

DETECTION, CONFIRMATION AND VALIDATION OF CHANGES ON SATELLITE IMAGE SERIES. APLICACION TO LANDSAT 7

Lucas Martínez, Mar Joaniquet, Vicenç Palà and Roman Arbiol

Remote Sensing Department. Institut Cartogràfic de Catalunya. Parc de Montjuïc s/n, 08038 Barcelona (Spain)

ABSTRACT

In this paper, a methodology developed for the detection of significant changes for cartographic purposes on a set of satellite images is introduced. The main aim of this work is to assist the user in cartographic updating processes. As a previous step, a series of atmospheric compensation and correction processes are applied to the imagery. Besides, several covers such as clouds and water layers that are prone to generate blunder changes are detected and marked off. Next, multitemporal pairs of images are generated using the oldest image of the series as a reference image. Then, the pairs are photo-interpreted to delineate the areas that show significant radiometric differences. The difference images obtained are analysed within a tree classification structure in such a way that the changes detected in the first difference image can be confirmed on the second one, and can be validated with the third image. The methodology for detection, confirmation and validation of changes has been applied to a multitemporal set of four Landsat 7 images (pan band) on Banyoles area (Spain). The results show that the suggested technique is appropriated for the pursued objective. Additionally, the results of the methodology have been successfully verified by comparison with 1:25000 orthophotomaps of the area.

Key Words: Change detection, cartographic updating, radiometric difference, classification, Landsat 7, Banyoles.

INTRODUCTION

The detection of territorial changes, such as those derived from public works, is a keystone for the assistance to the scheduling of the cartographic updating projects. That is because updated cartography allows a better territorial management. For this reason the Institut Cartogràfic de Catalunya (ICC) develops a project aimed to the detection of actual territorial changes on satellite images.

Images acquired with a sensor as Enhanced Thematic Mapper Plus (ETM+) onboard the Landsat 7 platform, are an adequate instrument for the analysis of those changes, as a result of temporal, spatial and radiometric resolution of the imagery. The satellite Landsat 7 has a repeat cycle of 16 days, a set of 6 bands on solar spectrum with a pixel size of 30 meters, and a panchromatic band of 15 meters. Besides, it also has a band on thermal infrared with a pixel size of 60 meters (See Table 1). Panchromatic band is especially interesting because of the spatial resolution, while the rest of the bands allow obtaining additional thematic information suitable to be added in the detection process.

Band number	Wavelength (μm)	Nadir resolution (m)
1	0,45 - 0,52	30
2	0,52 - 0,60	30
3	0,63 - 0,69	30
4	0,76 - 0,90	30
5	1,55 - 1,75	30
6	10,4 - 12,5	60
7	2,08 - 2,35	30
Pan	0,50 - 0,90	15

Table 1. Spatial and spectral resolutions of Landsat ETM+ sensor.

Classical methodologies for change detection by means of satellite images are based on post-classifications or multitemporal classifications with on images (Singh, 1989). On the other hand, there is the possibility of performing the monitoring of the territory with a series of images using basic arithmetic procedures (Jensen, 1996). In this paper, we are taking a different approximation by using a series of images to manage the territory and change detection, in such a way that new images allow validating or refusing the results of the previous images.

In cartographic updating processes, the more interesting changes are the artificial ones. Those changes have special radiometric, morphologic and temporal period characteristic that have important influence in the methodology to detect them. Regarding radiometry, large artificial land modifications produce high radiometry variations due to the bare soil present during the change compared to most of the anthropogenic covers. With regard to morphology, there is a wide variety of shapes in the changes suitable to be controlled. They range from very compact shapes like urban areas, to pure lineal structures such as ground communication tracks. Finally, regarding the temporal period, the significant modifications for territorial management ranges from few months to several years.

Images included in the series to be used in the change detection are multitemporal. That means that each one was acquired with different illumination geometry and suffers from different atmospheric effects. Thus, it is essential to compensate the impact of each acquisition geometry and atmosphere state on the radiometry. At the end a set of atmospherically corrected and normalised images is finally obtained (Martínez *et al.*, 2003 iii). Moreover, there are natural and irrelevant changes for cartographic proposes as clouds, the casted shadows, and natural variations of water layers. Those must be previously detected and removed from the images (Martínez *et al.*, 2003i). The set of images used in this kind of study suffer from the presence of sparse clouds. This kind of cloud cast a recognizable shadow on Landsat imagery as a result of the high spatial resolution of the sensor. Besides, the shadows of the clouds must be also delineated or they will appear as a huge change due to the reflectance shift in the differences image (Martínez *et al.*, 2003).

The objective of this paper is to set up a working methodology based on satellite images for the detection of real changes on the territory, suitable to be reflected on the updated cartography. In the next section the proposed methodology for this study is explained. Then, the application area is introduced. Finally conclusions are shown.

METHODOLOGY

Atmospheric effect correction

Atmospheric correction of the images is performed by means of the methodology described by Martínez *et al.*, (2003iii) and Martínez *et al.*, (2003ii) and consists on the consecutive application of an atmospheric correction system based on a physical method and radiative transfer simulations, plus a statistical normalization method based on pseudoinvariant areas that allows smoothing deviations not previously considered.

Discrimination of non-interesting covers

The proposed methodology to identify the clouds is based on three sources of information. First, the high reflectance of clouds in solar spectrum, that supposes and increasing of the reflectance compared with the mean reflectance of the series. Next, the lower temperature on the top of the clouds that produces a decreasing of the radiance on the thermal image (Martínez *et al.*, 2000). Finally, the shadows casted on the ground by clouds produce a decrease on the reflectivity. From each source of information a mask is made applying a threshold criterion. The mask is supervised and linked together into a single mask that shows the real clouds detected with the alignment of clouds and shadows in according with illumination geometry.

The methodology proposed for the detection of water layer is done in this study with a classical threshold method applied on Landsat band 4 reflectance, because in that spectral region there is a high contrast between water layers and general vegetation cover (Martínez *et al.*, 2003i)

Generation of multitemporal pairs and images classification

The variations of the spectral signature are directly related to the variations of ground covers. After compensating for geometric and atmospheric influences during the acquisition, spectral signatures are supposed to be dependent only on

radiometric behaviour of the observed surface. Thus, the radiometric differences that images show can be interpreted as real changes on the cover. For a proper observation of the differences we adopt the methodology of generating RGB images made from two different images using a chromatic configuration as Table 2 shows. The channel selected to make the pair is the panchromatic, due to the high pixel resolution and to avoid an excess of information during the photointerpretation process. The pairs generated with that process have in common the oldest image of the series, in such a way that it is possible to study the evolution of the changes observed on the territory combining the information from each pair.

Color	Information
R (red)	Older image
G (green)	Newer image
B (blue)	Older image

Table 2. RGB configuration for multitemporal pairs.

Each single pair is analysed by a photointerpreter to manually generate an image with the observed radiometric changes (Figure 1). As a result of the previous processes applied to the images, when the pair is observed with the RGB configuration described, the regions that do not have radiometric variations show grey shades. The regions that have increased its reflectance show green shades. Regions that have decreased the reflectance show magenta shades. During the photointerpretation process, information from multispectral and thermal bands is used in such a way that all the information produced by the sensor is suitable to be incorporated to the land change detection process. For all that, the main source of radiometric is the panchromatic bands.

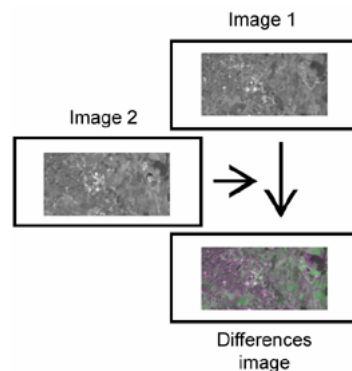


Figure 1. Image differences generation from single pan images.

The photointerpretation of each pair provides a differences image. Those images must be processed to obtain real changes on the territory. In order to do that, we use a minimum of three differences images obtained by photointerpretation of multitemporal pairs. The procedure is a tree classification system (Figure 2) that allows discriminating the differences on the first by comparing to the differences observed on the following images. So, detection on the first image can be confirmed on the second one and validated when incorporating the third one.

The process of detection, shown in the Figure 2 is the following:

- **First image of differences:** all the differences are labelled as “Possible” changes, so they need to be validated and confirmed.
- **Second Image of differences:** some previously detected changes are confirmed in this step and they are labelled as “Yes” changes. But previously detected changes that are not confirmed now are labelled as “No” changes. On this second image there are detection of new changes, so they are labelled as “Possible” changes.
- **Third Image of differences:** Previously confirmed changes that are also shown on the third image are validated, and they are finally labelled as “Yes” changes. Previous confirmed changes that are not present on the third image, and detected changes not confirmed on the second image presume an erratic behaviour of the cover, so they are labelled as “Alternating” and must be studied with further information. On the other hand, previously detected changes but not confirmed and not present on the third image are finally discarded and they are labelled as “No”. As in previous cases, on the third differences image there is new change detection. Those changes are classified as “Possible”.

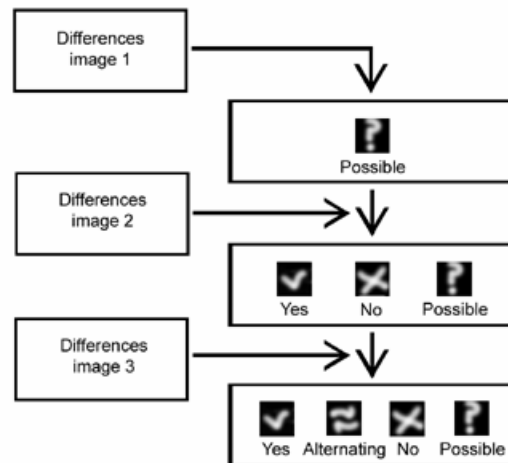


Figure 2. Classification tree for detection, confirmation and validation of changes.

After incorporating the third differences image the initialisation process of the classification system is completed. The number of categories is not incremented when incorporating more difference images to the process, but then it is possible to confirm and validate changes detected for the first time on the second and subsequent difference images.

Comparison with ortophotomap 1:25000

As the last step of the study, the validated changes on the remote sensing images are compared to the 1:25000 ortofotomapa cover of the area. This way, an estimation of the effectiveness of the proposed methodology discriminating real and interesting changes for cartographic proposes is performed.

RESULTS

The procedures described have been applied to a series of four Landsat ETM+ images (Path 197 and Row 031 on the World Reference System). Corresponding dates are: 23-07-1999, 03-03-2000, 10-08-2000 and 13-08-2001. The image set is geometrically oriented in a simultaneous adjustment block using the geometric model of *Palà and Pons* (1995), and it is geocoded using a nearest neighbour procedure in 15m sized pixels for the pan band, and 30m sized pixels for the rest. The set of images was processed to eliminate the clouds and shadows and finally the water layer was removed for all the images to avoid natural changes. Figure 3 shows a detail of the whole area studied.

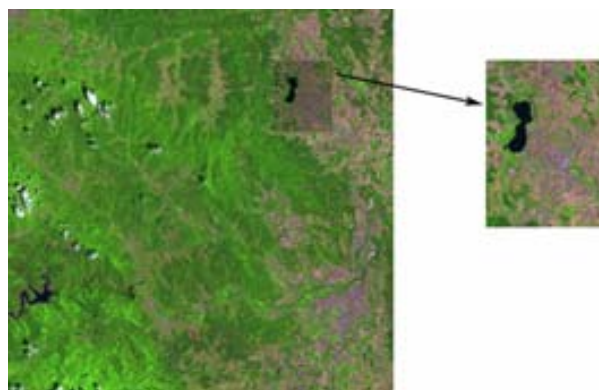


Figure 3. Area of study and detail where results are showed. (Image date 23-07-1999).

The four images of the set for this study were used to make three multitemporal pairs using the older image as the common image for every pair. The pairs were analysed by an expert photointerpreter, who delineated the areas with

significant radiometric variations, and a differences image was elaborated with each pair. The mean time for the photointerpretation and the delineation of the differences image on each pair was five hours. For the study area, the main difficulties during the photointerpretation process were: problems with geometric correspondence on Landsat imagery, phenologic variations of the crops near urban areas, and rivers with variable flow that sometimes had vegetation on the river bank. Geometrical problems are a huge limitation for the proposed methodology, so the better is the coincidence of the images, the more accurate is the delineation of the changes.

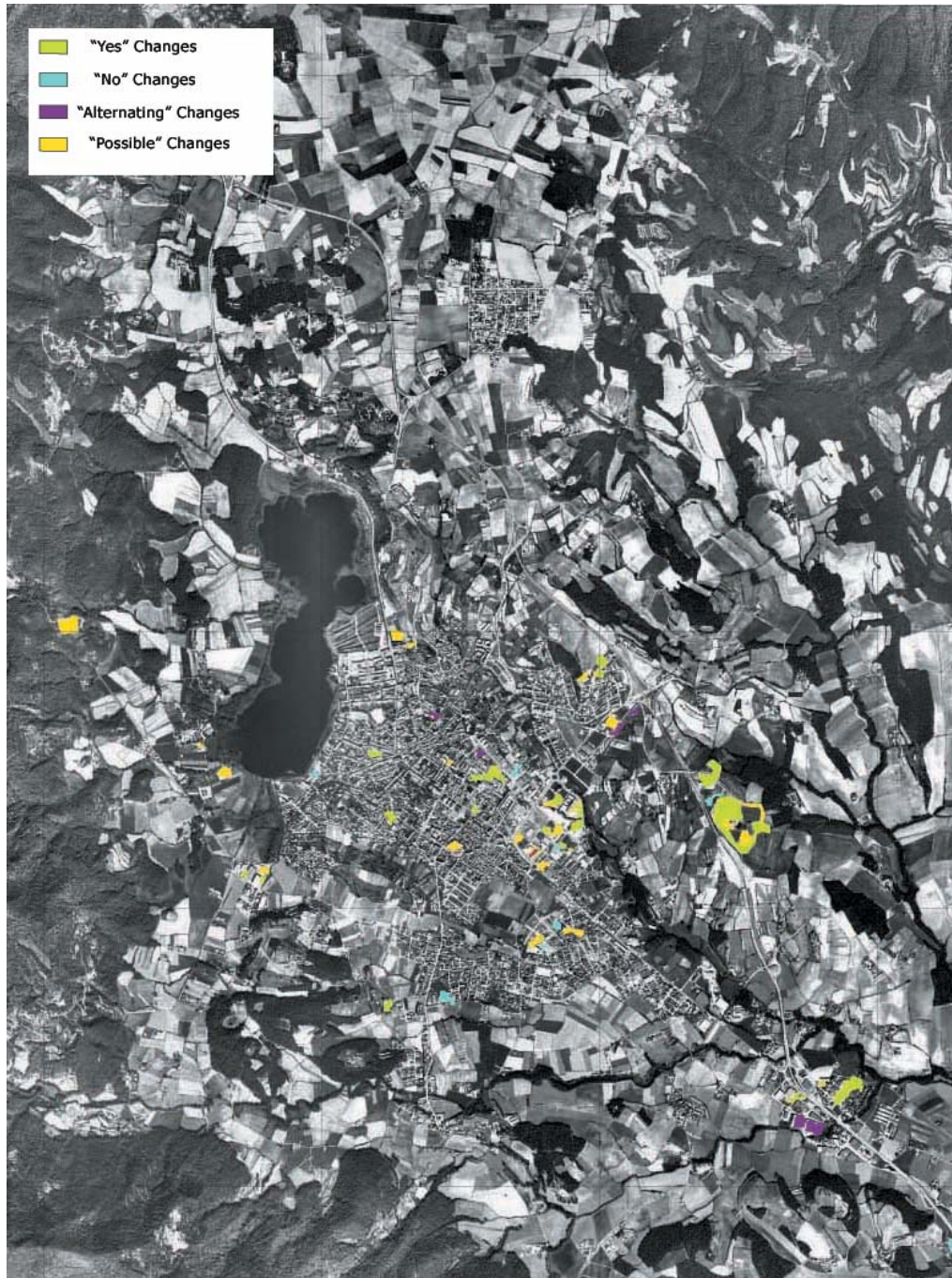


Figure 4. Changes classification after the third differences image (Detail on orthophotomap 1:25000 of Banyoles)

The Figure 4 shows the result of applying the classification tree process to the differences images. The four classes of changes are found on the study area. That fact points out to the bigger accuracy of the proposed methodology against a single differences image on detecting real changes. Moreover, the use of several images generates new actual changes when adding each new image.

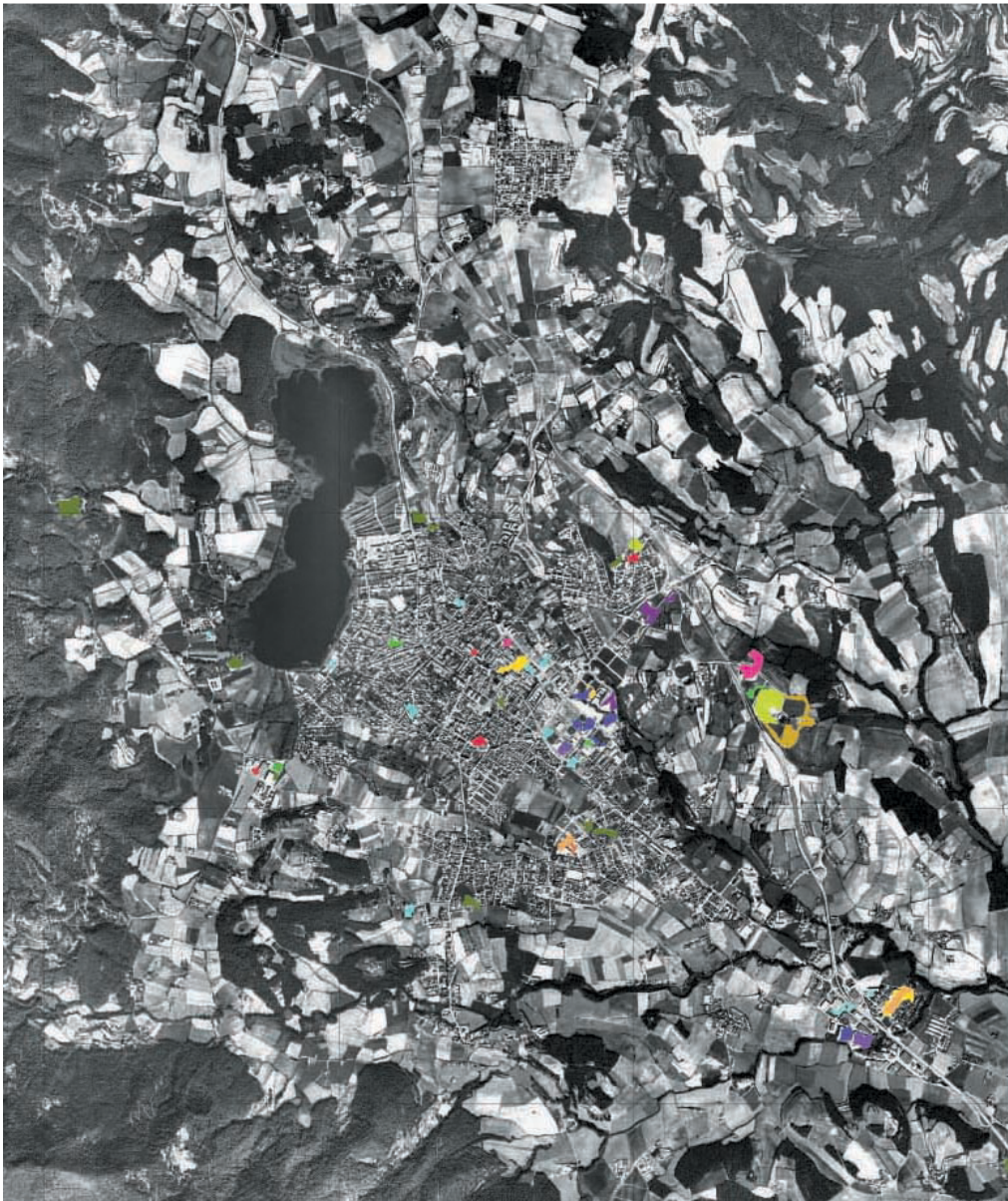
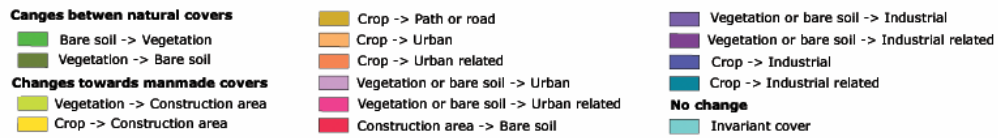


Figure 5 Comparison of changes with ortophotomaps 1:25000 and thematic classification of changes (Detail on ortophotomap 1:25000 of Banyoles)

The changes validated with the proposed methodology are now located on two ortophotomaps 1:25000 generated from photo flown before and after the satellite images. As Figure 5 shows, there are a few changes that do not seem to correspond to a real change, but most of them are. Real changes can be split into two categories: rare changes between natural covers, and changes towards artificial covers. These ones are the most interesting for cartography updating and territorial management, and the proposed methodology seems to provide good results for the aim of the work. Moreover, the detection methodology is robust, so it is difficult that a real change goes unnoticed.

CONCLUSIONS

In this paper, a methodology for the detection of significant cartographic changes on a series of Landsat 7 ETM+ has been proposed. The undesired natural changes have been discarded and a tree classification procedure has been applied to classify three differences images made with four Landsat images. The final results show good accuracy on detection of the actual changes, as is confirmed when comparing to ortophotomaps of the area at 1:25000 scale. The main difficulties are related to Landsat imagery geometry that limits the detection of small site changes. However, spatial, temporal and spectral resolutions of Landsat imagery are appropriate to assist the cartographic updating processes with these methodologies.

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BIOGRAPHY OF THE PRESENTING AUTHOR

Lucas Martínez Rodrigo received his degree in Physics at the University of Valencia in 2000. He is currently carrying out a PhD. thesis research focused on atmospheric correction. Since 2000, he cooperates in the research of the Remote Sensing Unit of University of Valencia. Additionally, since 2001 he works as a researcher in the Remote Sensing Dept. of the Cartographic Institute of Catalonia (ICC). His main research interests involve: temperature and emissivity measurements, atmospheric correction procedures for airborne and satellite sensors, precision farming, and multi-temporal analysis for land cover change and cartography update.