Jacksonville Mill Region (J-T), Lower Coastal Plain, Flatwoods, 30,000 hectares (76,000 acres); Pensacola Mill Region (P-T), Middle Coastal Plain, 6,800 hectares

(17,000 acres); and the Mississippi Mill Region (M-T), Middle Coastal Plain, 31,600 hectares (79,000 acres), respectively.

On all three test areas, aerial data were collected at various altitudes, yielding scales of 1:31,680, 1:15,840, and 1:7,920. The data included mylar transparencies and contact prints from color negatives and color infra-red aerial film positive transparencies. It was planned during the process of this investigation to determine an optimum combination of scale and media for interpretation.

I. Photo-Interpretive/Ground Sample Correlation

Hypothesis.- Basic correlation is possible between photo based estimates of forest data and the same data as measured on the ground, such that sample efficiency will be improved enough to significantly reduce the ground sample necessary at the Operating Area level.

Objectives.- The basic objective of this phase of the investigation is to review and gain an expertise in existing photo-interpretive techniques and methodology, and to establish a reasonable correlation between ground samples and photo-estimates from low to medium scale photography. To achieve this objective, the photo-interpretive ground sample phase was divided into three investigative segments.

1. A review of statistical design and ground sampling selection criteria and compatibility with photo interpretive techniques.
2. Direct stereo measurement capability in premerchantable, non-commercial, understocked and non-stocked forest land in terms of frequency and area allocations.
3. Direct stereo measurement and estimation capability in merchantable timbered land in terms of relative timber quantities and timber stand conditions, and the establishment of a degree of correlation between such photo estimates, and the corresponding ground sample.

Procedures.- The procedural approach to this phase of the investigation will follow methods and procedures already developed and documented and will include variations of this technology as seems appropriate.

Stereograms: To establish an expertise in photo interpretation and to serve as a future training tool, stereograms were constructed representing insofar as possible the range of cover types, density and broad site/productivity levels. Bernstein (1968) defines stereograms as "...mounted stereographic pairs of photographs which present three-dimensional views of known conditions or objects of interest". Normally, relationships established by the stereogram are applied to other areas of similar composition.

The stereograms were constructed from color aerial photographs flown at an average scale of 1:15,840. Choosing by observation the most representative area for the conditions being depicted, a cluster sample was taken in a 16 hectare (40 acre) block as a primary sample unit within which 16 sample points were systematically distributed. Data collected from these points describe in detail the characteristics of the conditions represented. Figure 5a and 5b illustrate the stereogram format and the included detail information as gathered from

the sample block. Figure 5c illustrates the ground representation of this stereogram. For narrow or small areas of significance, where the establishment of a 16 hectare block was not possible, smaller areas were delineated and sampled accordingly; figure 6, a-c.

Sample Design: The sampling scheme for Phase I might be best called a stratified double sample design. Stratification is used to break down a basically heterogeneous forest into more uniform strata in an attempt to reduce the variation within the forest subdivisions; Husch, et al (1972). A broader range of variation was allowed within the strata than would be allowed within an Operating Area; however, the strata did reflect generalized areas of similar cover type, age and density classes. Work to date has occurred only in the Pensacola area, and for this area, five strata were recognized:

1. Merchantable Natural Pine^{3/}
2. Regenerated Merchantable Pine, ≥ 18 years old
3. Regenerated Merchantable Pine, < 18 years old
4. Merchantable Pine-Hardwood/Hardwood
5. Non-stocked, Understocked, Non-Productive, Premerchantable.

Upon completion of the stratification process, a sample point network was installed for double sampling. Double sampling involves the estimation of a secondary variable X in a first phase and the subsample of a related primary variable Y in a second phase. Generally such an approach is used where the obtaining of the variable X is relatively inexpensive with relation to obtaining the variable Y. Photo/ground sampling procedures are a classic example of the double sampling technique. In this case, X is a photo estimate of stand density derived from the evaluation of the photograph's tonal and textural attributes. Photo estimates are relatively inexpensive. The primary variable Y is the measured stand density, in terms of volume, on the ground based upon individual tree estimates. Ground samples are relatively expensive.

Since tree volumes are of concern, double sampling is extended to a final stage wherein the individual tree volume estimate becomes X, and the measure of the tree's volume becomes Y. Precise individual tree measurements are secured using a Barr & Stroud Dendrometer. Both phases of a double sample are mutually dependent since the measurements in the second phase are taken as a portion of the sample in the first phase. It is vital, therefore, to make sure the actual selected photo location is occupied on the ground, and that individually measured trees are included in those estimates.

The method of selecting Y in the second stage, is one of unequal probability, wherein the probability of an item being selected is proportional to some predictive quantity, hopefully correlated with the values of interest such as volume.

^{3/} Merchantability is an arbitrary size limit associated with stem diameter as measured 1.27 meters (4.5 feet) above the ground (diameter breast height, DBH). Minimum merchantability criteria is 12.7 cm (5.0 inches at DBH) for all species.

Such a procedure is known as 3P sampling; Grosenbaugh (1971). The measured values of Y taken as a light second phase sample will be used to correct the estimated variable X, obtained from a heavy first phase sample. Such a correction takes the form of a correction regression made between X and Y. The measure of efficiency of double sampling is the degree of correlation achieved between X and Y. Such a correlation can be expressed as a coefficient of simple correlation of the form:

$$r = \sqrt{1 - \frac{SX^2}{\sigma Y^2}}$$

where: r = coefficient of simple correlation
 SX^2 = standard deviation of the difference between X and Y
 σY^2 = standard deviation of the sample population

At each sample point, a multi-stage sample cluster was established consisting of four subsample points located one chain^{4/} from the center point in cardinal directions. The clusters sampled a primary unit of .4 hectares (one acre) in size. This rather large plot size is used because it permits the interpreter to average minor variation in stand structure. Also, this provides a larger "target" for the field crew. The exact correspondence between the areas estimated on the photo and on the ground is considered essential in establishing a high correlation between X and Y.

Photo estimates have been made on all primary sample units and field measurements are now in progress.

Upon completion of this work, an Administrative Unit/Operating Area overlay will be superimposed and through further double sampling with photo interpretation, strata volumes will be distributed to the associated Operating Areas. The interpreter will have the benefit of the stratified results in terms of averages and ranges of the quantities of interest.

Possibility of Success: The idea of cruising timber from aerial photographs is not new, it has just been overlooked in many areas. The benefits in efficiency were pointed out in the late 1940's and early '50's; Moessner and Jensen (1951). Elaborate aerial volume tables were published; Avery and Myhre (1959), to be followed by forest typing techniques, Avery (1960). It is probably safe to say, with few exceptions, that more serious photo interpretive efforts were made in the South in these early years than has been done since. Currently aerial photographs are used primarily as locational and mapping tools.

It is felt that during a period where knowledge of the forest was slight and access difficult, aerial interpretation was relied on out of necessity. As

^{4/} Gunters chain, a standard forestry unit of linear measure.
 1 chain = 66 feet = 20 meters.

management intensified, information needs transcended that available from the then current photogrammetric techniques. Several things have occurred since to indicate this may no longer be the case.

1. The high quality of photo products available both in color and color infra-red.
2. The change of the primary unit of management from a rectangular heterogeneous block to relatively uniform biological entities.
3. The existence of a substantial base of information built upon prior knowledge.
4. Development of more efficient sampling techniques.
5. The availability of high quality, relatively inexpensive photo interpretive equipment.

In light of the above, it is felt that the probability of establishing an information base suitable for management requirements through a photo/ground double sampling procedure, alleviating the ground sampling effort, is encouraging.

II. Multi-Spectral Digital Data Analysis

Hypothesis.- Given adequate correlative capabilities from Phase I, that similar correlation can be established between ultra-small scale imagery (as may be secured from LANDSAT or other airborne platforms), and conventional middle to large scale aerial photographs; negating the necessity of correlating such small scale imagery directly to ground sample units.

Objectives.- The overall objective of this phase of study is to evaluate the usability of multi-spectral, small scale digitized data as a viable data source in forest data acquisition, such that these techniques become a significant contributor to a multi-level sampling system.

A coordinate objective will be to ascertain the applicability of existing ADP software in achieving the analysis and output necessary and to determine if such software packages can be modified and streamlined for more general use with existing hardware, as might be available to any user group.

In addition to the broad objective statement made for this phase, it would seem that several ancillary objectives, not so dependent on the success of Phase I, could be reasonably expected, and would include:

1. Broad cover type identification and delineation.
2. Separability of various forest density classifications.
3. Geometric resolution.
4. Changing land use patterns.

Procedures.- The procedures to be followed in Phase II are largely dependent upon Phase I. It is fully expected that LANDSAT data will be used because of its availability and reasonable cost. It is further anticipated that these data will be evaluated in both the multi-band photo interpretive mode and in the multi-spectral digital mode.

With the data source available, there will be a need to establish the system of software packages to be used, if indeed such exist, to meet our objectives. It is strongly felt that considerable commitment must be associated with this phase, and possibly a consortium may be the most logical approach to the problem. With institutional representation as part of such a cooperative approach, the other participating members could be from interested companies or as inter-divisional participation within our own organization. The commitment might well include sponsorship of graduate assistantships at various levels. In any case, the procedures followed at this stage of the investigation are not well established, and often may be just hints of possible directions to pursue.

Known classification techniques will be investigated to ascertain the level of precision possible in separating the many densities involved. Assuming classification can progress beyond broad forest types of a level 1 classification; Anderson, et al (1972), is the geometric fidelity sound enough to establish property boundaries given digitized maps? If this capability is possible, then how well can density classifications be separated; and can there be a correlation established between these density levels (X) and those levels as established on aerial photographs (Y)?

Possibility of Success.- The procedures to be followed and the following discussion are, of course, largely conjecture. Accordingly, the degree of success of this phase is speculative; however, there are some indications of at least partial success in most areas. At the outset, forestry applications are well suited to ultra-small scale imagery, due to the non-critical nature of absolute resolution. Forestry operations, in general, occur over broad areas, usually at least 8 hectares (20 acres) and generally from 40-120 hectares in size (100-300 acres). Given reasonable geometric fidelity, most of these areas could be readily identifiable.

It is true that digitized data lack the tonal, textural and geometric characteristics of a photograph, but hopefully the multi-spectral aspects of the imagery will overcome some of these disadvantages and will add some advantages of their own. Multi-spectral data, in contrast to photographs, can take advantage of spectral "signature" characteristics. Analyses have been successful in delineating several land and vegetative classes, and have aided in differentiating areas of contrasting densities; Yost, et al (1971).

Finally, it should be pointed out, that this study is not and cannot be dependent on satellite imagery, LANDSAT or any other, simply because there is no guarantee of a data continuum from this source. Rather, efforts are being directed toward multi-spectral digital analysis applicable to data from whatever source. It seems fair to expect success at least in generalized terms especially in the area of the ancillary objectives, and the possibility of success in achieving the primary objectives is too provocative to overlook.

III. A Semi-Automated Multi-Level Sampling System

Hypothesis.- Given reasonable success in Phase I and Phase II, a semi-automated multi-level sampling system is achievable in which data acquired at several scales can be integrated with digitized ground truth and geometric area boundaries to provide an updated, computer oriented data bank of information at precision levels commensurate with the needs of management.

Objectives.- The overall objective of this third and final stage is to integrate the salient features of Phase I and II into a functional data acquisition system, semi-automated and compatible with the long range planning data base required.

Procedures.- Procedures at this point in time are largely uncertain since implementation of Phase III is still somewhat in the future. Multi-level sampling as used in the context of this paper refers to a sampling scheme where data are collected at various levels of precision. At the broadest level estimates are made, hopefully related to other variables measured more precisely at some lower level, with these variable estimates in turn, being related to variables measured at still another lower and more precise level. In effect, a multi-level sample is merely a system of inter-related double samples. The basic multi-level approach as put forward in the past establishes a broad generalized data base from digitized ultra-small scale imagery, Aldrich (1971). From this base, subsample blocks are superimposed as a basis for an underflight estimate; finally, strips of extremely large scale photography are flown upon which ground sampling takes place utilizing some form of unequal probability sampling much like the 3P/dendrometry procedures outlined by Grosenbaugh. From the ground sample, data are expanded to the strip and then to the block and finally to the entire area. Although Aldrich had mixed results in this study, the concept was statistically sound and with some more refinements could be a workable approach. Unfortunately, such an approach would necessarily ignore the Operating Area, or any other small subdivision.

Because of the Operating Area's central role as a primary inventory, projection and management unit, classical multi-level sampling procedures must be modified to meet our basic objectives. The modification involves the tie between the Operating Area and the other levels of sampling units. For this reason, the establishment of a sound correlation between photo estimated average quantities and average quantities as measured for an Operating Area, is essential for success of the proposed system. Such a correlation would provide the link between a standard multi-level sampling procedure and the Operating Area. Such a link, then, would allow for the exploitation of the multi-level results at the ownership, district or mill region level without compromising the integrity of the Operating Area.

Possibility of Success.- If Phase I and II are successful at least to the degree of establishing the multi-level concept as a feasible option, success in Phase III is assured, at least in theory. The principal and most difficult task of Phase III, is to relate the multi-level approach to an information system, operationally executable, economically feasible, with results that enjoy the confidence of management. From a practical standpoint, this task represents the bottom line of the entire project.

DISCUSSION

Operational considerations in adapting any new technology are always a challenge. New ideas must be presented with gusto in almost a revolutionary context just to

attract attention. Once given the sanction to proceed, however, an evolutionary philosophy must be adopted to assure success, or at least to avoid disaster; witness the development of the computer sciences in the '50's and '60's.

Remote sensing as a relatively new technology, and its integration into an ongoing data acquisition system, is no exception to the above. It is vitally important not to be "carried away" by the dazzling possibilities and to look toward this technology as a tool and not a panacea to all data acquisition problems. It was felt that stepwise progression toward a multi-level sampling system was the logical approach to the problem, where expertise could be built on past experience.

Because of the nature of a modular approach to the problem, the objectives as stated for the various stages and the procedures outlined are subject to change as experience dictates. Although the overall complex of the problem solution may change, there seems to be a reasonable chance of at least a partial solution based upon work already done.

Remotely sensed ultra-small scale imagery is being viewed as one of many data acquisition tools which collectively establish a data base far more comprehensive than any one method could singly provide.

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**TABLE I.- ST. REGIS TIMBERLANDS -
HECTARES BY TYPE OF HOLDING, BY DIVISION**

Location	Thousands of Hectares		
	Owed	Controlled	Total
Northern Timberlands	497 (1,243) ^a	5 (12)	502 (1,255)
Southern Timberlands	312 (782)	380 (949)	686 (1,716)
Northwest Timberlands	196 (489)	66 (164)	262 (653)
Canadian Timberlands		765 (1,912)	765 (1,912)
Totals	1,006 (2,514)	1,215 (3,037)	2,221 (5,551)

**TABLE II.- SOUTHERN TIMBERLANDS DIVISION
HECTARES BY TYPE HOLDING, REGION AND STATE
JANUARY 1, 1975**

State	Hectares		
	Owed	Controlled	Total
Jacksonville Region			
Alabama		286 (715)	286 (715)
Florida	52,152 (130,380) ^a	62,653 (156,633)	114,805 (287,013)
Georgia	27,257 (68,142)	148,383 (370,958)	175,640 (439,100)
Total Region	79,409 (198,522)	211,322 (528,306)	290,731 (726,828)
Pensacola Region			
Alabama	38,676 (96,671)	65,946 (164,864)	104,622 (261,555)
Florida	103,920 (259,799)	31,583 (78,958)	135,500 (338,751)
Total Region	142,596 (356,490)	97,529 (243,822)	240,122 (600,306)
Mississippi Region			
Louisiana	1,520 (3,799)	3,392 (8,480)	4,912 (12,279)
Mississippi	79,949 (199,873)	70,800 (177,000)	150,749 (376,873)
Total Region	81,469 (203,672)	74,192 (185,480)	155,661 (389,152)
Total Division	303,474 (758,684)	383,041 (957,602)	686,514 (1,716,286)

^a Figures in parenthesis represent thousands of acres.

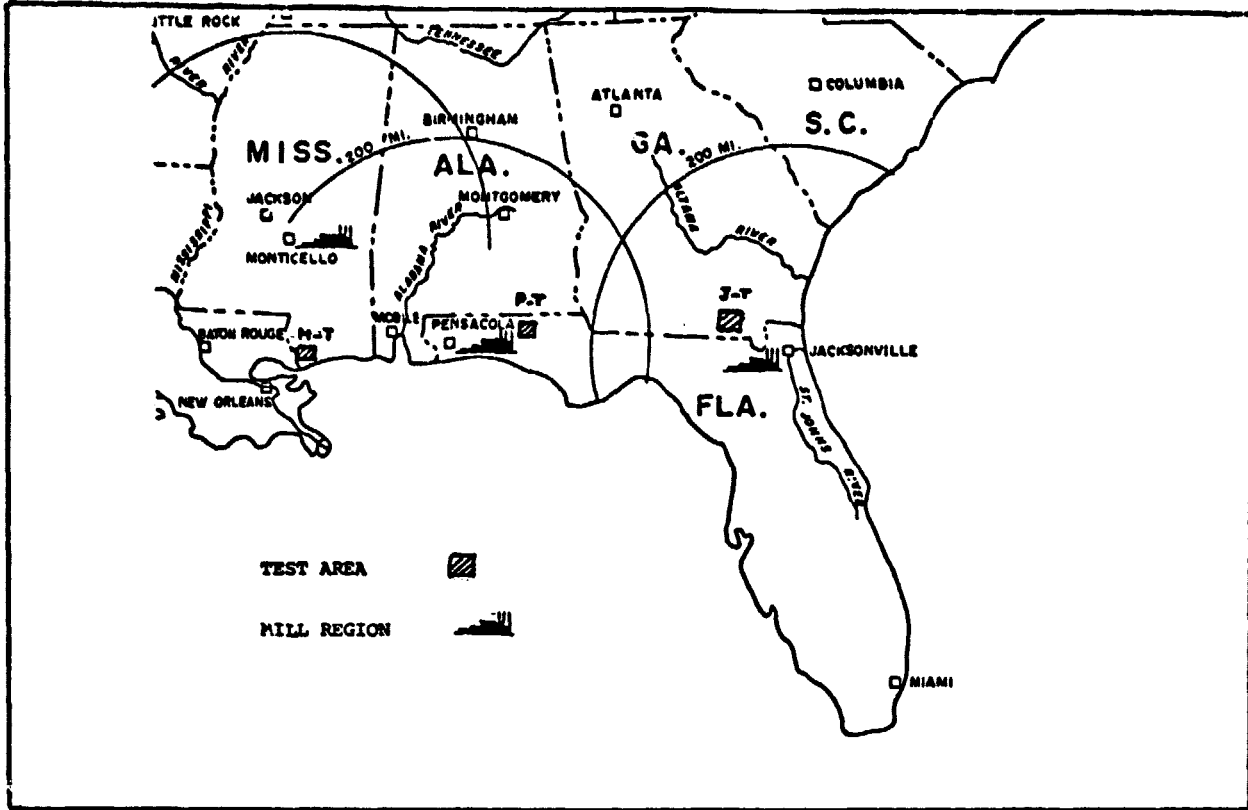


Figure 1 - St. Regis, Southern Timberlands Mill Locations and Remote Sensing Test Areas.

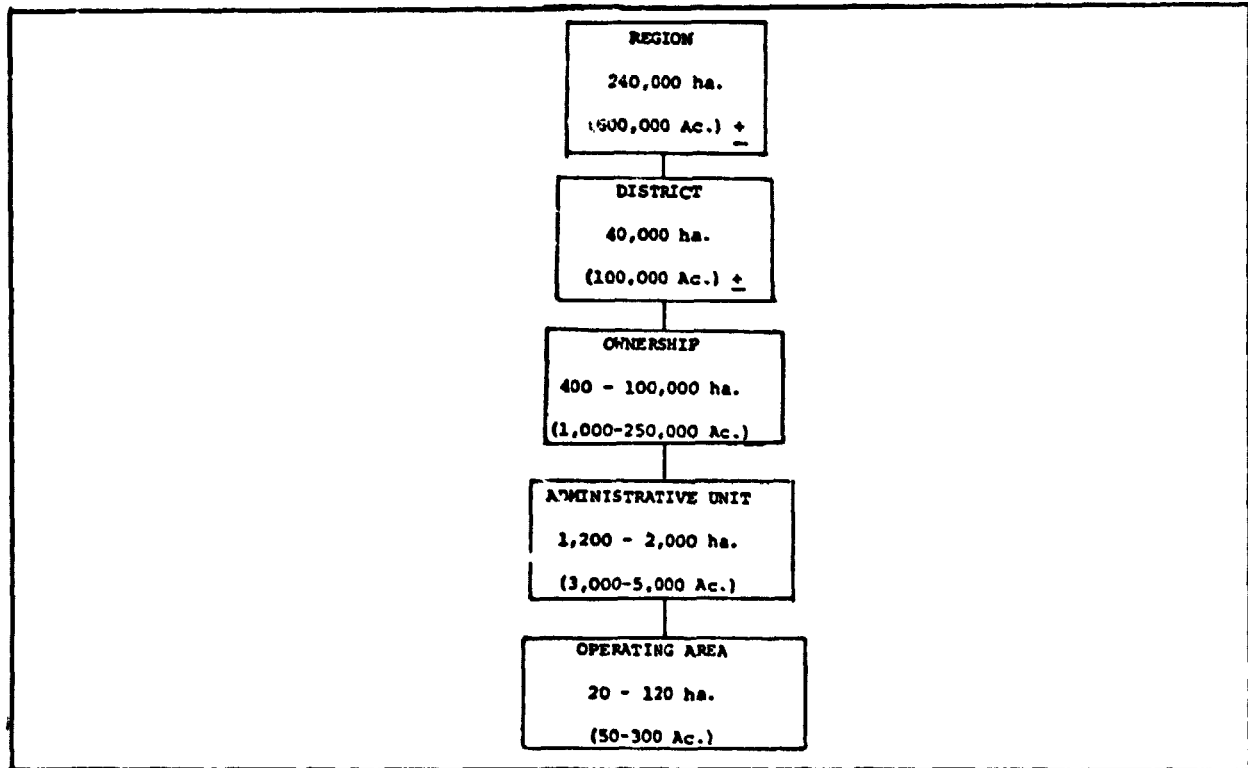


Figure 2 - St. Regis Southern Timberlands Mill Region Administrative Hierarchy

**ST. REGIS PAPER COMPANY PERMANENT GROWTH SAMPLE
FIELD TALLY SHEET**

State County T R S Crew						-1-	-2-	-3-	-4-	-5-	-6-	-7-												
						Plot No.	Date	Mill Region	Dist.	Owner.	A.U.	O.A.												
Pl. Yr. District No. Trees (Surviving)						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
						-8-	-9-	-10-	-11-	-12-														
P.B.						For. Type	For. Topo	Size Class	Age Cl.	Ht. Cl.														
						20	21	22	23	24	25	26	27	28	29									
Dist. Chains Tree Dist. Bearing ... Ft. Bearing						-13-	-14-	-15-	-16-	-17-														
						Site	Gr. Cvr.	Pine Rep.	Hwd. Rep.	Cyp. Rep.														
						30	31	32	33	34	35	36	37	38	39	40								
						-18-	-19-	-20-	-21-	-22-	-23-	-24-												
						Density (Crn. Cvr.)	Stand Cond.	Past Mgt.	Injury	Slope	Asp.	Growth												
						41	42	43	44	45	46	47	48	49	50	51	52							

25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Tree No.	Species	DBH	Crown			4	5	6	7	8	9	10	11	12	13
20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
			Cl.	Diam.	Length.			CTF	Sw	Total	Ht. to	Ht. to			
								Soundness	Soundness	Ht.	4" Top	8" Top			
											44	45	46	47	48
											49	50	51	52	

OAT FIELD TALLY SHEET

TRACT: _____ DATE: _____ CREW: _____

DISTRICT: _____ OWNER (AO, UNIT) O.A.: _____ POINT NO.: _____

SITE INDICATOR TREE

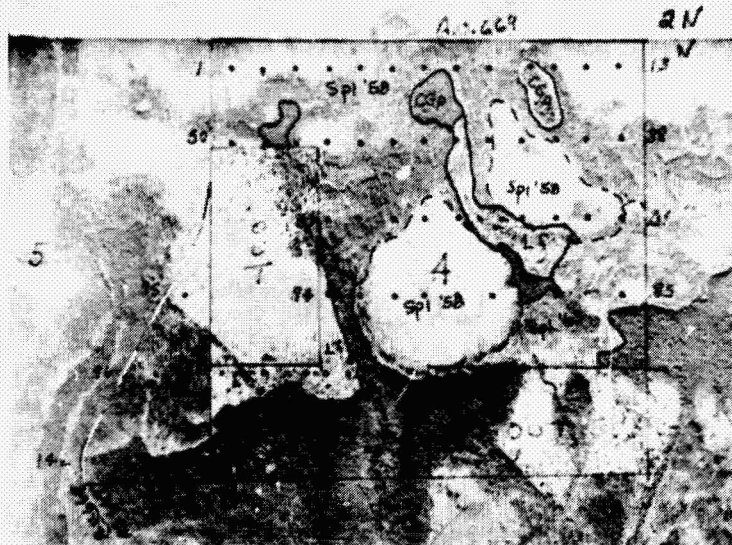
ST	TOWNSHIP	RANGE	SEC	SLOPE	AS	SA	TYPE	TOPO	AGE	SI/50	CND	DMG	SPEC	DBH	HT.	AGE

PINE PRE-MERCHANTABLE HARDWOOD PRE-MERCHANTABLE CYPRESS PRE-MERCHANTABLE

TREE DATA

IND	SPECIES	DBH	CR	VG	PAD	URL	TWS	PULPWOOD		SANTIMBER		QUALITY	
								HEIGHT	SOUNDNESS	HEIGHT	SOUNDNESS	SOUNDNESS	OTH
1													
2													
3													

Figure 3 - St. Regis Data Acquisition Field Tally Sheet Forms

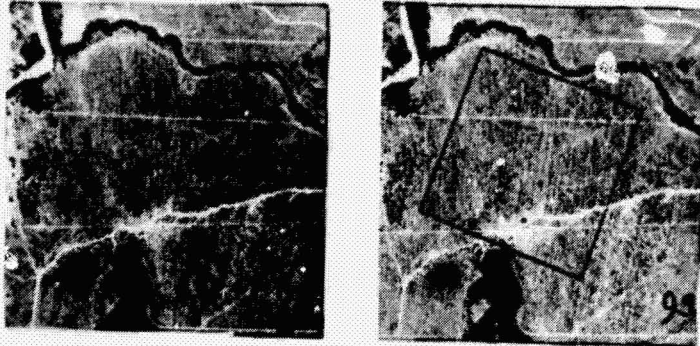


KEY:

- | | |
|------------|--|
| Out | property not owned or controlled |
| Spl | Slash pine plantation and date of planting |
| PHb | Pine/hardwood branch |
| CGp | Cypress gum pond |
| Lf | Longleaf flat |

Figure 4 - An administrative unit with included operating areas and ground sample grid.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR



(a)

BLOCK NO. P-9

Condition	Structure
For. Type <u>PLANTED SLASH</u>	Cords/Acre
Topo. <u>UPLAND</u>	Pine <u> </u>
Ground Cover	Hardwood <u> </u>
<u>SHORT GRASS</u> <u>55</u>	Av. Merch. Ht. <u> </u>
<u>WIRE GRASS</u> <u>20</u>	PM Pine S/A
Site <u>Q 1</u> <u>57</u>	1-2" <u>280</u> 3-4" <u>150</u>
Soil Color <u>03</u>	Crown Closure <u>25%</u>
Age <u>6</u>	C. V. <u>2.3</u>

(b)



(c)

Figure 5 - A standard stereogram format showing: (a) a stereo pair with primary sample unit layout; (b) associated statistical data; (c) ground representation.

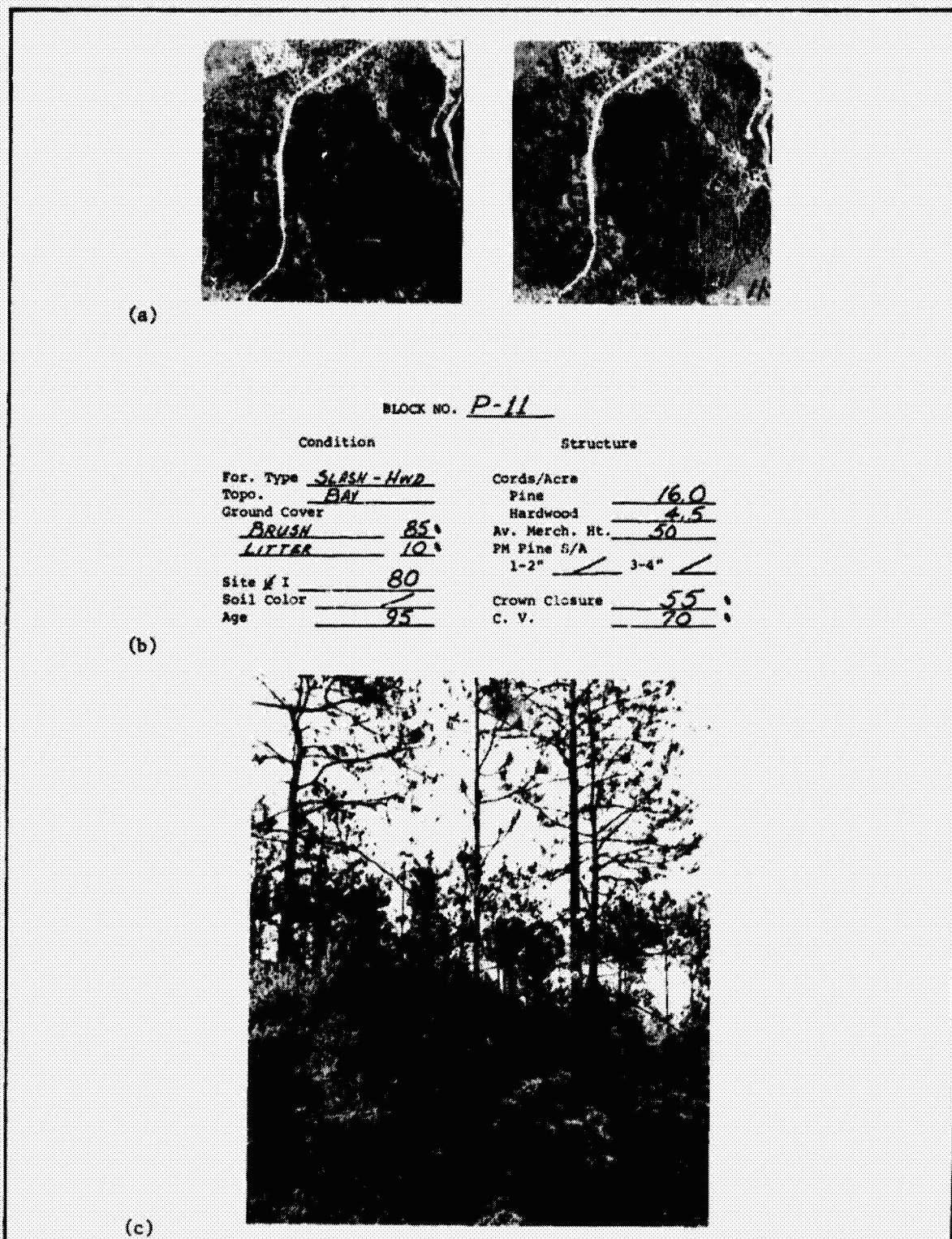


Figure 6 - A standard stereogram format showing an abbreviated sample unit layout showing: (a) a stereo pair with primary sample unit layout; (b) associated statistical data; (c) ground representation.