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Research Note / Note de recherche

Large-area forest structure change detection: An example

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Abstract. We used the Landsat Thematic Mapper (TM) enhanced wetness difference index (EWDI) to detect forest changes in the Fundy Model Forest, a large, multi-jurisdictional forest management unit in southeastern New Brunswick. The average annual change on the landscape was approximately 3068 ha over a 15 year interval (1984–1999). The estimate of total change (almost 50 000 ha) as a percentage of the total Fundy Model Forest available productive forest land (approximately 240 000 ha) translates into a rate of change of approximately 1.3% annually.

Résumé. Nous avons utilisé l'indice EWDI (enhanced wetness difference index) de Landsat TM pour la détection des changements dans la Forêt modèle de Fundy, une grande unité de gestion forestière sous juridiction multiple située dans le sud-est du Nouveau-Brunswick. Le changement annuel moyen observé dans le paysage correspondait approximativement à 3068 ha pour une période s'étendant sur 15 ans (1984–1999). L'estimation de la surface totale ayant subi un changement (presque 50 000 ha) en terme de pourcentage par rapport à l'ensemble des terres forestières productives disponibles de la Forêt modèle de Fundy (environ 240 000 ha) représente un changement d'environ 1,3% par année.
[Traduit par la Rédaction]

Introduction

The Landsat Thematic Mapper (TM) Tasseled Cap transformation (Crist and Cicone, 1984; Crist, 1985) is a useful tool in forest change detection over large areas and reasonably long (e.g., decadal) time periods (Horler and Ahern, 1986; Collins and Woodcock, 1996; Cohen et al., 1998). There is a paucity of good change detection examples in the literature, however, and more are needed to facilitate greater understanding of the role that this tool may play in forest management applications (Cohen and Fiorella, 1999). In southeastern New Brunswick, one formulation, the enhanced wetness difference index (EWDI) described by Franklin et al. (2000a; 2000b; 2001), has been used in the detection of forest structure changes caused by partial harvesting and clearcutting.

The EWDI was thought to be very accurate in classifying change between images in two time series (1992–1997 and 1997–1998 TM imagery). In this paper, this use of the EWDI is extended to detect changes in forest structure covering a 15 year time interval from 1984 to 1999 in the Fundy Model Forest (**Figure 1**). We acquired six Landsat TM images (sequential, non-anniversary) and created EWDI data for each image pair in the sequence. The difference in the wetness index between each two TM image dates was linearly enhanced to emphasize the forest differences of interest and a threshold identified iteratively.

Study area and data collection

The Landsat TM images acquired (path 9, row 28 on 18 September 1984, 21 September 1985, 23 August 1986, 10 August 1988, 7 August 1992, 6 September 1997, and 12 September 1999) represented the best imagery in the archive for the months of August and September in which the area was relatively cloud free; a few very small areas of cloud and cloud shadow were identified by thresholding bright areas and shadows supplemented with manual digitizing on-screen. Those areas were removed from the analysis with no effect on the image processing results reported here. The images were solar-zenith angle (illumination) and atmospherically corrected using a standard-atmosphere, model-based atmospheric correction routine (Richter, 1990). The image data were geometrically registered to the Universal Transverse Mercator (UTM) North American datum of 1927 (NAD27) projection with 40 GCPs points at key road intersections dispersed throughout the scene with a root mean square error (RMSE) of less than 0.5 pixels. A cubic convolution resampling algorithm was used to resample the images with a 25 m output grid.

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Figure 1. Study area in the Fundy Model Forest in southeastern New Brunswick.

Methods

Areas that were substantially cleared of standing biomass (e.g., clearcuts, shelterwood cuts, and partial cuts with legacy patches) were interpreted as a bright red tone in the EWDI imagery. The largest difference in wetness was found in the clear-cut areas, followed by shelterwood and seed-tree cuts, partial harvesting with legacy patches, and precommercial thinning. A threshold of wetness difference was used to develop a map. The determination of the EWDI threshold required an iterative and subjective process of adjustment; particular attention was paid to the location and distinctiveness of new roads, for example. Known road construction was used to gauge the effectiveness of the threshold in presenting the changes; for example, if the road were to "bloom", then the threshold was too low; if the road were to "disintegrate", then the threshold was too high.

This process is illustrated graphically for the 1984–1985 image pair in **Figures 2** and **3** for two small regions: (1) Hayward Brook sub-area, and (2) Bay of Fundy sub-area. The final results (i.e., accumulated changes) of the image thresholding process for these two sub-areas are shown for all the available image pairs in **Figures 4** and **5**, respectively. The available New Brunswick Department of Natural Resources and Energy (DNRE) forest inventory geographical information system (GIS) data were used to "mask" all non-forest areas from the change detection procedure; since the GIS forest cover data were a static layer (compiled in 1997 from 1993 photography), minor error may have been introduced in this masking process (i.e., some areas that changed in the 1984–1985 scene were not changes to forest cover but occurred in agricultural or wetland areas, for example, and may have "escaped" the mask).

Results

The final map of forest structural changes detected in forest areas of the Fundy Model Forest is contained in **Figure 6**. The average annual area of change on the landscape was approximately 3068 ha, with apparently declining mean annual change from the mid-1980s to the late 1990s. The maximum annual change was more than 7000 ha in 1985–1986; the minimum annual change was less than 2500 ha in each of the years from 1986 to 1992. This latter estimate of change is almost certainly low, an artifact of the 6 year time interval between the 1986 and 1992 Landsat TM images in which changes of lesser severity (e.g., some partial cutting and thinning) could not be distinguished. In the late 1990s, the annual change was approximately 3500 ha.

These estimates of total change (almost 50 000 ha) as a percentage of the total Fundy Model Forest land base (more than 400 000 ha) suggest that approximately 12% of the total land area has experienced a change in forest structure; annually, this is equivalent to a rate of change of 0.81%. Since the available productive forest land (approximately 240 000 ha) represents approximately 60% of the total land base, the true estimate of forest structure change is probably closer to 20% in the time interval studied, which translates into a rate of change of approximately 1.3% annually.

The large, intact white area in the bottom right (southeast corner) of Figure 6 comprises Fundy National Park; only a few small changes occurred inside the park boundary compared to the areas adjacent to the park but within the Fundy Model Forest. These small areas of change inside the park represent a number of small human disturbances (e.g., road widening) and natural disturbances (e.g., beaver pond flooding, tree blowdown, and insect defoliation) that are likely also present but undistinguished from other changes in the larger mapping product.

Conclusions

A useful tool in large-area, relatively long term (e.g., decadel) forest change detection studies is the Tasseled Cap enhanced wetness difference index (EWDI) (see Franklin et al., 2000a; 2000b; 2001). The EWDI is based on an emerging understanding of spectral differences and stand structure caused by partial harvesting and silvicultural practices. An example of the interpretation of the EWDI for Landsat TM imagery acquired in 1984, 1985, 1986, 1992, 1997, and 1999 in the Fundy Model Forest of New Brunswick is provided in this paper. The total change (almost 50 000 ha) as a percentage of the total Fundy Model Forest available productive forest land

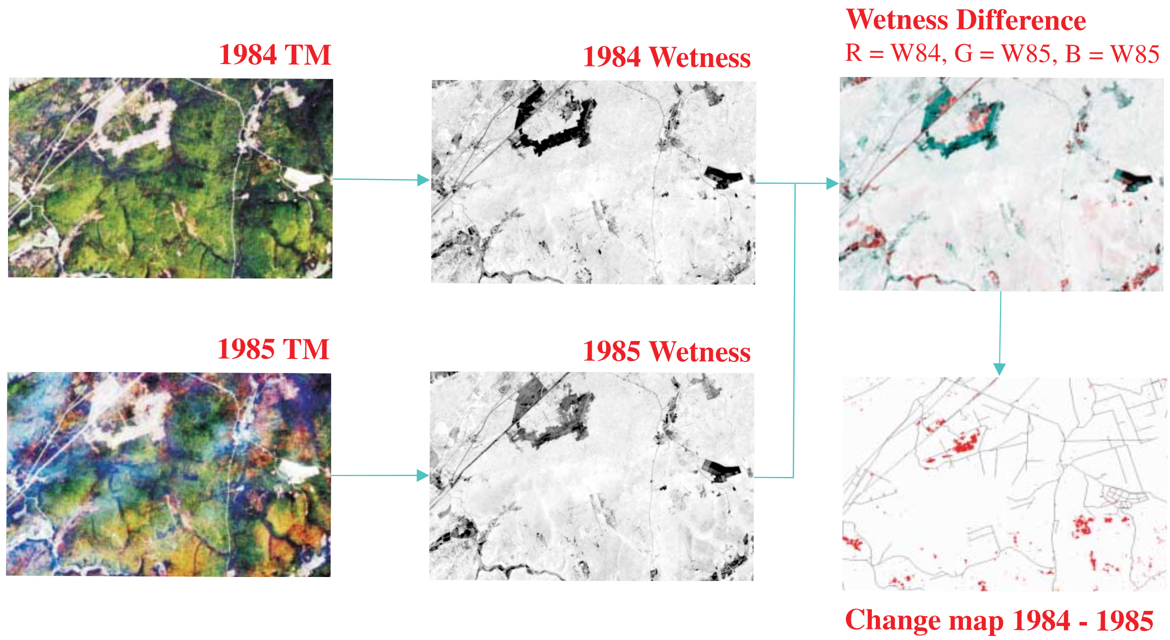

Figure 2. Graphical illustration of the enhanced wetness difference index (EWDI) and thresholding procedure for the Hayward Brook sub-area.

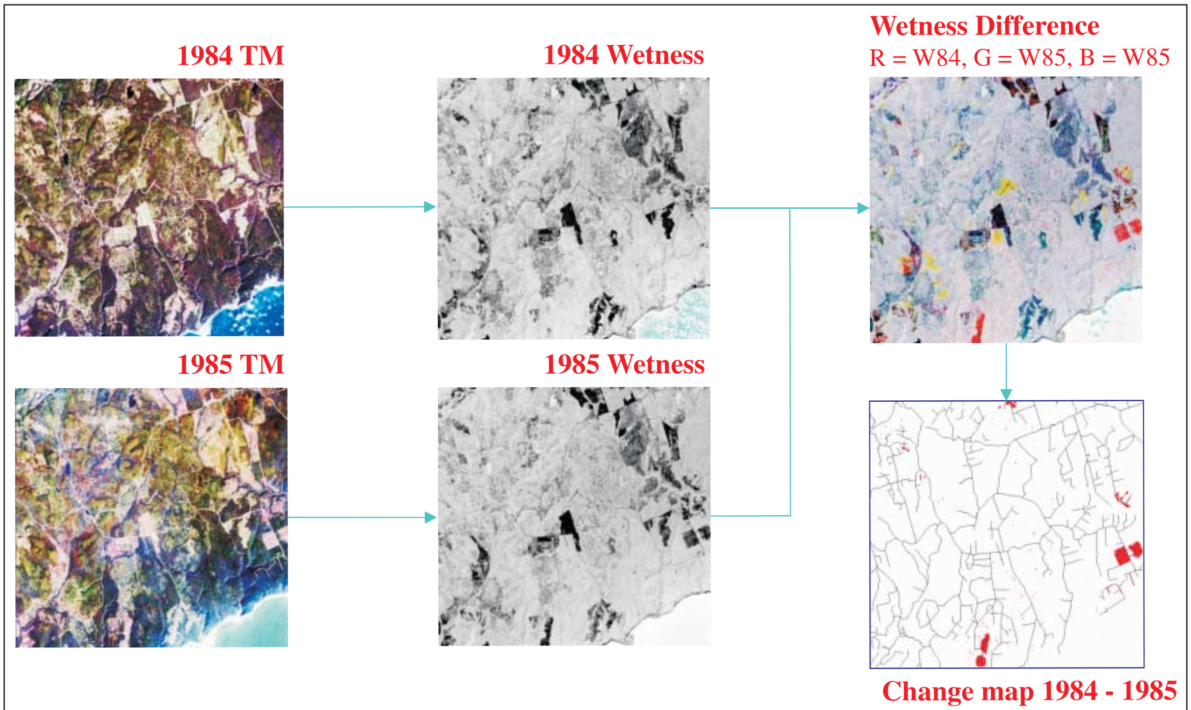

Figure 3. Graphical illustration of the EWDI and thresholding procedure for the Bay of Fundy sub-area.

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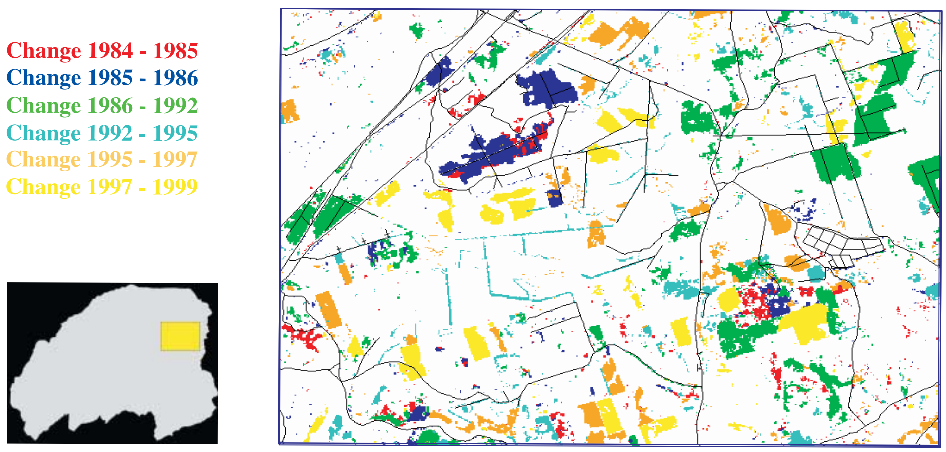

Figure 4. Accumulated change in forest structure for the Hayward Brook sub-area.

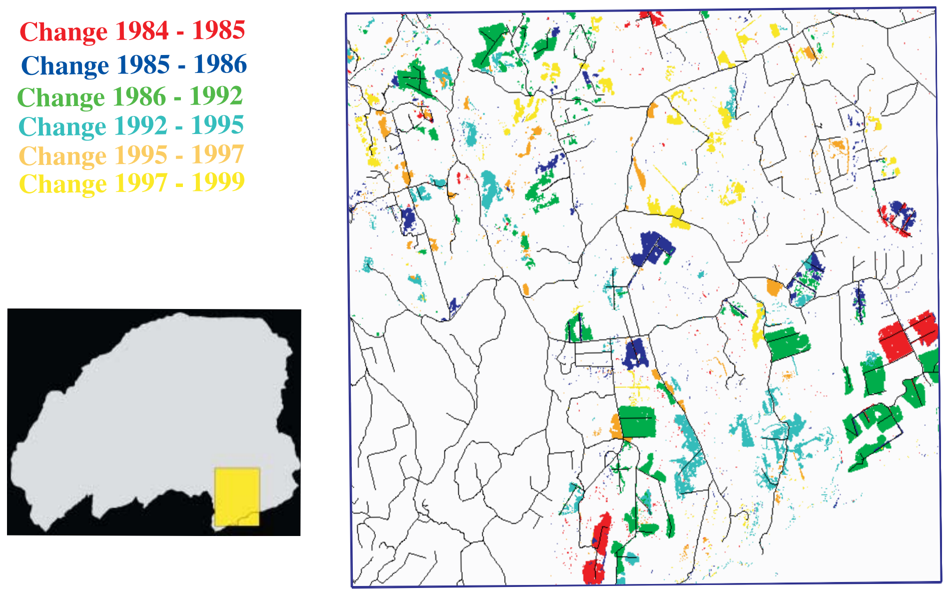

Figure 5. Accumulated change in forest structure for the Bay of Fundy sub-area.

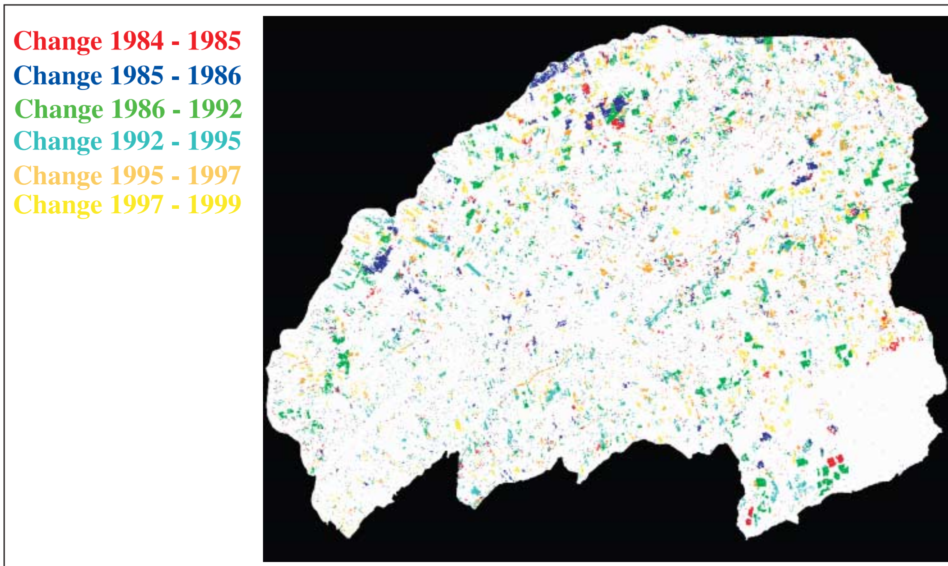

Figure 6. Accumulated change in forest structure for the entire 400 000 ha Fundy Model Forest including Fundy National Park (bottom right corner).

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