Use of high spatial resolution satellite data as a calibration data source to aid in the cluster labelling when classifying Landsat data

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Abstract

The robust classification of Landsat data requires data to calibrate between the reality on the ground and the corresponding image representation. Often ground data is difficult or expensive to collect. Further, in Canada where approximately 5 million km^2 are considered forested, much of the forest is not monitored through industrial or provincial/territorial forest monitoring activities on a regular basis. An issue that is compounded also by the lack ground data or aerial photography to help during pre-and post classification processes.

High spatial resolution remotely sensed data, such as the approximately 6 meter Indian Remote Sensing (IRS) 1C and 1D and 1 meter IKONOS panchromatic data, may be used as calibration data source where field or inventory data is unavailable. The labelling of clusters generated on Landsat imagery may be aided by interpretation of IRS imagery fused with the Landsat multispectral data, allowing for expert knowledge and texture information as basic entry levels.

In this communication we describe the method for clustering and labelling Landsat data using IRS and IKONOS data as a complementary information sources. The high spatial resolution data is used in a similar manner to air photographs, and due to the digital nature of the data, it has additional capabilities when fused with Landsat multispectral data. The fused data provide appropriate information for the cluster labelling of a limited number of classes. Recommendations are made based upon the use of high spatial resolution data as a surrogate data source to aid in cluster labelling for classification in northern or remote Canadian locations.

Introduction

Landsat data provides a favourable combination of spatial coverage (≈185x180km), pixel size (30x30m), and spectral channels (visible and infrared) to allow for useful landscape level image classification (Avery and Berlin, 1992). The landscape level coverage with sufficient spatial information content has led Landsat being selected as the sensor and data of choice for a number of large area mapping projects (Wulder, 2000). Both the Canadian Forest Service and Alberta Environment are utilising Landsat data for large area land cover mapping. The Canadian Forest Service is focused upon the forested area of Canada through the Canadian Space Agency supported project Earth Observation for Sustainable Development of Forests (Goodenough, et al. 1998). Alberta Environment, under the auspices of the Alberta Ground Cover Characterization (AGCC), is engaged in a land cover mapping and change assessment program.

A variety of methods have been used for the production of large area land cover maps (Franklin and Wulder, 2001). While many methods may be used to generate groups of pixels, these groups or clusters, need to be labelled to a class to provide meaning. Regardless of the method chosen to group or cluster the data, labelling is required to provide meaning to the groups. Cluster labelling is often the most intensive and expensive portion of land cover mapping projects. As a result, means to aid in cluster labelling are desirable. Air photos are typically used in conjunction with field plots to aid in cluster labelling. Yet, when large areas are to be classified there are often no air photos of the same vintage as the imagery (or none available at all). The lack of ground validation data is further exaggerated in areas not managed for forestry or Canada's northern areas. Many regions of Canada are remote and are not well surveyed with air photo data. The forested area of Canada, where greater than 10% of a Landsat frame can be expected to be forested, covers more than 400 images (Wulder and Seemann, 2001). Recent photos or ground data are not available in a systematic manner for many of these scenes. As a result, alternate sources from photos and ground data are explored for the potential in cluster labelling.

The higher spatial resolution of IRS data over that of the Landsat sensor provides an opportunity for a viable data source for cluster labelling. While IRS data may be suitable for fusion, IKONOS data is more appropriate for treatment similar to an airphoto. In the following sections we will describe classification and clustering methods where IRS and IKONOS panchromatic data are utilised to aid in cluster labelling.

Methods

IRS-1C labelling of Landsat data

Field Method

To aid with the field component of our research, the IRS and TM imagery were combined (Landsat-5 TM bands 2, 3, and 4) at a 15m resolution to be printed at 1:50 000 scale and used for navigation while in a helicopter. In some areas where the IRS imagery was not available, the maps were produced using TM alone. A comparison of the IRS-TM merge indicates that this fusion is ideal for navigation in the field not only because of its higher resolution, but also because of its enhancement of linear features such as roads and cut-lines.

Three methods of image fusion were attempted prior departure to the field: principal component, multiplicative, and Brovey transform (see Figures 1a to e). The best of which was determined to be the principal component method (Figure 1). Furthermore, textural features not seen in the TM image can be observed in the IRS-TM merge, such as topographic details and small vegetation units that cannot be distinguished on the Landsat alone.

In order to select training sites, predictions were made concerning the distribution of land cover throughout the study area. The area was then split into four portions in the south for ground-validation by ground crews and one larger portion in the north for ground-validation by helicopter. Each portion was expected to have a similar distribution and thus a representative number of sites were chosen. For the ground sites in the south, the IRS-TM image fusion was used as the basis for site selection. Each field map was labelled with sites to be visited according to the expected cover type, visually estimated by texture and colour. Each site was chosen in an area that appeared homogenous in cover-type characteristics. Areas that belonged to groups that were not easily identifiable were labelled as unknown. In all, approximately ten sites were chosen for each map sheet and each of these sites were visited by a ground crew.

Classification Method

The classification of the sites in this project was done using an hierarchical method in which groups of spectrally similar classes were removed from the image one at a time based on their distinguishing characteristics with respect to less distinct classes (Figure 2). One of the problems with automated classification arises when classes are spectrally indistinguishable. In this case the analyst must either accept substantial error in the form of mistaken classes or spend a substantial amount of time modifying the computer's results after a rigorous quality control session. The Hierarchical Classification Method requires constant attention from the analyst throughout the classification process, using personal experience to separate classes at the end of each step in the hierarchy.

The first step in the Hierarchical Classification Method is to prepare the imagery. For this study, Landsat band 6 was removed from the images due to low spatial resolution and limited addition of information to the process. After this point, the image was prepared for classification. Since the first step is to remove the most distinct features (roads, settlements, burns, water bodies, rivers and streams, and any clouds and their shadows), a 45 class ISODATA unsupervised classification was run with a class convergence of 0.98. Once complete, the analyst can easily isolate clouds, shadows, and hydrographic features. Urban features, burns, and smaller creeks and streams were identified with a rasterized version of a digitized base map provided by the provincial government.

The second most distinguishable set of features includes forest cut blocks and agricultural cropland and pasture. Since these features (especially cut blocks) are difficult to discern spectrally from urban features on occasion, the first group of classes is used to mask the image. The masked image is used for the second step while the classes in the first step (that is, the mask) are held back for reassembly at the final step (see Process 1 in Figure 2). The masked image is classified using the same unsupervised method as in the first step. At this point the analyst uses the classification to identify the cut blocks and agricultural land, setting out to delineate them as precisely as possible on-screen and lump them into distinct classes. In the case of cut blocks, delineation was aided by referencing the higher resolution IRS imagery. During the process of this study it was found that any more than about forty-five classes added too much confusion to the signature set from classification while less did not separate the features enough to help identify them prior to delineation.

Again, the product of the second step (cut blocks and agricultural features) is used to mask the image from which it was extracted. This leaves the analyst with an image containing no anthropogenic features (including features such as hydrography and burns). Of the remaining classes the next most distinguishable feature is deciduous forests. These forests are visually detectable in a TM 4, 3, 2 band combination (through the Red, Green, and Blue colour guns respectively) as a bright red feature and are, as a result, detectable in a separate forty-five class unsupervised classification. Once the signature sets are collected and labelled as deciduous, another mask is performed leaving only the most difficult classes to be grouped. Note that the analyst does not make the call on whether these deciduous forests are open or closed. Ancillary data collected in the field will be used to make that distinction later in the process.

IKONOS panchromatic data labelling of Landsat data

The study area for the investigation of IKONOS data includes a large portion of southern Vancouver Island covered by the Landsat 7 ETM+ scene and a smaller, sub-area covered by the IKONOS image in the Sooke Watershed, just north of Victoria, British Columbia. The climate is maritime, with warm, dry summers and wet, mild winters. The average annual daily temperatures range from 3°C to 14°C, with a mean annual temperature of 9°C. Average annual precipitation ranges from greater than 3500 mm on the western side of the Windward Island Mountains to less than 750 mm near Victoria.

Following the procedures outlined in Wulder et al. (2000) we used a K-means clustering on Landsat ETM+ image Path 48, Row 26, representing July 21, 2000. The classification legend proposed for EOSD was also utilised (Table 1). The IKONOS panchromatic image was collected June 3, 2000. The IKONOS panchromatic channel represents 0.45 - 0.90 microns. The Landsat and IKONOS data were ortho-rectified using BC TRIM data.

Table 1. Proposed EOSD land cover classification legend

Class
No Data
Cloud
Shadow
Snow/Ice
Rock/Rubble
Exposed Land
Water
Shrub - Tall
Shrub - Low
Herb
Bryoids
Wetland - Treed
Wetland - Shrub
Wetland - Herb
Coniferous - Dense
Coniferous - Open
Coniferous - Sparse
Broadleaf - Dense
Broadleaf - Open
Broadleaf - Sparse
Mixed Wood - Dense
Mixed Wood - Open
Mixed Wood - Sparse

Initially we performed a visual interpretation of the IKONOS imagery to enable a reference for the cluster labelling of the Landsat imagery. The results of a classification of the Landsat data with, and without, the use of the IKONOS data as a cluster labelling aid was then undertaken. The sample IKONOS image covers only a small portion of the full ETM+ scene (less than 1%) and a limited range of classes from the EOSD scheme. To assess the information content of the IKONOS image relative to the classification schema, classes were manually delineated (visual image analysis) on the IKONOS image through a heads up, on screen digitizing process. In order to emulate a scenario in a remote northern region of the country where supporting data would be non-existent or very limited, classes were assigned purely on the basis of visual interpretation and no ancillary data was referenced.

Summary and Conclusions

IRS-1C aided cluster labelling

From the design and implementation of field campaigns we can conclude that IRS/TM merged imagery can play an important role of the identification of sites from the helicopter as well as to compliment efforts to label land cover classes in areas that may not be accessible from roads. Despite of their usefulness during the field campaign, it is difficult to conclude on the full applicability of IRS/TM merges as a tool for classification and class labelling. At best, IRS/TM merged data sets can serve as tool when attempting to separate anthropogenic features from natural ones. This is the primary recommended use of the IRS, (largely due to the time of image acquisition after seasonal leaf-off, limiting the data as an aid to any deciduous vegetation discrimination). Imagery collected in the winter is best for determination of features such as those anthropogenic in nature and coniferous stands. We recommend that if IRS is to be used to aid in a vegetation classification, it should be captured during the same time of year as the Landsat data.

IKONOS aided cluster labelling

Visual interpretation of IKONOS panchromatic image yielded the following observations:

- Large visual units (past harvest blocks) can be further delineated into treed coniferous open and sparse.
- Herbaceous polygons can be delineated. These areas appear very smooth and seem to occur more frequently near depressions in the terrain. Some of these areas may be (probably are) wetland herbaceous. (A DEM would help distinguish between the two classes.)
- Shrubs (either tall or low) may be distinguishable, using the rule that a shrub is tall if you can resolve it in an air photo (otherwise – its texture is significantly different from that of a herbaceous area and this often forms the basis of assignment to the shrub class).
- Road right of ways that are more than approximately 10 metres in width can easily be captured as exposed land. Delineating any road smaller than this becomes a challenge as the road blends in with recent cut blocks or is obscured by shadows.
- Some older stands (high density, large trees) or stands around lakes appear to have some areas that have a higher reflectance. This could indicate deciduous trees, but it could also be the ground showing through the canopy. Mixed wood patches are often not of sufficient size to be delineated off of this image.
- No pure broadleaf stands were identified.
- Of the wetland classes, wetland-herb and wetland-coniferous can be distinguished relatively easily based on contextual clues.

Based upon the information available from the IKONOS imagery clusters generated on the Landsat data were labelled. The initial clustering was refined to reflect the manual delineation of the classes on the IKONOS image. This refinement of classes led to the elimination of the wetland herb class and the treed coniferous dense class from the classification. The most significant difference between the two classification trials was a large decline in correspondence for the rock class. This decline was caused by the confusion between rock and herb and the reassignment of many areas originally defined as rock to herb (based on the information content of the IKONOS image). Unfortunately this refinement of class assignment was detrimental in other areas of the image. This suggests two possible issues: that the herb and rock class are not spectrally separable using the clustering method implemented for this study and/or that the herb classes were incorrectly identified in the IKONOS image. Without adequate supporting ancillary data or air photos the latter is difficult to determine.

The results of the classification trials conducted in this study would therefore suggest that the information provided by the IKONOS image is limited to the classes that are present in the IKONOS image, not necessarily all the classes present in the Landsat image. The use of the IKONOS imagery as calibration data will also depend not only on the quality of the information which it provides to the analyst, but also on the cost-effectiveness of its application. Although the cost of IKONOS data is high relative to aerial photography, its use may be most beneficial in those areas where the latter is not realistically feasible to acquire.

While this study with the IKONOS imagery representing conditions on southern Vancouver island, the need for the approach is in more northern and remote areas. The use of IKONOS data as a cluster labeling source appears to be more appropriate for homogenous forest areas in northern Canadian regions than for a heterogeneous area with a complex mosaic of natural and anthropogenic features.

References

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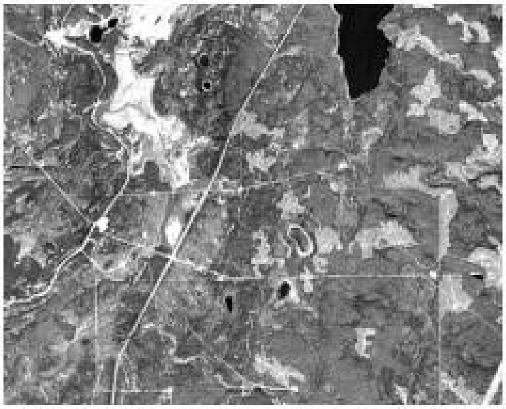

Figure 1a. IRS 1-C panchromatic image.

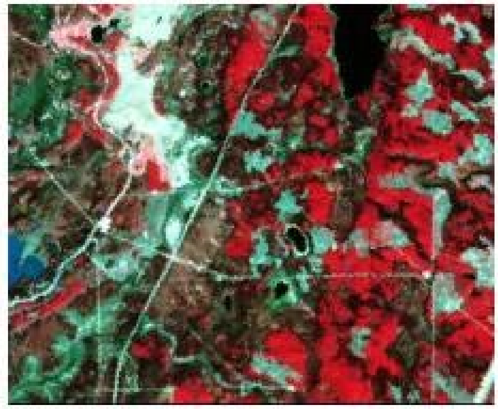

Figure 1b. Landsat 5 TM image.

Figure 1c. IRS-TM merge using Brovey Transform.

Figure 1d. IRS-TM merge using multiplicative method.

Figure 1e. IRS-TM merge using Principal Component Transform.

Figure 2. Hierarchical Classification Method

The principle behind this method is to improve the separability of signatures during a classification by removing well-defined features from the landscape. Each level, a more undifferentiated feature than the last is processed and removed from the image. The final output is an assembly of the four classifications.