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Mapping irrigated areas using multi-sensor remote sensing data in a Mediterranean environment

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ABSTRACT

Water managers need map of irrigated areas (defined as the identification of their location and their areal extent) to plan a rational use of water under limited availability and to prevent the unauthorized withdrawals. Many authors have shown that the Earth Observation techniques are an effective tool for mapping irrigated areas worldwide at different spatial scales (global/regional/and local). This study presents a methodology for mapping irrigated areas in semi-arid environment based on Earth Observation techniques and by fully exploiting datasets freely available processed by open source software and tools (i.e QGIS and its plugin). Data acquired with the Landsat 8 Operational Land Imager (OLI) and the new Sentinel 2A MultiSpectral Instrument (MSI) sensors were integrated to obtain cloud free dense time series allowing monitoring the vegetation development throughout the growing seasons. Irrigated areas were identified by analysing the growing patterns under water deficit conditions from NDVI values under the assumption that, in arid and semi-arid environment (like the Mediterranean Region), high trend of vegetation growth are compatible only with irrigation. The method was applied inside the Cixerrri and Basso Sulcis Irrigation and Land Reclamation Consortia perimeter, South Sardinia Italy.

Keywords: Irrigated Area, Remote Sensing, Landsat-8, Sentinel 2A, NDVI

INTRODUCTION

The assessment of irrigated areas is an essential information for the management of water resources, particularly in arid and semi-arid areas, where irrigation is the largest share of water consumption. Rational management of water resources for irrigation requires information characterized by high spatial and temporal variability, which cannot be monitored with traditional

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on-site inspections. Satellite observations of the Earth's surface in different regions of the electromagnetic spectrum have been used in recent decades for the monitoring of the Earth's surface. In particular, the potential of EO techniques for the management of land and water resources management has been widely recognized. (FAO, 1995; Schultz & Engman., 2000). The repeatability of the observations at regular time intervals, the availability of multispectral data with high spatial resolution, are particularly suitable for the mapping of the irrigated areas and for the monitoring of their evolution in time, with a satisfactory accuracy and in a convenient manner. Over the last years, the amount of available satellite sensors, the development of open source software applications dedicated to processing and analysis of satellite images, have enabled the realization of numerous operational applications for the support to the management of water resources, thanks to ITC's progress. Currently is possible to receive through Internet satellite images within hours of their capture, process and distribute products to end users in near real time. The use of remote sensing for the study of irrigated areas involves the development of methods and algorithms to derive information of interest in the study of specific processes and applications. This study presents a methodology for mapping irrigated areas in semi-arid environment based on Earth Observation techniques and by fully exploiting datasets freely available processed by open source software and tools (i.e QGIS and the Semi Automatic Classification plugin, which is a free open source plugin for QGIS that allows for the semi-automatic classification (also supervised classification) of remote sensing images. Also, it provides several tools for the pre processing of images, the post processing of classifications, and the raster calculation, Congedo Luca, 2016). Data acquired with the Landsat 8 Operational Land Imager (OLI) and the new Sentinel 2A MultiSpectral Instrument (MSI) sensors were integrated to obtain cloud free dense time series allowing monitoring the vegetation development throughout the growing seasons.

MATERIAL AND METHODS

Study Area

The case study area is the Cixerri catchment located in the south–western part of the Sardinia island, Italy (39°09′ North latitude, 8°29′ West longitude, city of Carbonia) (Figure 1). It is characterized by flat and ondulating topography, which extends from the coastline to inland rugged areas, with elevation ranging from 1 to 450 m a.s.l. The climate of the area is between semi-arid and dry sub-humid, with the typical bimodal pattern of precipitation distribution (i.e. peaks in autumn and spring). Average annual rainfall is about 550-600 mm and annual mean temperature reaches 16° C. The area is mainly covered by arable land over flat terrain, to a lesser extent vineyards, and fruit tree.

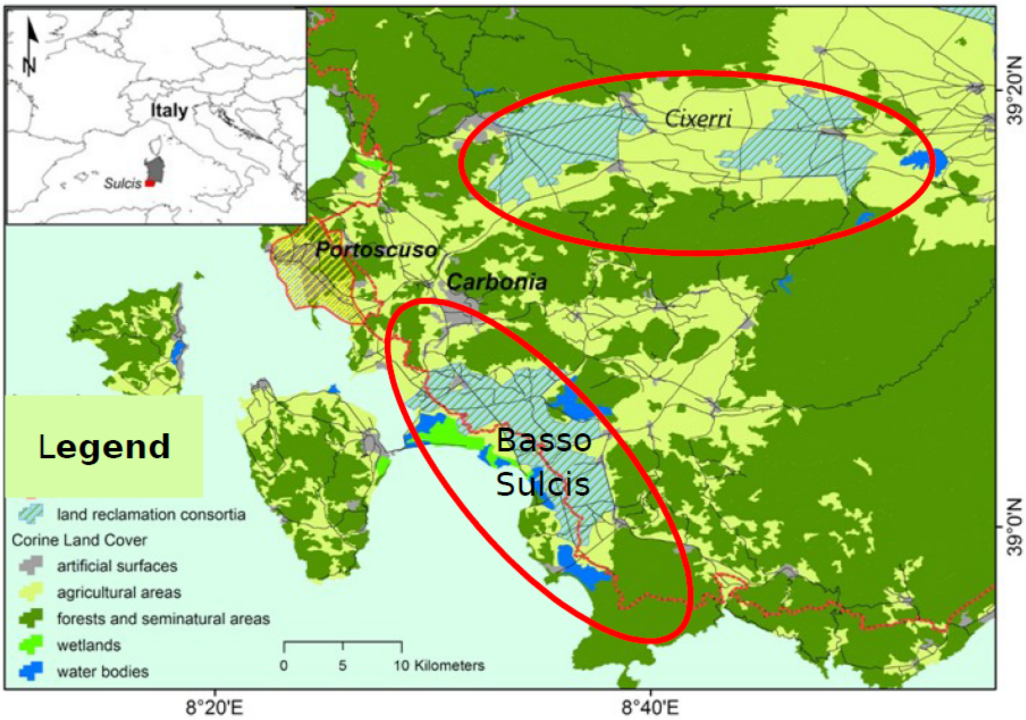

Figure 1. Study area location

Resources

The dataset includes Landsat-8 and S2A optical images (in the visible and near infrared ranges), agrometeorological data and ancillary data.

Satellite images

Earth Observation images used were collected from the sensor OLI (Operational Land Imager), on board the Landsat-8 Mission, and S2A. The data are available for download free of charge from the U.S. Geological Survey-USGS Earth Explorer data repository, and the ESA Sentinels Scientific Data Hub.

Agrometeorological data

Meteorological data were provided by ARPAS – Dip. Meteoclimatico of Autonomous Region of Sardinia (RAS - Iglesias station), and SCIA database (Sistema nazionale per la raccolta, l'elaborazione e la diffusione di dati Climatici di Interesse Ambientale – UTA station).

Ancillary data

To obtain based knowledge about the crop phenology in a given area, Corine Land Cover and a

Land use map provided by the Sardinia Region have been used.

METHODS

Data processing for deriving EO-based crop development maps

Agrometeorological data are used to compute the Water Climatic Balance (WCB = P – ETo), in order to identify the growing season where irrigation is necessary. The climate of the study area is classified as Mediterranean semi-arid, characterized by moderately cold and rainy winters and dry summer seasons. Annual precipitation is about 500 mm, concentrated in the fall and winter season, while annual ETo is around 1,400 mm, concentrated in spring/summer season (1,010 mm). The WCB is negative from April to September, which correspond to the irrigation period. (Fig. 2).

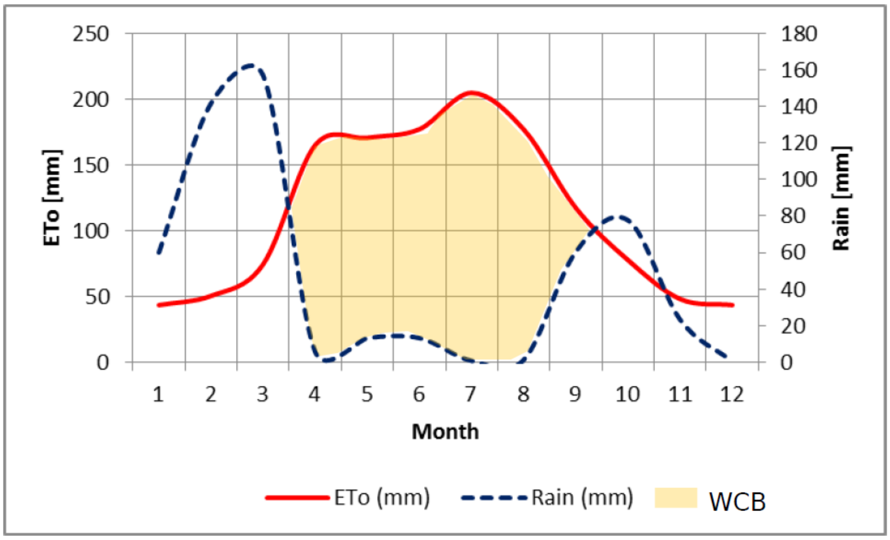

Figure 2. Climatic characteristics of the Study area (UTA station year 2015)

The detection of irrigated areas (defined as the identification of their location and their areal extent) requires land use/land cover maps, combined with agrometeorological data (Evapotranspiration - ETo - and precipitation - P) that allow distinguishing irrigated from non-irrigated crops, which is crop and weather dependent (De Michele C., 2014). This is accomplished by a “multi-temporal analysis” based on a time series of Vegetation Indices (like NDVI, the Normalized Differential Vegetation Index, Tucker, C. J., 1979) derived from of EO images, based on the assumption that in arid and semi-arid environment (like the Mediterranean Region), high trend of vegetation growth are compatible only with irrigation (Fig. 3).

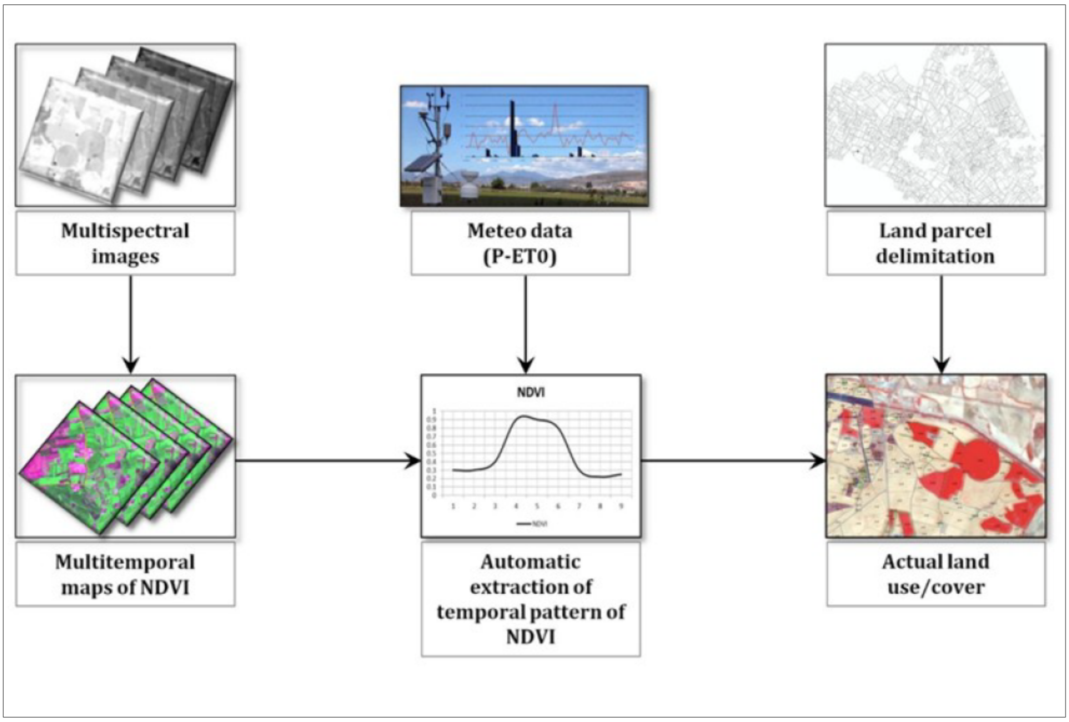

Figure 3. Flow chart of the adopted methodology

The temporal pattern recognition based on the differences from the canopy cover and development was pivotal to assign each pixel to a vegetation class. Overall, the following 8 classes were identified: 1) irrigated arable land; 2) non irrigated arable land; 3) orchards; 4) olive trees; 5) vineyards; 6) urban area; 7) woodland; 8) water. The procedure requires basic knowledge of crops and their phenology and implies further a subsequent validation by an experienced operator of the study area. Moreover, additional information like orthophotos and existing land use/cover databases are necessary for interpreting some irrigated crops such as fruit trees, vineyards or olive trees, which exhibited with low limited canopy growth, could require additional information like orthophotos and existing land use/cover databases. For this reason, recent orthophotos were used as geometric reference, while the infrared images and NDVI time series supported the thematic photo-interpretation and parcel delimitation. The following figure shows the different temporal pattern of NDVI for same classes identified.

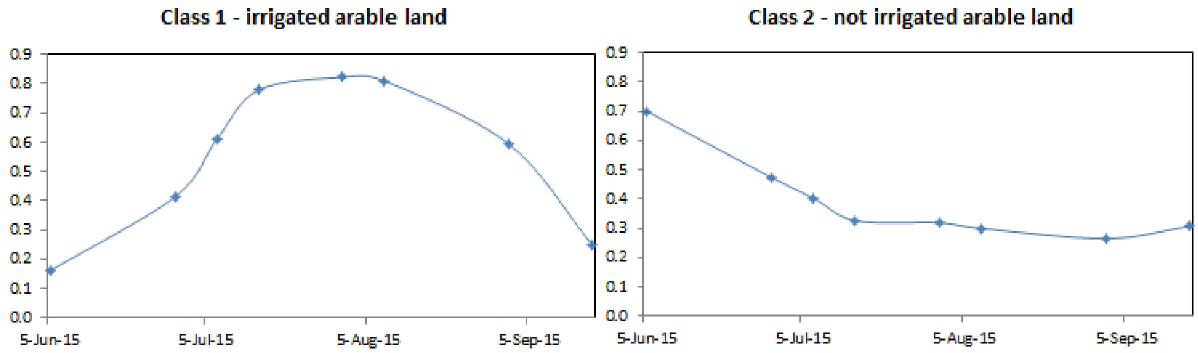

Figure 4. Temporal pattern of NDVI for class 1 and 2

In order to ensure the consistence of the time series a comparative analysis of spectral reflectance derived from both sensor has been carried out, considering two pseudo-invariant feature (full vegetation cover and bare soil), and the band of the two sensor share. Two images in narrow date have been analysed (L8: 31/07/2015 and S2A: 03/08/2015) and processed using the Semi Automatic Classification plug in available in QGIS, Figure 5).

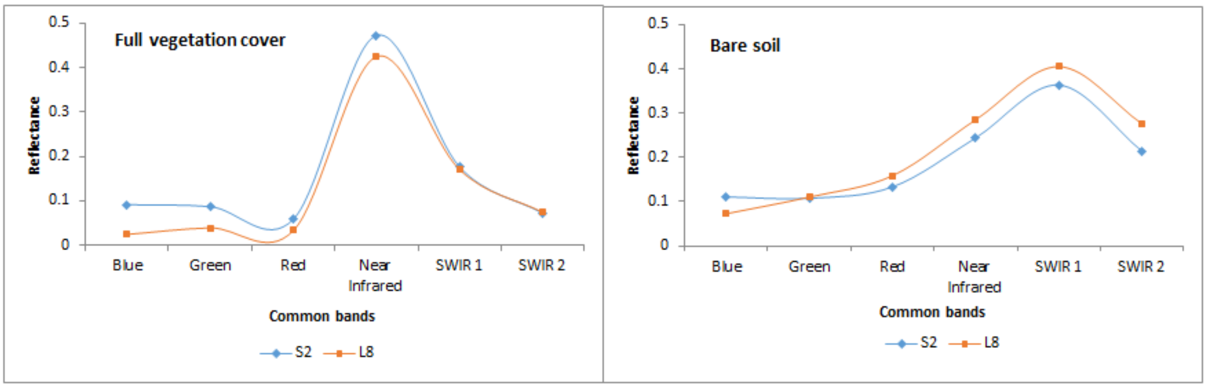

Figure 5. Comparison between spectral reflectance of L8 and S2 sensor

The result obtained has been compared with those coming from the Cixerrri and Basso Sulcis Irrigation and Land Reclamation Consortia, resulting in a good accuracy assessment of the irrigated maps produced.

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