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Aiken, S.G., P.R. Newroth, and I. Wile. 1979. The Biology of Canadian Weeds. 34. Myriophyllum spicatum L. Canadian J. Plant Science 59:201-215.

Ferguson, E.L., Jorde, and J.J. Sease. 1981. Use of 35mm color aerial photography to acquire mallard sex ratio data. Photogrammetric Engineering and Remote Sensing. Vol 47. no.6. June 1981. pp. 823-827.

Hardt, F.W., G. Hodgson and G.F. Mikol. 1983. Draft manuscript. Saratoga Lake diagnostic-feasibility study and management plan. September 1983.

Heinen, Joel T. and R. Mead. 1981. Inventory of wildlife habitat from color aerial photography for Cobb Island, Virginia. In: Proceedings of the Eighth Biennial Workshop on Color Aerial Photography in the Plant Sciences. Amer. Soc. Photogrammetry. Falls Church, VA. pp. 39-44.

Martin, et al. 1951. American wildlife and plants. Dover Publications. New York.

Mead, R.A. and P.T. Gammon. 1981. Mapping wetlands using orthophotoquads and 35mm aerial photographs. Photogrammetric Engineering and Remote Sensing. Vol. 47. no. 5. May 1981. pp. 649-652.

Meyer, M. and P. Grumstrup. 1978. Operating manual for the Montana 35mm aerial photography system. 2nd revision. IAFHERSL Research report 78-1. University of Minnesota.

Meyer, M., N. Miller and R. Hackett. 1981. Application of 35mm aerial photography to forest land use change analysis in the Upper Peninsula of Michigan. IAFHERSL Research Report 81-2. University of Minnesota.

Spencer, R.D. 1978. Map intensification from small format aerial photography. Photogrammetric Engineering and Remote Sensing. Vol 44. no.6. June 1978. pp 697-707.

PRELIMINARY RESULTS FROM A METHOD TO UPDATE TIMBER RESOURCE STATISTICS IN NORTH CAROLINA

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BIOGRAPHICAL SKETCH

The principal author began his higher education as a physical geographer. Contact with graduate faculty engaged in remote sensing and years of work experience in custom photofinishing, led to a career choice involved in the monitoring of natural resources. Following a graduate degree in Forestry, the author began working for the Multiresource Inventory Techniques Project of the USDA Forest Service, with whom he is currently employed.

ABSTRACT

Forest Inventory and Analysis units of the USDA Forest Service produce timber resource statistics every 8 to 10 years. Midcycle surveys are often performed to update inventory estimates. This requires timely identification of forest lands. There are several kinds of remotely sensed data that are suitable for this purpose. Medium scale color infrared aerial photography has the spatial resolution necessary to locate and identify forest lands undergoing transition. This study examines the land cover and timber resource acreage classification results produced by the photointerpretation of 111, 1,000 acre plots in North Carolina imaged on 1:12,000 scale color infrared aerial photography acquired in November of 1985. The results are compared with timber resource statistics produced by the Southeastern Forest Inventory and Analysis unit in 1983. There is a high degree of agreement between the two data sources in the majority of categories. The discrepancies, however, may prove to contain much useful and timely information.

INTRODUCTION

Continual periodic inventory provides an information basis for making decisions regarding the use or replenishment of renewable resources. The Forest Service was first directed to undertake periodic nationwide surveys of timber resources by the McSweeny - McNary Act of 1928, and more recently by the Forest and Rangeland Renewable Resources Planning Act of 1976.

The Southeastern Forest Inventory and Analysis (SE FIA) unit is responsible for producing a statistically reliable inventory of timber resources in the five States of the southeastern U.S. every 8 to 10 years. Required data are collected from permanent field survey plots with a sample size sufficient to produce State and regional estimates of the timber resource base. These surveys provide reliable information regarding the status of the timber resource at the date of inventory, but subsequent changes in land cover/land use rapidly outdate the results. Gathering and compiling these data are time-consuming, and limit the frequency of full field surveys. Desire for more frequent updates on the status of the timber resource has generated pressure to accelerate the survey cycle to every 6 years.

Procedures to monitor recent harvest, regeneration, and land cover change through time are needed. Such procedures must be rapid, reliable, repeatable, compatible with current SE FIA procedures, and implementable at a reasonable cost.

OBJECTIVE

Remote sensing meets many of the needs identified above in the inventory of natural resources. The overall study considers interpretation of remotely sensed data of a variety of scales in an extensive sampling framework. The long-term objective is to integrate routinely available remotely sensed data that will provide timber resource acreage data for updating SE FIA field survey statistics. This paper discusses the overall proposed method, and then focuses on the results obtained from the interpretation of one source of information: medium scale color infrared aerial photography.

SELECTION OF REMOTELY SENSED DATA

Several sources of remotely sensed data would be periodically available for use in estimates of acreages undergoing harvest, regeneration, or other land cover change. Options include National High Altitude Photography (NHAP), digital or analog Landsat satellite imagery of the Thematic Mapper (TM) or Multispectral Scanner Subsystem (MSS), and specially acquired aerial photography.

Medium Scale, Color Infrared, Custom Aerial Photography (MSP)

Land cover and forest resource acreage estimation and change detection using medium scale (1:10,000-1:30,000) aerial photography has been investigated frequently and is well documented (e.g., Loetsch and Haller 1973, Aldrich 1979, American Society of Photogrammetry 1983, Avery and Berlin 1985). Although its high spatial resolution facilitates the identification of harvest and regeneration conditions, high cost per unit area coverage is a limiting factor. Color infrared (CIR) aerial photography provides more forest type information than either color or panchromatic aerial photography at similar or smaller scales (Stephens 1976).

Harvesting and development of access roads was monitored in a cost-effective manner in Canada using 1:15,840 scale panchromatic aerial photography (Catto 1965). Assessing the success of regeneration, Swantje (1957) utilized 1:15,840 scale panchromatic aerial photography and found that coverage acquired in the fall provided the best discrimination of fir seedlings under dense willow

and fern coverage. Nelson (1977) studied regeneration on forest industry lands in North Carolina using 70 mm CIR aerial photography at scales of 1:12,000 and 1:24,000. The use of aerial photography resulted in a 40% cost reduction when compared with ground monitoring of areas prepared for regeneration, while aerial estimates were within 1% of ground measured acreage.

Ashley and Cohen (1985) separated spruce and fir regeneration into 3 stocking percentage categories using aerial photographic scales of 1:1,200 to 1:12,000. The ground-measured stocking level of overtopped stands was overestimated by 2.2 percent based on the visual interpretation of the 1:12,000 scale photography. The researchers note that reports of high accuracy in estimating regeneration stocking are contingent upon the matching of aerial photographic scales with the size or age of seedlings in the population.

National High Altitude Photography (NHAP)

The U.S. Geological Survey initiated the NHAP program in the spring of 1980. One of the proposals of the program proposed to provide 1:58,000 scale CIR aerial photographic coverage for all areas of the conterminous U.S. on a 5 year cycle. The first cycle was made during leaf off conditions (NHAP I). Repeat coverage is planned for acquisition during leaf on conditions (NHAP II) at 1:40,000 scale, although some of the NHAP II coverage has already been produced at a scale of 1:58,000. An attempt will be made in the NHAP II program to acquire photography of entire states on a sequential basis, thereby reducing the delay in obtaining state wide aerial coverage, which required 5 years in North Carolina (1981-1986).

A study completed in Minnesota examined the utility of 1:58,000 scale NHAP photography for updating forest resource inventories (Duncan et al. 1984). NHAP imagery was able to provide information concerning areal extent of harvest and regeneration regions, softwood species delineation, site preparation methods and success, and the location of various terrain features (i.e., water bodies, forest access trails) to a 0.5 acre ground resolution. The authors noted that the leaf off condition of the NHAP I photography limited hardwood species determination. It was concluded that NHAP photography will play a major role in updating resource inventories whose baseline may have been previously established using conventional larger scale aerial photography.

A study comparing the precision and accuracy of general land cover classification using NHAP and optical bar panoramic photography (OB) of 3 counties in New Jersey found that there was no significant difference in precision between the two with overall accuracies of 91.5% and 82% respectively (Scott et al. 1987). Separation of non-forest land from non-forest land with tree cover and forest land was best accomplished using stereo interpretation of NHAP. The photointerpretation of OB photography was done monocularly. Not only does this highlight the important advantage of stereoscopic interpretation, it also suggests that NHAP may be used to distinguish areas that have tree cover but are not actually part of the land base involved in timber resource production.

The major drawback to the use of NHAP in repetitive aerial survey is the long acquisition cycle. The present frequency of SE FIA field inventory is comparable to the number of years required to obtain cyclic aerial photographic coverage of North Carolina from NHAP. However, this may change according to levels of funding channeled to the NHAP and SE FIA programs.

Satellite Imagery (Landsat MSS and TM)

Analysis of satellite imagery for forest resource information has been going on for well over a decade (American Society of Photogrammetry 1983). The Multispectral Scanner Subsystem (MSS) and the Thematic Mapper (TM) represent the first and second generation of electro-optical, scanning radiometers flown aboard Landsat satellites and designed for monitoring natural phenomena. Seven channel TM data, with 30-meter ground resolution (in all but one thermal channel) also features radiometric improvements over the four-channel, 80-meter ground resolution of MSS data (Irons 1982). Both imaging systems currently provide repeat target coverage every 16 days. TM data are more expensive to acquire and analyze digitally than MSS data covering the same area. Either type of data can be acquired as a computer-compatible tape (CCT) or as a photographic product.

Digital analysis of TM data in CCT format has greater potential for classifying land cover and forest resources to a finer level of detail than does MSS data (Dottavio and Williams 1982). Conversely, the increased spectral and spatial heterogeneity, and volume of higher resolution TM data dictates the need for development of new data handling methods to decrease computing loads. Visual analysis of TM data may be most beneficial to practicing foresters (Williams and Nelson 1986).

Digital classification of land cover, using both MSS and TM data, have revealed consistent sources of error. The shifting of spectral signatures of a given land cover type from one scene or one date to another precludes the rapid universal extension of spectral signatures and necessitates constant, localized classifier training, especially over large geographic regions (Aldrich 1979). Landscape shadowing plays havoc with classification algorithms, as does the separation of forest from forested urban neighborhoods (Hoffer et al. 1978). The low spatial resolution of MSS data increases the likelihood of boundary pixels and subsequent misclassification (Irons 1982).

A widely used, all-purpose, land cover classification scheme for use with remotely sensed data was developed by Anderson et al. (1976). The "Anderson" scheme of classification was designed to establish a basis for the categorization of land cover into increasingly detailed conditions. Forest lands are separated from other types of land cover at Level I by "having a tree-crown areal density of 10 percent or more, are stocked with trees capable of producing timber or other wood products and exert an influence on the climate or water regime." At Level II resolution forest lands are separated into deciduous, evergreen, and mixed classes. The "Anderson" scheme was purposefully left open-ended to encourage goverment agency cooperation at the lowest, most general land cover classification levels (I and II) and agency specific scheme development at more detailed levels.

A study of the capability of digital classification of MSS and simulated TM (TMS) data conducted over forest industry land in North Carolina reported accuracies of 39% and 60% respectively while separating forest cover details to an arbritary "Anderson" Level III

categories including clearcut, mixed forest, hardwood forest, and 4 pine age classes (Williams and Nelson 1986). Reaggregation of land cover into Level II categories increased classification accuracy of MSS and TMS data to 71% and 77% respectively. When examining the results of this study, two considerations should be kept in mind. The area being classified was relatively homogeneous with regard to forest cover, and since the verification of classification results was accomplished by examination of 1:40,000 scale CIR photography, accuracy assessment was limited to the resolution of detail provided at this scale.

Visual and digital analysis of satellite data have been successful in detecting major disturbances to the landscape and in classifying forest types on a national scale (Aldrich 1975, Nelson et al. 1987). In both of these cases, however, aerial photography at scales of 1:58,000 or smaller was used to verify the classification results. These scales can provide resolution suitable for separating among mature forest types in most cases, but may not be adequate for determining land cover type on areas in transition.

These results may give the impression that digital classification of satellite data can reliably monitor land cover changes and, therefore, trends. On the other hand, no digital classification study reported has dealt primarily with separating among clearcuts, fallow agricultural fields, early natural regeneration, plantation, abandoned agricultural fields, non-productive woodlands, selectively harvested areas, and wooded pasture. These are the types of land cover conditions that are difficult to distinguish and yet are the transition categories of land cover change. In North Carolina, especially in the Piedmont, the average size of traits in these conditions, excluding the large tracts of industry held land, is more likely to be tens of acres and not hundreds.

METHODS

MSP was photointerpreted to estimate State-wide acreage of land cover and forest resources from permanent, large sample plots in North Carolina. This photography represents part of a study to integrate MSP, NHAP, and TM into a technique for updating field inventory figures by applying recently estimated land cover acreage statistics. This paper focuses on preliminary results obtained from the photointerpretation of MSP. To date, stereoscopic photointerpretation of over 100,000 acres of land in North Carolina from 1:12,000 scale, CIR aerial photography (MSP) has been completed by a single interpreter in less than 8 months. The preliminary results are compared with SE FIA figures from the most recent field survey approximately two years earlier.

Study Area and Reference Data

One reason North Carolina was chosen as the study site is that it embodies much of the land cover and topographic diversity found in the southeastern U.S. Timber industry shares the land base with non-industrial private landholders, who own a majority of the acreage in the State. This situation creates a landscape exhibiting a broad range of forest management practices. Increasing urbanization and other economically driven land cover shifts influence the land ownership and therefore, land mangement practices.

The second reason North Carolina was selected was that it was recently surveyed (November, 1982 to September, 1984) by the SE FIA field crews. Data from the prism cruising of 5,355 systematically selected ground sample plots were tallied and used to estimate current forest cover conditions. The acreages in forest and non-forest are established by the photointerpretation of 91,765 systematically selected, 16 point clusters applied to either 1:40,000 scale black and white Agricultural Stabilization and Conservation Service (ASCS) aerial photography or NHAP. The photography is utilized in the form of prints at 2 times enlargement. Five percent of these clusters were checked in the field, and original interpretation was adjusted using the results. SE FIA results represent the most comprehensive and current information available concerning North Carolina's forest and are therefore used as the verification of this study's results.

Sampling Procedure and Classification Scheme

To coordinate the location of sample areas on imagery of different scales, a grid was selected whose nodes corresponded to the center of every U.S. Geological Survey 7.5 minute topographic quadrangle covering North Carolina. To save costs, this grid was reduced to include every other latitudinal row of topo quads. This network of potential sample plots provided a large sample size (421 quad centered grid nodes) and coincided with the most recent NHAP stereo coverage (1981-1986). During MSP acquisition, 18 grid nodes were not photographed, which reduced the number of locations with both MSP and NHAP to 403 (Figure 1).

A plot size of 1,000 acres was selected to facilitate the registration of ultra small-scale satellite data. It was also thought that a large, high-resolution sample of the landscape on MSP would reveal important spatial relationships among land cover elements within the plot, thereby aiding photointerpretative classification. Circular plots were chosen because they were expected to be influenced the least by intersection with natural or man altered spatial patterns of land cover. The circular plot shape also eliminated photointerpretation within the corners of MSP, where scale distortion, lens aberration, and light fall-off are the most severe.

The general classes of Level I, displayed in Table 1, were chosen to facilitate cooperative efforts among government agencies. This type of frame-work was suggested by an interagency coordination group (Powell 1981) and might decrease redundancy by government sponsored inventory efforts at a Level I resolution. Level II of the classification scheme was designed to test the limits of practical information that might be reliably photointerpreted off the MSP and would be compatible with and of use to SE FIA forest resource inventories.

Acquisition and Photointerpretation of MSP

MSP in the form of stereo triplets covering quad centers for every other row of 7.5 minute topo quads was acquired by Forest Service personnel, using a Loran C navigational system, in seven flying days during the period October 25 to November 9, 1985. This produced 403 MSP plots covering 753,099 acres in stereo distributed over the entire state of North Carolina (30,958,648 total land acres). Each 9 by 9 inch CIR transparency (Aerochrome 2443) was made with an 8.25

inch focal length lens at a altitude selected to produce a 1:12,000 scale photo. This scale ensured that complete coverage of 1,000 acres would be provided by each set of triplets.

Plot center was defined by the center of the middle photo of the triplet set and was pin pricked. This center was transferred visually onto 1:24,000 scale, U.S. Geologic Survey 7.5 minute topographic quadrangles. Using elevation data from the map and altitude information from the data block on the photo containing the plot center, an average photoplot scale was determined. This scale was employed in the calculation and pen drawing of a circle encompassing photoplot center and 1,000 acres. Processed film was received in rolls from the laboratory, but was cut into frames and sleeved in acetate. All annotation was done on the sleeve, and sleeves were marked to provide consistent photo to sleeve registration.

A subset of 111 out of 403 plot locations on MSP was chosen by systematic sampling with a random starting point (Figure 1). Relatively homogeneous land cover conditions, as defined by the classification scheme of Table 1, were delineated as polygons drawn with a fine point felt-tipped pen on the acetates within the 1,000 acre tracts.

For each of the 111 MSP sample plots, an average of 3 hours was required to photointerpret, delineate, and encode the results. An average of 150 polygons per sample plot were numbered sequentially and planimetered. The acreage of each polygon was computed based on the assigned average plot scale, except in areas of substantial relief where polygons were divided into 200 foot elevation increments and acreage was computed for each subpolygon unit. Since the average time required to planimeter an MSP sample plot was 2 hours, the average amount of time spent extracting information from one plot was 5 hours. Computer algorithms were developed to provide access to a database of over 12,000 polygons of forest cover photointerpreted from MSP, comprised of variables describing plot, polygon, location, acreage, and type.

Polygon acreages were summed by land cover condition for each of the four physiographic regions recognized by the SE FIA unit; Mountains, Piedmont, Northern Coastal Plain, and Southern Coastal Plain. Land cover acreage sums produced by photointerpretation were expanded to provide physiographic region and State-wide estimates. An average of 1 out of every 310 acres in North Carolina was photointerpreted for land cover on MSP.

RESULTS AND DISCUSSION

SE FIA acreage estimates of total forestland fall within the 2.5 million acre, 95% confidence interval surrounding total forestland estimates based on the photointerpretation of MSP (Table 2). Confidence intervals are not currently available for most FIA estimates because of complexities in their methods. The MSP estimate is 0.75 million acres higher than the SE FIA estimate. The difference between these estimates can be due to errors in sampling and photointerpretation, or changes in land cover. Quantification of these differences is underway. SE FIA estimates of cropland and grassland do not fall within the 95% confidence intervals of MSP estimates, but some of this difference can be attributed to the rotation of croplands in the 1 to 3 year period separating the SE FIA and MSP photointerpretation surveys. When these two categories are aggregated, the acreage estimates fall within the confidence interval.

Table 3 reveals five forest resource categories whose SE FIA acreage estimates do not fall within the MSP estimate's 95% confidence interval range. Subjective visual examination of NHAP photography and comparison with similar locations on MSP separated by 2 to 3 years in time led to the hypothesis that some of the overestimation of plantation by MSP photointerpretation represents the recent establishment of planted pine acreage at the expense in upland hardwood. This hypothesis fits the observations that MSP photointerpretation results are higher than SE FIA figures in the amount of plantation, pine, and seedling sapling acreage, but lower than the estimated acreage of upland hardwood. It is possible that the lower estimates of upland hardwood acreage from MSP interpretation may be attributed to the higher estimates found in the oak-pine class.

This study seeks to be compatible with established SE FIA definitions. This allows for the direct comparison of results and rigorous tests of the accuracy of photointerpreted estimates necessary if the credibility of the remote sensing approach is to be established. Presently, 180 SE FIA, 1 acre field plots that occur on MSP coverage are being photointerpreted in stereo by SE FIA personnel to provide some measure of accuracy. Preliminary results of that investigation indicate that plantation can be quite reliably separated from natural forestland, although sample sizes of interpreted planted lands are small. Further investigation is needed to be able to determine if the increase in planted lands indicated by MSP analysis is correct and so demonstrates that this type of imagery can be effectively used to quantify short term changes in the timber resource base.

Registration of 1 acre, SE FIA field survey plots onto MSP is difficult. Misregistration by as little as 30 feet may cause a substantial shift in forest stand size, closure, or type, not to mention land cover. Accurate registration of 1 acre plots onto smaller scale imagery becomes increasingly difficult. Stereo photointerpretation requires intense concentration and a thorough familiarity with the ecological and artificial characteristics of the landscape in order to produce maximum classification accuracy. Just as digital image analysts would not think of using "any old algorithm" to produce land cover classification, photointerpretation duties should be assigned to the most qualified personnel for the reliable results. There is no algorithm in existence that can utilize image information as expertly as a well trained human mind.

The application of satellite data to define a landscape still results in numerous misclassifications, especially in the transition categories that define landscape change. Satellite data can classify the landscape into large, homogeneous land cover types. But usually, it is the small heterogeneous conditions that make up the seemingly homogenous category of interest. The separation of forest from non-forest land is an "Anderson" Level I classification. To achieve this land cover separation and meet the needs of the SE FIA survey, however, land cover conditions must consistently be determined to a much more detailed level of resolution. To produce more timely timber resource statistics, the transition zones (e.g., young regenerating stands) must be identified as soon as possible. This is best accomplished with remotely sensed data of high spatial resolution.

Four factors governing the selection of remotely sensed data for updating regional timber inventories are dependability, coverage frequency, resolution, and cost. TM and MSS data meet the criteria of dependability and coverage frequency, even though commercialization of the Landsat program has met with funding difficulties. Other countries are now marketing satellite imagery of spatial resolutions higher than TM. The costs associated with digital analysis are much higher than the more reasonable costs of visual interpretation for small areas or extensive plots, but both must be considered in the context of the quantity of useful information obtained at satellite resolutions. NHAP is a source of much higher resolution information for an excellent price, but has not yet proven to be dependable and is limited by a longer coverage frequency.

Compared to TM and NHAP, MSP covers the least amount of acreage with the highest information content at the highest price. It is labor intensive, and probably capable of producing the most accurate inventory updates. MSP estimates of land cover and forest resources in North Carolina were produced in less than 8 months at a total cost under $60,000.00. A combination of MSP with NHAP and/or satellite data may yield the most cost effective estimates while limiting dependence on any one data source. Satellite data could be used to identify areas based on the degree of disturbance exhibited, while simultaneous photointerpretation of NHAP and MSP acquired from different dates could then be employed to estimate the types and extent of land cover changes taking place.

Periodic monitoring of large, permanently located plots with sampling photography is a way of providing information about trends in land cover change. An attempt will be made to acquire similar MSP coverage of North Carolina in 1989 at the same time SE FIA field crews are conducting ground survey. This will allow direct comparison of land cover and forest resource acreage estimates from photointerpretation and ground survey with minimal confounding due to land cover change. In the meantime, simultaneous examination of the already acquired NHAP and MSP may help to further define the rates and types of land cover and forest resource change that were underway in North Carolina a couple of years ago.

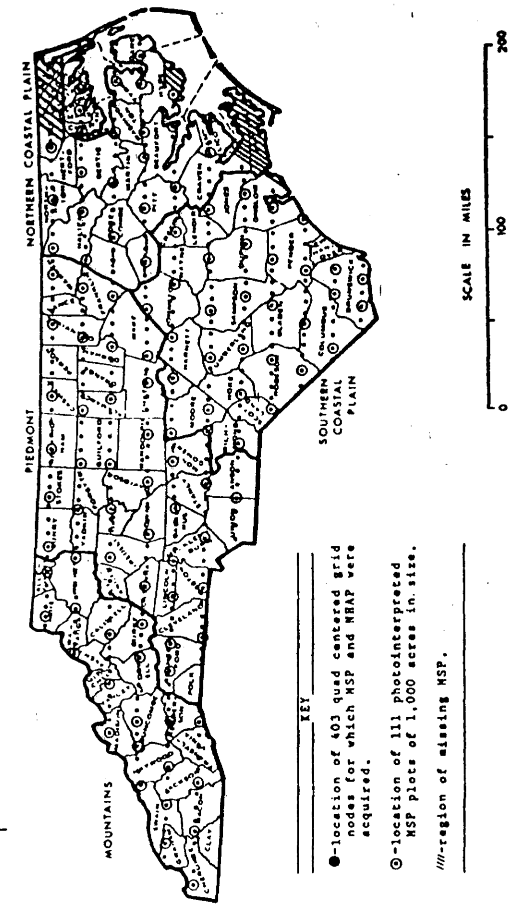

FIGURE 1. Location of coincident aerial photographic coverage of MSP and NHAP in North Carolina.

Table 1. Classification categories employed in the separation of land cover and forest condition in North Carolina.

Level I	Level II			
Landcover*	Origin	Size	Closure	Type
Barrenland	Plantation	Sawtimber	Closed	Pine
Cropland	Natural	Poletimber	Open	Mixed Pine
Grassland		Seed/Sap		Oak-Pine
Shrubland		Non-Stocked		Bottomland hardwood
Urban				Upland hardwood
Water				
Treeland				

* - There was also a Level I category entitled "Obscured". It was assigned to polygons hidden from view by clouds or mountain shadows.

Table 2. Comparison of land cover acreage estimates from the photointerpretation of 1:12,000 scale, color infrared photography (MSP) acquired in November, 1985 and those from the Southeastern Forest Inventory and Analysis unit (SE FIA) field survey conducted from November, 1982 to September, 1984 in North Carolina.

Land cover category	SE FIA	MSP and 95% C.I.
	Thousands of acres	
Grassland	6768*	5421 +/- 1080
Cropland	1680*	2415 +/- 554
Treeland	18952	19770 +/- 1269
Urban & Other	3557	3353 +/- 728

* - Denotes SE FIA estimates that do not fall within the 95% confidence interval of the photointerpreted MSP estimates.

Table 3. Comparison of forest resource acreage estimates from the photointerpretation of 1:12,000 scale, color infrared photography (MSP) acquired in November, 1985 and those from the Southeastern Forest Inventory and Analysis (SE FIA) unit field survey conducted from November, 1982 to September, 1984 in North Carolina.

Forest resource condition	SE FIA	MSP and 95% C.I.
	Thousands of acres	
Stand Origin		
Plantation	1614*	3161 +/- 1037
Natural	16836	16609 +/- 1195
Stand Size		
Sawtimber	8979	9631 +/- 882
Poletimber	5287	5006 +/- 545
Seedling-Sapling	3857*	4922 +/- 786
Non-stocked	328	211 +/- 124
Stand Type		
Pine (> 50%)	6345*	8876 +/- 1183
Oak-Pine	2277*	3300 +/- 477
Bottomland Hardwood	2704	2607 +/- 802
Upland Hardwood	7125*	4987 +/- 672

* - Denotes SE FIA estimates that do not fall within the 95% confidence interval of the photointerpreted MSP estimates.

REFERENCES

Aldrich, R. C. 1975. Detecting disturbances in a forest environment: Photogrammetric Engineering and Remote Sensing, 41(1):39-48.

Aldrich, R. C. 1979. Remote sensing of wildland resources: a state of the art review: General Technical Report RM-71, Rocky Mountain Forest and Range Experiment Station, USDA Forest Service. 56 p.

American Society of Photogrammetry 1983. Manual of Remote Sensing, Volume II, 2nd Edition: R. N. Colwell (ed.), Falls Church, Va 12240.

Anderson, J., E. E. Hardy, J. T. Roach, and R. E. Witmer 1976. A land use and land cover classification for use with remote sensor data: Geological Survey Paper 964, U.S. Govt. Printing Office, Washington, DC.

Ashley, M. D. and W. B. Cohen 1985. Making a regeneration survey using aerial photos: CFRU Technical Note 4, Univ. of Maine, Orono.

Avery, T. E. and G. L. Berlin 1985. Interpretation of Aerial Photographs: 4th edition, 323-354, Burgess Publishing Company, Minneapolis, Minnesota.

Catto, A. T. 1965. Aerial photography for mapping cutover areas: Pulp and Paper Magazine Canada, 66(3):120-124.

Dottavio, C. L. and D. L. Williams 1982. Mapping a southern pine plantation with satellite and aircraft scanner data: a comparison of present and future Landsat sensors: Journal of Applied Photographic Engineering 8:58-62.

Duncan, N., M. Meyer and N. Moody 1984. Applications of National High Altitude Photography (NHAP) to forest land management: IAFHE RSL Research Report 84-4, Univ. of Minnesota, St. Paul.

Hoffer, R. M., S. C. Noyer and R. P. Mroczynski 1978. A comparison of Landsat and Forest Survey estimates of forest cover: Proceedings of the Fall Tech. Mtg. of the Amer. Soc. Photogramm., Albuquerque, New Mexico, 221-231.

Irons, J. R. 1982. Summary of research addressing the potential utility of Thematic Mapper data for renewable resource applications: NASA Tech. Memo., TM-83965.

Loetsch, F. and K. E. Haller 1973. Forest Inventory, Volume I, 2nd edition: BLV Verlagsgesellschaft mbH, Munchen, pp. 393-414.

Nelson, H. A. 1977. Small format color photography for forest plantation planning in the Southeast: Proceedings of the 6th Biennial Workshop "Aerial Color Photography in the Plant Sciences and Related Fields", CSU, Fort Collins, CO, Aug. 9-11, pp. 141-145.

Nelson, R., D. Case, N. Horning, V. Anderson and S. Pillai 1987. Continental land cover assessment using Landsat MSS data: Remote Sensing of Environment 21:61-81.

Powell, D. S. 1981. A solution for resolving conflicts between land use and land cover inventories: In-Place Resource Inventories: Principles and Practices, National SAF Workshop, August 9-14, pp. 665-668.

Scott, C. T., H. T. Schreuder, and D. M. Griffith 1987. A comparison of optical bar, high altitude, and black and white photography in land classification: Photogrammetric Engineering and Remote Sensing, 53(2):203-206.

Sheffield, R. M. and H. A. Knight 1986. North Carolina's Forests: Southeastern Forest Experiment Station Resource Bulletin SE-88, USDA Forest Service Southeastern Forest Experiment Station, Asheville, NC.

Stephens, P. R. 1976. Comparison of color, color infrared and panchromatic aerial photography: Photogrammetric Engineering and Remote Sensing 42(10):1273-1277.

Swantje, H. 1957. Photogrammetric methods in reforestation surveys: Photogrammetric Engineering and Remote Sensing 23:789-790.

Williams, D. L. and R. F. Nelson 1986. Use of remotely sensed data for assessing forest stand conditions in the eastern United States: IEEE Transactions on Geoscience and Remote Sensing. FE-24(1):130-138.

AREAL DETERMINATION OF FOREST DAMAGE THROUGH INFRARED AERIAL PHOTOGRAPHY 1:9000

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ABSTRACT

In 1984-1986, as part of the Sanasilva project organized by the Swiss Federal Institute of Forestry Research, color infrared aerial photographs were taken of approximately one third of the area of forest in Switzerland, at a scale of 1:9000. The methods of aerial photograph interpretation used are described and the experiences gained in flight planning, flight coverage, interpretation of photographs, construction of damage maps, data evaluation, and application of the findings in practical forestry are summarized. The experience of the cantonal authorities to date has shown that the aerial mapping of forest damage is a valuable aid in practical forestry. It provides an overall picture of the local situation and facilitates decision-making in silvicultural planning. Infrared aerial photographs are accurately dated documents and can be effectively employed in public relations work.

INTRODUCTION

In late 1983 the growing problems of forest damage lead the federal government to initiate a special program within the framework of the Sanasilva project, which in itself comprises 11 sections. The special program is entitled "Areal Determination of Forest Damage" and is based on the use of color infrared aerial photographs at a scale of approx. 1:9000. The main objective is not to produce a regional or nationwide overview, but to provide a detailed stand-by-stand survey of the damage situation for forest owners and local forest services.

ORGANIZATION OF THE PROGRAM

The program is a joint project of the federal government and the 26 Swiss cantons. The federal institutes organize the flight planning, order the films, order and supervise the flights and train and supervise foresters through photointerpretation courses, bearing all relevant costs. The cantons, under the proviso that they strictly adhere to the prescribed methods, have the free use of the photos but must pay for and organize photographic interpretation, mapping and data interpretation themselves.

FLIGHT PLANNING AND CONDITIONS

Flight planning is based on the use of the photoscale of 1:9000, the WILD RC 10 or RC 10a camera, with a 210 mm objective, with a longitudinal overlap of 85% and a sidelap