IDENTIFYING CLASS STRUCTURE OF WHITE SPRU UNDERSTORY BENEATH DECIDUOUS OR MIXEDWO STANDS FOR IMPROVED CLASSIFICATION RESUL

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ABSTRACT

A satellite remote sensing approach was used to determine class structure of wh understory occurring within deciduous and mixedwood stands in northern Alberta. The determination of a class structure that is amenable to an operational implementation is needed to identify and stratify large areas that may comprise conifer understory. Landsat TM imagery acquired in late April (leaf-off) and late July (leaf-on) were used to generate an Isodata unsupervised classification to aid in identification of a class structure. These classes were cross-mapped to a GIS overlay containing three levels of understory (heavy, light, nil) in five overstory classes acquired from leaf-off aerial photographs and field observations. Class signatures generated from the intersection of the GIS understory polygons and the Isodata clusters were used for a supervised classification. Analysis of separability statistics suggests understory can be discriminated for understory absence or presence under two overstory strata.

INTRODUCTION

A current inventory problem in the Mixedwood Section of the Boreal Forest Region B.19a (Rowe 1972) is to determine the location and amount of conifer understory within deciduous and mixedwood forest stands (Brace and Bella 1988; Expert Panel on Forest Management in Alberta 1990; Peterson and Peterson 1992). Current efforts to map softwood understory in the boreal mixedwood zone involve the interpretation of leaf-off aerial photographs and field surveys that are costly to undertake over large areas. A satellite remote sensing method for the detection of understory could significantly aid in the time and cost in such surveys by providing an initial stratification of large areas to identify likely locations of softwood understory.

Previous studies (Franklin *et al.*, 1986; Spanner *et al.*, 1984; Peterson *et al.*, 1986) have acknowledged the contribution of understory to stand spectral response. Stenback and Congalton (1990) have also attempted to classify vegetated understory in the Sierran mixed conifer zone with mixed results. Ghitter *et al.*, (1995) conducted supervised classifications with class signatures based on a digital GIS overlay of 15 classes mapped to three understory (heavy, light, nil) and five overstory categories (based on 10% increments in conifer overstory composition).

Discriminant analysis testing indicated that the greatest success for mapping understory could be expected by collapsing overstory classes but this increases the variability of the class and the distinctiveness of its spectral signature. Because the mapped polygons from the GIS overlay are often averaged during photo interpretation, and that understory is often unevenly distributed within overstory stands, signatures generated using these polygons as training areas may contain too much variation in their spectral signatures to accurately discriminate these classes during production of an image map.

The purpose of this paper is to investigate a 'modified supervised' classification technique similar to Chuvieco and Congalton (1988), and to identify polygons that can be used as training areas for creating class signatures. Using a two-date (leaf off/leaf on) Landsat TM data set, this technique is based on the intersection of classes produced by an Isodata unsupervised classification and the GIS polygon overlays.

STUDY AREA

The study area consists of four townships (about 625 square km) in north-central Alberta (Figure 1). This area is within the Mixedwood Section of the Boreal Forest Region (B.18a, Rowe 1972) that is characterized by mixtures of trembling aspen (*Populus tremuloides* Michx.), balsam poplar (*Populus balsamifera* L.), white spruce (*Picea glauca* [Moench] Voss) and jack pine (*Pinus banksiana* Lamb.). A few isolated stands of white birch (*Betula papyrifera* Marsh.) and balsam fir (*Abies balsamea* [L.] Mill.) are found on dry and wet sites, respectively. Black spruce (*Picea mariana* [Mill.] B.S.P.) may also be found on poorly drained sites throughout the area. The study area has been mapped to the Alberta Vegetation Inventory (AVI) standards (Resource Information Division 1991), which describe cover types by moisture regime, crown closure, stand height, species composition, and origin.

DATA ACQUISITION AND METHODS

Landsat TM images were acquired in geocoded format for April 18, 1991 (representing leaf-off) and July 23, 1991 (representing leaf-on) with solar conditions of 40.58° elevation/150.71° azimuth, and 49.52° elevation/144.77° azimuth, respectively. Atmospheric effects were corrected using the dark-object pixel subtraction technique (Chavez 1988). A solar zenith angle correction algorithm was implemented to permit the direct comparison of reflectance between the two dates. Topographic correction was not necessary in the relatively flat terrain of the study area.

Conifer understory stands were mapped to three levels (heavy, light, nil) beneath five overstory stand structures that ranged from pure deciduous (100% deciduous) to a 60% deciduous - 40% coniferous mixedwood composition (Table 1). The ISODATA unsupervised clustering algorithm was used to generate a map of the spectral classes for comparison to the GIS polygons. Three runs of the ISODATA routine were initialized with an expected number of clusters (12 to 20) and with a standard deviation of 8, 12, and 16. Three class variations of eight classes, six classes and four classes derived from the original 15 class scheme (Table 1) were chosen for testing based on the relatively high average spectral separability of the classes (Table 2). Each ISODATA unsupervised classification result was combined with the understory map using a logical 'AND' function to create an image map that illustrates the intersection of every ISODATA cluster with its corresponding understory polygon. In all, nine tests were conducted. The results when using an initial cluster standard deviation of 12, cross-mapped to the four class scheme are presented in Table 3. Each ISODATA cluster is ranked in descending order according to the percentage of pixels overlapping with each overlay class. Only the largest 7 of 19 ISODATA clusters are presented with their percent intersections ranging from 86.4 to 94.7.

ISODATA clusters accounting for a minimum of 70% of the overlap were thresholded to create bitmaps from which new signatures for a maximum likelihood classification could be created. For example, the intersection of ISODATA clusters 7, 4, 5 and 8 accounted for 71.3% of the overlap with Class 1 and was used to create a new signature. It was hypothesized that signatures created using this approach would more adequately describe their spectral variation while maintaining the basic character of the original GIS polygons.

RESULTS AND DISCUSSION

The nature of this investigation precludes using accuracy assessment techniques based on confusion matrices and the Kappa statistic (Congalton 1991) without further field measurements. Bhattacharyya distance (B-distance) has been used, however, as a measure of separability between pairs of classes based on a set of spectral bands (Jorial *et al.*, 1991; Ghitter *et al.*, 1995), and its interpretation is considered a measure of the likelihood of correct classification (Mathur 1987). B-distance is asymptotic to 2.0, and its interpretation is straight forward: If 0 < B-distance < 1.0 then the data demonstrate very poor separability, if 1.0 < B-distance < 1.9 there is poor separability and if 1.9 < B-distance < 2.0 there is good separability (Richards 1993). Table 4 gives B-distances associated with the class signatures generated by the *modified supervised* classification. Average separability for this test was 1.52, significantly higher than the test for the same classes based on the signatures generated by the GIS polygon overlays alone (Table 3).

Significant confusion is evident between classes 1 and 2; classes with heavy understory but with different canopy mixtures, and classes 3 and 4, classes with nil understory and different canopy mixtures. Separability is very high between all classes with heavy or nil understory, indicating that the maximum likelihood classification routine is sensitive to understory components regardless of overstory mix. The rise in sensitivity can be attributed directly to the new signatures created by this modified method.

Visual inspection of the classification output also gave qualitative evidence of the potential for increasing map accuracy. Classes generated from the modified supervised method appeared to match the spatial occurrence exhibited in the polygon overlays quite closely. In addition, when compared to classification maps trained on the GIS polygons alone, the classes tended to have well defined boundaries with a decrease in speckling, which may be associated with confusion among similar classes.

CONCLUSIONS

An intersection technique based on a remote sensing-GIS integration for the detection of forest class structure has shown potential for mapping understory in deciduous and mixedwood stands in northern Alberta. Spectral class signatures generated by training on areas of intersection between an unsupervised classification and a GIS polygon overlay had 10-15% greater average separability than the GIS overlay alone. The intersection of spectral classes from an unsupervised classification and physical classes from the GIS overlay may provide more realistic training areas for supervised classification routines by increasing class separability and potential map accuracy.

Future work with this method may lead to a procedure for extracting class signatures based on GIS-remote sensing integration. Broad classes can be input into a GIS and intersected with an unsupervised classification to produce class signatures with reduced spectral variation because training areas are more homogenous. A secondary benefit may be in the reduced time that is spent on ground truthing land cover classes that fall in the study area, but are not of interest. Spectral classes are usually created so that they are exhaustive and mutually exclusive. By using a modifed supervised classification approach, spectral classes based on GIS polygons tend to be more separable because they are based on their statistical properties as defined by parameter values used in the unsupervised classification algorithm. Future work includes plans to acquire the additional field data to conduct independent accuracy assessments of the classified understory map.

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Table 1. Original class schema of overstory stand and understory composition (15 classes).

Overstory - understory	Class Number	Class Label
100% deciduous		
heavy	1	H100
light	2	L100
nil	3	N100
90% deciduous - 10% coniferous		
heavy	4	H90
light	5	L90
nil	6	N90
80% deciduous - 20% coniferous		
heavy	7	H80
light	8	L80
nil	9	N80
70% deciduous - 30% coniferous		
heavy	10	H70
light	11	L70
nil	12	N70
60% deciduous - 40% coniferous		
heavy	13	H60
light	14	L60
nil	15	N60

Table 2. Test classes and average spectral separability values.

	8 Classes	6 Classes	4 Classes
Class 1	H100	H100+H90+H80	H100+H90
Class 2	H90	L100+L90+L80	H80+H70
Class 3	H80	N100+N90+N80	N100+N90
Class 4	H70	H70+H60	N80+N70
Class 5	N100	L70+L60	
Class 6	N90	N70[a]	
Class 7	N80		
Class 8	N70		
Average Separability [b]	1.21	1.07	1.31

[a] The nil 60% class (N60) does not appear in the study area.
[b] Bhattacharyya distance measure

Table 3. ISODATA cluster overlap with GIS polygon overlay.

Class 1		Class 2		Class 3		Class 4	
Isodata Cluster	Percent Overlap	Isodata Cluster	Percent Overlap	Isodata Cluster	Percent Overlap	Isodata Cluster	Percent Overlap
7	28.5	4	38.9	8	58.6	4	34.7
4	28.4	7	12.8	10	15.7	8	23.7
5	7.2	1	12.3	14	6.0	10	9.9
8	7.2	3	8.4	7	5.4	12	8.0
10	5.1	2	7.4	12	5.2	7	7.4
1	5	5	6.2	16	2.2	14	4.0
2	5	8	2.7	5	1.6	5	3.3
Total	86.4	**Total**	88.7	**Total**	94.7	**Total**	91.0

Table 4. Bhattacharyya distance measures among class 1 to class 4.

Class	1	2	3
2	.903		
3	1.77	1.97	
4	1.67	1.92	.887

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