Detecting land cover changes through remote sensing and GIS techniques

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Abstract – This note concerns the updating of the land cover map of the Arno River basin (9.000 km^2) developed in the frame of a research project aimed at landslide risk assessment. The land cover map has been produced through the analysis of panchromatic/multispectral Landsat ETM+ images and TERRA-ASTER data; those data were integrated and compared with B/W and color ortho-photos. To improve photointerpretation and to obtain a higher resolution of the multispectral data, some image fusion techniques have been applied to Landsat data, such as Hue Saturation Value (HSV), Color Normalized (CN) and Principal Component Substitution (PCS). The land cover data base of the CORINE Land cover Project have been updated and improved to a scale 1:50.000.

Keywords: land cover, satellite images, photointerpretation, landslide hazard.

1. INTRODUCTION

A land cover map represents the physical description of the environment regarding several aspects such as geomorphology, pedology, vegetation and anthropic activities (such as agriculture, urban areas, infrastructures); information on land cover, together with information on relief and drainage systems is essential for the management of the environment and natural resources. For landslide hazard assessment, data on land cover are fundamental and represent also an input to define elements exposed to landslide risk.

The aim of this work was the realization of an updated land cover map at scale 1:50.000 using remote sensing data validated through ground surveys in the Arno River Basin, Italy. In fact the capability of detecting land cover changes trough remote sensing analyses can allow low cost spatial and temporal updating.

1.1 Study area

The Arno River Basin, with a spatial extension of about 9.000 km^2, represents one of the widest hydrographical basins of the Italian territory (Fig. 1). It can be considered a relatively homogeneous area from the viewpoint of its general geological characteristics, being located in correspondence to the Northern Apennines, in Tuscany. In fact, this mountain chain is mainly made up of arenaceous and calcareous turbidite sequences and chaotic argillaceous units of sedimentary and tectonic origin.

The type and frequency of mass movements are primarily controlled by lithological and structural factors, secondarily by the high relief and the rather severe meteorological conditions.

Regarding land cover, in the mountainous part of the area coniferous forest prevails, taking place to broad leaves forest or sparsely by open meadows, while the valley bottom is occupied by complex cultivation patterns resulting from the juxtaposition of small parcels of diverse annual crops, pasture and permanent crops. Several towns and human settlements are widespread along the river and in the floodplain.

Figure 1. Location of the Arno River Basin.

2. METHODOLOGY

2.1 Background and procedure

The land cover data base was classified according to the CORINE (Coordination of information on the environment) Land cover Project legend (Cumer, 1984; Heyman et al., 1994).

One of the aims of the CORINE programme of the European Commission was to compile information on the state of the environment with regard to certain topics which have priority for all the Member States of the Community; in the CORINE system, information on land cover and changing land cover is directly useful for determining and implementing environment policy and can be used with other data (on climate, topography, soil, etc.) to make complex assessments (e.g. mapping erosion risks and landslides risk).

The legend developed for this purpose is a hierarchical numeric three level legend widely adopted in Europe: the first level (5 items) indicates the major categories of land cover on the planet; the second level (15 items) is for use on scale of 1:500.000; the third level (44 items) was used in the Project on a scale 1:100.000.

In this work the third level was applied improving the scale to 1:50.000 due to the improved Landsat ETM ground resolution at 15 meters.

The study was focused on the analysis and use of optical data: panchromatic and multispectral Landsat images from the last ETM+ satellite have been acquired dated 20 June 2000 and 15 February 2001; B/W ortho-photos (1:10.000 scale) dated 1998

(from AIMA archive) and color ones of 1998 to 2000 were obtained for the whole basin; visible-near-infrared TERRA-ASTER image of October 2001 was free downloaded in Internet for a part of the basin.
Remote sensed data have been processed by means of ENVI® software and thus analyzed in a G.I.S. environment for the photointerpretation phase. Specific ground truth surveys were carried out for the definition of photointerpretation keys on satellite images and for results validation. Fig. 2 shows the procedure applied in this work.

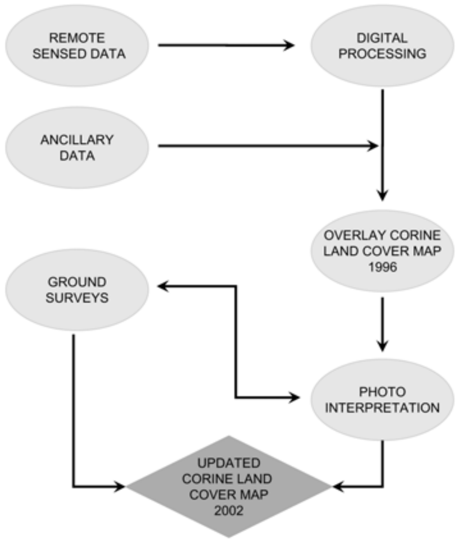

Figure 2. Flow diagram of the procedure applied in this work.

2.2 Data Processing

The aim of data processing was to obtain higher resolution multispectral images to improve photointerpretation for land cover mapping, using satellite data; for this purpose some methods for merging multispectral 30 m resolution images with a 15 m resolved panchromatic image of Landsat ETM+ data have been tested in order to produce suitable images for visual interpretation of land cover feature at scale 1:50.000.
Data fusion means the combination of two or more different images to form a new image of high quality by using a certain algorithm in order to obtain a high resolution multispectral image (Wald, 1998; Pohl & Touron, 1999). A high quality of geometric information on satellite data is important to map different features of anthropic environment, both urban and rural, while the multispectral characteristics are fundamental to develop thematic maps (Fritz et al., 1999; Peccol & De Luca, 2001).
We applied different methods of data fusion: Hue Saturation Value HSV, Principal Component Substitution PCS (Li et al., 1999), and Color Normalized CN (Pohl, 1996; Vrabel, 1996).
The Hue Saturation Value method transforms the data from actual color space (Red Green and Blue, RGB) into another space (HSV) and replace the value band with the more highly resolved panchromatic image, while the hue and saturation bands are resampled to the high resolution pixel size.
After replacement, the merged result is converted back into RGB color space.
In order to merge the data sets using the Principal Component Substitution model, the multispectral data set is subjected to a Principal Component Analysis. When a PCA is implemented, the first principal component contains information related mainly to intensity or brightness. The panchromatic data is substituted for the first principal component and an inverse PCA is performed on the combined data set.
The Color Normalized technique separates the multispectral image space into color and brightness components. It works by first normalizing the band to be displayed by the intensity of the RGB image.
It then multiplies the result by the panchromatic image data to add the brightness (shadows or albedo information) of the higher resolution image back into the color image that was removed by the rationing.
In this work the first step in image processing was to geocode the panchromatic image with the multispectral one projected in UTM ED 1950 Zone 32. Then all three fusion method have been applied to Landsat images and the data set obtained have been studied.
All the methods have shown reliable results in improving the geometric resolution and in producing highly readable color composites; the HSV seemed to be the best technique at all for visual interpretation even if for band 2 the PCS was the best performing one. In Fig. 3 some examples of the results obtained are shown.

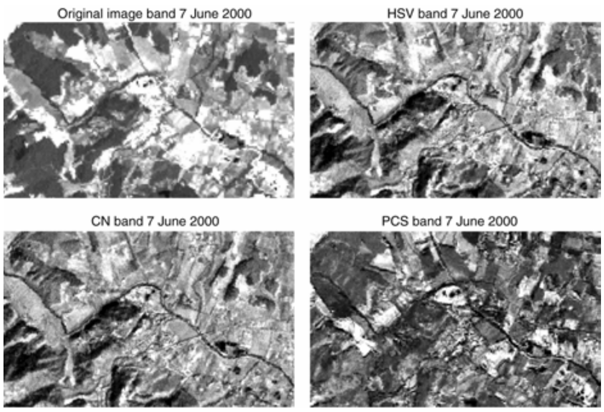

Figure 3. Comparison between the results gathered applying the three different fusion methods to the original image on June 2000.

The general methodology for Corine Land Cover updating was based on the Technical and Methodological Guide for Updating CORINE Land Cover Data Base (Perdigão & Annoni, 1997) guide lines.
The photointerpretation of the land cover changes was carried out by the integration of the whole information available in order to obtain the new updated land cover map; land cover changes were digitized as lines (Fig. 4).
Uncertain areas were verified trough ground surveys and cross checks before setting the final polygons and data base.

Figure 4. Newly created areas 121: industrial or commercial areas. Landsat ETM Band 7 HSV fusion technique: 15m resolution.

2.3 Ground Surveys

Ground surveys were carried out for two different purposes: the definition of interpretative keys on satellite images for photointerpretation and the solution of uncertainties during the work. Some examples are shown hereafter.

An area with high reflectivity was detected in all composites of the February and June scenes while the presence of escarpments were noted in topographic maps. During the ground survey a quarry of marble located near the village of Casole d'Elsa (Siena province) was found the activity of which started in 1999 (Fig. 5).

Figure 5. Quarry of marble (Casole d'Elsa, Siena province).

The second example concerns an area classified as olive groves (class 223) in 1996; in the color aerial photo dated 2000 it remains the same while in the Landsat ETM image of 2001 it appears clearly different from the surroundings with high reflectivity in the visible and mid infrared and without vegetation. In the field survey the area was recognized as a construction site for a new little reservoir for drinkable water supply of the surroundings villages. As shown in Fig. 6 the area is bare and some sheds are evident.

Figure 6. Construction site.

3. RESULTS AND ANALYSES

The updating work has interested 7320 polygons, 2560 of which (corresponding to 913 km^2) were involved in land cover changes. This means that the 10% of the whole coverage of the river basin has undergone changes in 6 years.

From the original 44 classes, 34 were implicated in total or partial modifications, for example several classes were totally converted in different codes and some others were splitted in two or more new typologies. The reclassification and the modification of the limits is closely connected to the better resolution of the data set.

In the figure below (Fig. 8) 15 selected items are shown along the interesting and consistent degree of variation.

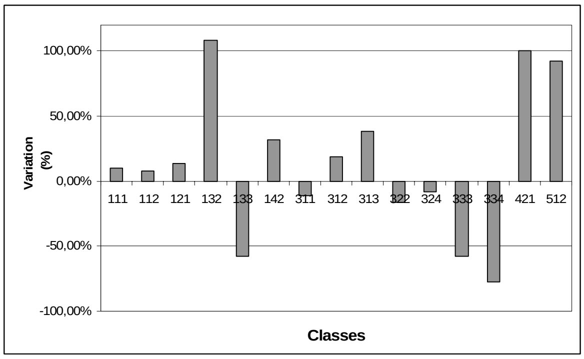

Figure 8. The histogram shows the differences between the situation in 1996 and the updated Corine Land Cover of 2002. Positive values represent territorial increase and negative values represent territorial decrease (see table 1 for details).

Table 1 shows the percentage variation of the most significant land cover types between 1996 and 2002 and the coverage difference of each class in the same period.

Classes		Area in '96 (ha)	Area in '02 (ha)	%
111	Continuous urban fabric	2.542	2.787	9,6%
112	Discontinuous urban fabric	28.696	31.029	8,1%
121	Industrial/commercial units	9.164	10.440	13,9%
132	Dump sites	26	54	108,3%
133	Construction sites	277	116	-58,1%
142	Sport and leisure facilities	342	450	31,6%
311	Broad-leaved forest	247.632	219.588	-11,3%
312	Coniferous forest	21.887	26.001	18,8%
313	Mixed forest	73.504	101.742	38,4%
322	Moors and heathland	12.452	10.396	-16,5%
324	Transitional woodland/shrub	22.326	20.522	-8%
333	Sparsely vegetated areas	509	216	-57,5%
334	Burnt areas	1.499	339	-77,4%
421	Salt-marshes	0	369	new
512	Water bodies	891	1.715	92,4%

Table 1. Percentage variation for 15 selected classes.

As it can be seen classes such as urban fabric or industrial units present increasing values thus reflecting the increase in population density. Conversely, items such as 133 and 311 present negative values. The first one (133) is the obvious result of construction activity, whilst the decrease of the second one (311) is probably connected to the parallel increase of 312 due to a different choice in forest classification and also due to a better resolution of the images used. More interesting is the decrease of burnt area and transitional woodland and shrub that were converted into forests.

The high variation of the 512 class (92%) is justified by the emplacement from the year 2001 of the Bilancino reservoir in the Mugello valley; it is an artificial lake still under construction in 1996 that was completed at the beginning of 2001; this lake is now covering more than 5 km^2 and its environmental impact is still under development.

The final map of land cover shows that more than 10% of the total area has changed in 6 years. This variation is very important for two reasons: the temporal interval of 6 years is short and the Arno River basin is a territory already greatly affected by human impact.

4. CONCLUSIONS

The updated land cover map has been used as one of the input parameters for the computing of landslides hazard and risk assessment. This new map shows that the Arno River Basin has experienced a lot of changes due to anthropic activities in the time investigated. These changes underline a situation of warning because of their role for landslides hazard assessment and definition of elements exposed to landslides risk. In fact, statistic analysis showed that landslide hazard is particularly affected by land cover type.

The results obtained in this phase will be implemented in a risk model available for urban planning purposes in areas defined as prone to slope failures, starting from geomorphological factors controlling landslide occurrences.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

A. Cumer, “Il progetto CORINE Land Cover in Italia: un modello da seguire” Documenti del territorio Anno VIII N. 28/29 giugno/dicembre 1994.

R. Fritz, I. Frech, B. Koch, and Chr. Ueffing, “Sensor fused images for visual interpretation of forest stand borders” Archives of Photogrammetry and Remote Sensing, 32/7-4-3 W6, Valladolid, Spain, 1999.

Y. Heymann, C. Steenmans, G. Croisille, and M. Bossard, “CORINE land cover project” Technical guide. European Commission, Directorate General Environment, Nuclear Safety and Civil Protection, ECSC-EEC-EAEC, Brussels-Luxembourg, 136 pp. 1994.

J. Li, Y. Zhou, D. Li, “PCA Wavelet transform for fusion panchromatic and multispectral images”. SPIE’s International Symposium on Aerosense ‘Image exploitation and target recognition’ Orlando, Florida, USA Vol 3719, pp369-377, 1999.

E. Peccol, A.De Luca, “Valutazione di tecniche di fusione ai fini del rilevamento di superfici a prato”. Atti 5° Conf. Naz. ASITA ‘La qualità dell’informazione geografica’, Rimini, Italia, 2001.

V. Perdigão, A. Annoni “Technical and Methodological Guide for Updating CORINE Land Cover Data Base”, 1997.

C. Pohl, Geometric aspects of multisensor data fusion for topographic map updating in the humid tropics. ITC publication, N0.39, ISBN 90 6164 121 7, pp.37-38, 1996.

C. Pohl, H. Touron, Operational applications of multi-sensor image fusion. International Archives of Photogrammetry and Remote Sensing, 32/7-4-3 W6, Valladolid, Spain, 1999.

J. Vrabel, Multispectral imagery band sharpening study. Photogrammetric Engineering and Remote Sensing, 62/9: 1075-1083, 1996.

L. Wald, An European proposal for terms of reference in data fusion. International Archives of Photogrammetry and Remote Sensing, 32/7, 651-654, 1998.