Hierarchical Alberta Vegetation Inventory (AVI) Classification Using Aerial Digital Frame Camera Data

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Abstract

Aerial multispectral digital frame camera imagery were acquired with 32 by 25 cm pixel resolution from approximately 150 m above a mature forest ecosystem near Barrier Lake in Kananaskis Country, southwestern Alberta in July 1996. Alberta Vegetation Inventory data, including species composition and crown density, were collected at 40 plots scattered throughout several pure and mixedwood deciduous and coniferous stands. A test was conducted to determine image classification accuracy using existing classification techniques applied in a hierarchical fashion to these data and to AVI class labels at decreasing levels of detail. Initial accuracy was low, but use of a hierarchical decision process suggested in earlier work, by which image classes were merged, eliminated, or accepted, increased average accuracy to over 60% across a wide range of AVI class labels for this region. The high spatial detail in the digital frame camera data combined with the known deviations from the statistical assumptions required by the maximum likelihood classifier were identified as the primary problems in image classification. An optimal method of image classification might use a series of GIS thresholding steps based on pure image signatures to separate individual features such as tree crowns, understory, shadows, resolved in the image data; then, a contextual classifier could be used to reconstruct the AVI label at the required level of precision.

Introduction

The Alberta Vegetation Inventory (AVI) is an operational, integrated field inventory system using aerial photointerpretation and field surveys based on species composition, crown closure, height, stand origin (age), site class, and moisture regime with additional descriptors for stand structure (i.e. single or multi-story), disturbance, treatments, and understory (Alberta Forestry, Lands and Wildlife 1991). Since 1991 we have conducted a series of experiments to provide AVI mapping and classification from aerial and satellite digital remote sensing data in a variety of ecological systems using a wide range of image sensors and classification procedures (Franklin et al 1991; Franklin 1994; Wilson 1996; Getty 1996). The overall goal of these efforts is two-fold: (i) to determine the appropriate role of such digital data and computer-based methods in large-scale inventory (see Franklin and McDermid 1993) and (ii) to develop large-area inputs to ecological process models (see Wulder et al 1996) of vegetation in boreal, subalpine and montane ecoregions. In general, because our first goal is *inventory-based*, the data and methods used must be relatively common and easily applied; output products must resemble existing map formats and be as simple to use and understand. Perhaps then there will be an increased likelihood that digital maps and methods will be used widely in forestry and ecology.

Earlier work (Fish et al 1995) using similar aerial imagery in this area indicated some promise for a hierarchical approach which might be designed to be sensitive to differences in stand density and species composition. In this study we test aerial digital frame camera imagery acquired using the Multispectral Video (MSV) package described by Roberts (1995), and we determine the level of detail and classification accuracy that can be obtained using existing image analysis methods in montane forest AVI classification. Initially we have simplified or ignored the complex geometric and radiometric uncertainties associated with such imagery, and have attempted to answer the question: *To what extent are AVI class types separable in digital frame camera imagery?* We combined a hierarchical decision rule structure to determine the effectiveness of the high spatial resolution data and the maximum likelihood decision rule in classifying various AVI stand labels obtained in the field survey.

Data Collection and Signature Generation

The study site is located on a south-west facing slope on Barrier Lake, in Kananaskis Country, Alberta (51.02 N, 115.01 W) at an elevation of approximately 1400 m (figure 1), and is dominated by trembling aspen (*Populus tremuloides* Michx.), balsam poplar (*Populus balsamifera* L.), white spruce (*Picea glauca* [Moench] Voss), and lodgepole pine (*Pinus contorta* Lamb.). Estimates of Alberta Vegetation Inventory (AVI) were acquired on July 10, 1996, at 40 field plots, located on 10 transects through the forest stands of interest. Each plot measured approximately 10 x 10 m. Plots were surveyed to determine species and crown density class, and were labeled with an appropriate AVI code (figure 2). Each test site was located using differentially-corrected GPS.

On July 11, 1996 three co-registered and calibrated digital frame cameras with spectral filters centred at 537.1, 617.2, and 718.0 nm were flown from approximately 150 m above ground from a small single engine, fixed-wing airplane, yielding a measured pixel size of 0.32 by 0.25 m. Four overlapping lines were flown, yielding 34 images. The study area was predominately under clear skies throughout the flight. The auto-gain function of the digital frame cameras was disabled to allow for multi-image comparisons. Images were frame-grabbed approximately every second. Band to band registration was performed on each of the images from the three digital cameras to eliminate a systematic rotation and shift that had occurred during image acquisition. The images were corrected for atmospheric aerosols using the dark object subtraction method; histograms of each image were analyzed to find the lowest digital numbers. Bitmaps were created for each of the plots that were clearly visible on the imagery. Spectral signatures were generated for each of the field plot bitmaps, a confusion matrix was created, and a class separability test (B-distances) was performed to determine the separability of the training signatures. A series of four iterative classification runs were made to merge, eliminate, or accept existing classes.

Results

Figure 2 outlines the hierarchical structure employed in the collapsing of classes from the original 26 field plots to the final five AVI covertypes based on the analysis of separability statistics, classification accuracy, class means and standard deviations, and field summaries. The first image classification was conducted on all 26 field plots, using each as a separate training signature. Overall accuracy was just 21%, which was expected at this first hierarchical level since there were many plots which shared similar AVI labels. A second image classification iteration was conducted on the merged C density pure aspen class and the remaining 19 original field plots. Overall accuracy was again low, with an average of 19.03%. Class separability was also low, with an average B-distance of 0.864.

At Level 2 the classifier could separate out the B and C density pure classes (B-distance 0.735), probably as a result of the greater understory contribution, but could not make any distinction between C and D density classes (B-distance 0.213). The B density class had higher mean DN values in the visible bands. The mixedwood class could be subdivided into three different density classes (A, B, and C). However, plots of class separability for the B and C density classes showed very low separabilities of 0.134 and 0.177, respectively. Separability measures for the mixed conifer plot were generally quite high. In the mixed field plots with a deciduous dominating species crown classes D, C, and A could be differentiated from one anther, and the D density and B density coniferous dominant mixedwood classes could be differentiated by the classifier. Average accuracy increased from 21% to 34% (Hierarchical Level 2).

At Level 3 the various density classes of aspen are reasonably accurate (for example, 46% and 63% of the pixels in the C and B density pure aspen class were classified correctly, respectively). Errors were more obvious in the mixedwood classes.

Overall accuracy for the fourth classification iteration increased to 65%. The elimination of all classes with poor separability increased overall accuracy and average separability as expected (B-distance average separability of 1.178). Three of these final five AVI classes were either pure conifer or pure deciduous species. However, the B density mixed coniferous class was 76% correct, and the D density coniferous dominant mixedwood class was also classified well with 70% correct. The two pure aspen classes exhibited were 66% correct (C density), and 50% correct (B density). The A density mixedwood class had an overall accuracy of 55%.

The AVI field codes were re-grouped into five covertype classes for the fourth level of the hierarchy with the additional subdivisions based on crown density classes: Pure Aspen, Mixedwood, Coniferous Dominant Mixedwood, and Mixed Coniferous; and a classification accuracy of 65% was obtained (Hierarchical Level 4). This is consistent with the earlier classification result of approximately 68% correct (Fish et al 1995) using the CASI sensor system and a larger sample (15 classes) in this same forest area.

Conclusion

Hierarchical image classification using high spatial resolution digital frame camera imagery yielded an overall accuracy of 65% in five distinct AVI field classes, but as more classes were introduced in the classification scheme, overall accuracy decreased significantly. The classifier performed reasonably well in pure species classes of different densities, but was unreliable in the mixedwood classes when handled together with the more 'pure' signatures. A whole series of radiometric and geometric problems have been ignored in this study, which was designed only to determine the level of accuracy in AVI classification that may be obtained using these data and methods and a complex set of classes. For example, when dealing with such high resolution imagery, training class statistics may violate assumptions in the classifier (e.g. data do not exhibit a Gaussian distribution as many sites have multiple sub-classes, including varying vegetation species and understory/shadow influences). Short-focal length digital cameras experience a high degree of radial displacement which may have caused some difficulties in image classification. For example, plots that were located on the outside edges of the images exhibited tree shapes that were tilted on edge, overshadowing shorter species beneath them. This problem was more evident with plots with conifer species.

The next phase of this work involves designing an optimal classifier for use with high spatial detail and AVI forest inventory applications. This new classification procedure involves the integration of remote sensing processing techniques with GIS analytical operations. By segmenting the classification process into various levels (figure 3), where individual forest measurement is conducted at each level, more detail in the class structure may be obtained; the final step is to integrate each level into one AVI map product.

Acknowledgments

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Figure 1 Location of the Study Area in Kananaskis Country
Figure 2 Hierarchical Image Classification Scheme
Figure 3 Classification Procedure for Use with High Resolution Imagery and AVI Forest Inventory Applications

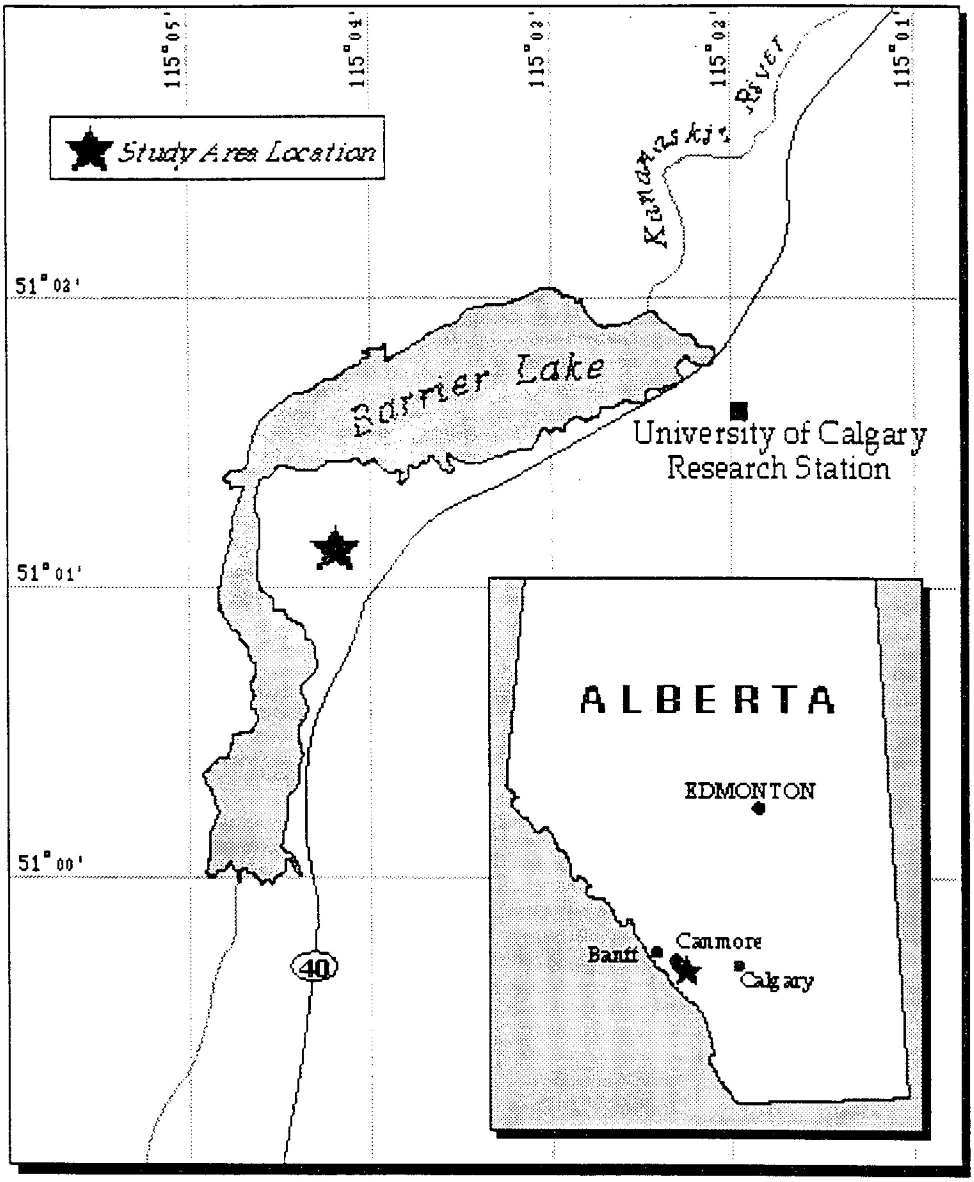

Figure 1 - Location of the Study Area in Kananaskis Country, Alberta.

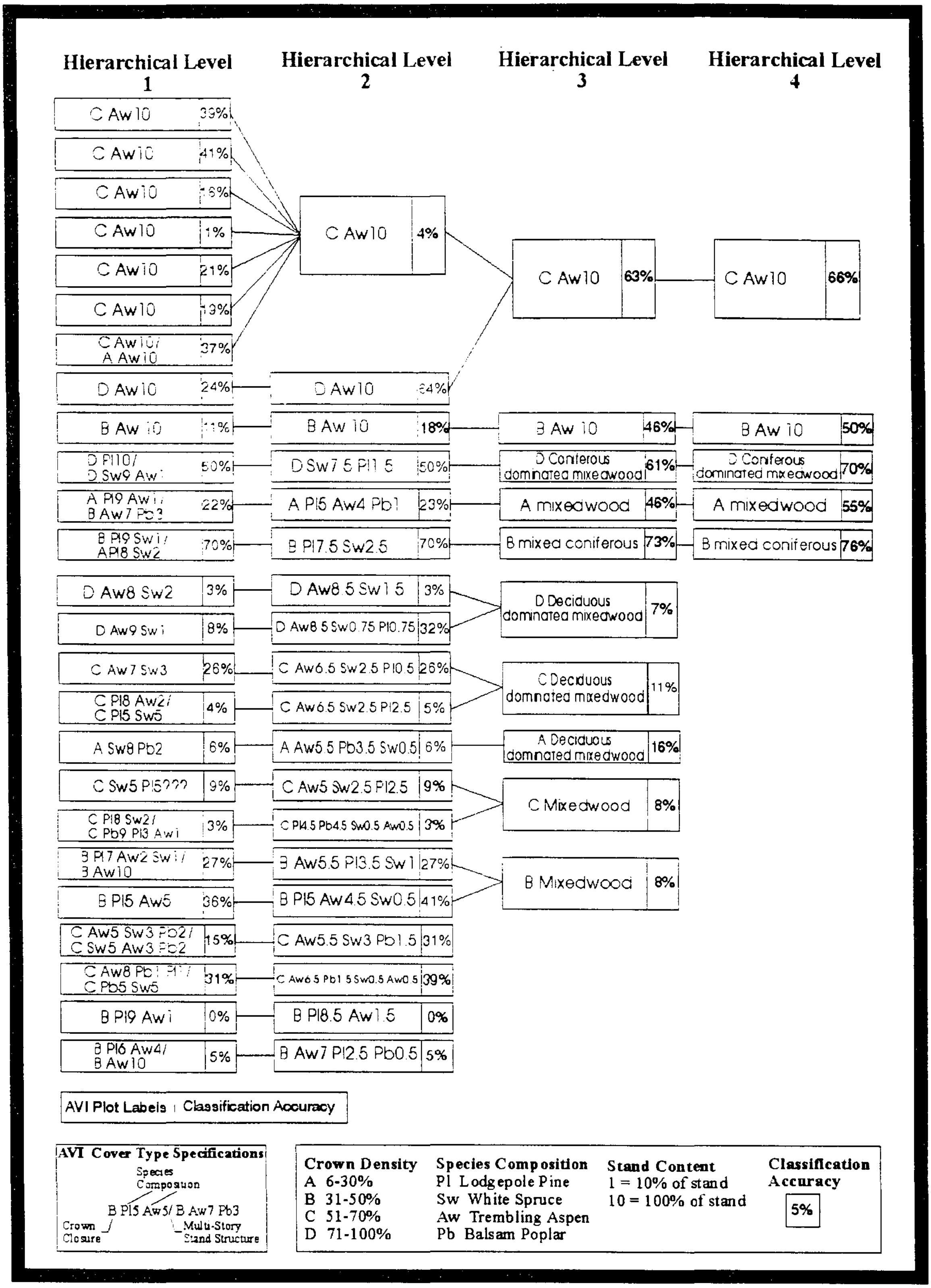

Figure 2 - Hierarchical Image Classification Scheme

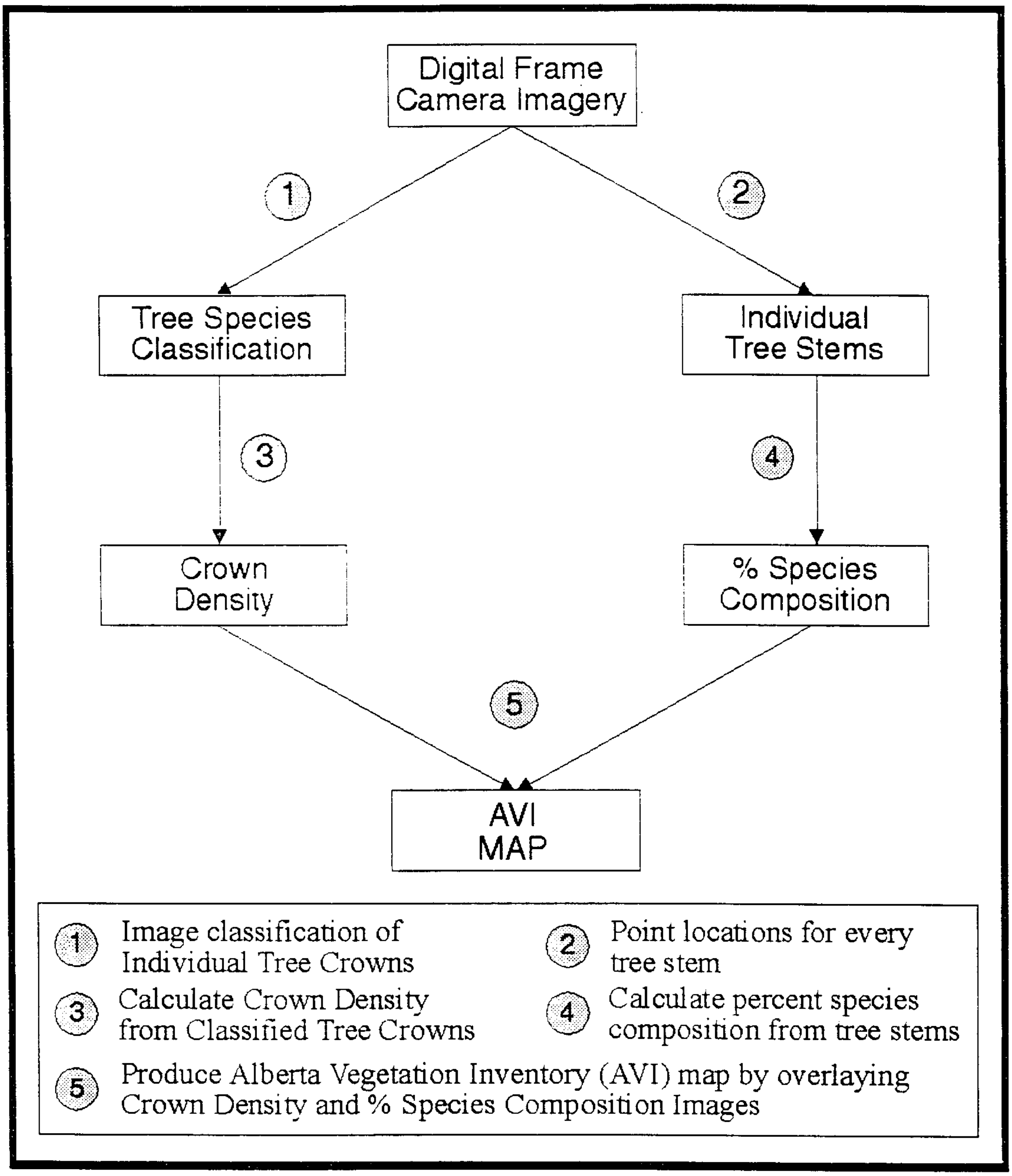

Figure 3 - Classification procedure for use with high resolution imagery and AVI forest inventory applications.

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