A COMPARISON BETWEEN METHODS – A SPECIALIZED OPERATOR, OBJECT ORIENTED AND PIXEL-ORIENTED IMAGE ANALYSIS – TO DETECT ASBESTOS COVERAGES IN BUILDING ROOFS USING REMOTELY SENSED DATA

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ABSTRACT:

All the risks concerning the long lasting exposition to the asbestos, for instance diseases affecting the respiratory system, are known very well. In particular, it's the friable asbestos the most dangerous element, above all as for the easily dispersing fibres. Despite the above mentioned risks, the number of asbestos covered block is still high in many nations, in particular they are buildings characterized by eternit coverings (a mixture of cement and asbestos), certainly due to the features of materials and their low cost.Various legislations implement reclamation works on the asbestos roofs, but in several countries building farms keep on using such material, despite it's forbidden to them. The present work has as objective one to supply a cheap tool for the automatic identifying with the buildings which do use for its covering of this very dangerous technology; they are taken back three alternative methodologies of development of the tool, everyone working on remote sensed images and of a procedure of specific classification for the problems in exam, skilled actually turned out to offer useful on the applicatory plan. In the specific one the three configurations melt their work on the comparison between the spectrum of a building, spatially considered well known, characterized by covering in cement-asbestos with the spectrum of the pure material obtained from laboratory measures.From such comparison it is generated, in the first two cases, the building and the implementation of a suitable operator that through the estimate of an opportune equalization coefficient (built respectively using the neural nets and the ionized plasma (electromagnetic fields)), it allows to identify in automatic way the present coverings on the territory and therefore proceed to the next phase of pixel-oriented classification of the whole image.The last methodology is responsible for making a comparison between the classifications obtained with the methodologies preceding (pixel-oriented) and that coming from the use of an object-oriented method consisting in a Nearest Neighbor classification tool following a multi-resolution segmentation worked on the whole scene.

1. INTRODUCTION

Minerals defined "asbestos", having a very interesting chemical physical features in the industrial level, (it's resisting to fire and heat, to the chemical and biological agents, to the abrasion and the wear) were employed in a considerable way, to produce large spreading items and, in particular, in the building sector. Their wide usage, especially in the industrialized countries, had a decrease when the danger for man, because of fibres released in the environment, and that are responsible of different diseases, affecting the respiratory system was detected.

Nevertheless, today, there's a considerable percentage of artefacts, above all buildings, where asbestos has been used together whit cement, to produce cement-asbestos coverings, and, even if it's not a factor of risk in the incoming, it'll be in the future, certainly, with the increasing of the material degradation and the possibility of fibres releasing (thanks, in particular, to the action of agents, such as acid rains, thermal stress, wind erosion, vegetal micro–organisms).

It's just for this reasons, that many nations have included in their own legislation, authorities indicating methods and ways of beneficiation (such as removal, encapsulation and confining) for cement–asbestos coverings.

The geographical and cadastral detection of buildings employing such technologies for their own coverings, is an obvious prerequisite to implement the above mentioned authorities. This work wants to show three different methodologies, aiming at the definition of a tool which automates such operation, using, for such purpose, the interpretation of satellite images and put beside from (GIS) tools for the location of the interest zones. The developed model to recognize the cement–asbestos coverings, shows three different methodologies (of which two pixel-oriented and one object-oriented) working on images produced by the Ikonos satellite, depicting a South Italy coastal zone (Melito Porto Salvo, R.C.) Subsequently to the estimate of an experimental operator useful for the punctual recognition of the investigated coverings, the test image is initially georeferred using the ENVI software, classified (using it both the pixel-oriented and object-oriented methodology), and therefore integrated in a GIS containing a space data bank concerning the land register of the zone exposed to analysis.

The examined method has, as basic characteristic, that of fit to the historical and ambient context of the examined zone; that becomes possible because a few mathematical functions, which the method refers, are modified in relation to the characteristics of the spectrum of one or more coverings in asbestos present in the interest area and of which it is necessary to have, evidently, knowledge to priors. This hypothesis if, at a first moment it can seem restrictive, in front of a careful analysis of the problems in exam and the experience on the field of several technicians and representatives of the corporations dedicated to the reclamation, turns out, to opinion of the writing, actually not to be it.

2. PRELIMINARY CONSIDERATIONS TO THE DESCRIPTION OF THE METHOD

Before explaining the method applied to the detection of the interested elements, it's useful to talk about the hypothesis done on the basis of data in our possession, and which mathematic instruments we've adopted to define this method, according to the same hypothesis. First, we've realized that detected spectra are considered as functions having as x coordinate, the wavelength, and as the y one, the reflectance. They are continuous in the interval, where sensor Ikonos acts, and void outward. So, we can detect the following relation:

$$\int_{+\infty}^{-\infty} |S(f)|^2 df < \infty \tag{1}$$

where *S(f)* is the function, describing the spectrum and it's obtained by the linear interpolation of the reflectance values of the generic pixel of Ikonos image (it's no secret that the image is organized according the red band, the green one, the blue one, and the infrared); for this reason, such function represents a "signal" of energy (adopting the standard nomenclature of the signals theory, concerning a function in a frequencies' domain, instead of the time). The energy's signals, as we know, meets different properties which allow to express as elements of a real linear space with the following associated scalar product:

$$\int_{-\infty}^{+\infty} xy \ df \tag{2}$$

In this case, energy signals are defined positive result to real values. In fact, if we consider the energy signals *x* and *y*, and indicate the relative scalar product, seen in the (2), with the symbol <*x,y*>, we can realize that

$$\begin{cases} \langle x,x \rangle \geq 0,\ \langle x,x \rangle = 0 \ \text{solo se x} = 0 \\ \langle x,y \rangle = \langle y,x \rangle \\ \langle ax,y \rangle = a\langle x,y \rangle, \forall a \in \Re \\ \langle x,y+z \rangle = \langle x,y \rangle + \langle x,z \rangle \end{cases} \tag{3}$$

through the scalar product, we've introduced the following norm:

$$\|x\| = \sqrt{\langle x,x \rangle} \tag{4}$$

consequently, the energy signal's space (whose spectra are obtained by Ikonos images) becomes normalized and in particular, we've the Hilbert space; so, all the present work, the signals, on which the investigation will be made, will be considered as like Euclidean vectors, and their spectrum judged (or to the limit coinciding) if the values of their modules (theory of the signals) is near, that is when the angle (or phase of the signal) they form tends to be void. In particular, we consider the angle between two signals as the arccosin , (ρ) , through the following formula:

$$0 \leq \frac{|\langle x,y \rangle|}{\|x\|\|y\|} \leq 1 \tag{5}$$

The formula (5) represents a consequence of the Cauchy – Schwarz inequality; its value, is 1 when signals are lined up; it's identically void when they are orthogonal (completely unequal). The algorithm to detect coverage in asbestos concrete exposed beyond, consider the "closeness" among spectra signatures (a spectrum associated from a pixel datum of the Ikonos image and known one), using the properties of the scalar product given in the formula (3) and together with the (4).

$$\text{if } |\langle x,y \rangle| = \|x\|^2 \text{ then } y = x + \varepsilon \text{ where } x \perp \varepsilon \tag{6}$$

The formula (6), is true, because, if we suppose, in an absurd way, that $y \neq x$, then we can think that is $y = x + \varepsilon$ with $|\varepsilon| \neq 0$, and as $\|x\| \neq 0$, then y is not orthogonal to vector *x*, so:

$$\langle x,x+\varepsilon \rangle = \langle x,x \rangle + \langle x,\varepsilon \rangle \rightarrow \|x\|^2 + \langle x,\varepsilon \rangle \neq 0 \tag{7}$$

So, it's necessary that ε must be orthogonal to *x* or, in a module, their scalar product equal to zero. We have this last condition when we assess the formula (5).

3. CONSTRUCTION OF THE AD OPERATOR FOR CARRIED OUT SURVEYING

The detection of cement asbestos coverings, is done by a function operator, called AD (Asbestos Detector), opportunely built starting from the scalar product defined among the energy signals.

It's a function having as an inlet, the spectrum concerned with the pixel to examine, and another spectrum of library, employed to compare spectral signatures; the output of the operator AD runs about 0 and 1; the more it's close to the unit, the more spectra are similar, and so, we can suppose the material concerning the pixel, is cement-asbestos; consequently the building, containing the geographical coordinates associated to the pixel, will be classified as an element to reclaim.

The AD operator is therefore defined:

$$AD\langle S_L(f), S_R(f) \rangle = \langle S_L(f), S_R(f) \circ eq(f) \rangle \tag{8}$$

Where:

S_L,S_R are, respectively, the library spectra, used for the comparison and the one associated to the analyzed pixel.

eq(f) is an equalization factor, whose implementation changes according to the methodology persecuted. The component *eq(.)*has the task to filter the relief errors, before carrying out the inherent operations the scalar product for the verification of similarity. It is constructed in order to mitigate, in surveyed signal, the frequency components relative to the contextual disturbances of the geographic zone on which it comes carried out the survey, and that generally interest the alteration of the physical chemical characteristics of the cement-asbestos (due as an example to local polluting details, mildews, etc.).

a) In the first configuration the *eq(.)*is represented from a neural net, which is specialized through a typical technique of learning on the cover of the test building (known one). In the detail the operator AD carries out, before the calculation of the scalar product classic, an equalization on the library spectrum:

$$eq(f)S_R(f) \approx S_L(f) \tag{9}$$

The construction of the factor *eq(.),*in order to model the before said disturbances, is based on a neural net feedforward, whose training set are the ratios between the values of the normalized spectrum of library signal, obtained from laboratory measures, and of surveyed signal relative to one or more known buildings, having covering in cement asbestos (eternit). The chosen algorithm for the training of the net is the error back propagation, the function of activation for its neurons is the sigmoidal one.

b) In the second configuration the $eq(f, \omega_p, \sigma)$ is an equalization factor, depending on two parameters, besides the frequency that however is an intrinsic parameter, determined when the example building is defined. The *eq(.)* is introduced in order to diminish the effect jamming in the ionosphere relative to the electromagnetic fields cross that it; moreover, the procedures in order to determine the equalization are of the type of "search of the minimum", on an error function. The construction of the *eq(.)* factor, uses the following model to represent the interactions of the ionospheric plasm on the electromagnetic fields (Marzano, 2002). Such model must meet, both the Maxwell equations and the formula of the interaction of fields with the ionized plasm, that's the equation concerning the Lorenz force (third term in the following system of equations)

$$\begin{cases} \nabla \wedge \underline{h} = \varepsilon_0 \dfrac{\partial}{\partial t}\underline{e} + n_e q \underline{v_e} \\ \nabla \wedge \underline{e} = -\mu_0 \dfrac{\partial}{\partial t}\underline{h} \\ n_e m_e \dfrac{d}{dt}\underline{v_e} = n_e q \underline{e} + n_e q(\underline{v_e} \wedge \underline{b}) \end{cases} \tag{10}$$

Where n_e = electron's number for every volume unit
m_e = electron's mass
$\underline{e}$ = electric field
$\underline{b}$ = magnetic induction's field
$n_e\, q\, \underline{v_e}$ = electron's current density
ε_o = dielectric constant of the hollow
μ_o = magnetic permeability of the hollow

Opportunely arranging the first and the third equation of the system precedence, and translating all in Fourier domain, we can obtain:

$$\nabla \wedge \underline{H} = j\omega\underline{E}\left(\varepsilon_0 + \frac{n_o q^2}{(j\omega)^2 m_e}\right) \tag{11}$$

Where $\underline{H}$ = vector of magnetic field in the Fourier domain
$\underline{E}$ = vector of magnetic field in the Fourier domain

From it we've obtained an expression that synthesize for ε the effects of the jamming, inserted in the ionosphere on the propagation of the electromagnetic fields. Such expression can be generalized, including the effects of the shocks among particles, keeping on sensing the ionosphere as a not dispersive mean:

$$\varepsilon_{eq} = \varepsilon_0\left[1 - \frac{\omega_p{}^2}{(\sigma^2 + \omega^2)}\right] \tag{12}$$

Where σ is a constant of shocking effects
and $\omega_p^2 = \dfrac{n_0 q^2}{m_e \varepsilon_0}$

Supposed the ε_{eq} as function of transfer of the "ionospheric layer of the atmosphere" in the Fourier domain and given such linear and not dispersive system in the space, we have:

$$\underline{D}(\omega) = \varepsilon_{eq}(\omega)\underline{E}(\omega) \tag{13}$$

Where $\underline{D}(.)$ = field of electric induction.

Considering that the detected signal spectrum is the module of the electro-magnetic field in the spectrum region, where Ikonos is sensible, we have

$$eq(f, \omega_p, \sigma) = \left[1 - \frac{\omega_p{}^2}{(\sigma^2 + \omega^2)}\right]^{-1} \tag{14}$$

We can state that, in the ideal case, the product of the detected spectrum $\overline{S}_R$, belonging to the concrete asbestos material and the equation is equal to the library spectrum S_L.

From such observations, it follows that

$$F(\omega_p,\sigma)=\int_{-\infty}^{+\infty} S_L(f)\overline{S}_R(f)eq(f,\omega_p,\sigma)df-\|S_L(f)\|^2 \quad (15)$$

where $\overline{S}_R$ is the spectrum of the real asbestos cover known to priors. Therefore the methodology is based on the minimization of an error function, F (·), from which the specialization parameters will be obtained, the ω_p and σ.

This minimization has been obtained through an other, implemented in Matlab, and known like library DLL Mex, developing, in automatic way, all the steps from the calculation of the library spectrum to the numerical resolution of the integral, and to the successive search of the relative minimums; it's saying that this minimization is fundamental, because it is same that searches the values in order to modify the known spectrum $\overline{S}_R$, thus to render it a carrier overlapped to that one of library. Between the numerous values found minimums, we consider only those, for which the value of |F (·) | does not exceed 0,10, and at the same time the formula (5), turns out approximately 0.90 and 1, while the squared norm of the library spectrum is equivalent to 2.5849.

c) In the object-oriented classification methodology, a segmentation procedure set offs that tends to the minimization of the spectral heterogeneity of every polygon obtained from the values of digital number of the pixel included on the base of the geometric heterogeneity due to the form of the obtained polygons. The spectral heterogeneity h_s of every polygon generated with the segmentation process is the weighted sum of standard deviations of the values of digital number of every spectral band obtained for everyone of the pixel included in the polygon:

$$h_s = \sum_{c=1}^{q} w_c \sigma_c \quad (16)$$

h_s = spectral heterogeneity of the polygon; q = number of spectral bands; σ_c = standard deviation of the values of digital number of c spectral band; w_c = weight assigned to c band.
In order to avoid the generation of polygons excessive fragmented with frattal dimension much elevating because of the high geometric resolution of the image, the obtained polygons must at the same time diminish the value of geometric heterogeneity (h_g), defined from the two form factors: frattal and compactness. The factor frattal (h_{g_smooth}) depends from the complexity of the perimeter of the polygon regarding its extension:

$$h_{g\_smooth} = \frac{l}{\sqrt{n}} \quad (17)$$

where : h_{g_smooth} = frattal factor of the geometric heterogeneity of the considered polygon; l = length of the perimeter of the considered polygon; ***n*** = number of pixel of which the polygon is constituted.

The compactness factor ($h_{g\_compact}$) depends from the dimensional ratio of the axes of the polygon:

$$h_{g\_compact} = \frac{l}{b} \quad (18)$$

in which: $h_{g\_compact}$ = factor of compactness of the geometric heterogeneity of the considered polygon; l = length of the perimeter of the considered polygon; b = length of the smaller side of the smallest quadrilateral parallel to the data raster in which the considered polygon is in-written.

Starting from every pixel of the image, the segmentation algorithm fuse adjacent polygons till when the change of observable heterogeneity between the two primitive polygons and the new obtained polygon does not exceed the assigned scale factor, exceeded which the polygons remain distinguished. It follows a simple classification Nearest Neighbor through the use of Sample Test. In this classification when an object changes the relative classification because of the classification of the other objects connected to it, a problem, due to the fact that the same object could be a characteristic of context for the evaluation of other objects, is born. Consequently, the classification must be an iterative process in cycles in which every classified object repeatedly considers the changes in the classification of the connected objects.

4. APPLICATION OF THE SPECIALIZED AD OPERATOR AND CLASSIFICATION PIXEL-ORIENTED

In Figure 1 the image used for the present note is shown: it represents municipality of Melito Porto Salvo, a coastal zone of South Italy, surveyed by Ikonos sensor, in which the example buildings are brought back, and of which they will come discussed the obtained results successively, they are a building with sure covering in cement-asbestos (building 1), a building with a covering where the asbestos is mixed with other materials (building 2), and a building with a covering where the asbestos is totally absent (building 3).

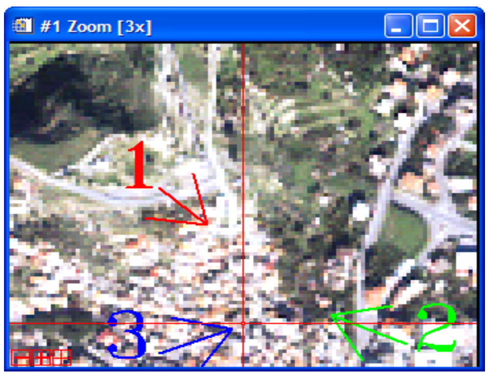

Figure 1

After to have passed the phase of geographic context of analysis, that is to have defined the component *eq(f),* indispensable in order to specialize the AD operator to the examined context, for the single methodology (in the first configuration it is proceeded to the training of a neural net, in the second one they are detected the parameters ω_p and σ), it can be passed to the phase of use of the same operator in order to carry out the screening of the chosen zone.

The AD operator is the heart of a methodology of composite surveying and articulated in several phases carried out from various software subsystems (Envi, IDL, Matlab, ArcGIS, ad-hoc modules) where some of these represent the implementation of various algorithms useful to carry out specific tasks. In detail, the above-mentioned phases are (Barrile, Cotroneo Haifa 2005; Barrile, Cotroneo Asita 2006):

1) Georeferring the Ikonos image used in the examples brought back in this note.
2) Detection of ROI (Region Of Interest): in the specific case they are chosen the portions of image, exclusively, relative to the only covering of buildings (eliminating the zone not interested to the procedures of detection) through overlay of layer GIS (cartographic information) dedicated to the representation of the buildings.
3) The ROI, thus selected and represented as matrix of pixel, come exported by into the language IDL , which executes (only on such pixel, which they are associated spatial coordinates) the iterative software procedures that implement the operator AD<.,.>. The coordinates associated to the pixel, whose spectrum has been classified by AD<.,.> , as of cement-asbestos, come saved in an ASCII file together with the relative value AD<.,.> and the value of ρ .
4) General classification of image, using the pixel-oriented method (Maximum Likelihood).
5) Integration of obtained classification in a GIS module (ArcGIS). In specific, the used ArcGIS software imports, through a Visual Basic function integrated in it, the ASCII file from which it will be generated the layer of the points positively classified; the alphanumeric attributes of the relative features will contain the value of AD<.,.> and ρ . It is therefore obvious that the buildings in cement-asbestos, contained in GIS, are those which intersects the punctual features of which before.

In Figures 2 and 3 they come brought back, respectively, the spectral profiles, relative to the cases of buildings having sure coverings in cement-asbestos and these ones having coverings realized with a different material of cement-asbestos. More, in particular, in Figure 2, it brought back the effect of the equalizator AD, estimated on the comparison between the spectrum of the building with sure covering, in continuous feature, and that known one, in discontinuous feature; it can note as two spectrum have similar course, except for some intervals (due to the disturbances that interest the examined geographic context and for which the role of the equalization component is important in order to define the exact overlap).

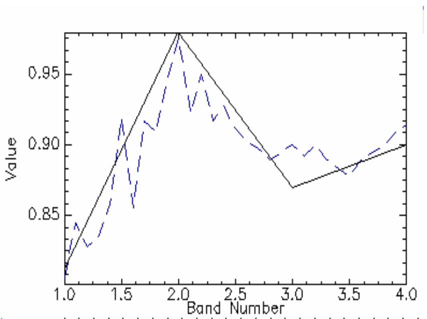

Figure 2

In Figure 3 the effect of the equalizator AD is estimated on comparison between the library spectrum and that one of a building with covering constituted of a different material from asbestos. The diagrams of the two constants *eq()* obtained from the two precedent methodologies (in red that relative one to the neural net, in green that relative one to the ionized plasm). Given the diversity of the materials, the effect of the equalization component isn't sufficient to guarantee the overlap of the spectrum of the building with that one of library.

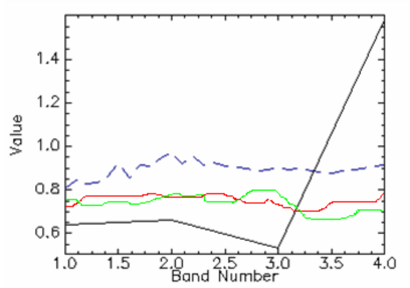

Figure 3

In Table 1 they come brought back the values obtained from the AD operator, for every of the two precedent methodologies, with the parameters that define the component of equalization (scalar product, the S. P. in the table, and coefficient ρ for the first methodology, ω_p e σ for the second methodology). It can be observed as the values obtained in the two methodologies are comparable. In fact, although the equalization components depend from distinguished parameters, like previously said, they however isn't much different in value, as it has shown in the diagram in Figure 3, and so in the following table it's evident as the operator, independently by the considered methodology, carry out, however, a correct distinction of the elements present in the geographic context under investigation.

	AD (Neural Net)	AD (Ionized Plasm)	Object-oriented Analysis
Overall accuracy	90.8235%	89.6470%	94.3529%
Unclassified	39	44	48
Real Asbestos	139/149	135/149	127/149
Mixed Asbestos	127/135	125/135	124/135
Non Asbestos	125/141	121/141	126/141
Total	386/425	381/425	377/425

Table 1

In Figure 4, it's brought back an extract of the layer GIS, relative to the zone of Melito, that it collects the buildings dealt in the present note. In particular the point with the brown cross represents a classified covering in cement-asbestos with high value of operator AD<,> (high probability of obtain a correct result) and therefore low probability of being false positive ones. The building with red cross represents a covering in cement-asbestos mixed with other materials, and in the end the building with orange cross is the building with a covering constituted of a different material from asbestos. For the results of pixel-oriented classification is sent back, instead, to the comparison brought back in the successive paragraph.

Figure 4

5. OBJECT-ORIENTED METHODOLOGY OF CLASSIFICATION AND COMPARISON WITH PIXEL-ORIENTD METHODOLOGY

The methodology used to the aim to confront the obtainable result with how much already obtained in the precedent methodologies previews a multi-resolution segmentation operated here creating an only level, holding account of the characteristics of dataset the IKONOS, and therefore with a medium scale factor (equal to 15), spectral homogeneity (reduction of the spectral heterogeneity) equal to 0,8, compactness equal to 0,7 and fractal factor equal to 0,3.

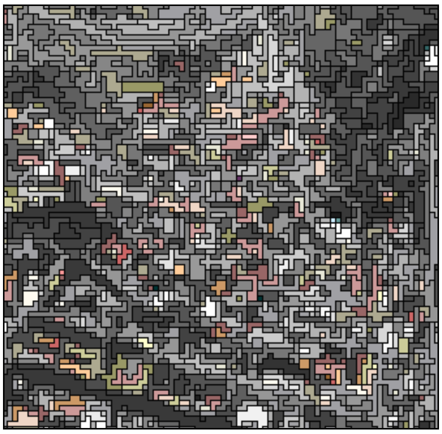

Figure 5: Multi-resolution Segmentation

Through the inclusion in the procedure of segmentation of a shapefile containing the detected test areas, it has proceeded to the location of the Sample necessary tests and has been executed a classification Nearest Neighbor to 5 iterative cycles for the discrimination of the buildings with covers containing asbestos.

In table 2, the matrix of comparison of the three methodologies up to here exposed is brought back, while it is brought back only in terms of image the result obtained with the technique object-oriented, figure 6. It is obvious, although all the methodologies introduce a good result of classification approximately the location of the material, the two methodologies pixel-oriented, based on the operator AD offer better performances, regarding the technique object-oriented, in detecting the buildings where the asbestos is mixed with other materials.

Image Used	Operat AD	S. P.	Coef f ρ	ω_p	σ	$\lvert F(\omega_p, \sigma)\rvert$
Real Asbestos	2.33	2.7	0.79	100	99999991	0.0
Mixed Asbestos	4.70	5.5	0.43	1000	95700089	0.25
Not Asbestos	10	13.6	0.1	10000	95700089	417.44

Table 2

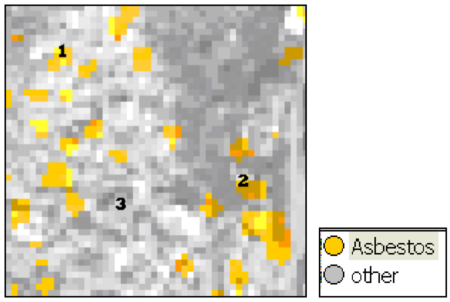

Figure 6: Classification (1, 2 and 3 are the detected and above mentioned buildings)

An assessment on the place has confirmed the validity of obtained result, (it should be observed, moreover as the examined example evidences how the implemented operator is effective to detect asbestos, even in little dimensioned buildings). It can be observed that, according to authors' opinion, even if it would seem more obvious to use hyperspectral sensors (with high spectral resolution), in the specific case is preferential to use sensors with high spatial resolution (even if with not elevated spectral resolution) because it needs classifying also buildings of small dimensions, considering that the spectral profile of the several materials used for the coverings of buildings diversifies those a lot that enough to the *eq(.)* in order to exalt differences and to allow to the operator AD to classify with a high degree of reliability.

6. CONCLUSIONS

In this work we have dealt two various useful methodologies approximately the problem of real the asbestos location, and successively put to comparison the result obtained with an other that it is based on the classification object-oriented. This job puts in prominence the efficient character of the operator, which is re-usable in any geographic context, it's sufficient to redefine a simple factor of equalization.
In particular from the comparison with the analysis object-oriented, we can establish like the method developed, thanks to the specialization operating on it, the analytical instruments employed, and the hypothesis on the *eq (.)*, it represents a valid instrument for the scenes, as regards the detection of buildings, necessary of intervention.

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