Geomatic techniques for disseminating processed remotely sensed open data in an interactive WebGIS

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Abstract

There has been increasing research on the influence of environmental indicators in policy and management contexts. To provide meaningful trend studies or comparison analyses, collecting geospatial data is one of the most important tasks for many spatial information users, but persistent data gaps still remain. Satellite remote sensing has the potential to overcome these gaps by providing continuous coverage over decadal time scales for important environmental parameters. However significant barriers to the use of satellite data for indicator development persist. These relate to difficulties in accessing and using data, differences between decision-makers' parameters of interest and what satellites actually measure , limited collaboration between the environmental measurement and Earth observing satellite communities to develop robust satellite based indicators, as well as technical issues such as cloud cover interfering with satellite data collection, and a lack of cross-cutting technical and funding resources.

In this paper we preliminary discuss methods for collecting raster data in a geodata base by processing open multi-temporal and multi-scale satellite data aimed at retrieving

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indicators for desertification phenomenon (i.e. land cover/land use analysis, vegetation indices, trend analysis, etc.). Then we describe a prototype created for disseminating geospatial raster results (processed imagery and statistical map analysis) through an interactive WebGIS. The system was designed using a suite of open source WebGIS software (Apache http Server, Geo-server – Map server for the representation of geographic data and Pmapper as Web mapping framework). Moreover, it allows querying raster data to know sub-set values of different thematic maps simultaneously on a specific site, downloading the results of the structured queries in an easily and processable format.

Keywords

WebGIS, Remote sensing data, NDVI, Desertification data

Introduction

Desertification is the persistent degradation of land in arid and dry sub-humid environments due to climatic variation and human intervention (Herrmann and Hutchinson, 2005). The Mediterranean region is considered one of the world's hotspots for landscape degradation and desertification (Salvati, 2014). Despite the large number of studies on desertification risk carried out in southern Europe at different geographical scales maps, showing changes of land sensitive to degradation over large areas are difficult to represent (Salvati *et al.*, 2014). The explicit definition of the minimum threshold values signaling the conversion towards an irreversible state of land degradation represents a particularly complex issue. This is particularly the case in many semi-arid Mediterranean environments where the numerousness and variability of the factors influencing the process makes it difficult to integrate and synthesize all of them in a unique value representing the threshold of degradation (Ladisa *et al.*, 2010). Remote sensing performed with valuable instruments for monitoring environmental change holds great potential for desertification assessment (Lam *et al.*, 2010; Weiers *et al.*, 2004). Overlaying desertification severity maps interpreted from multi-temporal satellite imagery in a GIS (Liu *et al.*, 2003) allows to asses trend analysis accurately due to continuity of observations, thereby supporting the prediction and management of this problem (Han *et al.*, 2015). Some of the best methods available to quantify desertification arethe f Land Cover/Land Use (LULC) map interpretation and the assessment of loss of vegetation through vegetation indices analysis, i.e. the Normalized Vegetation Index (NDVI). Among many satellite data products, the LANDSAT data archive has played an important role across many disciplines, being used as a tool to achieve improved understanding of the Earth's land surfaces and human impacts on the environment (Wulder *et al.*, 2012). The instrument characteristics (30 m spatial resolution for VIR/NIR and 120 m for TIR, 185 km swath width and 16 day repeat cycle) are intentionally specified to detect the local and regional patterns of change characterizing the Earth's land processes (Caprioli *et al.*, 2003; Aquilinoa *et al.*, 2013). Several methodologies can be used to generate LULC maps. The fact that artificial neural networks (ANNs) behave as general pattern recognition systems and assume no prior statistical model for input data makes them an excellent technique for change detection analysis when no ground reference data are available for historic satellite imagery (Kavzoglu and Mather, 2003; Joshi *et al.*, 2006). The Normalized Vegetation Index (NDVI) is the most commonly used vegetation index (Tucker, 1979). It varies in a range of -1 to +1 and is provided from many satellite datasets at different spatial and time resolutions (Hagolle *et al.*, 2005). NDVI itself does not reflect drought or non-drought conditions. But the severity of a drought may be defined as NDVI deviation from its long-term mean. If related to other environmental analysis it demonstrated its effectiveness in monitoring the vegetation health and consequently the desertification process (Telesca and Lasaponara, 2006; Bååth *et al.*, 2002). Interactive mapping or Internet GIS were launched about twenty years ago (Plewe, 1997) and they are now effectively applied in many fields (Murgante *et al.*, 2011; Pirotti *et al.*, 2011). These considerable applications for acquiring heterogeneous datasets, performing spatial analysis and providing flexible data visualization capabilities all prove that WebGIS is a valuable technology in disseminating geospatial data through open tools. On the other hand, there are some primary difficulties in working with open source when compared to commercial products. Open source applications often require greater amounts of time and computational skill and the professional support available often depends on the maturity of software and the size of the user community (Steiniger and Bocher, 2009). These complexities aside, however, it is the low cost and customizability of open source that still makes it an appealing alternative for many users.In this paper we tested an interactive WebGIS for sharing online geospatial datasets, i.e. LULC maps over the area of Taranto and NDVI maps over the whole territory of Apulia. First of alla geodatabase with raster and shape data was created. A multi-temporal dataset of LANDSAT satellite images was processed through the MLP feed-forward neural network method aimed at the characterization of land usewithin the area of Taranto. To allow the final user to interpret the vegetation condition along the time, high temporal resolution satellite data were preferred. In this case, among many datasets available, the SPOT VGT S10

NDVI data were chosen to populate the database. In the second phase an INSPIRE compliant WebGIS was implemented. The architecture integrates two different open source platforms: the WebGIS server MapServer, for publishing spatial data and interactive mapping applications on the web, and the Pmapper automatic mapping technology, a GUI front-end written in PHP and Javascript allowing for a dynamic control of MapServer (Caradonna *et al.*, 2015). The features offered were those commonly provided by a WebGIS system as downloading data in shp and geotiff formats. With respect to other WebGIS platforms the prototipe offers the possibility to query raster data displaying values of different maps simultaneously on a specific site.

The study area

The study area is Apulia, the most Eastern region of Italy. More specifically, the area of Taranto is an Apulian province overlooking the Adriatic sea, bordering to the west with Lucania, to the north with the province of Bari, to the east with the province of Brindisi and to the southeast with the province of Lecce. The Apulia region is characterized by a lot of different vegetation species. Apulian landscape changes considerably from season to season. In fact, a marked differentiation exists between seasonal and permanent vegetation. The site is marked out by Mediterranean heterogeneous climate with strong inter-annual variability and a marked annual seasonality (Balacco *et al.*, 2015).

Data and Methods

Dataset

Two data sources were used for populating the geodatabase and implementing the WebGIS: 1) LULC maps from LANDSAT data for a specific year of the Taranto area; 2) NDVI maps from SPOT VGT time series for the period 1999-2013 over the Apulia region. LULC maps had been produced in previous research works. The LANDSAT-TM scenes selected to obtain maps are nine (Tab 1.). As shown in the table the data are all LANDSAT 5 data except 06/07/2001 ETM + data. LANDSAT data can be freely selected through the USGS EROS web site (http://glovis.usgs.gov/) and nominally processed as Level 1 terrain corrected (L1T). The L1T data are available in GeoTIFF format in the Universal Transverse Mercator (UTM) map projection with World Geodetic System 84 (WGS84) datum (Aquilino *et al.*, 2013). LULC maps were obtained with the supervised classification method (Demir *et al.*, 2014). The data were pre-processed to improve their classification performance and consequently used as input of Artificial Neural Network Classifier. A double approach was used for the extraction of land use classes involving both the decomposition of a selected training class and the use of synthetic channels (Tarantino *et al.*, in press). The NDVI satellite data used in this study came from two instruments, Vegetation 1 and Vegetation 2, onboard SPOT 4 and SPOT 5 satellites for the period 1999-2013. The VEGTATION (VGT) instrument includes four spectral bands in the blue, red, NIR and SWIR: the red and NIR bands are usually used to characterize the vegetation and the blue band is used for atmospheric corrections. The orbit of the VGT sensor ensures daily global coverage of the Earth's surface with a 1-km footprint of the pixel in the ground (Figorito *et al.*, 2013).

The Vlaamse Instelling voor Technologisch Onderzoek (VITO) (www.vgt.vito.be) routinely operates atmospheric and angular corrections of reflectance data from SPOT-4/VGT-I and SPOT-5/VGTII, which results in two 10-day composite products (S10 and D10 data) delivered in a Plate-Carrée projection (WGS84 ellipsoid) (Maisongrande *et al.*, 2004). VGT S10 data are MVC (Maximum Value Composite Syntheses) products, i.e. synthetic products obtained from the ensemble of the best acquisitions made over 10 days.

Table 1 - LANDSAT-TM scenes used for multitemporal land use classification

Scene id	Data	Sensor	Cloud cover %	Quality
LT51870321986234XXX01	22/08/1986	tm	0	9
LT51870321987109AAA02	19/04/1987	tm	0	9
LT51870322000241FUI00	28/08/2000	tm	0	9
LE71870322001187EDC00	06/07/2001	etm+	0	9
LT51870322003265MTI01	22/09/2003	tm	0	9
LT51870322004236MTI00	23/08/2004	tm	0	9
LT51870322009201MOR00	20/07/2009	tm	0	9
LT51870322010236MOR00	24/08/2010	tm	0	9
LT51870322011191MOR00	10/07/2011	tm	0	9

The acquisitions were compared pixel to pixel according to the criterion of maximum reflectance. To facilitate the publication of data on the WebGIS, it was necessary for the data set to be in a single map coordinate system, in this case Universal Transverse Mercator projection (zone 33) and datum WGS84. Data were reprojected and resampled using a nearest neighbor operator within QGIS 2.8 software. The NDVI index was calculated for each pixel's digital number of each data using the linear relationship provided by VITO agency:

$$\boldsymbol{NDVI}(\boldsymbol{t})_{\boldsymbol{ij}} = \left(\boldsymbol{DN}(\boldsymbol{t})_{\boldsymbol{ij}} * \boldsymbol{a}\right) + \boldsymbol{b}$$

where:

$\boldsymbol{NDVI(t)_{ij}}$ and $\boldsymbol{DN(t)_{ij}}$ are the NDVI and DN at the time t and at ij coordinates;

$\boldsymbol{a = 0.004}$;

$\boldsymbol{b = -0.1}$

Finally, the two data sources were placed in the WebGIS file system.

The WebGIS architecture components and function

The opportunity to consult complete multi-temporal remote sensing datasets is a noteworthy advantage. In fact, the WebGIS allows to evaluate landscape changes without downloading a large amount of data, by simply looking at maps or downloading only the NDVI values for a specific site, for instance. The WebGIS prototype is composed of four different component programs: UNM MapServer (version 6.4.1), the WebMapping Framework –Pmapper; Apache 2.2.22 webserver and a browser. The user, on the client’s side, sends a request to the web server through a browser. Then the Apache Web Server receives and processes HTTP requests and invokes Mapserver through Pmapper infrastructure (Gkatzoflias *et al.*, 2013). On the server side, there is a common gateway interface (CGI) software, a map file and input raster and vector data to produce an image map and send the result back to the client. MapServer consists of 3 different components: map file, template file, CGI program. The map file needs to set cartographic parameters, cartographic objects, data loading, classification, displaying and query objects. It is implemented using Mapserver software's built-in object-oriented scripting language (Brovelli, Magni, 2003). The template file is a common HTML page that serves as an interface between users and the application. It is what users see from browser and includes all information which the WebGIS designer wants to offer to users. CGI program is the real engine. CGI output is a temporary image or value update at each work session. WebGIS interface is more friendly and easier to use (Fig.1). Layers are organized in 3 thematic levels: Administrative Boundaries, Taranto LULC/LANDSAT, Normalized Vegetation Index (NDVI)/SPOT VGT. For each layer, a legend is provided.

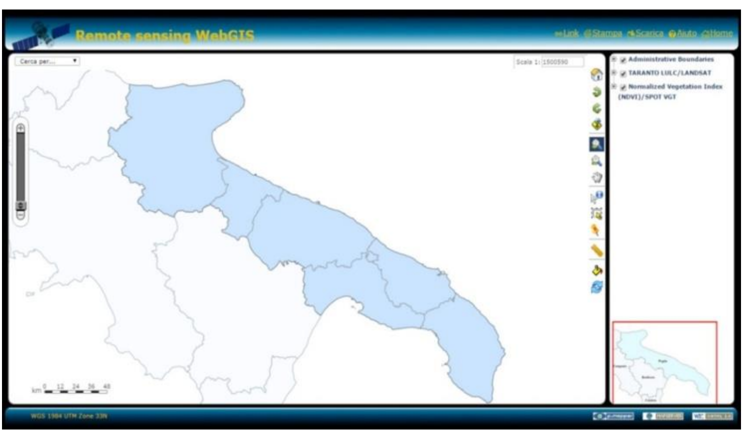

Figure 1 - The WebGIS Layout provided by the prototype

NDVI SPOT/VGT layers are divided in years and each year is divided in months. The LULC layers of Taranto were also divided in the nine years evaluated. The Remote Sensing WebGIS used in this study has common features

of WebGIS. The major components are navigation tools, search tools, geometric tools and the possibility to export the result. In particular the user can use these provided functions: 1) Map Browsing(pan, zoom in, zoom out, predefined views) 2) Layer selection, 3) Map queries (single queries or multiple queries). Every layer can be selected through a click on the map visualizing through a summary table all the information about the object (i.e. land cover) that belongs to each selected layer. At the same time the user can identify the land use of the area, the information about the selected region and NDVI value.
Knowing the NDVI value for each year of the chosen territory, users can compare values and evaluate changes in the vegetation health state qualitatively but also quantitatively. Query results can be downloaded and exported in 3 different formats: xls, pdf, shp (Fig. 2). Users can select an area on the map and download it straight into GeoTiff format usable in GIS software (Fig. 3).

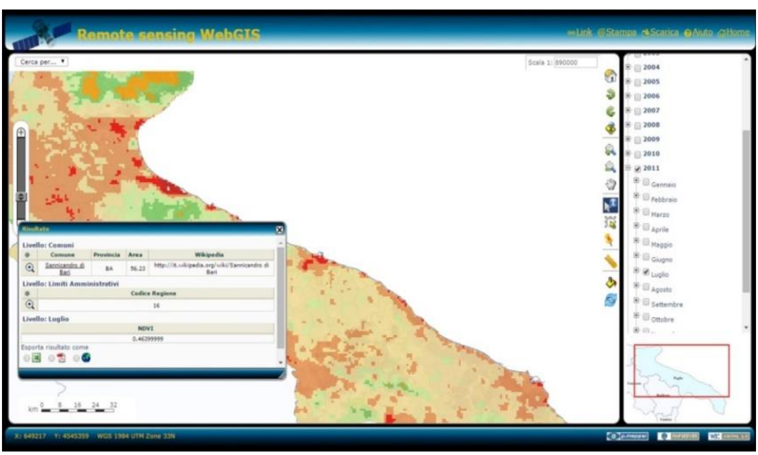

Figure 2 - Example of attribute table and download formats

Figure 3 - Example of GeoTiff download

Conclusions

The purpose of this paper was the development of a Web GIS prototype based on raster Remote sensing data. The interface is intentionally simple and interactive since aiming at a fast and easy tool to consult remote sensing data. In fact, finding these data is often more difficult than gathering other geospatial data: not everyone knows where to find them, websites providing them request a registration and the whole process can be very long-lasting. The web system developed under this study consists of various user-friendly open source GIS tools for spatial data visualization, analysis, querying and lastly production of maps in the form of map prints and shape format (Boulos and Honda, 2006). In addition to all the classic features of GIS such as zooming, pan, query, print and downloading, the Web GIS developed has the advantage of simultaneously querying raster data and displaying pixels quickly. Future developments are foreseen to implement tools for geo-processing raster and vector data on the web in order to have a complete instrument enabling users to fast analysis on the Web without the need for desktop software GIS.

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