Synergy between GMES and Regional Innovation Strategies: Very High Resolution Images for Local Planning and Monitoring

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Abstract
In the European strategy for a sustainable territory management, the European Commission (EC) gives great relevance to the active participation of the final Users, with the purpose of gathering their specific requirements in the definition processes and in the qualification of the services. Starting from the results obtained by GSE LAND project, funded by ESA within GMES initiatives and by its successor GEOLAND2 project, financed by EC within the FP7 Programme, Regione Puglia supported a regional project aimed to provide EO value added products and services in the fields of environmental monitoring and urban planning. This paper describes the operational case of the construction of the new General Urban Plans for a local Municipality.

Keywords: Urban planning, land monitoring, very high resolution remote sensing.

Introduction
Environmental assessment is a procedure that ensures that the environmental implications of decisions are taken into account before the decisions are made. Environmental assessment can be undertaken for individual projects, such as a dam, motorway, airport or factory, on the basis of Directive 85/337/EEC [EU, 1985], known as ‘Environmental Impact Assessment’ – EIA Directive, as amended by Directive 97/11/EC, or for public plans or programmes on the basis of Directive 2001/42/EC [EU, 2001], known as ‘Strategic Environmental Assessment’ – SEA Directive. The common principle of both Directives is to ensure that plans, programmes and projects likely to have significant effects on the environment are made subject to an environmental assessment, prior to their approval or authorisation. Consultation with the public is a key feature of environmental assessment procedures.
European Directives require Member States to achieve specific environmental objectives to contribute to objectives of smart, sustainable and inclusive social and environmental growth. European Commission (EC) and the European Space Agency (ESA) are working together to start and to fund initiatives aimed to support the Member State in their recurrent mandatory check aimed to monitor the urban growth and the land change. In this context, one of the main activities is represented by GSE LAND project (http://www.gmes-gseland.info/), funded by ESA within GMES initiatives, and developed by Planetek Italia for Veneto Region Government as service final User. The project was focused on the assessment and demonstration of an Earth-Observation based service to support the decision-making, both institutional and private, in environmental protection and land monitoring. The service, named Urban Atlas, provides very high resolution hot spot mapping of urban functional areas at scale 1:10.000 with a nomenclature based on CORINE Land Cover. Veneto Region was directly involved in the project during the achievement of the first results over some test areas and their contribution was fundamental during the quality assessment phase. The results achieved during GSE LAND have found their natural prosecution in GEOLAND2 project (http://www.gmes-geoland.info/), financed by EC within the FP7 Programme. The main goal was to obtain an important step towards the complete functionality of GMES Land Monitoring Core Services (GMES LMCS). Urban Atlas, as a component of LMCS services, is one of the research topics of the project, whose purpose is to improve its processing chain, increase the semi-automatic processes and find new technical solutions for an effective product update testing new sensor capabilities.

In GEOLAND2 project a new land mapping product has been designed in order to fulfill the Regional requirements to enhance the spatial resolution and increase the level of information content. The resulting new Urban Atlas, named High Resolution, is a multilevel land cover map derived from WorldView-2 satellite images with a higher level of detail enabling the delineation of single buildings, additional information regarding the density of impermeable surfaces in the urban area, NDVI average, and indication of new construction buildings and roads. In order to be compliant with European and national directives, all Italian Regions are governed by local regulations aimed to guarantee the right territorial and urban management by observing the European rules. In particular, in Apulia Region, the DRAG document (Regional Document for General Arrangement http://www.regione.puglia.it/drag/) is the local instrument that gives the Municipalities the indications for the construction of the new General Urban Plans (PUG). PUGs must be compliant with the rules of environmental sustainability and territory preservation and valorization through the introduction of evaluation procedures for the urban planning process. In this context the DRAG document establishes that the Strategic Environmental Assessment (SEA) is an essential part of the elaboration and approval process of a PUG. DRAG document also suggests remote sensing data as a potential information source to be used to support the urban planning process. Satellite data are able to support the construction of an updated, objective and standardized knowledge of the landscape in general and of the urban territory in particular.

In this context, Planetek Italia, a multi-disciplinary Geographical Information Services (GIS) and Earth Observation Apulian SME (www.planetek.it), in collaboration with ISSIA (Institute for Study Intelligent System for Automation) of Italian Research National Council (CNR) has developed a research project named MaTRis (Very High Resolution Thematic Maps from Aerospace). The MaTRis project is an action funded by Industrial Research and
Technological Innovation Department of Apulia Region, in the framework of the “Regional Operative Program 2007-2013” for SMEs: the aim of the project has been to define added value products and services derived from EO data in different application areas that range from environmental monitoring to urban and landscape planning. In MaTRis project a convention with Apricena Municipality has been signed, in order to support the PUG development. Following this objective, the project activity has required the development of detailed specifications for the production of geospatial data functional to the activities of strategic planning of the territory and derived from high resolution multispectral satellite images. The data are compliant with the DRAG requirements and represent the basis for the construction of some cartographic indicators able to measure the effects of changes associated with the plan and to provide a measure of the environmental compatibility of the planned actions. The products developed in MaTRiS project are multi scale and multi layer maps compliant with the current National and European requirements and suitable to different territory government levels (regional, provincial, municipal). The final products are also compliant with the European CORINE Land Cover nomenclature system [EEA, 2000]. The different feature classes and the respective metadata are organised into a Geodatabase compliant with INSPIRE interoperability standards.

Geospatial Data For Urban Planning
The geospatial data developed to support urban planning consist of a multilevel product, resulting from processing of high resolution multispectral satellite images and the integration of any available ancillary information. The multilevel structure of the product is organized as presented in Table 1.

| Informative level | Description | File format |
|-------------------|-------------|-------------|
| Level 0           | Orthoimage. Is the basis for all the updating activities | TIFF, ECW Metadata ISO 19115 |
| Level 1 (Land Use) | Land use map with a legend of 43 classes compliant with the European CORINE Land Cover nomenclature system | SHP, GDB Metadata ISO 19115 Statistics Report |
| Level 2 (Transport Infrastructures) | Roadway and Railway Layer | |
| Level 3 (Buildings) | Buildings Layer classified on the basis of their use | TIFF, ECW Metadata ISO 19115 |
| Level 4 (SoilSealing) | Soil Sealing Layer. Binary raster map of the sealed areas | SHP/GDB Metadata ISO 19115 Statistics Report |
| Auxiliary levels | Available ancillary data (i.e. CTR, historical LCM, DTM, etc.) | |
**Thematic detail**

The urban territory is mapped with single-building details that are classified accordingly with the available reference cartography. Old buildings are extracted from the reference cartography while new buildings are identified and mapped on the basis of the updated satellite data. One of the peculiar characteristic of this product is the classification at level 4 of the urban density. The urban density is calculated through the implementation of two different approaches:

1) on the basis of the sealed area percentage into a single urban polygon (derived from the soil sealing layer);
2) on the basis of the buildings area percentage into a single urban polygon (directly derived from the land use map).

**Geometric detail**

The Minimum Mapping Unit (MMU) has been defined accordingly with the guidelines proposed by Land Use National Group during the last seminar of Interregional Center for GIS Systems (CISIS). The land use map has a resolution of 0.16 ha for the artificial surfaces and a resolution of 0.25 ha for the natural classes (Agricultural, Forest and semi-natural, Wetlands, Water bodies). Regarding the buildings delineation those already mapped on the reference cartography are completely reported, regardless their size, in the level 3 layer, while the new buildings extracted from the satellite data have a minimum size of 50m². Roadways, railways and rivers have a minimum mapping distance of 5m while the network continuity is guaranteed. An important characteristic of the Land Use Map is the geometric congruence with the reference data finalized in maintaining the reference geo-informative content of the data integrated by the new features derived from the satellite data. The Technical Regional Cartography, for example, can be used to construct the geometry of the new map while reference land use maps can be used for the thematic content updating. The same reference data, together with the new satellite acquisition, are used for the thematic and topologic quality control. An example of the geospatial data realized for Apricena Municipality is presented in Figure 1.

Based on the produced data, a number of derived maps have been extracted in order to represent the territorial resources, the dominant characteristics of the landscape, the mutual relationships between them and the territorial transformation trends.

**Methodology**

The automatic analysis of very high spatial resolution sensor data, is probably one of the most intriguing challenge in the development of effective geographical information systems [Yu et al., 2006] and the significant amount of geometrical details present in a high-resolution scene requires completely new data analysis approaches [Grignetti et al., 2011, Tarantino et al., 2011; Cerra and Datcu, 2010]. The reason is that the improvement in spatial resolution increases the internal variability of each land cover, so the increase in volume of information could create a sort of noise for a traditional classifier [Fiorentino et al., 2011]. To face this problem, in MaTris project, we have adopted an approach to the classification of very high spatial resolution images, where the remote sensed “new” information is assimilated and “fused” with the pre-existing knowledge about local territory. This a priori knowledge is represented by the historical data stored in the GIS. Therefore the proposed
methodology is based on the idea that historical data (in our case existing Corine Land Cover Map and Transportation Network) could usefully drive the analysis of up-to-date remote sensed images for highlighting the changes which have occurred on the ground.

Essentially changes were due to the increase in the built-up areas and in the transportation network modification. The adopted approach is based on the following steps: 1) preliminary segmentation in the spectral domain, using a pixel based supervised classifier; 2) region creation, exploiting contextual relationship; 3) semantic object recognition and change detection analysis, exploiting spectral and geometrical features, contextual rules and congruence with historical data.

In the first step a Maximum Likelihood per pixel Classifier is adopted. Using Corine Land Cover map and photo interpretation, two separate sets of point have been randomly selected for training the Classifier and for verifying the classification output. Special attention is given in the selection to the test set of a sufficient samples of new built-up areas, in order to have a statistical significance for change evaluation. This first step is a preliminary and tentative image segmentation based on spectral value at pixel level. After this step, the classification result is used as input for creating spatial regions, following a region growing strategy: contiguous pixels with the same label are assigned to the same region. In order to detect “new artificial area” elements, for the objects characterized by the tentative label “urban artificial”, some geometrical
features (such as size, shape, length) are computed. Finally objects are classified using spectral and geometrical characteristics. Classification accuracy for two macro classes “built-up” and “non built-up areas” has been computed considering the points belonging to the test set and it has been > 85%. The methodological scheme for the multilevel Land Use Map generation is presented in Figure 2. The final step is represented by the geodatabase construction that allows the generation of the multilevel product.

The above mentioned approach has been applied to a WorldView-2 satellite data. WorldView-2, launched the October 8, 2009, is a commercial Earth Observation satellite that provides panchromatic imagery of 50 cm resolution and eight-band multispectral imagery with 2 m resolution. WorldView-2 represents the latest innovation among the sensors for remote sensed imagery. In addition to the standard four multispectral channels the sensor has a shorter wavelength blue band in the range from 400 to 450 nm, two new “agricultural” bands in the range from 585 to 625 nm and from 705 to 745 nm, plus a longer wavelengths band, in the range from 860 to 1040 nm. For the project the Apricena images were acquired in April 2010.

The process has been implemented to identify the land cover basic classes such as artificial surfaces, forests, agricultural areas and water bodies. The next step is a screening of the territorial changes with respect to the reference data in order to create a hot spot map where the successive photo interpretation phase is intensified. In this context the spatial resolution of satellite data is a crucial factor for the land use change analysis allowing a direct comparison between the available reference land use maps and the result of the automated classification. A successive elaboration allows the production of the soil sealing layer [Kopecky, 2009], leading to a binary map of built-up area. This layer is the basis for the urban density class definition of the artificial surfaces according to CORINE nomenclature. The urban density layer is raster dataset of 40 x 40 m2 (0.16 ha) cells where the cell values represent the number of built-up area pixels within one 40 x 40 m2 cell. The implementation of an automated density classification process allows the generation of a homogeneous classification reducing the effect of an subjective classification of the photointerpreter.
Derived Territorial Indexes
The geospatial data for urban planning are suitable for the derivation of a set of territorial indexes useful to describe the environmental situation and to evaluate the environmental consequences of programs and plans implementation on the idea of a sustainable development. An example of such indicators list is presented in Table 2. The soil loss index is one of the most important of the indicators. The soil loss is due to sealing and can be considered in large part as irreversible in relation to the time needed for soil to form or regenerate itself. A measure of the soil loss should be objectively repeatable and updateable. In Table 1 a detail of the land use map legend for artificial surfaces is presented. The artificial surfaces classes are defined by the degree of urban density accordingly with Corine Land Cover specifications.

| Indicator          | Description                                                                 |
|--------------------|-----------------------------------------------------------------------------|
| Soil loss          | Measures the soil loss incidence due to urban sprawl and transport infrastructure construction |
| Land use           | Measures the surface size of the principal land use types (artificial, agricultural, forest, etc.) |
| Landscape fragmentation | Measures the medium size of natural areas that are not interrupted by transport infrastructures |
| Landscape diversity | Measures the diversity of the landscape that is very important from the perceptive point of view |
| Others             | Specific indicators can be derived by the intersection with other ancillary information |

| Informative level | Description                                                                 |
|-------------------|-----------------------------------------------------------------------------|
| 1                 | Artificial surfaces                                                         |
| 1.1               | Urban fabric                                                                |
| 1.1.1             | Continuous Urban fabric                                                     |
| 1.1.1.1           | Center city with mixed use, continuous and very dense Urban fabric           |
| 1.1.2             | Discontinuous urban fabric                                                  |
| 1.1.2.1           | Discontinuous Dense Urban Fabric with mixed use (S.L.: 50% - 80%)            |
| 1.1.2.2           | Discontinuous Medium Density Urban Fabric, mainly residential (S.L.: 30% - 50%) |
| 1.1.2.3           | Discontinuous Low Density Urban Fabric, mainly residential (S.L.: 10% - 30%)  |

The application of the methodology to Apricena Municipality case identifies a soil loss of 29 ha between 2006 and 2010. The extension of Apricena Municipality is nearly 171 square kilometres, corresponding to 17,100 ha. The built-up area in the Corine Land Cover Map (referred to year 2006) is nearly 786 ha, corresponding to 4.6 % of entire Municipality. The overall built-up
area resulting from the analysis of 2010 WorldView-2 image is 815 ha (4.76% of total the Municipality’s extension). The increment is 29 ha, corresponding to an increase of 3.7% of 2006 urban area. It is important to note that the estimated accuracy for this increase is nearly 85%. Figure 3 shows the spatial distribution of the soil loss derived from the mutual difference between the soil sealing layer 2010 and 2006 calculated from two different satellite acquisitions.

By intersecting the soil loss spatial distribution with the available land use maps it is possible to provide auxiliary information on what the soil lost was in 2006 and what has become in 2010. Figure 4 gives an example of statistical information derived the soil loss map.

**Pug-Geoportal**

An important phase of the entire planning process is the publication and dissemination of the documentation regarding the planning process in order to allow the citizens to be involved during the plan development. A web portal is the solution to manage and disseminate not only the documentation but also the maps through an interactive WebGIS, thus constituting a real GeoPortal. Through the GeoPortal all the citizens are able to send feedback about the planning process to the municipal administrations allowing also the knowledge and information sharing and interchange based on social networking systems in a Web2.0 modality. The GeoPortal that has been implemented for Apricena Municipality is composed of four main modules:
Figure 4 - Statistical elaboration derived from sealing map of Fig. 3 (Above Soil loss in 2006, under Soil loss in 2010).

1) Consultation of documents:
The GeoPortal users can easily access all technical and administrative documents, reports, and maps produced in the planning process. Documentation can be accessed by the interactive map viewer (Fig. 5) or by consultation of documents in .pdf format.

2) Light Community Tool (GeoNews and Blog)
This tool allows the GeoPortal users to publish a GeoNews that is news geo-positioned on a map. All the users can read the news or receive the feeds through an RSS service. Moreover, the user can insert their own comments generating a common area of community information consisting in a geographic blog (GeoBlog).

3) Web browsing of the spatial data
The GeoPortal provides a geo viewer tool that allows users a full browsing experience of the
cartographic resources and maps. The viewer is allowed to browse not only maps generated during the planning process but also maps of external data providers such as Regional Administrations that make available their own maps through standard protocols like WMS.

4) Feedback and reporting tool
The Feedback module allows users to send reporting about the PUG to the central administration. The users can make geocoded comments, identifying a point or polygon on the map and also general comments to the PUG documentation.

![Image of Apricena web GeoPortal: Map of landslide perception (useful to PUG definition).](image)

**Conclusion**
The European Commission emphasizes the necessity of increasing the knowledge of soil resources and degradation processes. Soil sealing degree, measured as a percentage of the amount of built-up or non-built-up impermeable surfaces, is the quantitative indicator recommend by the European Environmental Agency to describe urban environmental situations. In this paper we have presented a methodology based on the use of remote sensed images for evaluating the trend of artificial area increment in the Municipality of Apricena. The method is based on the automatic analysis of high resolution remote sensed images and on the comparison with historical data. Classification accuracy of built-up non built-up areas has been > 85%. The sealing map produced is a raster dataset of 40 x 40 m² (0.16 ha) cells where the cell values represent the number of “sealed” 2 x 2 m² pixels (full image resolution) within one 40 x 40 m² cell.

With respect to a traditional field review method, a methodology based on Remote Sensing has shown the following main advantages: up-to-date data gathering; fast data processing, easy integration into GIS. Moreover the proposed methodology is characterized by high degree of automation, so assuring reproducible and transferable results.

Understanding of the landscape is improved by the production of objective indicators that
depict the territory evolution process, enabling comparisons to be made with planning assumptions and, informing and, possibly, modifying the eventually adopted planning decisions. In this context, Very High Resolution satellite data are a precious resource able to provide the current landscape status and to guarantee the periodic monitoring of the landscape. Based on satellite data, Land Use maps focused on urban areas and objective indicators for the Strategic Environmental Assessment can be developed. The standardization of geospatial data for urban planning such as the multilevel Land Use map, other derived maps and indicators, is the challenge to win for the operative and diffuse use of such EO products in the modern urban planning process.

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