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IMAGE SPATIAL AND SPECTRAL MODELS FOR ESTIMATING CONIFER FOREST STRUCTURAL ATTRIBUTES

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ABSTRACT

The ability to provide accurate estimates of stand structural attributes with satellite data would be advantageous to managers of large tracts of forestland. Here, we evaluate the utility of SPOT HRV 10 m panchromatic data and LANDSAT TM 30 m multispectral data to provide these estimates. Measures for a variety of structural attributes are derived from ground data for 51 conifer forest stands in the Pacific Northwest region of the United States. Regression models are developed to estimate these structural variables from spectral and spatial attributes derived from the satellite data.

INTRODUCTION

The extent of old-growth conifer forest remaining in the western United States and Canada is of great interest to a number of land management agencies and environmental groups. This interest has precipitated a flurry of research activity designed to characterize old growth, distinguish it from young and mature stands, and to identify the location of individual old-growth patches across the landscape. The primary distinguishing feature among conifer forest ageclasses of the region is their canopy structure (Spies and Franklin, 1991). Thus, a means with which to quantify the canopy structure of individual forest stands throughout the broad geographic area of interest is desirable. We are evaluating the utility of satellite image data to provide the needed information.

The overall objective of our research is to determine what image data sets and analysis techniques will provide the most accurate estimates of stand structure in the conifer forests of the Pacific Northwest region of the United States. In an earlier study we found that stand structural information can be extracted from digital imagery using semivariograms, but that the amount and reliability of the information was a function of image spatial resolution (Cohen et al., 1991). In this paper we summarize the next phase of our research. Here, the objectives were to: 1) determine the strengths of the relationships between forest stand structural attributes and the spatial and spectral properties of LANDSAT TM multispectral and SPOT HRV panchromatic data; and 2) build simple regression models for estimation of stand structural attributes from variables derived from HRV and TM data. A more thorough description of the research reported here appears in Cohen and Spies (1991).

METHODS

The geographic area of this study is the central Willamette National Forest located in the Oregon Cascade Mountains. We concentrated on 51 forest stands having a variety of structural conditions and ranging in size from 5 to 25 ha. Ground data, collected as a part of another study (Spies and Franklin, 1991), were analyzed to determine for each stand the mean and standard deviation of tree diameters at breast height (DBH), mean and standard deviation of crown diameters at the maximum crown width, tree density, basal area, and the canopy diversity index (CDI) number. The CDI, more fully described in Cohen and Spies (1991), was developed as a part of this study and ranges from zero to 15.

An HRV 10 m panchromatic image and a TM 30 m multispectral image of the study area were acquired. The six reflectance bands of the TM data were transformed into the brightness, greenness, and wetness axes of the TM tasseled cap (Crist et al., 1986). The absolute difference texture algorithm described by Rubin (1990), using a three by three moving window, was applied to the brightness, greenness, and wetness data and to the HRV data to create four texture images. Subsequently, the pixels of each stand were extracted from the original brightness, greenness, wetness and HRV images and from the four texture images. From the pixel data we calculated for each stand the mean and standard deviation of the spectral values from the original images and the mean, standard deviation, and coefficient of variation of the texture values from the texture images.

Data from 26 of the 51 forest stands were used to build the regression models and the data from the other 25 stands were used to validate the models. Stepwise regression procedures were used and the alpha level for independent variable inclusion into the models was 0.15. Three types of models were built for each stand structure variable: 1) those using the HRV data only (**HRV models**); 2) those using the TM data only (**TM models**); and 3) those using both image data sets (**combined models**). To determine how well each model performed it was applied to the validation data set and the coefficient of correlation (*r*) was calculated for the relationship between the predicted and observed values of the stand structural variable of the model.

RESULTS AND DISCUSSION

In general, the most important spectral variables over all models, as selected by the stepwise regression procedure, are mean stand brightness and greenness, and the most important spatial variables are the mean texture number and DN standard deviation from the HRV data. For six of the models other image variables are important, including the standard deviation and coefficient of variation of the HRV texture numbers, mean wetness, and the standard deviation of brightness and wetness. The TM texture values were not selected for inclusion into any of the models.

Performance of the regression models using the validation data set was highly variable, depending on the model type and stand structure variable considered (Table 1). There is no combined model for the CDI and for basal area. This is because the stepwise procedure did not select variables from both types of imagery for these stand variables when the combined models were built. The combined models performed better (based on *r*) than the HRV and TM models only for the standard deviation of DBH and mean crown diameter. The HRV models performed better than the other model types for the standard deviation of crown diameters, the CDI, and basal area. The TM models performed better for the mean DBH and tree density. For four of the seven stand variables, standard deviation of DBH and crown diameter, CDI, and basal area, the HRV models performed better than the TM models. These include the stand variables most diagnostic of different stand development stages (Spies and Franklin, 1991).

The mean *r* among stand variables for the HRV models is 0.630 and for the TM models it is 0.641. This indicates that if one is interested in estimating all seven stand variables, and does not weight the value of one stand variable more than any other, use of the HRV data alone would yield as accurate results as TM data used alone. If one is most interested in the key stand variables that best discriminate among ageclasses then the HRV data should provide more accurate results. The mean *r* for the combined models is 0.662. However, if one were to have both types of imagery, the best model type for each stand variable could be used. Using the model type with the highest *r* for each stand variable, the mean *r* is 0.716. Thus, using both types of imagery one can expect to obtain significantly more accurate results than by using either type of imagery alone. However, the cost of using both types of imagery may be prohibitive.

The standard deviation of DBH and the CDI were the stand structure variables most accurately predicted by the image variables ($r = 0.85$ and 0.79, respectively). The other variables were predicted with essentially the same accuracy if one considers only the model type having the highest *r* for each variable ($0.65 < r < 0.70$).

CONCLUSIONS

Estimates of important structural attributes for conifer forest stands can be obtained from satellite remote sensing data. The most important measures derived from the 10 m resolution HRV imagery, mean texture number and DN standard deviation, are measures of spatial variability in the data. From the 30 m resolution TM imagery the most important variables, mean brightness and greenness, are measures of the spectral properties of the data. That spatial measures derived from 30 m TM data are not useful for estimating stand structural attributes supports the findings of our earlier study in which we found that semivariograms of 30 m data contained little useful stand structure information under the stand conditions prevalent in the conifer forests of the Pacific Northwest.

Together spatial measures derived from SPOT HRV panchromatic data and spectral measures derived from LANDSAT TM data will provide the most accurate results for a variety of stand attributes. Used alone, spatial measures derived from HRV 10 m data are as valuable as spectral measures derived from TM 30 m data for estimating structural attributes in the high density conifer forests of the Pacific Northwest.

Considering that spatial measures of HRV data relate best to the key variables for discriminating among ageclasses, this type of imagery should be more valuable than TM imagery for determining the location and extent of old-growth forest stands.

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TABLES

Table 1. Coefficients of correlation (*r*) for the relationship between predicted and observed stand attribute values using the HRV, TM, and combined regression models with the validation data set.

Stand Variable	*HRV*	*TM*	*Combined*
DBH (mean)	0.46	0.65	0.62
DBH (standard deviation)	0.74	0.65	0.85
Crown Diameter (mean)	0.50	0.69	0.70
Crown Diameter (standard deviation)	0.68	0.50	0.63
CDI	0.79	0.72	--
Basal Area	0.69	0.63	--
Tree Density	0.55	0.65	0.51

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