Monitoring and valuing the European geological heritage: operational uses of satellite applications

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Document type: Article.
Manuscript history: received …………. 2013; accepted ………….. 2013; editorial responsibility and handling by Domenico Calcaterra.

ABSTRACT

Geological and landscape diversity is an essential part of the European culture. It characterises our rural and urban environments and offers the resources needed to sustain human communities.

To monitor and protect geological heritage, back in 2003 the European Parliament stressed the importance of harmonising analytical methods to obtain comparable soil data and of increasing the exchange of information among Member States on soil, topography, structure and natural form of the land in Europe (European Parliament, 2003).

Today, satellites offer the opportunity to collect and access geological and biological information covering large areas, including urban, rural and natural environments at the micro and macro regional levels. On their own initiative, or within European and national schemes, local and regional managers are already using satellite services to monitor, protect and promote geological, landscape and biological diversity.

To disseminate the results of these initiatives is fundamental to capitalise on experience to develop new services adapted to local needs, and to set the basis for the establishment of an integrated coherent system to manage geodiversity in Europe. Eurisy, a non-profit association of space agencies, works to foster awareness of operational uses of satellite applications in this and other sectors.

KEY WORDS: Satellite services, Earth Observation, Satellite navigation, Soil protection.

INTRODUCTION

Designing and implementing management policies regarding cross-border issues such as natural and man-made hazards, landscape monitoring, and conservation of geological and biological diversity, among others, require the involvement of all the stakeholders acting on a specific territory, who are connected by an immediate interest in its welfare.

This paper aims at informing such public managers and stakeholders about some satellite solutions already available and used by European local managers to map and monitor geological and landscape changes, to improve territorial planning and to raise awareness and enhance education on earth heritage.

Such experiences will be presented from the end-user perspective, with the intention of focusing on the results of the satellite solutions adopted rather than on the technology per se, in line with the Eurisy mission of connecting space to society.

THE EUROPEAN GEOLOGICAL HERITAGE: CONSERVATION THREATS

Geological heritage includes geo-morphological, geological, hydrological, pedological, special archaeological values originated throughout the long history of the evaluation of the Earth's crust (Ilic, 2006).

This heritage is vulnerable to global phenomena, like climate change, and to human activities, such as inappropriate agricultural and forestry practices, industrial activities, tourism or urban development carried out at local and global scales. Indeed, the EC policy report of February 2012 on the implementation of the Soil Thematic Strategy stresses an increase in soil erosion, sealing, desertification, contamination, landslides and flooding, among others, in Europe (European Commission, 2012). At the same time, recent natural catastrophes, like the earthquakes which occurred in Italy in the last few years, revealed gaps in the information available for policy makers and emergency managers when facing geo-hazards.

TOWARDS A EUROPEAN MANAGEMENT FRAMEWORK FOR EARTH HERITAGE

Geological heritage is clearly an issue of transnational relevance, and its monitoring and conservation has been the object of concern and discussion among European governmental and non-governmental institutions at various levels. Although this interest has not yet led to the establishment of a coherent strategy for geological heritage monitoring and conservation in Europe, different intergovernmental and non governmental institutions expressed the need to improve management of geological heritage through the use of better inventorying techniques, wide dissemination of scientific information on nature and improved cooperation among decision-makers working in complementary sectors (Council of Europe, Committee of Ministers, 2004).

Also the EU Biodiversity Strategy for 2020, often protecting sites having also a geological interest, emphasises the need for "*digitised, accessible maps containing accurate information* *about the principal natural resources, protected areas, land uses, water bodies and areas at risk*". Moreover, the Strategy recommends that scientific data on biodiversity and examples of best practices are made "*widely known and shared among policy-makers and key stakeholders, and that the relevant ICTs play a crucial role in delivering new opportunities and tools*" (European Commission, 2011).

The EU has been also working, since 2002, to a "Thematic Strategy for Soil Protection", complemented in 2006 by a Soil Framework Directive that has been rejected by a minority of Member States (March 2010, Environment Council) on grounds of subsidiarity, excessive cost and administrative burden (European Commission, 2012). The proposed Framework Directive–asked for an integrated framework of actions, implemented by each country according to the characteristics of the soil.

In 2004, the European geoscience community and the voluntary sector–published a Manifesto on Earth Heritage and Geodiversity, urging the EU to "*incorporate Earth Heritage and Geodiversity in policy, planning and related procedures*".

SATELLITE SERVICES AS A VALUABLE TOOL IN ENHANCING GEOLOGICAL KNOWLEDGE AND MANAGEMENT

The EC policy report of February 2012 on the implementation of the Soil Thematic Strategy envisages the establishment of mechanisms for harmonised European monitoring of soil parameters for a whole range of statistical, research and policy purposes, and specifies that "*To consolidate harmonised soil monitoring for a variety of purposes* [...] *the Commission is considering repeating soil investigations at regular intervals (five-ten years), also by using new remote-sensing techniques.* [...] *The Global Monitoring for Environment and Security (GMES) programme will also be a source of information, particularly on soil sealing*" (European Commission, 2012).

Indeed, European engagement in space activities, and in particular the two flagship initiatives Galileo and Copernicus (formerly GMES) will provide European managers with consistent and comparable EU-wide information products across administrative boundaries that will enable an integrated approach towards efficient soil use.

Satellites in fact make it possible to have a comprehensive overview of regional ecosystems, and offer valuable information on changes on the Earth's surface, like soil sealing and vegetation coverage, that can be used by public managers to improve soil management and spatial planning and to evaluate processes influenced by the state of the soil, such as floods (GMES, 2013). Furthermore, mobile services based on satellite navigation allow for new interactive ways to inform the general public on geological and biological issues and to raise awareness on environmental concerns.

LOCAL AND REGIONAL AUTHORITIES AS INNOVATION LEADERS

Many actors intervene on territorial management and conservation, including urban and rural planners, civil protection officers, environmental managers and policy makers at local, regional and national levels, but also national geological surveys, industrial associations, trade, farmer and land owner organisations, science and research institutes, as well as several associations and NGOs. In the absence of a coherent European policy on geological monitoring and conservation, soil management remains mainly an issue of national concern, often entrusted to local and regional public managers.

On their own initiative, or within national and European frameworks, local and regional managers are indeed experimenting new solutions for geological monitoring and conservation. Satellite-based information, in particular, is used to identify sites of geological or geomorphological interest, to monitor geological trends and changes, to raise awareness and to educate the public on the value of these sites.

The examples provided below are only a few among the numerous initiatives undertaken by European local and regional authorities to harness the benefits of satellite applications for improved territorial management. A wide dissemination of these experiences is essential to ensure capitalisation of results and to foster the development of better solutions, adapted to local needs and to the variety of European landscapes.

ENHANCING MAPPING AND SURVEYING TO PROTECT HEARTH HERITAGE

Mapping land cover: the experience of the Dorset County, United Kingdom

The **Dorset County** includes a variety of habitats and land covers such as woods, agricultural cultures, urban conglomerates, and coastal zones on which a number of private and public entities intervene. As from 2005, the Dorset County Council adopted a Local Geodiversity Action Plan, which fosters the creation of a Geographic Information System (GIS) with a layer for geodiversity data (Dorset County Council, 2005).

Geoconservation is complementary to biological conservation, and indeed land cover and vegetation management have a key role in protecting geodiversity processes. In order to acquire reliable data on land cover and vegetation, the **South West Protected Landscapes Forum** -the umbrella body for the most prized places of natural beauty in Cornwall, Devon, Dorset, Gloucestershire, the Isles of Scilly, Somerset and Wiltshire- uses a combination of aerial and satellite imagery to produce landscape maps of the territory. Although information on land cover existed also prior to the use of satellite imagery, it had never been combined into one map, leaving the potential for overlap and duplication (Dorset AONB Partnership, 2013).

Remote sensing techniques used since 2010 within the framework of the Cordiale project (www.cordialeproject.eu), allowed for land cover classification (woodland, grassland, heathland and wetland) over a large area (884.8 km2) in a homogeneous way, and for the identification of core habitat sites and a 'functioning ecological network' (with regards to species movement).

The land cover and habitat maps have been made available to different public and private entities operating on the territory. In fact, these maps provide guidance not only to environmental managers and urban and rural planners, who can better target actions where the restoration effort will yield the fastest and most robust ecological benefit, but also to land owners and farmers, who are encouraged to use the maps when considering a new application for Environmental Stewardship and/or Forestry Commission grant aid (Eurisy Website, Nov. 2012).

The use of remote sensing reduces the need for labour intensive, time consuming site Surveys and inventories (Environment Systems, 2012), and helps to easily detect land cover and habitat changes by comparing images taken at different moments in time.

Managing land use conflicts to protect geological and archaeological heritage: the experience of the Vestfold County Council, Norway

Vestfold, in Norway, is also a county in which urban, rural and natural environments coexist. The Vestfold County is in fact relatively close to the capital, Oslo, and is characterised by large areas of arable land with patches of forests, interspersed with exposed bedrock. The county has a unique natural environment, botany and geology, including the Vestfold "Ra", a gigantic, visible but mostly covered ground moraine from the ice age. Moreover, the area hosts some impressive ship burials from the later Iron Age. The **Vestfold County Council** is responsible for protecting such geological heritage from infrastructure development and agriculture exploitation.

Although many archaeological sites were known thanks to field surveys and excavation works, recent surveys showed that many sites are still hidden under cultivated land. This discovery was made possible with the combined use of aerial photos and satellite imagery. The latter has been analysed with a new software, CultSearcher, developed and tested through a collaboration among the Vestfold County Administration, the Norwegian Computer Center, the Norwegian Institute for Cultural Heritage Research, and the Norwegian Directorate for Cultural Heritage (Rune Solberg at al., 2009). The use of satellite-based information allowed for the discovery of over 30 new ring ditches surrounding a grave mound in the last three years and will enable territorial planners to take better informed decisions on new infrastructure. On the basis of the Vestfold experience, the Norwegian Directorate for Cultural Heritage envisages the establishment of a system using the same software on a national level (Eurisy, 2012).

RAISING AWARENESS ON GEOLOGICAL HERITAGE TO PROMOTE CONSERVATION AND LOCAL DEVELOPMENT

Educating on Earth heritage: the example of the Swiss National Park

Article 15 of Chapter IV of the proposed Framework Directive on Soil "Awareness raising and public participation" invites Member States to "*take appropriate measures to raise awareness about the importance of soil for human and ecosystem survival"* (European Commission, 2006).

The **Swiss National Park** has a long experience in using remote sensing and satellite navigation to update its geographic information system (GIS), which is used for research and management purposes. Moreover the Park, which is a category 1 strict nature reserve and wilderness area, where no human can leave the established paths, has used since 1998 GPS to track mammals and reptiles to better understand their behaviour. The area has a particular interest both in terms of biodiversity and geology, since over 200 fossilised dinosaur footprints were discovered in the eastern part of the park. In order to allow visitors to witness the unique landscape without a park guide while remaining on the established visiting perimeter, "IWebPark", a multimedia guide has been created by geolocating images, audio tracks and texts covering a wide range of information, such as the user's position, the animals and plants in the park and geological and historical facts, among others. The multimedia guide can be rented in the Park or it can be downloaded directly on smartphones. This initiative aims both at making young visitors interested into the biological and geological heritage of the area and at promoting a dynamic image of the National Park (Eurisy Website, May 2013).

Valuing Earth heritage to promote local sustainable tourism: the experience of the Swiss Region of Mendrisiotto and Basso Ceresio, Switzerland

The previous is an example of how satellite-based services can support environment managers in their educational mission. Similar mobile applications can also be used to foster ecotourism, which is an important example of how economy can be oriented towards activities which are respectful of the territory and its inhabitants.

That is the case for the Swiss region of **Mendrisiotto and Basso Ceresio**. The region, relatively unknown to people visiting the country, is covered by 60% with forests, including areas of outstanding natural beauty, as the Parco della Breggia and the UNESCO World Heritage site of Monte San Giorgio, where fossils can account for the geological history of the area over the last 240 million years. In addition, the region hosts some endangered habitats and species, included in the Emerald list of protected areas. To foster tourism in the region while valorising its natural and cultural heritage, the regional Tourist Board created a series of thematic itineraries over a range of about 300 km and made available the GPS tracks to follow them autonomously, walking or biking. Some of the itineraries have been designed in collaboration with other tourist offices, or other environmental organisations. The collaboration with the World Wide Fund for Nature (WWF), for example, led to

the creation of nine geolocated itineraries to discover the "Emerald" zones in the territory, including a geo-paleontologic itinerary on Monte San Giorgio.
To involve local business, e-bike itineraries have been created involving hotels renting electric bikes, while other tracks guide visitors through vineyards and cheese factories, thus promoting not only the beauty of the landscape, but also local products (Eurisy Website, Apr. 2013).

MONITORING SOIL CHANGES TO MANAGE GEO-HAZARDS

Slope hazard detection to reduce impacts on human settlements: the initiative of the Campania Region, Italy

Geological heritage needs to be monitored not only to protect its diversity and beauty, but also to observe, prevent and manage hydrogeological movements that can seriously damage the landscape and human settlements. Satellite services proved to be extremely effective in supporting local managers to monitor soil changes and cope with geo-hazards, as exemplified by the Campania Region and the Arno River Basin Authority in Italy.

The varied landscape of Southern Italian region of **Campania** includes hills, plains, a part of the Apennine Mountains and six important volcanic sites, which have determined the morphology of the area throughout the centuries. The Region has a medium-high seismic hazard and a high exposure and vulnerability to this risk (due to the fragility of the buildings and infrastructure and to the population density). Seismic and hydrogeological movements make the region also affected by bradyseism, the gradual uplift or descent of the Earth's surface.
The **Sector for Soil Protection of the Campania Region** uses a permanent satellite monitoring system of slow-moving landslides to detect slope hazards in urban areas. Within the framework of the Tellus project (2005-2009), a local GPS network was built on the regional territory (Regione Campania, 2007). The information provided by the fixed and mobile GPS stations is combined with aerial and satellite imagery and with geological surveys to control the impact of soil deformation, soil erosion and slow-moving landslides on urban settlements particularly exposed to hydro-geological risks.
Data collected by the local GPS stations are automatically sent to the Soil Protection Sector and the Civil Protection Office of the Campania Region. Moreover, all the geological and geomorphological data obtained through aerial imagery, satellite imagery, the GPS stations and the field surveys have been collected into a cartographic and thematic GIS web portal, which enables different public entities to access and share such information. This allows for an integrated analysis on the whole regional territory of some of the slow-movements of the soil caused by seismotectonic, volcanic, gravitational and human activity. Furthermore, the system enables a detailed analysis of the single landslides and deformations with an impact on residential areas, transport infrastructure and productive areas (Carlo Terranova et al., 2009).

Flood and landslide monitoring: the experience of the Arno River Basin, Italy

Similarly to the example of the Campania Region, satellite imagery is used, in combination with other sensors and surveying tools to integrate the Landslide Geographic Database used by the **Arno River Basin Authority**, in the Italian Tuscany Region, to map and monitor old and new unstable areas (Filippo Catani et al., 2006).
The Arno River Basin covers about 9 131 km2, and it is particularly affected by landslides. In fact, there are more than 300 areas within Italy's Arno Basin at high risk of landslides (European Space Agency Website, 2005) and more than 600 landslides have been mapped between March and April 2013 (Autorità di Bacino del Fiume Arno Website, 2013).
To build its Hydro-geological Structure Plan, as required by Italian law, the Arno National Basin Authority profited from the ESA-funded project SLAM (Service for Landslide Monitoring). Within the project, more than 350 satellite images of the region were combined with ground information to identify and assess slope instability and risk across 8 830 km2 of territory (European Space Agency Website, 2005). This procedure has been coupled with an intense geological interpretation phase characterized by the analysis of traditional in situ monitoring data, ancillary data and the performing of field surveys (P. Farina et al., 2004). The data collected permit to characterize and monitor temporal changes of existing and new unstable areas, like the modification of boundaries, and to forecast slope behavior and future landslides, hence supporting local managers in focusing monitoring and prevention in the areas where landslides are most likely to happen.
The Hydro-geological Structure Plan is constantly updated in cooperation with Municipalities and is the main planning and programming tool for risk reduction in the Arno Basin.

CONCLUSIONS

The previous examples demonstrate that satellite services do have the potential to support environmental managers in acquiring information essential to monitor and protect Earth heritage. Moreover, the information collected with satellite applications is objective enough to be used by a number of stakeholders in complementary sectors, like water and forest managers and land owners. Finally, it can also support the design and implementation of local development strategies focusing on the protection and valorisation of natural heritage.
The experiences presented here exemplify only a few of the satellite applications available for public managers to collect information, monitor and valorise geological heritage in Europe. The wide dissemination of these and other operational initiatives of use of satellite information and services is essential to capitalize on experience, to identify replicable good practices and to develop new services adapted to the specific needs of European landscapes.
The greatest advantage of satellites is to offer precise, comparable and sharable information on large portions of territory. In order for this information to be fully exploited by

land planners, researchers and stakeholders working on geological monitoring and conservation, it is desirable the creation of a common platform to share harmonized data at the European level. Some platforms already exist to provide public managers and stakeholders with satellite-derived information of geological characteristics and changes. For example, the **INSPIRE Geoportal** (http://inspire-geoportal.ec.europa.eu/) permits to search for spatial data sets and spatial data services and, subject to access restrictions, to view spatial data sets from the EU Member States within the framework of the INSPIRE Directive. Also the **European Soil Data Centre –ESDAC** (http://esdac.jrc.ec.europa.eu/), hosted by the Joint Research Centre (JRC) of the European Commission aims at collecting all relevant soil data and information at European level. The ESDAC Map Viewer allows to access information on several geological characteristics of the European soil, such as land use, primary, chemical, hydrological and mechanical properties, water management systems and others. The EC **PanGeo project** (http://www.pangeoproject.eu/) instead, provides free access to ground instability geohazard information for many of Europe’s largest cities, combining satellite measurements of ground and building movement and geological information already held by National Geological Surveys. Such data can be viewed in Google Earth or via the portal integrated into the PanGeo website. Moreover, a **Digital Observatory for Protected Areas** (http://dopa.jrc.ec.europa.eu/index.html), also hosted by the JRC, provides park managers, decision-makers and researchers, among others, with satellite-based information and tools to assess, monitor and forecast the state and pressure of protected areas at the global scale.

As an example of a portal collecting information at the global scale instead, the **International Charter Space and Major Disaster** (http://www.disasterscharter.org) offers a platform to access information on major natural disasters, such as earthquakes, landslides, floods and volcanic eruptions. Authorised users (and soon any national disaster management authority) can request support from the Charter for emergencies in their own country, or in a country with which they cooperate for disaster relief and obtain satellite data on a disaster occurrence.

These initiatives clearly aim at giving the widest dissemination to geological information collected through satellites and other means, and are to be welcomed as the starting point for the establishment of integrated regional and global monitoring systems for Earth heritage.

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