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COMPUTER TRAINING PROCEDURES FOR THE WESTERN WASHINGTON FOREST PRODUCTIVITY STUDY UTILIZING LANDSAT DATA

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I. INTRODUCTION

The Western Washington Forest Productivity Study was a demonstration and application project utilizing Landsat data and multistage sampling techniques to generate inventory data for all forest lands in Western Washington. This project was conducted to demonstrate the feasibility of using Landsat data in a large scale forest inventory and to determine present and expected future timber supply in Western Washington.

The project was undertaken by the State of Washington, Department of Natural Resources (DNR) in conjunction with the Pacific Northwest Regional Commission, with support from NASA/Ames Research Center, and the USGS EROS Program. ESL Inc. of Sunnyvale, California, was contracted to provide machine processing facilities for the project.

The first phase of the Forest Productivity Study conducted in 1974-1975, identified the need for a more current, consistent, comparable, and reliable data base covering all ownership groups (U.S. Forest Service, State, Other Public, Industrial and Other Private). The Other Private ownership group, which owns twenty-five percent of the commercial forest land, but produces only twelve percent of the timber volume, had the poorest available information base and was identified as a top priority.[1]

It was determined that for a small additional dollar increase, a data base covering all forest ownerships could be developed instead of just for the Other Private, due to the efficiency of stratifying large areas with Landsat. A multistage sampling scheme was designed to adequately measure the components required for the development of an inventory base covering all commercial forest lands of Western Washington.

Landsat data was used to stratify the area into six cover-type groups in order to increase sampling efficiency. These categories were:[2]

(1) Old growth conifer; 96+ years

(2) Second growth conifer; 26-95 years

(3) Hardwoods

(4) Reproduction; 5-25 years

(5) Non-stocked forest; 0-5 years

(6) Non-forest

This information, coupled with the photo and ground sample plots within each strata, produced summary statistics for number of acres in each forest cover type group by stocking (basal area or stems per acre), age, size, and site class by the five ownership groups. Only net cubic foot volume was produced for the old growth category.

The project area encompassed all Washington west of the Cascade Crest, which lies between 45° 30' and 49° north latitude, approximately 19,000,000 acres. Most of the highly productive forest land in Washington is located within this area, which is known as the Douglas fir region. Major subdivisions include the western hemlock zone (coastal) and Douglas fir zone (interior). Approximately twenty-four percent of the forested acreage is old growth, while the remaining has been logged since the late 1800's.[1] Until the adoption of the Forest Practices Act in 1945, these logged areas were left to regenerate themselves naturally. This resulted in the regrowth of a variety of stand compositions ranging from pure hardwood, mixed hardwood, mixed conifer-hardwood, to conifer second growth. Tremendous variability also exists in the physiographic, topographic and climatic conditions encountered which affect forest characteristics in the study area.

The use of Landsat data to classify this expansive area into broad forest cover type groups required the development of the following: (1) Effective training procedures to handle the forest variability encountered. (2) Acceptance procedures to insure an adequate level of classification accuracy throughout the study area. This paper will discuss the training techniques used in the Western Washington Forest Productivity Study, acceptance procedures, and classification results. Emphasis will be placed on the forest situation.

II. SELECTION OF DATA TAPES

The dates of the Landsat computer compatible tapes utilized in the classification of cover type groups should be considered carefully. Tape dates affect the capability and reliability of discriminating cover type groups. Certain categories easily separable at one time during the year may be extremely difficult at another time due to phenologic changes and resultant spectral reflectance variability that occur through the year. Tapes should be selected that optimize spectral differences between desired classes to be separated. However, large operationally oriented programs place many constraints on procuring optimum dates, so in many circumstances, tape selection criteria must be modified. In the Western Washington Productivity Study, the variety of physiographic conditions encountered due to the expansive size of the study area made optimization of spectral differences impossible. Snow and cloud coverage proved to be the two major constraints in tape selection. Eight scenes were selected which covered the project area; five September, and three June.

The eight scenes were then subdivided on township lines into ten image blocks (Figure 1) to minimize the effect of clouds and snow, as the winter of 1973-1974 produced near record snowfall in the Cascades.
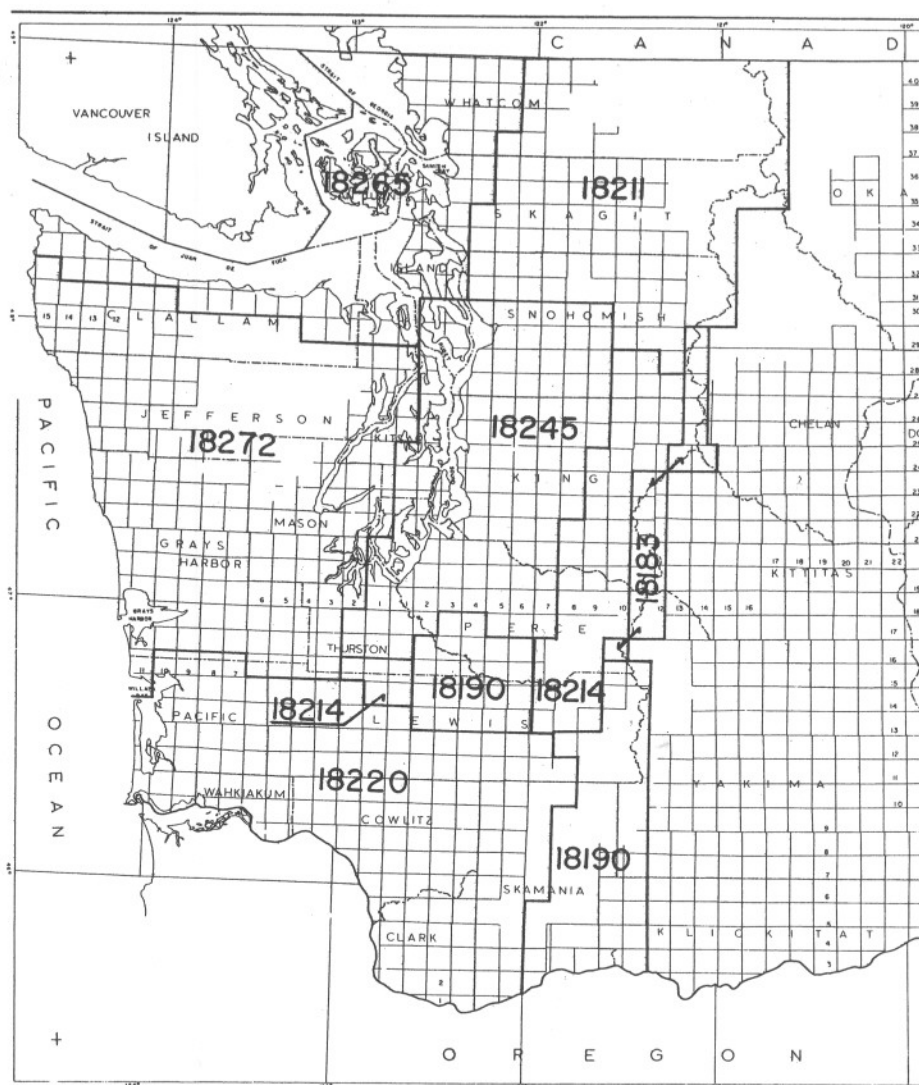

Figure 1: The Subdivisions of Landsat Scenes with I.D. Numbers and Image Blocks Used

III. SELECTION OF INTENSIVE STUDY AREAS

Training areas or Intensive Study Areas (ISA's) each 512 by 512 pixels in size, were selected by a Resource Analyst where a wide range of spectral responses for cover type groups due to aspect, slope, stand density and date of imagery were expected. Each of the ten image blocks were required to have at least one ISA. The Resource Analyst's familiarity with the area, supplemented with: (1) NASA U-2 small scale aerial photography, (2) Department of Natural Resources' aerial photography, and (3) Displayed Landsat digital data, assisted in the selection of twenty-two ISA's (Figure 2) representing approximately thirty percent of the project area.

The ISA's were delineated on a State of Washington Public Lands Map, 1:1,000,000 scale, and on 1:500,000 scale Landsat hardcopies to verify that all major vegetative conditions, ownerships, and image blocks were adequately covered. Due to the different management practices that occur in the five ownerships, it was extremely important that each ownership was adequately sampled. After some of the ISA boundaries were adjusted to pick up more of a particular ownership class, the Landsat line and sample coordinates for each ISA were selected with the aid of 1:500,000 scale hardcopy and displayed digital data. The ISA's were then transferred to separate tapes for training purposes.
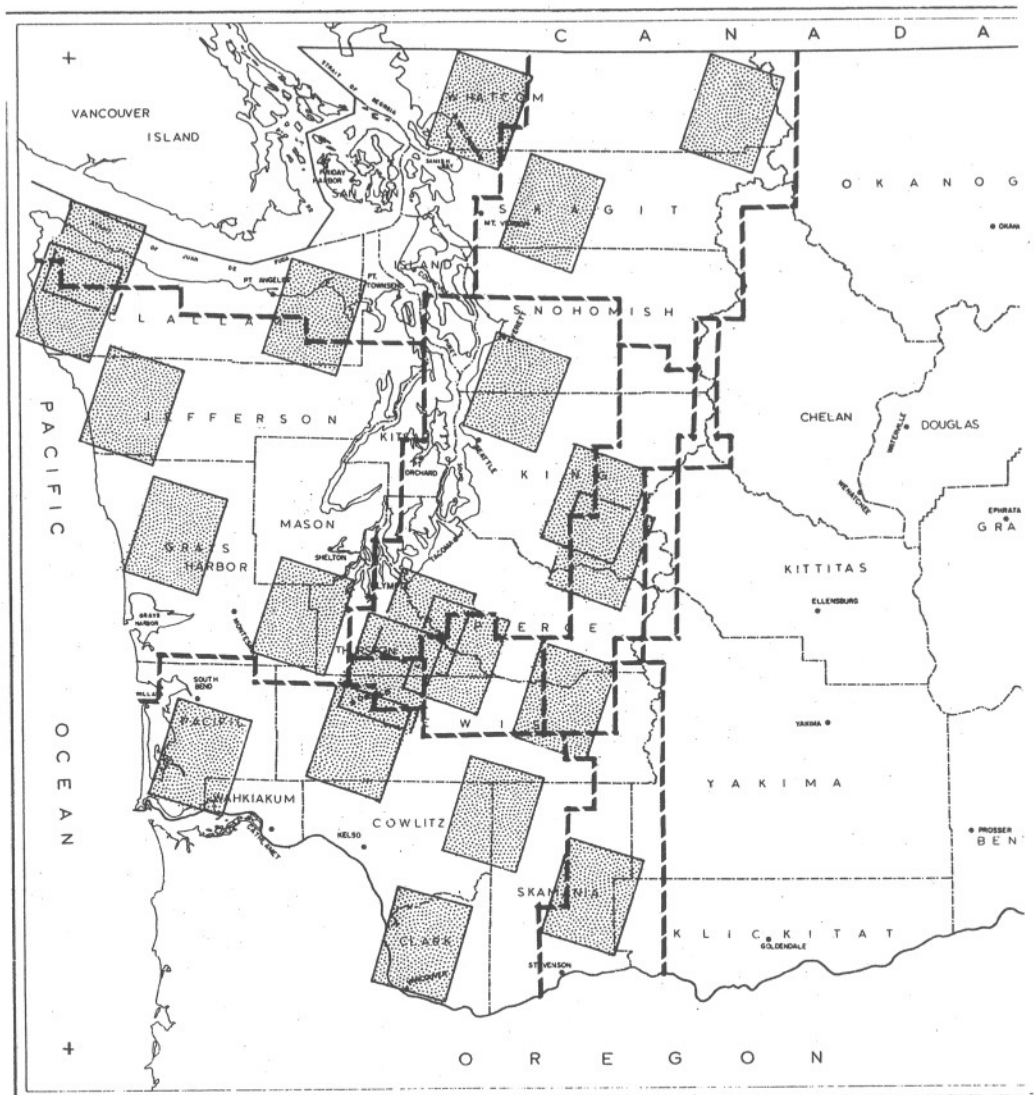

Figure 2: The Location of Intensive Study Areas Selected for Training

IV. TRAINING SITE SELECTION AND CLASSIFICATION

A. Large Blocks

At first training was attempted on a few large blocks within each ISA, using ESL's ISOCLAS routine (unsupervised classification)[3]. Identifying the spectral classes proved extremely slow, due to the large number of classes obtained (55 to 65), and the inability to quickly and accurately locate and identify many of the classes on aerial photography. This approach was abandoned.

B. Pure Stands:

As an alternative, numerous small areas consisting of pure stands were selected, utilizing aerial photography. Available photography included NASA 1:120,000 color infrared, DNR 1:24,000 true color, or 1:12,000 black and white. The pure stands selected were normally 2 to 20 acres in size and located in the middle of larger pure stands in an attempt to reduce the inclusion of border pixels. Location of these small pure stands sometimes proved to be extremely difficult.

Each ISA contained up to 35 training sites, with normally 6 to 8 selected in second growth conifer, old growth, hardwood, reproduction, and a lesser number in water, snow, urban, and other nonforest categories. Training sites included a variety of timber conditions based on slope, aspect, elevation, and stand density to account for potential spectral variability within each class.

The like cover type groups from all the ISA's of an image block were aggregated so that training statistics could be generated by ESL's ISOCLAS routine. The statistics developed in this manner accounted for (1) the spectral difference that occurred between ISA's, (2) reduced the development of duplicate statistics for common spectral classes, and (3) verified that the small training areas were of a single spectral class.

When a single training area developed more than one cluster, it was compared with aerial photography in an attempt to identify the reasons it was spectrally different. When more than one class was present (old growth and second growth conifer, or second growth conifer and conifer-hardwood-conifer mix), the clusters generated were classified into the appropriate cover type group. If the training area had two different clusters for second growth conifer due to aspect or stand density, they were retained as two different sets of training statistics for second growth conifer.

This process was then repeated for each group on which training was conducted; hardwood, reproduction, water, snow, urban, shadow, mud, bare ground, agriculture, etc.

C. Mixed Stands

The mixed stands were not handled in the same manner as the pure stands. Several large training areas in each ISA were selected and ESL's ISOCLAS routines utilized. This approach was used for mixed stands because it was impossible to physically select isolated training areas for all the various combinations of percentages that occur in these stands. The unsupervised techniques grouped mixed stands into distinct clusters, then aerial photography was used to determine the percentage of conifer and hardwood in each cluster. Each cluster was then assigned to one of four predetermined categories. Four broad categories for mixed stands were developed from the assumption that hardwood stands with up to 30% conifer, yield the same volume as pure hardwood stands.[4]

(1) Pure conifer   (0-30% hardwood)

(2) Conifer-hardwood mix   (31-49% hardwood)

(3) Hardwood conifer mix   (50% - 69% hardwood)

(4) Pure hardwood   (70 - 100% hardwood)

The two mixed categories of greater than or less than 50% hardwood appeared to be spectrally separable based on interpretation of clusters from the aerial photography. In this manner, it was assumed that the mixed stands would be consistantly classified over the entire project area.

After all training statistics had been generated within the image area, each of the ISA's took approximately 15 minutes to process. At this point, the classification was ready for acceptance or rejection by the Resource Analyst.

V. ACCEPTANCE PROCEDURES

A major challenge of the Western Washington Productivity Study was developing a procedure for accepting the classification results. The tremendous size of the study area made it impossible to examine the entire classification output within the time constraints of the project. This was known at the beginning of computer training procedures, so the acceptance procedures used were closely tied with the initial selection of the Intensive Study Areas. The assumption was made that if the classification results were valid for selected areas within each ISA, then they were acceptable for the ISA. If all ISA's within an image block were acceptable, then the classification was valid for the image block.

Portions of each ISA were examined closely, as well as a superficial evalutation of the entire ISA. After all ISA's within an image block passed both levels of scruitinizing satisfactorily, then the classification results for that image block were accepted. This procedure was then repeated for each of the remaining image blocks.

The Resource Analyst examined approximately 60,000 acres of the 262,000 in each ISA during the intensive scrutinization phase of the

acceptance procedures. Areas where problems or confusion could be expected to exist in the classification were selected based on his knowledge of the area. If these areas were classified at an acceptable level of accuracy, then the remaining portion of the ISA was assumed to be classified accurately.

No areas outside the ISA's were examined, as the ISA's were carefully selected initially to sample the expected variability within the entire project area.

When these examination procedures resulted in the rejection of the classification, additional training in the failing areas was conducted, and the process repeated.

VI. CLASSIFICATION RESULTS

A total of 279 spectral classes representing the six broad cover type groups were developed from the 8 Landsat scenes. 166 of the 279 spectral classes represented the forest condition as depicted by four of the broad cover type groups (Figure 3). The conifer-hardwood and hardwood-conifer mixes were included in the second growth conifer and pure hardwood cover type groups respectively, since there was not a broad cover type group for mixed stands.

The wide range of physiographic conditions within the study area caused a few problems within the classification:
(1) Shadows were produced by extremely steep north slopes caused by the low sun angle due to the date of the tapes used.
(2) In some of the higher elevations of the Cascade Mountains, the forested areas were still covered by snow which caused them not to be classified into a forest cover type.
(3) Non-forest cover types (bare ground) because of their spectral similarity appeared in the non-stocked forest cover type.

A second factor that made the classification of some forest stands difficult, was the use of traditional definitions for some of the cover type groups. Old growth conifer was defined as trees greater than 96 years of age. This was an arbitrary age established by management objectives and was not based on any age criteria that would optimize spectral separability from the contiguous classes. This made the separation of older second growth from younger old growth quite difficult. A re-definition of the age separating these two cover type classes may have eliminated this problem because a distinct spectral change did occur at an older age.

At this time, no accuracy statement for the classification can be made.

FOREST COVER TYPE GROUP

Landsat Scene Number	Old Growth	Second Growth	Hardwoods	Reprod	Total
18183	4	3	4	4	15
18190	3	5	14	2	24
18211	2	7	7	2	18
18214	1	11	6	2	20
18220	3	3	3	4	13
18245	3	8	2	6	19
18265	3	4	9	4	19
18272	8	13	10	6	38
TOTALS	27	54	55	30	166

Figure 3: The Number of Spectral Classes for Each Cover Type Group by Landsat Scene

VII. SUMMARY

The Western Washington Forest Productivity Study used satellite remote sensing data to generate inventory data for all forest lands in Western Washington. Landsat digital data was processed to stratify the project area into six broad cover type groups in order to increase sampling efficiency during remaining steps of the project. This paper describes the computer training techniques, classification acceptance procedures and classification results.

Eight Landsat scenes, subdivided into ten image blocks, were required to cover the study area. Twenty-two intensive study areas representative of the variability encountered in the project area were selected for use as training areas and for testing the classification results. Supervised training techniques were used on all cover type groups except for the mixed stands of conifer and hardwood where unsupervised methods were employed. A total of 279 separate spectral classes, which were reduced to six broad cover type groups, were developed from the training areas within the eight Landsat scenes.

The Western Washington Forest Productivity Study represented one of the first studies to utilize Landsat data to produce inventory statistics for use in regional forest management activities.

IX. REFERENCES

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