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Computer Classified Landsat Data Used as a Forest Stratifier

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Abstract

The majority of the Landsat classifications performed prior to 1975-76 contained limited information on the forest environment. General categories such as; conifer/non-conifer or forest/non-forest did not provide the detailed information needed for intensive forest stratification and associated ground plot inventory. Developments in guided clustering techniques have increased the potential for more detailed classifications. Conifer species groupings, vegetative cover classes and tree size classes can be discriminated with accuracies ranging from 83 to 91 percent. Classifications oriented to timber volume determination show the potential for providing the stratification necessary to carry out a stratified random sampling design on the ground.

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INTRODUCTION

Analysis of Landsat data has shown a great utility for natural resource inventory when processed by computer (Rohde, 1978). Several researchers have used space photography and computer analysis of Landsat data as the first stage in multi-stage resource sampling designs (Langley, 1971, Titus, et al., 1975). Until recently, simple classifications such as conifer/non-conifer, or forest/non-forest were the limit of information content available from Landsat (Heller, et al., 1975). Many scientists felt that the multi-stage sampling approach to forest inventory using Landsat was appropriate, as it seemed unlikely that analysis of Landsat data alone could provide a detailed stratification.

Recent improvements in interpretative methodology have increased the detail of information available from digital computer analysis (Fleming, et al., 1975; Gaydos and Newland, 1978; Fox and Mayer, 1979; Walsh, 1980). Detailed categories of percent vegetative cover of successional brush types as well as conifer and broadleaf forest species have been identified and mapped with high accuracy (91%) through the use of guided clustering techniques. In the past, conventional medium scale (1:15,840) aerial photography has been the only reliable source providing this detailed information. Landsat computer classifications currently exhibit the potential to provide forest stratifications with expenditures in time and money greatly reduced. Considering these facts, we feel that Landsat digital data has become a more valuable tool for stratifying the forest environment to a detailed level.

DISCUSSION

To illustrate this theme, we would like to discuss the results of two recently completed projects that relate to the problem of forest stratification.

Hoopa Square Project

As part of a cooperative project funded by the McIntire Stennis Forestry Research Program, NASA-Ames Research Center and the Humboldt State University Foundation, a vegetative mosiac of the Hoopa Valley Indian Reservation was produced using computer classified Landsat data (Soto, 1980). The Reservation lies within the mixed evergreen forest ecosystem of Northwestern California and comprises approximately 35,326 hectares. The Landsat classification was a forest stratification, as 100 percent of the land area was classified. Image sampling was not used.

The vegetation type map and area summary developed for the project contained categories that were similar to standard land-use and land cover classifications developed by the US Geological Survey (Anderson, 1976). Thirty-three statistically differentiable Landsat spectral classes were aggregated to represent 11 broad categories of vegetative cover (Table 1). The spectral classes were developed through the use of guided clustering (Fleming, et al., 1975).

Table 1. Vegetative Cover Categories and Area Aggregations for the Landsat/Computer Inventory.

Landsat Vegetation Type	Dominant Species/ Communities[1]	Area (hectares)	Percent of Study Area
Pasture	grass/forb	398	1.1
Mixed Range	grass/berry	2,310	6.5
Soil	bare/sparse grass	176	0.5
Regrowth	grass/forb/brush/tanoak	4,822	13.7
Evergreen Hardwood	tanoak /madrone	3,797	10.7
Deciduous Hardwood	black oak/white oak	4,357	12.3
Mixed Conifer	50% hardwood/tanoak 50% conifer/Douglas-fir	11,995	34.0
Mixed, Heavy to Conifer	>70% Douglas-fir/tanoak	5,332	15.1
Pure Conifer	Douglas-fir	1,728	4.9
Snow/Water	--	411	1.2
	TOTAL AREA	35,326	100 %

[1]Scientific names for the species listed are: Arbutus menziesii, madrone; Lithocarpus densiflora, tanoak; Pseudotsuga menziesii, Douglas-fir; Quercus kelloggii, black oak; Quercus lobata, white oak.

Fifty-four percent of the Reservation was classified into conifer forest with a varying combination of broadleaf forest types. Note that pure Douglas-fir (Pseudotsuga menziesii) was differentiated from conifer dominated mixed forest, with Landsat spectral data, as well as from mixed conifer/hardwood forest (in near equal proportion). Twenty-three percent of the land was identified as pure hardwood. Furthermore, it was possible to distinguish between deciduous as well as evergreen mixed hardwood types. The Landsat data was obtained on April 12, 1977, when the deciduous trees had not completely flushed. This fact contributed to the difference in the spectral signature between the two broadleaf forest types.

The regrowth category contained areas in various succession stages following clear-cut harvesting of timber on the Reservation. These regrowth areas were further divided into vegetation cover classes by percent crown closure using Landsat spectral signatures (Mayer, et al., 1979). Percent crown closure categories were: <10, 20, 30, 40, 50, 60, >80.

Overall classification accuracy was 91.1 percent given that a Landsat pixel was truly in the category being evaluated and 90.6 percent given that the pixel being evaluated was classed by Landsat into the category being evaluated. Individual category accuracies varied from 97.6 percent for conifer to 67.0 percent for the >80 percent crown closure category. This category was being confused with mixed forest categories; not a significant error. The next lowest individual category accuracy was 80.4 percent for the bare soil.

Topographic slope and aspect influenced the spectral signatures in this mountainous area. Using these changes in illumination, the accuracy of the classification was enhanced since a change in aspect is associated with a change in microclimate and therefore a change in the vegetative cover type.

McCloud Project

In the fall of 1978, the McCloud Ranger District of the Shasta-Trinity National Forest entered into a cooperative program with NASA-Ames Research Center and the Humboldt State University Foundation to provide a forest type map of the Ranger District using Landsat digital data (Fox, et al., 1980).

The major objectives of this project were: (1) to provide a Landsat classification of the timber resources on the District (135,351 ha) based on species grouping, percentage of crown closure, and tree crown diameter; and (2) to produce an estimate of timber volume per acre for one selected compartment using ground data previously collected.

Landsat data provided 100% forest inventory by stratifying the forest into the following species groupings:

Mixed Conifer Forest	Consisting of pine and fir types with no one species dominating the canopy.
Ponderosa Pine Forest	Canopy was dominated (>80% crown closure) by ponderosa pine (<u>Pinus ponderosa</u>), white pine (<u>Pinus monticola</u>), and sugar pine (<u>Pinus lambertiana</u>).
Fir Forest	Canopy was dominated by white fir (<u>Abes concolor</u>), red fir (<u>Abes magnifica</u>), and Douglas-fir (<u>Pseudotsuga menziesii</u>).
Lodgepole Pine Forest	Canopy dominated by lodgepole pine (<u>Pinus contorta</u>), knobcone pine (<u>Pinus attenuata</u>).

Each species grouping was divided when possible into large (≥3.6 meter crown diameter) versus small (< 3.6 meter crown diameter) timber, these categories being labeled as commercial and pre-commercial, respectively. Species groupings were also divided into two forest stocking classes based on crown closure: Good Stocking (≥ 40% crown closure) and Poor Stocking (< 40% crown closure). These categories provided the basis for an accurate stratification of the forested region using Landsat spectral signatures defined through guided clustering. Overall mean classification accuracy was 83 percent given true vegetation cover (Table 2).

Table 2. Full Classification Detail for the 16 Resource Categories Defined from Landsat Digital Data, McCloud Ranger District.

Resource Category	Mean Probability of Correct Classification Given True Vegetation Cover for the Test Pixel	Total Hectares Identified
Mixed Conifer/Large trees/ Good Stocking	0.849	35,424
Mixed Conifer/Small trees/ Good Stocking	0.724	10,897
Mixed Conifer/Large trees/Poor Stocking	0.766	5,614
Ponderosa Pine/Large trees/ Good Stocking	0.730	23,780
Ponderosa Pine/Small trees/ Poor Stocking	0.857	1,428
Ponderosa Pine/Small trees/ Poor Stocking	0.830	5,094
Fir/Large trees/Good Stocking	0.732	4,054
Fir/Large trees/Poor stocking	0.772	8,493
Lodgepole Pine/Large trees/ Good Stocking	0.676	3,594
Brush	0.892	12,538
Grass	0.835	2,685
Transition	0.806	10,532
Hardwood	0.600	1,749
Lava	0.955	7,990
Snow	0.958	1,350
Water	0.999	129
Overall/Total	0.830	135,351

To further evaluate the usefulness of the timber stratification for guiding ground based timber inventory, ground plots that had been inventoried previously by the US Forest Service were labeled according to the Landsat category they were classified into. The plots were previously obtained through a stratified random sampling procedure using conventional aerial photography to provide the strata. These were used as if they had been sampled at random within the Landsat generated forest stratifications.

Coefficients of variation for the mean cubic meter volume per hectare for the Landsat categories analyzed are shown in Table 3.

Table 3. Coefficients of Variation of the Mean Cubic Meter Volume per Hectare for the Landsat Categories Analyzed.

Landsat Category	Coefficient of Variation	Sample Size No. of Ground Plots
Mixed Forest Large trees/Good Stocking	7.2 %	90
Mixed Forest Large trees/Poor Stocking	92.9 %	9
Mixed Forest Small trees/Good Stocking	28.4 %	23
Ponderosa Pine Large trees/Good Stocking	15.0 %	14

Variation was high for the small tree category and extremely high for the poorly stocked category. While the precision of these two estimates seems inadequate, it is well to remember that a high level of variation would be expected for a category with a stocking range from 10 to 40 percent. Imprecision in the small tree category would have a minimal effect on overall volume precision due to the smaller amount of volume in this category. When the area was covered with large trees and stocking levels were also high, Landsat provided strata which, when used to group ground samples, yielded an average coefficient of variation of 11.1 percent.

CONCLUSIONS AND RECOMMENDATIONS

These applied research projects have provided an excellent testing ground for 100 percent inventories of vegetative cover using Landsat Data. These inventories have provided forest stratifications which have the potential to adequately guide ground inventories through a stratified random sampling approach. We feel that the following conditions should be met to realize the full potential of Landsat data in stratifying a forested area:

1) Classification schemes should be made compatable with expected variations in spectral signatures.

2) Reliable and adequate ground truth information should be available for all categories defined.

3) Guided clustering techniques should be used to develop a maximum number of spectrally distinguishable classes for each category of interest.

Landsat digital data can provide detailed forest stratifications when analyzed with a guided clustering approach.

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