Agricultural Water Management 147 (2015) 82–95

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Satellite-based irrigation advisory services: A common tool for different experiences from Europe to Australia

Francesco Vuolo[a], Guido D'Urso[b,c,*], Carlo De Michele[c], Biagio Bianchi[d], Michael Cutting[e]

[a] University of Natural Resources and Life Sciences (BOKU), P. Jordan Str.82, Vienna, Austria
[b] Department of Agriculture, University of Naples Federico II, Via Università 100 Portici (NA), Italy
[c] Ariespace s.r.l., Spin-off company of the University of Naples Federico II, Centro Direz. Is.A/3, Naples, Italy
[d] Dept. Agriculture and Environm. Sci., University of Bari Aldo Moro, Via Orabona 4, Bari, Italy
[e] South Australian Murray-Darling Basin Natural Resources Management Board, Strathalbyn, South Australia

ARTICLE INFO

Article history:
Available online 28 August 2014

Keywords:
Remote sensing
webGIS
Crop water requirements
Irrigation advisory services

ABSTRACT

Earth Observation techniques are widely recognised in supporting the management of land and water resources and they are nowadays being transferred to operative applications. In this paper, we present the current status of a satellite-based irrigation advisory system based on dedicated webGIS or farmers and district managers, in three different agricultural systems and environments: Southern Italy, Austria and Southern Australia. Maps of canopy development (leaf area index, albedo and soil cover) are derived from high-resolution (20 m) multispectral satellite images, delivered in near real time (24–36 h) and processed by using in-situ agro-meteorological data. The outputs of this procedure are: (i) a personalised irrigation advice, based on the calculation of crop evapotranspiration under standard conditions (according to FAO-56 definition and by using the direct approach) by taking into account the actual canopy development and crop variability at sub-plot scale; (ii) timely delivery of the information, consisting in maps and suggested irrigation volume applications, timely published on a dedicated webGIS-site with access restricted to growers and basin authorities in order to better control the irrigation process and consequently improve its overall efficiency. The key-points of this procedure are: (a) personalised irrigation advice; (b) timely delivery of the information. Final users have provided important feedback on the usage of the information provided; i.e. farmers are able to recognise without difficulties their parcels on the images and they schedule the irrigations by taking into account the information provided. The crop heterogeneity captured by the high resolution images is considered as a valuable add-on information to identify the variability of soil texture and fertility, plant nutrition, or different performance of irrigation systems. All the farmers have evaluated positively the usefulness of the information provided, and in most cases an increase of irrigation efficiency was achieved, because of the reduction of water volumes.

1. Introduction

Earth Observation (EO) data and geo-spatial tools are more and more frequently used to support various agricultural practices. The first feasibility studies, description of methodologies and prototypes for precise crop management date back to the early 1980s. A review can be found in Moran et al. (1997). In the study, the authors analysed different aspects of information requirements and identified various areas of application (e.g. soil mapping, yield estimation, crop evapotranspiration, phenology, etc.) to which satellite-based remote sensing could contribute. They also highlighted the technical limitations of sensing instruments and provided recommendations for the integration of these technologies in crop management practices. In recent years, continuous advancements in space technologies brought new observing capabilities in terms of spectral, spatial and temporal resolutions and most of the critical issues described in Moran et al. (1997) are now overcome. Recent changes in pricing policy also allowed a cost-effective use of high spatial resolution imagery (10–30-m pixel size). For instance, free-of-charge access to Landsat 8 data (by U.S. Geological Survey – USGS – & NASA) is now available within less than 24 h of acquisition. The availability of free and open access data for scientific and commercial use is expected to

* Corresponding author at: Department of Agriculture, University of Naples Federico II, Via Università 100, Portici (NA), Italy. Tel.: +39 3472310830..
E-mail addresses: durso@unina.it, guido.durso@unina.it (G. D'Urso).

http://dx.doi.org/10.1016/j.agwat.2014.08.004
0378-3774/

further improve with the launch (scheduled for 2014) of Sentinel 2 missions, developed by European Space Agency (ESA) within the Copernicus initiative (former Global Monitoring for Environment and Security – GMES – programme). This initiative has also stimulated the development of various operational services and technical capacities at European level (NEREUS, 2012).

Thanks to these progresses, the use of remotely sensed data has become more common and will be further integrated in agriculture services to support management, monitoring and controlling activities at different spatial scales including precision farming (Lee et al., 2010). For instance, maps of biophysical parameters of vegetation are used in yield prediction models at administrative level (Doraiswamy et al., 2005; Ma et al., 2011; Rembold et al., 2013). Other examples are implemented at country or regional level to derive crop water needs from satellite estimates of biophysical parameters assimilated in agro-meteorological models (D'Urso et al., 2010), to monitor the nitrogen status and to apply fertilizer with variable rates (e.g., FarmSat) or to derive agronomical variables (Casa et al., 2012; Jégo et al., 2012). On the other hand, surface energy balance methods based on satellite observations in the thermal region (Bastiaanssen et al., 1998; Allen et al., 2007; Kustas and Anderson, 2009) have been developed and applied in many areas with the aim of determining actual evapotranspiration. These methods have shown their potentiality in assessing the water balance of irrigated areas and the corresponding water accounting practices (Allen et al., 2005; Anderson et al., 2007; Karimi et al., 2013) but their use for irrigation advisory services is constrained by the limited spatial and temporal resolution of E.O.-based thermal observations and by the complexity of algorithms for near real-time operational procedures (Osann Jochum et al., 2005). Reviews of different procedures to determine crop evapotranspiration and water requirements from remote sensing can be found in Courault et al. (2005) and Verstraeten et al. (2008).

Diversely, a temporal resolution of about 7–10 days between satellite observations is usually considered adequate to monitor the various phases of the crop development throughout the growing season. This temporal resolution can nowadays be assured by using different platforms or constellation of platforms carrying visible (VIS) and near infrared (NIR) sensing cameras.

The objective of this study is to present an advanced and fully operational irrigation advisory service based on the utilisation of VIS–NIR satellite observations for crop water management at field and irrigation scheme levels; the service has been implemented in three different countries, by using a similar webGIS platform but different names:

- **IRRISAT** (www.irrisat.it), a regional operational service supported by rural development funds in Southern Italy.
- **EO4Water** (www.eo4water.com), a case study of knowledge and technology transfer in Lower Austria funded by the Austrian Space Application Programme.
- **IRRIEYE** in Southern-Australia (www.irrieye.com), co-funded by South Australian Murray-Darling Basin Natural Resources Management Board.

The first concept of satellite-based irrigation advisory services was designed in the context of the DEMETER UE-RTD project in 2005 (D'Urso and Calera Belmonte, 2005). It was successively improved and automatised to meet the requirements of individual farmers with personalised weekly irrigation advices at field scale and regional level by using SMS (Vuolo et al., 2005; De Michele et al., 2009). The development of advisory services based on webGIS platforms has been initially developed within the PLEIADeS UE-project (www.pleiades.es) and further tested in SIRIUS (www.sirius-gmes.es). More recently, a similar application has been developed in California by NASA, within the TOPS Satellite Irrigation Management Support project (ecocast.arc.nasa.gov/simsi/).

Generally, the service concept is based on two main components: (a) the processing of time-series of high spatial resolution (10–30-m pixel size) images from satellite, currently available from public and commercial data providers, to timely monitor the crop growth; (b) the estimation of the crop water requirement by taking into account the actual canopy development throughout the growing season; (c) the adaptation and integration in local management practices & tools of easy to use geo-spatial technologies to make the information available to users and to support the decision-making process.

In this paper we give a detailed description of methodological approaches and processing chain, with results from the three applications in Europe and Australia.

2. Users' requirements in satellite-based irrigation advisory services

Irrigation advisory services are addressed to three different user segments:

- Farmers, small and large scale agri-businesses.
- Water managers at irrigation scheme or catchment level.
- Authorities in charge of water management (such as river basin authority, government), National Irrigation Plan Monitoring Office.

Maps of crop water requirements, irrigated areas, crop vigour and other products of the satellite image processing, can be aggregated over different temporal scales (weekly, monthly, etc.) and land management units (field, farm, district, etc.) to meet the requirements of different users.

The technological *implementation* of satellite-based irrigation advisory services needs to find a compromise between the following elements:

i. availability of ancillary input data, with no or minimal contribution from end-users;
ii. elaboration and processing time, with minimum possible time lag between E.O. acquisition date and information delivery to final users;
iii. accuracy of algorithms for deriving crop water requirements, with minimum possible parameterisation.

For example, it is difficult to provide an irrigation advisory service based on a daily soil water balance, which needs as input soil hydraulic characteristics and actual irrigation scheduling. If soil maps may be found at different level of detail and accuracy, actual irrigation volume and dates are very seldom available, unless automatic metering devices are installed or a continuous direct input is demanded to farmers for each individual plot.

The second requirement for near-real time processing of E.O. data generally conflicts with the generation of crop maps, which can be elaborated with some confidence only at the end of the irrigation season.

On the basis of these considerations, the irrigation advice provided by IRRISAT/EO4WATER/IRRIEYE described in this work is meant to limit excess water application, in order to achieve a better utilisation of water resources and cost savings (irrigation fees, equipment runtime, energy required for pumping and fertilizer consumption). The irrigation advisory service is delivered weekly and it is only concerning the suggested amount in the considered period, as defined later in Section 3, and not the scheduling, which is left to farmer's decision.