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A geomatic application for water management in precision farming for a LIFE European project

Alessandro Lambertini, Gabriele Bitelli, Emanuele Mandanici, Luca Vittuari

Dept. of Civil, Chemical, Environmental and Materials Engineering (DICAM), University of Bologna
alessandro.lambertini, gabriele.bitelli, emanuele.mandanici, luca.vittuari)@unibo.it

Corresponding author: A. Lambertini
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1. Introduction

The activities and the approaches described in this work are carried out in the frame of the current European LIFE project AGROWETLANDS II (Principal Investigator: M. Speranza, University of Bologna). This multidisciplinary project aims at the integration of multi-source data, to provide a valuable support for a more efficient and sustainable management of territorial resources, through an innovative approach to precision farming.

The implementation of a smart irrigation management system is a central task of AGROWETLANDS II. A pilot system is operational in a study area located close to the Northern coast of the Adriatic Sea, in the Ravenna province (Italy). It is a farming area affected by soil and groundwater salinization, due to the ingression of sea water. The permanent monitoring network records several parameters for the weather, soil and groundwater. The expected results of the project include: a mitigation in the soil salinity, an improvement in the productivity of the crops, a reduction of the environmental impact and the implementation of a decision support system (DSS), which is able to advise farmers on the management of their agricultural activities (LIFE AGROWETLANDS II, 2019).

In fact, one of the main goals of the project is to reduce the water use for crop production and to ensure a sustainable water management for an efficient agricultural production. In order to achieve significant results in precision farming and water management, an accurate survey is needed to create precise numerical models which are the necessary base for each subsequent analysis.

2. Materials and methods

Several geomatic techniques were adopted at different scales of survey in the project area: satellite, aerial, UAV and terrestrial. As a first step, a single and continuous Digital Elevation Model (DEM) with 1 meter spatial-resolution was produced, covering the whole area of the project, integrating data obtained from airborne laser scanner survey (ALS LIDAR) and data obtained from bathymetric survey along the coastline.

Furthermore, in order to detect the elevation of piezometers in the study area with a greater accuracy, a levelling campaign was planned. The survey was carried out through the combined use of geodetic GNSS receivers, total stations, and levels, and provided the orthometric height of each piezometer, enabling accurate analyses for the water level. The DEM was used to perform an analysis of the salt contamination in the area, based on the creation of a three-dimensional stratigraphic model (Lamberti et al., 2018).

Multidisciplinary teams working for the project contributed to the acquisition of heterogeneous geographical data. Each dataset collected was imported in a comprehensive GIS. The resulting database is described in the following chapter.

In the perspective of a high frequency monitoring of the crop status for the entire project area, an analysis was carried out to identify the most suitable multispectral data acquisition solution. The availability of free satellite data with high temporal resolution was the optimal and cost-effective solution compared to an aerial overflight.

In order to achieve the desired result, the sensor and acquisition specifications of the multispectral satellites covering the project area were reviewed. The goal was to identify the time and period of acquisition of the images that are suitable for the computation of relevant vegetation indexes. In a preliminary analysis, both Copernicus Sentinel-2 and USGS Landsat 8 were considered as input for multispectral data processing. Sentinel-2 was preferred for the better spatio-temporal resolution (5 days combining both Sentinel-2A and Sentinel-2B acquired data).

A series of thermal surveys to further assess crop health is ongoing at the time of writing. Previous experiences confirmed the possibility to identify spatial variation in crop water stress from thermal remote sensing (Tilling et al., 2007). Moreover, in a comprehensive review was found out that visible and near-infrared wavelengths

were widely used for the computation of soil properties, while mid-infrared and thermal-infrared regions were less commonly used (Yufeng et al., 2011). Nevertheless, recent availability of higher spatial-resolution thermal surveys from low-altitude UAV platforms may provide further possibilities to better understand and prevent soil and vegetation problems (Figure 1).
In this project, data will be acquired and processed both from satellite and UAV platforms, with different spatial-resolutions and coverages. For the UAV surveys, a significant sample area of 5 hectares spread among different crops was identified.
Even for low-altitude UAV flights, the atmospheric effects are relevant for an accurate thermal survey (Berni et al., 2009). In most cases it is difficult to obtain an adequate model of the atmospheric conditions at the time of the flight. Therefore, in order to avoid excessive accuracy losses, an approximate estimation of the atmospheric parameters is performed with data acquired from ground surveys of temperature and emissivity parameters (Bitelli et al., 2015; Mandanici et al., 2016). This is possible thanks to the meteorological data acquired continuously from the sensors of the permanent monitoring network displaced over the study area, integrated with further surface temperature measurement acquired on field using special targets easily detectable on the UAV imagery.

Figure 1. The UAV platform and sensors used for the survey

The thermal sensor used from the UAV platform was carefully chosen given the technical specifications needed for this particular survey. The chosen sensor has the ability to capture and record calibrated temperature measurements for each pixel, with a resolution of 0.3 megapixel (640 rows and 512 columns in the raster output). The flight parameters in the planning of the UAV survey were computed given the field size, the focal length of the camera, the sensor size and the desired Ground Sample Distance (GSD) of 0.15 meters. Custom thermal targets to be used as Ground Control Point (GCP) were created using aluminum foils in order to make them visible from the UAV platform with sufficient temperature contrast and an appropriate size compared to the GSD (Figure 2).

Figure 2. Example of a thermal Ground Control Point (GCP)

The parameters for an automated UAV flight over the 5 hectares area were computed considering also the UAV flight autonomy with the survey payload configuration and the necessary overlap between subsequent flight lines. The placement of GCPs was particularly challenging due to the farming activities to be carried out in the fields. The limited number of stable natural or manmade surfaces offered only a few possibilities to identify permanent reference points, measured with RTK GNSS, to be used as a target in the UAV survey (Figure 3).

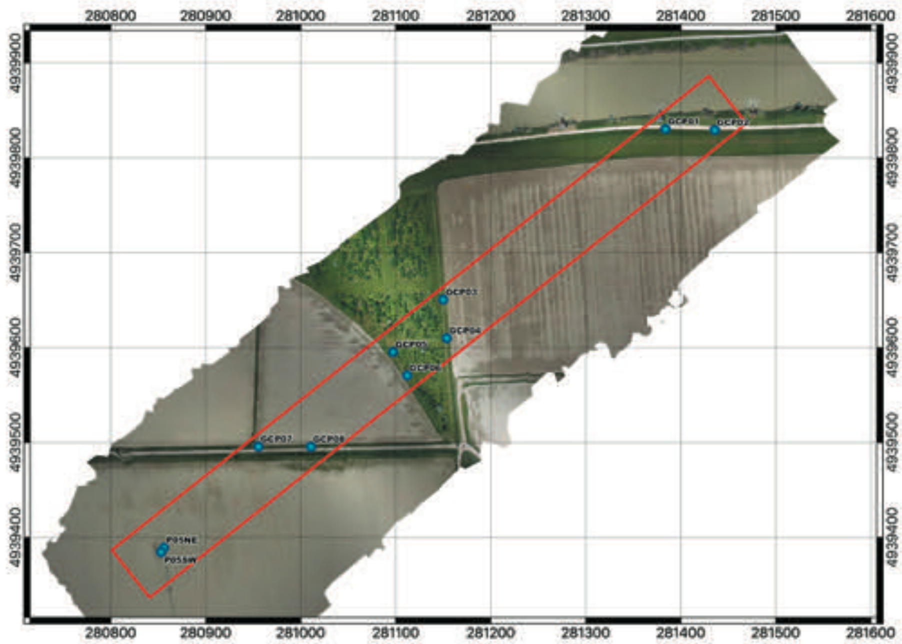

Figure 3. Ground Control Points (in blue) placed over the 5 hectares UAV survey area (in red)

The UAV flights are scheduled to match Landsat 8 overpasses. Landsat 8 satellite, indeed, can acquire thermal data over the entire study area with its TIRS (Thermal Infrared Sensor). Thanks to the availability of satellite orbit information, it was possible to predict well in advance each satellite acquisition during the whole agricultural season.

3. Results and discussion

In the context of the project, currently in progress, all the outputs of the geomatic procedures and techniques described in the previous section was integrated in a unique database. This database was designed to serve as a common platform to share and combine all the heterogeneous geographical data, acquired for each different discipline involved in the project, encompassing the analysis of soil, climate, water and environment. The aim is to gather information within a unified platform, usable for further analysis. The database structure is tuned to deliver data and metadata in compliance with the INSPIRE directive, using Free and Open-Source Software (FOSS). Each thematic layer containing geographic information is appropriately added in a GIS environment and converted into a unique coordinate reference system defined for the whole project (European Terrestrial Reference System 1989 in UTM zone 33N) (Figure 4).

At the time of writing, a complete series of at least 30 multispectral images were acquired from Copernicus Sentinel-2 during the main agricultural season in 2018 with less than 10% cloud cover. NDVI was processed from the images providing straightforward information about health and phase of each crop (Figure 5). The same procedure will be repeated for 2019 season.

The UAV thermal survey is planned for the entire 2019 agricultural season and is expected to provide the first results at the end of the summer. Among the interesting preliminary results, it is worthwhile to mention the complexity of the processing of accurate high-resolution thermal orthomosaics. In fact, it is a challenging task due to the low resolution of thermal sensors and their low dynamic range. Furthermore, some best practices were recently discussed for an automated generation of thermal orthomosaics with Structure from Motion techniques (Conte et al., 2018) and are going to be adapted for the present

Figure 4. Thematic map produced from the GIS database in the study area

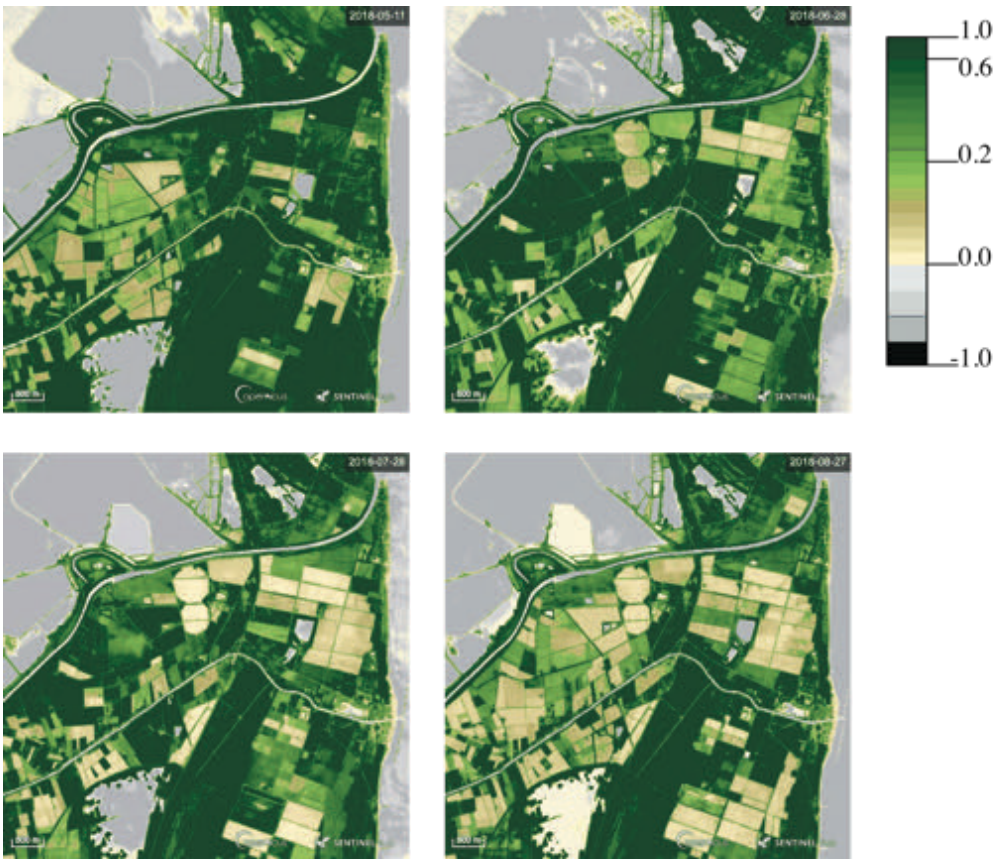

Figure 5. NDVI change over the studied area during 2018 crop season, in a series of maps sorted in chronological order from left to right and from top to bottom, acquired from Sentinel Hub, Sinergise Ltd

application. These and other practices are to be taken into account during the entire workflow of this project, starting from the survey to the processing of thermal datasets.

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