Exploring the Potential of Remote Sensing in Irrigation Management at District Scale. Study on Lis Valley, Portugal

Susana Ferreira[1](✉), Juan M. Sanchéz[2], and J. M. Gonçalves[1]

[1] IPC Instituto Politécnico de Coimbra, Escola Superior Agrária de Coimbra, Coimbra, Portugal
{susana.ferreira,jmmg}@esac.pt
[2] UCLM Universidade de Castilla-La Mancha, Inst. de Desarrollo Regional, Albacete, Spain
juanmanuel.sanchez@uclm.es

Abstract. Irrigation plays an important role in agriculture, with impact on land productivity and economic prosperity of farmers. Water management is complex but can benefit from remote sensing satellite images, which provide a monitoring of soil, crops and water, in harmony with the requirements of precision agriculture. The surface data from the combined constellation Sentinel-2A, 2B and Landsat 8 offer unique opportunities with this aim. The SpiderwebGIS tool, developed by the Instituto de Desarrollo Regional, from the University of Castilla La-Mancha (UCLM), allows a friendly management of satellite images, providing information to the community in a simple and accessible way. This communication explores the potential applications of remote sensing in irrigation management at district scale, aiming to improve water management in the plots, under the responsibility of farmers, and in collective distribution, by water users' associations. This study focuses on the Lis Valley Irrigation District. The methodology considers ground observations at a local scale of climate, soil and plant parameters, for the development and calibration of models based on satellite images. The ultimate objective is the operational use of temporal series of spatially distributed information to support agricultural management and optimize the use of water, energy and economic resources. This study is supported by Instituto Politécnico de Coimbra and UCLM and is integrated into the activities of the Lis Valley Water Management Operational Group.

Keywords: Remote sensing · Sentinel-2A and 2-B · Landsat 8 · Rational management of water · Lis Valley Irrigation District

1 Introduction

New risks to global water security are emerging due to global changes [1], urging water saving in irrigated agriculture and irrigation intensification to increase the food production for a growing population [2]. Collective irrigation schemes play a major role in irrigated agriculture around the world, impacting land productivity and peasants well-fare [3], and their governance is complex, pressed to improve the effectiveness of scheme

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systems, demanding knowledge, funds and the participation of farmers to adapt to each particular water saving context [4]. Irrigation management demands timely and frequent information on soil, crop and water, with a spatial resolution meeting the requirements of the precision agriculture (PA) paradigm [5, 6]. Remote sensing (RS) is largely used in the context of irrigated agriculture [7, 8], exploring the quantitative relations between remotely sensed spectral information and crop characteristics. RS used in irrigated agriculture is accepted by end-users and has become a valuable tool to support water management in irrigation schemes, complementing ground level and conventional monitoring [9]. As a first approach, this study analyses the RS tools to support irrigation management in Lis Valley, Portugal [10], This paper is a preliminary step of an ambitious research project aiming to survey and systematize the potential of RS in irrigation management at district scale.

2 Remote Sensing Tools and Techniques

Since the 1970s, satellite images have been extensively used in PA, namely to monitor the changes of physical and physiological traits and characteristics of crops over time. Sensors used for RS differ based on the spatial, spectral, radiometric and temporal resolution that they offer. In the past years, also aerial platform, including aircraft and unmanned aerial vehicles (UAVs) are being used to collect data about crop growth and provide this information at fine temporal and spatial resolutions [11].

The combined use of Sentinel 2 (VNIR, spatial resolution of 10-20m with a revisit time of 2–3 days) and Landsat 8 (spatial resolution of 30 m in the VNIR and 100 m for TIR, with a revisit time of 8–15 days) imagery, provides the suitable resolution to capture surface variability. Surface reflectance and radiance data are used for the calculation of the classic vegetation indices (VI), such as NDVI and SAVI, Vegetation development, crop water requirements, water consumption or field water productivity can be explored from biophysical models using these index data as inputs. In addition, land surface temperature (LST) can be an attractive variable in water stress scenarios. In addition to satellite images.

For the management of satellite image data sets, a webGIS platform (SpiderwebGIS©) developed by the Universidad de Castilla La-Mancha – Instituto de Desarrollo Regional (UCLM-IDR) was used (https://maps.spiderwebgis.org/webgis/). This platform makes the information available to the community in an easy and accessible way.

UCLM-IDR has also developed HidroMORE©. This is a software that applies FAO 56 methodology, assisted by RS images, for the determination of water availability on the plant surface. This is based on the retrieval of the basal crop coefficients (K_{cb}) through the dependence NDVI-K_{cb} [12]. This model has been applied in several studies [13, 14], including water accounting on the Water Users' Association (WUA) management scales [15, 16].

3 Lis Valley Case Study: The Challenges of RS Application

The study area is located in the Irrigation District of Vale do Lis (LVID), which is a public irrigation district, located in the Coastal Centre of Portugal (coordinates 39°51′22.1″ N

8°50′56.1″ W), belonging to the Administrative District of Leiria and managed by WUA. The total area is about 2000 ha, mainly with modern alluvial soils of high agricultural quality, although some have poor drainage conditions, and the main crops cultivated include maize, fodder, horticulture, orchards and rice [17].

RS can give a valuable contribution to monitor irrigation, due to the synoptic nature of the data and easily available image archives [18]. Due to its operationally and constant progress, RS operative applications are being offered to different water managements, as it introduces the advantages of monitoring large areas at plot spatial scale [15].

The issues related with water management in LVID that could be effectively supported by RS are presented below:

- **Mapping of irrigated areas** – The crop distribution on several fields is a determinant information for irrigation management at district scale. It allows to predict the irrigation scheduling and the water requirements per secondary or tertiary branches, during the irrigation season. Mapping crop distribution of irrigated areas is required to carry out an optimal planning of water allocation, particularly during the peak period, safeguarding spatial equity in distribution and its management in water scarcity periods. This mapping, if assessed retrospectively, also allows the analysis of crop cultivation and its economic and environmental effects [19].
- **Crop water requirements and water accounting** – The calculation of crop water requirements could be favored by satellite RS data, processed by informatic platforms. It complements the agrometeorological data observed on ground and provides a more detailed spatial information. Note that the great strength of the reflectance-based models from the point of view of crop irrigation management is the capability to estimate the potential crop transpiration, based on the temporal evolution of the RS-based K_{cb} and the actual ET_o values [9]. This information, integrated with the mapping of irrigated areas, and the evaluation of crop development through vegetation indexes (e.g., NDVI), allows to calculate the crop water consumption, and the water used at on-farm and off-farm levels [20].
- **Management of sector water distribution** – Further applications are the monitoring of the irrigation system, the water accounting at several levels, and the performance analysis of collective distribution, including the equity of water distribution to several fields within the same sector [15]. This information, regularly updated by satellite data, allows the optimal planning of water supply, with a more rational pumping and more efficient distribution during the scarcity periods.
- **Development of precision irrigation** – PA systems applicable to on-farm systems are highly dependent of crop and soil data gathered by in situ sensors. The RS data obtained at irrigation district level could support spatially-distributed crop information to farmers. RS allows monitoring crop development and evapotranspiration (ET) in order to support crop growth models [21] and irrigation advisory services [9], as well as analysis of crop uniformity within the field [22]. Therefore, it can help to create a knowledge base to make precision irrigation control systems more robust and efficient.
- **Management of the drainage riparian vegetation** – The management of riparian vegetation on the drainage system is very important in many irrigation districts, becoming a costly and complex process. This vegetation decreases the ditches flow capacity and obstructs gates and hydrants. The management operation represents an

added difficulty for workers, because it is often located in areas of difficult access. The RS monitoring of this vegetation is a very useful task, since it provides information on its development and density, which is required to adjust the management plans, namely, to program each operation, avoids previous actions by workers, saving efforts and resources and allowing prevention of occupational risks [23, 24].

As an example, to illustrate the use of the SpiderwebGIS tool, Fig. 1 shows the temporal evolution of the NDVI, for the period 2019–2020, in a selected point of a chosen experimental parcel. An NDVI subset from a Sentinel-2 image, corresponding to 9th September 2020, is also shown in Fig. 1. The field chosen is cultivated with maize, in spring/summer and with forage crops, in autumn/winter. This type of information will allow to determine indicators related with crop and water management, namely, the spacial crop development and irrigation uniformity, the relationship of NDVI with crop productivity and soil fertility, and the identification of subareas with specific problems, such as drainage, or crop protection.

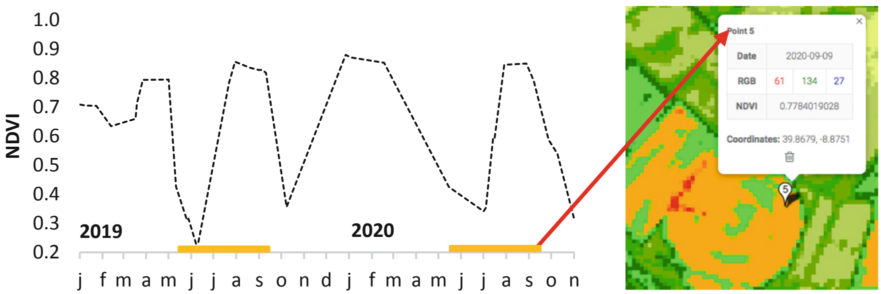

Fig. 1. Example of NDVI evolution of an Experimental Parcel, between 2019 and 2020, based on satellite remote sensing (note: orange bar represents the maize crop season). At right, details of the NDVI chart obtained with Sentinel-2, image of 9th September 2020 (source: SpiderwebGIS: https://spiderearth.appspot.com).

4 Final Considerations

The enrichment of RS applications over large and diverse irrigation surface areas offers both public and private water managers a complementary tool to obtain information. The combination of RS imagery and ancillary ground data (soil types, crop characteristics, meteorological), provides temporal and spatial information about the net irrigation requirements at on-farm level, and about the water distributed by conveyance system, as managed by WUA. The effective application of RS spatial information to support agricultural management and optimize the use of water, and linked resources, becomes a challenge, but the task will be embraced by this project, in collaboration with farmers and WUA.

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