Multilevel analysis for the identification of potential asbestos roofs

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Abstract

In this work a multilevel analysis has been developed for the identification of potential asbestos roof from remote sensing data. Asbestos is a material that was widely used in Italy before 1992 especially for civil and industrial roofs and its degradation is linked to several serious diseases. Recently, the Emilia Romagna region published a document containing guidelines for the evaluation of the conservation status of asbestos roofs and the evaluation of the relative risks. There is the need to have an updated census of asbestos roofs in order to determine their exact location on the territory and facilitate their monitoring. Therefore a methodology for a semi-automated pre-selection of asbestos roofs has been developed in this work using remote sensing data and territorial information. The procedure relies on a territorial multilevel analysis. Photointerpretation techniques, object oriented classification and the analysis of the roofs texture, allow to identify potential asbestos roofs. Tests and assessment of the developed protocol has been done through ground field investigations. The information collected by the classification has been organized in a GIS geodatabase combining the building information already available with the new results obtained from this analysis.

Keywords: asbestos, multilevel analysis, Geographic Information Systems, object oriented classification

1. Introduction

Asbestos is the general name of a group of Mg, Ca, Fe silicate minerals (amphiboles and serpentines) characterized by a peculiar fibrous structure. Asbestos containing products are widespread in Italy and in many countries all over the world. The reason is the peculiar and unique chemical and physical properties of this group of minerals, that include thermal and electrical resistance, extreme thermal stability, tensile strength, strong and flexible fibrous structure. They are also chemically inert. These properties have been exploited industrially to produce a wide variety of commercial products, using asbestos pure or mixed with other materials (mainly cement and vinyl). Examples include fire retardant coatings and textiles, pipes and fireplace cement, heat-, fire-, and acid-resistant gaskets, pipe insulation, ceiling insulation, fireproof drywall, flooring, roofing, concrete, bricks, lawn furniture, drywall joint compounds and adhesives. Starting from the discovery of the serious consequences on health of exposure to asbestos fibers, production and commerce of asbestos containing products has been precluded in many countries. In Italy the ban was stated by the Government Law 257 in 1992. As the ban regulation does not force removal of asbestos containing materials (ACM), they are still present and widespread. Most asbestos in Italy was used to produce asbestos cement (AC): a mixture of cement with a percentage between 10 and 20% of asbestos fibers (mainly crocidolite). A huge amount of AC was produced in corrugated or flat sheets or tiles for roofing civil and public buildings, industrial, commercial and agricultural structures. Asbestos cement roofs are still widely diffused in Italy and represent a huge amount of ACM still present in life and working environments. AC is a compact material that becomes a hazard only when damaged, or in a state of degradation or disrepair, because asbestos fibers may be released into the air and inhaled by building occupants, repairmen, and maintenance workers (Maiuri, 2009). In 2001, the Italian Government Law 93/2001 provided the complete mapping of asbestos presence over the national territory. With a subsequent decree (Min. D. 101/2003), Regional local authorities were committed for mapping. The decree prescribed that mapping should be georeferenced, managed through a Geographic Information System, and should include a set of information attributes, like the type of ACM (friable or compact) and its state of conservation according to criteria able to define a remediation priority. The data set should be updated periodically to monitor state of remediation activity. Most Regions (local government units) have now provided at least the first mapping of their territory for public or open-to-public buildings. Due to the extreme diffusion of ACM, the complete mapping of commercial, agricultural and private structures is very onerous in terms of resources needed. The complete set of information required by law can only be acquired by a census including self-declaration of building owners and on-site survey. However, since a huge amount of asbestos is contained in CA used for roofing, using remote sensing (RS) to map CA roofs offers the advantages of rapidly locate and map possible CA surfaces over a wide land area. Every remotely retrieved information must be confirmed by ground control, but the need of survey is limited to a set of “suspect” cases, so reducing time and resources needed for it. Scientific literature reports several experiences of CA mapping using hyperspectral RS (Marino *et al*., 2001; Bassani *et al*., 2007; Fiumi *et al*., 2001). However, only airborne hyperspectral sensors have been available in Italy so far, having the disadvantage of high costs for a new, on purpose aerial survey. Nevertheless, 8 Region local authorities, out of 20, used the airborne MIVIS hyperspectral sensor to map CA roofs, mostly on selected areas of variable extent. Main difficulties referred are the strong distortion of images acquired on mountainous terrain (due to the wide sensor field of view), the limited (respect to roof dimension) ground resolution (5-6 meter), and the need to transpose and improve classification results with photo-interpretation on ortophotos. Five Regions used multispectral (4 channel) ortophotos or high resolution satellite images to perform CA roofs mapping (in one case to update the previous MIVIS mapping). On these images, the new object-oriented approach was used just in one case in place of pure spectral classification methods. More recently, some local municipalities started a more detailed mapping of CA roofs to catch private buildings (in areas where traditional mapping was performed) and roofs of little extent. Use of UAVs is becoming more and more diffuse in this context: however this platform is manly used to “ground check” the mapping performed on high resolution ortophotos. In this work it has been developed a methodology for the characterization and identification of asbestos roofs in a medium size Municipality located in Emilia Romagna region, Italy. For privacy reasons related to the spread of this kind of data it is not possible to disclose the name of this Municipality. In particular, the protocol has been implemented in a GIS environment (Geographic Information Systems) where the remote sensing and spatial information data have been integrated. GIS platforms are in fact often used in this kind of analysis (Busetto and Michieletti, 2001; Atturo *et al*., 2001). The developed procedure is based on a territorial multilevel analysis. In particular, potential buildings of interest have been selected through the intersection of different thematic layers (information layers) of spatial data in a GIS environment (volumetric units, buildings, etc.). Then, the information obtained from remote sensing images have been used to obtain a classification of selected buildings’ roofs. Remote sensing images used in this study are orthoimages composed of three channels (RGB) with a spatial resolution of 50 cm.

2. Materials and methods

2.1. Data set

For this study, several digital orthophotos AGEA 2008 have been used. These images are provided by cartographic archive of the Emilia Romagna region. The study area, as mentioned above, is a Municipality of medium-small size, characterized by the presence of an important industrial area and several residential districts. Asbestos roofs information are sensibile data, thus the name of this Municipality cannot be disclose. The digital orthoimages used are made by three RGB channels acquired on 20/08/2008 with the following features:

- Spatial resolution: 50 cm
- Three spectral bands: blue, green, red, for representations in natural colors
- Projection System: Gauss-Boaga
- Geometric Accuracy: 4m
- Data format: 8 bits per pixel / spectral band

Few vector layers have been integrated with these orthoimages. These layers complete and enrich information for the territorial analysis. Vector data available are provided by the Regional Topographic Database (DBTR) of 2008. The acquired layers are in particular:

- Civil Buildings (EDI)
- Industrial buildings (MIN)
- Other mixed buildings both residential and industrial (MED)
- Roads (ACS)

2.2.Methodology

2.2.1 Construction of the reference database

The first step of the developed methodology is the acquisition, organization and management of the available data in a GIS environment (Geographical Information Systems). Orthoimages with a spatial resolution of 50 cm have been first of all georeferenced and rectified. The coordinates of vector layers have been converted (from UTM RER to WGS84) to make them compatible for the next phase of ground truth measurements. Some overlap problems between vector layers and orthoimages have been fixed through the implementation of a "buffer", that is, a narrowing of the original polygons, which best identifies the contours of the buildings. Some polygons have also been edited manually to ensure proper overlap with the orthoimages.

2.2.2 Classification of building’s roofs

The poor spectral resolution of the orthoimages does not allow the detection of the spectral signatures of asbestos and, more generally, of the different materials that compose buildings’ roofs. Therefore image classification has been performed using color information supported by photo-interpretation (texture analysis via software and using high-resolution images of GoogleTMEarth and GoogleTMMaps; site surveys). For the buidings’ roofs classification an object oriented approach [11] has been used through Definiens E-Cognition Developer software (Definiens Developer 7 User Guide, 2008). This approach allows a quick distinction between the different kind of land cover and also allows the use of available vector layers as a classification support. First of all, a segmentation between “roofs” and “roads” has been performed, then different types of buildings have been recognized (buildings, building products and industrial products) through the tables of attributes within the vector layers. Some subcategories have been also defined including:

- Generic buildings (mostly residential);

- Churches and places of worship;
- Buildings for industrial use;
- Sport Areas;

Because of the great heterogeneity of the objects contained in the shapefile of industrial and mixed buildings (perimetre walls, cabins, swimming pools, etc.) the classification has been performed on buildings with a minimum size of 150 m^2. For this purpose, a first classification based on the area of each object has been done in order to exclude buildings smaller than the minimum size chosen. Anyway the classification of objects smaller than 150 m2 would have involved mixed pixel problems due to the low spatial resolution of orthoimages and other problems due to the presence of trees, shadows of other buildings, etc. that would have hidden buildings' roofs. Then a new classification has been performed using a Nearest Neighbor algorithm combined with a texture analysis and a photo-interpretation analysis for the distinction of the following classes (Figure 1):

- Not asbestos (N.A): red roofs (tile roofs);
- Not asbestos (N.A): grey roofs (light / medium / dark grey roofs);
- Asbestos roofs;
- Roofs to be checked on the ground (they could be asbestos roofs).

2.2.3 Classification check

The classification results were first verified by comparing them with the high spatial resolution images of GoogleTMEarth. Also ground inspections have been carried out for classification check.

2.2.4 Output

The classification has been exported to shapefile format and included in the GIS project. In particular, for each building the name of the roof class has been included in the attribute table. To facilitate the verification phase of classification and enable the exchange of information between different actors who worked on the project, the output of classification have also been exported to .kmz format. This format can easily be included inside a GoogleTMMyMaps project.

3. Results

The developed procedure allows to export three output vector file, respectively, related to civil buildings, industrial buildings and mixed buildings. For privacy reasons it is not possible to report the number of asbestos roofs, thus Figure 2 show the percentage of the presence of these types of roofs on the territory. The relative area of asbestos roofs has been also computed and Figure 3 graphically provides an indication of the magnitude of the asbestos roofs areas.

Figure 1. Nearest Neighbor classification

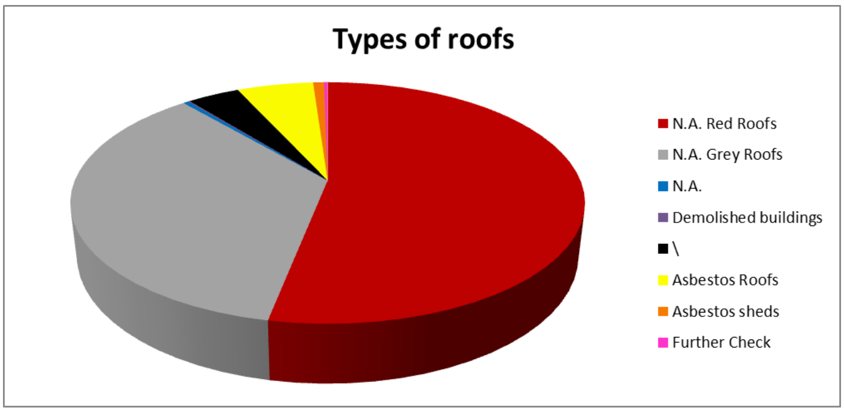

Figure 2. Percentage of different type of roofs

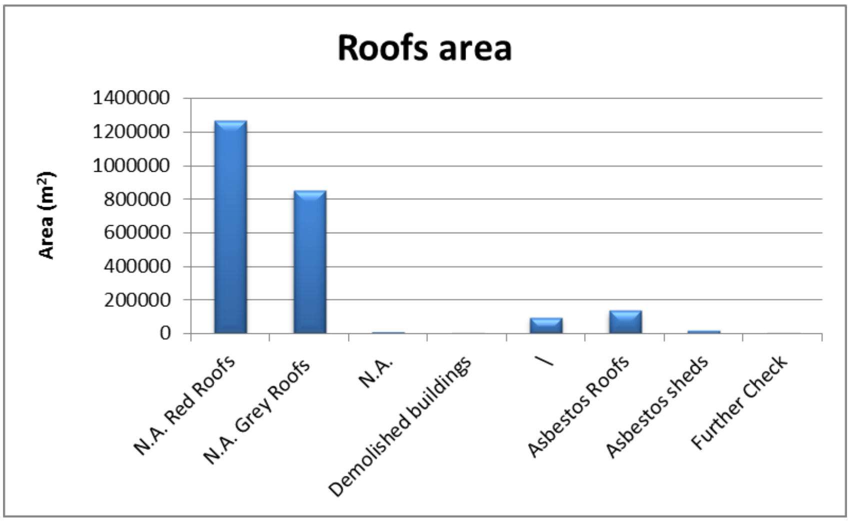

Figure 3. Area of the different type of roofs

4. Final assessments and conclusion

The main critical issue of this study are related to the temporal and the spatial resolution of the buildings' shapefiles provided by Regional Database(DBTR). The DBTR vector layers in fact date back to 2008, and during this study problems have been found to mismatch objects shapefile and GoogleTMEarth images (for renovated or demolished buildings). Within the same private property, roofs belonging to different buildings could be grouped together in a single object: in this case, as "Class_Name" attribute the predominant type of cover has been indicated, except for asbestos roofs where the attribute "Class_Name" is "Asbestos Roofs". Under the new guidelines ,for example, proposed by Emilia Romagna Region for the identification of asbestos roofs, and its state of conservation, a direct inspection by a qualified technician is necessary in order to collect and examine roofs materials. Collected samples must be sent for analysis in qualified laboratories to certify the composition. Later, the results of laboratory analysis and the inspection by the technician will decide whether the cover is in good condition (in this case a periodic monitoring will be necessary to assess the degradation over time), or if the asbestos cover is dangerous and has to be properly removed. From the combined results of the classification of roofs proposed by the methodology developed in this study and evaluation of asbestos conservation status it will be possible to ensure effective control of the territory and to protect the health of citizens. The developed methodology will be soon apply to other site of interest in order to have a further implementation and check the effectiveness of the methodology itself. .

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