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Polygon Decomposition:

a procedure for using remotely sensed data to supplement GIS forest inventories

Mike Wulder, Steven E. Franklin, and Mike B. Lavigne

Strategic Importance

Forest inventory data are typically composed of polygons that have been generalized from air photographs to represent homogeneous forest conditions. Forest management is based on the use of these maps that have been generalized from the interpretation of air photographs. The areas generalized from the air photos form polygons in digital map data stored in a geographic information system (GIS). These polygons represent an interpreted homogeneity of local stand conditions. Satellite remotely sensed data can be used to make measurements, or aggregate information, in a meaningful way within those generalized areas. Polygon decomposition is the process of analyzing previously delineated polygon areas using ancillary digital information acquired from an independent source, such as remotely sensed data. In polygon decomposition, the polygon areas provide a context for assessing the presence or absence of expected conditions. Polygon decomposition enables forest management (inventory) data to be used with remotely sensed data - both require spatially referenced datasets.

This note outlines the polygon decomposition procedures and provides an example. Polygon decomposition is a flexible approach and can be applied to several forest management issues such as:

- indicating changes in forest conditions (forest health or disturbance);
- predicting polygon composition and labels;
- estimating forest structural attributes; or
- undertaking inventory audits.

Current Inventory Creation

Each province or territorial government maintains a forest inventory database in a geographic information system (GIS). Their current methodology for creating these inventories includes:

- Collecting air photos, typically with a repeat interval of many years;
- Interpreting the air photos to delineate areas of similar forest characteristics (polygons); and
- Digitizing the photo-interpreted boundaries.

Areas characterized as homogeneous by the photo-interpreters are selected based upon similarity of characteristics on photographs, such as tone, texture, pattern, shapes, size of features, shadows and associations. These photo characteristics, in turn, are highly correlated with forest characteristics such as species composition, height class, age, density, and management regime. Areas delineated with similar characteristics are known as forest stands and represent the fundamental unit of storage, mapping, and analysis in the resulting forest inventory database.

Typically, forest stands are mapped with a 2- or 4-ha minimum mapping unit (MMU). However, the homogeneity assumed within each polygon is frequently not sufficient for management, analysis, or mapping purposes, or it may not properly represent dynamic forest characteristics.

Information on forest stands in the GIS can be used to create new information based upon known relationships between attributes stored in the forest inventory and previously developed look-up tables. For example, stand timber volume is commonly estimated using look-up tables that relate stand volume to the species, density, and height char-

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acteristics stored in the GIS. While an effective management tool, conventional forest inventory data have two major shortcomings:

1) The lengthy period between measurements. This can significantly reduce the usefulness of conventional inventory data. In a change detection study in New Brunswick, we found that an annual update of forest polygon data was needed since as much as 10% of the forest land base could experience major change in one year.

2) The lack of spatially explicit detail within the stand polygons.

Remotely Sensed Data

Remotely sensed data may be collected by satellite and airborne sensors over large areas with a short repeat cycle. The data may have a standard sampling protocol ranging from low spatial resolution (1 km pixels) through moderate spatial resolution (pixels ≈ 0.1 ha) to high spatial resolution (pixels < 0.0001 ha). Pixels in moderate and high spatial resolution imagery represent areas that are much smaller than forest stands and inventory polygons. This sub-polygon pixel data may be used to provide insight into the polygon contents that may then be used to create new attribute information.

The remotely sensed digital numbers (DNs) may be used directly, transformed to physical values (such as reflectance), or subjected to an image classification. When compared over time, pixels allow the assessment of change within conventional inventory cycles within each stand or polygon.

Remote sensing can also be used to characterize unmeasured polygons, such as those often found in forest inventory databases for private lands. The estimation of attributes from regression-based relationships between digital numbers and ground validation data is possible when each pixel value within a stand polygon can be accessed.

Polygon Decomposition Approach

Polygon decomposition may be implemented in a variety of ways. The key is to be able to summarize the remotely sensed values within the GIS forest inventory polygons. In Figure 1, we present a generalized data flow for polygon decomposition, following these steps:

- The initial polygon (an area with a single continuous label) is identified.
- That polygon is then rasterized. The resulting pixels are created at the same resolution as the remotely sensed images intended for integration. This allows for a georeferencing of the forest inventory information and remote sensing data.
- The third step is the decomposition of the GIS polygon. For instance, the results of an image-wide change detection procedure that identifies differences between two dates of images may be considered within the polygon. The change detection procedure creates new pixel values which may then be aggregated to create a new label for each polygon.
- The within polygon digital numbers are summarized and the data are recorded in the GIS as a new attribute.

The change detection and polygon decomposition steps

Two image samples with related simulated forest characteristics are compared conceptually in Figure 2. The data transformation (using formulae for the simulated forest characteristics of brightness, greenness and wetness) are calculated giving “change results”. The change results are processed within each forest inventory polygon. From the within-polygon aggregation, within polygon change is created for each polygon.

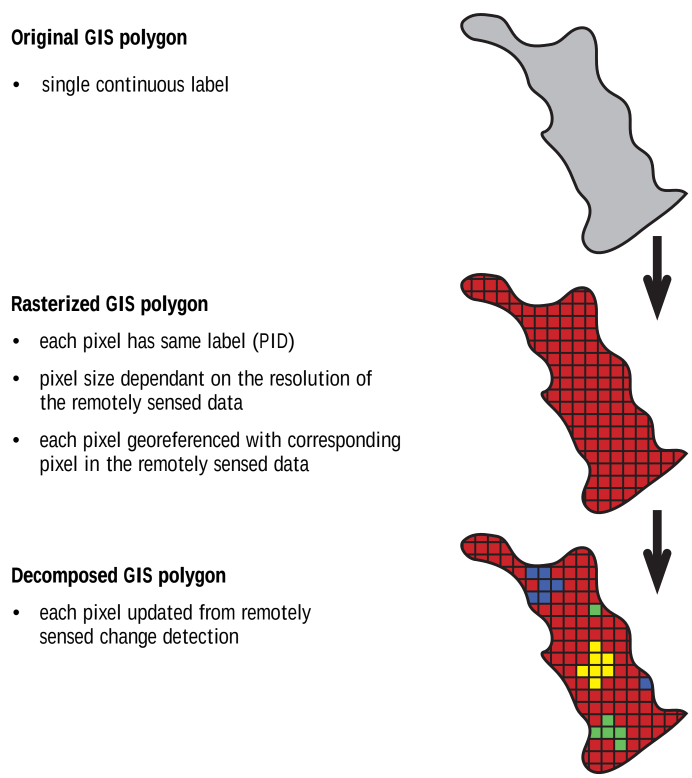

Figure 1. Polygon decomposition data flow, from area of generalization, to rasterization, to summarization. The results of the decomposition are recorded in the GIS as a new polygon attribute.

Two Landsat TM images, acquired on Aug. 7, 1992 (Figure 2A) and Aug. 8, 1997 (Figure 2B), were geometrically registered (0.2 pixel RMSE using 24 ground control points) and atmospherically corrected. This allowed for change detection between the two dates. By comparing the two images (Figures 2A and 2B), we can see that vegetation has been removed in this location.

Image processing in this example consisted of simple transformations of image data within the GIS-selected stand polygons on a pixel-by-pixel basis. The image reflectance data were transformed into Landsat TM Tasseled Cap brightness, greenness, and wetness indices (Crist and Cicone, 1984), which are linear combinations of Landsat TM bands 1 to 5 and 7. The next image processing step was to convert the brightness, greenness, and wetness variables from each of the two dates (1992 and 1997) to a difference image for each component. In the difference wetness image (Figure 2C), bright red indicates a large negative difference between the two years, light pink indicates a medium difference, and light blue indicates a small positive difference, while white indicates areas of no difference. Commercial thinning was interpreted as moderate to light change; approximately 30% of the stand basal area was removed from these areas, but typically the actual canopy change in these mature stands was not large. Pre-commercial thinning in plantations, however, often resulted in a significant reduction in growing biomass, resulting in a larger spectral difference, which could be interpreted as a moderate change.

A supervised classification of the changes was generated (Figure 2D). The training data for these classes were compiled from areas identified in each of the different land ownership types. Treatment types were used to organize the training data into three distinct, though qualitative, classes of change (severe, moderate and light). Some interpretation based on prescription reports from the ownership and the image data were necessary; for example, about 14 m^2/ha (basal area) of white pine remains on thinned areas. This was interpreted as a severe change on the image, but is different from a standard clear-cut in this area.

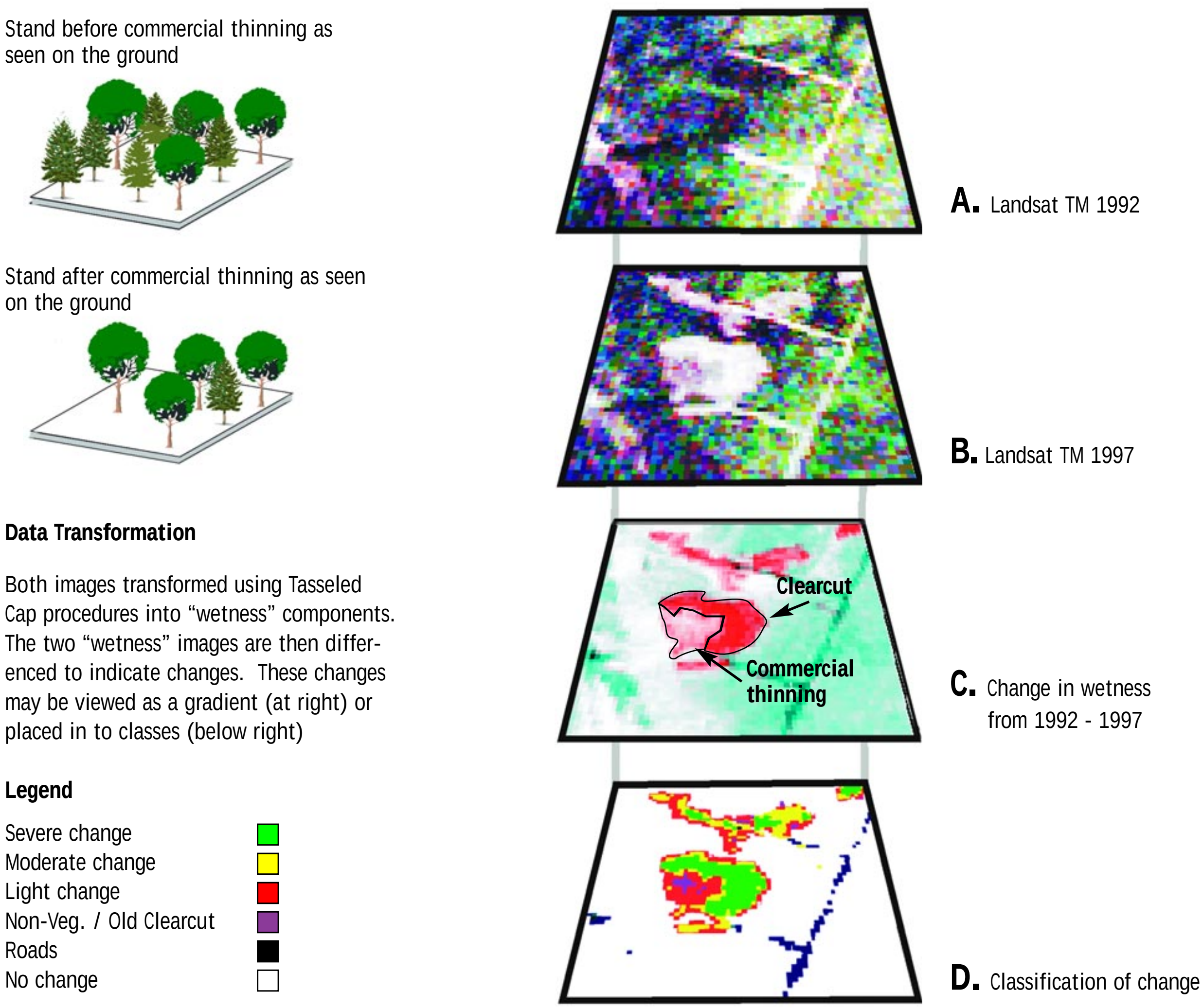

Figure 2. Illustration of Landsat TM image characteristics for differing dates. The data transformation procedure is shown to indicate change conditions that result in a map where changes of interest are classified.

In short, the change identification procedure used in this example is as follows:

- Each Landsat TM image is transformed into Tasseled Cap wetness;
- The wetness images are then differenced to indicate change;
- A thresholding of the changes is finally undertaken to place the changes into classes; and
- Changes are then summarized within the GIS polygons on a pixel-by-pixel basis.

Conclusions

Polygon decomposition is a means of quantifying change within forest inventory polygons.

Change detection through the comparison of existing, but dated, forest polygon data with recently collected remotely sensed data is a valuable new tool for resource managers.

Additional Reading

Crist, E.; Cicone, R. 1984. A physically-based transformation of Thematic Mapper data - the TM tasseled cap. IEEE Transactions on Geoscience and Remote Sensing GE-22(3): 256-263.

Franklin, S.; Lavigne, M.; Deuling, M.; Wulder, M.; Hunt, R. 1997. Landsat derived forest covertypes for modeling net primary production. Canadian Journal of Remote Sensing 23(3): 243-251.

Franklin, S.; Lavigne, M.; Moskal, M.; Wulder, M.; Maudie, A. 2001. Interpretation of forest harvest conditions in New Brunswick using Landsat TM enhanced wetness difference imagery (EWDI). Canadian Journal of Remote Sensing. *In press.*

Gillis, M.; Leckie, D. 1996. Forest inventory update in Canada. The Forestry Chronicle 72(2): 138-156.

Wulder, M. 1998. Optical remote sensing techniques for the assessment of forest inventory and biophysical parameters. Progress in Physical Geography 22 (4): 449-476.

Wulder, M; Franklin, S. 2001. Polygon decomposition with remotely sensed data: Rationale, methods, and applications. Geomatica 55 (1): 451-462.

Wulder, M.; Magnussen, S.; Boudewyn, P.; Seemann, D. 1999. Spectral variability related to forest inventory polygons stored within a GIS. Pages 141-153 in T. Zawila-Niedzwiecki and M. Brach, editors. FIRS (Forest Information from Remote Sensing). Proceedings: IUFRO Conference on Remote Sensing and Forest Monitoring, Warsaw Agricultural University, Rogow, Poland, June 1-3, 1999. Office for Official Publications of the European Communities, Luxembourg. EUR 19530 EN.

Contacts

Mike Wulder
Natural Resources Canada,
Canadian Forest Service,
Pacific Forestry Centre,
Victoria, BC, Canada
Phone: (250) 363-6090 Fax: (250) 363-0775
email: mwulder@pfc.forestry.ca

Steven E. Franklin
University of Calgary,
Department of Geography,
Calgary, AB, Canada

Mike B. Lavigne
Natural Resources Canada,
Canadian Forest Service,
Atlantic Forestry Centre,
Fredericton, NB, Canada

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