IRRISAT: the Italian On-line Satellite Irrigation Advisory Service

Guido D'Urso* [1,2], Carlo De Michele[2], Salvatore Falanga Bolognesi[2]

[1] Dept. Agriculture, University of Naples Federico II, Portici (NA) Italy, durso@unina.it;
[2] ARIESPACE s.r.l., Spin off Company of University of Naples Federico II, Italy

ABSTRACT

IRRISAT is a satellite-based irrigation advisory service developed in Italy and operational since 2007 in the Campania region (Southern Italy). The service aims at providing farms and managers of water resources with real time information on agricultural water needs. Irrigation needs are estimated using high resolution data from Earth observation satellites and FAO methodology for the calculation of crop water requirements. Data are aggregated at various spatial scales (from field or irrigation unit to district or river basin scale) and temporal scales (real time, historical series). Information is distributed in near-real time to the users (farmers and/or water agencies) by using ICTs, namely: SMS, email, and private access web-mapping applications.

Keywords: Earth Observation, web-GIS, irrigation, water management.

1. INTRODUCTION

The rational management of water resources in agriculture is becoming more and more a crucial issue for the environmental and economic sustainability of the primary sector. During past decades, our understanding of physical processes influencing irrigation systems has made huge progress, together with new monitoring technologies. Information about the spatial and temporal variability of crop water requirements is the basis for implementing more efficient irrigation distribution criteria at both farm and district levels.
A paradigmatic example is represented by the management in the Italian Consortia of Land Reclamation and Irrigation (state-controlled associations of farmers), which are responsible for the distribution of water resources for agricultural use in an efficient and equitable way. In most cases, even in presence of metered distribution networks, the water allocation (and the application of corresponding fees) is done on the basis of the extension of irrigated area and not of water volumes. As a consequence, farmers are not motivated to adopt efficient water saving strategies, which results in generalised over-irrigation and misuses of water resources. The availability of reliable, objective and timely information about crop water requirements allows the implementations of efficient water distribution criteria based on the actual irrigation needs of crops.

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Satellite observations of the Earth surface in different regions of the electromagnetic spectrum have been used for about three decades to monitor land surface patterns. The repeatability of observations on a cyclic basis and the availability of high spatial resolution multispectral data – which are common characteristic to the Landsat and SPOT satellites - are particularly suitable for mapping crops and irrigated areas with satisfactory accuracy and in a cost-effective way.
During recent years, the amount of available sensors, with enhanced observation capabilities, has increased enormously the possibilities of acquisition. The spatial resolution is one order of magnitude better than the Landsat TM, at an even more decreasing cost per unit area.
On this baseline, many operative applications have been developed and tested for supporting irrigation water management, thanks also to the impressive progresses in the field of Information and Communication Technologies.

The purpose of the present work is to present an Irrigation Advisory Service based on near-real time distribution of EO products, already operative in the Campania region since 2007 to provide farmers and water user associations with real-time information on crop water requirements. In 2011, the operational irrigation advisory service of Campania Region has reached about 400 farmers in three different consortia. The service is implemented in the framework of the Rural Development Plan of the Campania Region, Measure 124 Healt Check (www.irrisat.it), as a further step for the implementation of E.U. Directive n.60/2000 in the agricultural sector.

2. METHODOLOGIES

The methodology for the estimation of crop water requirements adopted in IRRISAT is the so-called "one-step" approach of F.A.O.-Paper 56 (F.A.O., 1998). This method calculates the maximum evapotranspiration of ET_p of a canopy under stardard conditions i.e. unlimited soil water availability, pest and disease-free crop, by using appropriate values of canopy variables such as the surface albedo and the Leaf Area Index (LAI); in this case, we assume a fixed stomatal resistance of 100 sm-1, corresponding to the minimum values for most crops.
The determination of the required canopy parameters (albedo, LAI and crop height) is the main limitation in the direct calculation of ET_p in the F.A.O.-56 procedure (one-step approach). However, methods of different complexity – from empirical to physically-based - are available to estimate surface albedo and Leaf Area Index from satellite-based surface reflectance with satisfactory accuracy for the present application. Broad-band sensors in the visible and near-infrared, i.e. Landsat, SPOT, IRS, Terra-Aster, have been intensively used for deriving maps of canopy parameters. These methodologies have also been validated in a number of field experiments in the context of the mentioned E.U. funded project (D'Urso et al., 2006; 2010). Platforms with pointing capabilities and the usage of different satellites are means currently applied to achieve a revisit time of 7-10 days, in order to adequately follow the phonological development of

crops during the irrigation season (Fig.1). Since the concept of crop coefficients K_c is still widely used in irrigation practice and it represents an information which can be easily transferred to final users, we may derive an analytical expression of K_c based on FAO-56, applied twice, a first time with canopy standard parameters for ET_0 and successively with the actual values for ET_p (D'Urso and Menenti, 1995).
Maps of canopy development (Leaf Area Index, LAI, albedo, crop coefficient and soil cover) have been derived from high-resolution multispectral radiometric satellite images, delivered in near real time (less than 36 hours) and processed by using in-situ agro-meteorological variables. In IRRISAT we have acquired multispectral high resolution images (22 m) from the Spanish satellite DEIMOS. The output of this procedure is: i) the calculation of an "effective" crop coefficient, which takes into account the crop variability at sub-plot scale; ii) the assessment of crop water requirements for a temporal interval of 7-9 days around the satellite acquisition date.

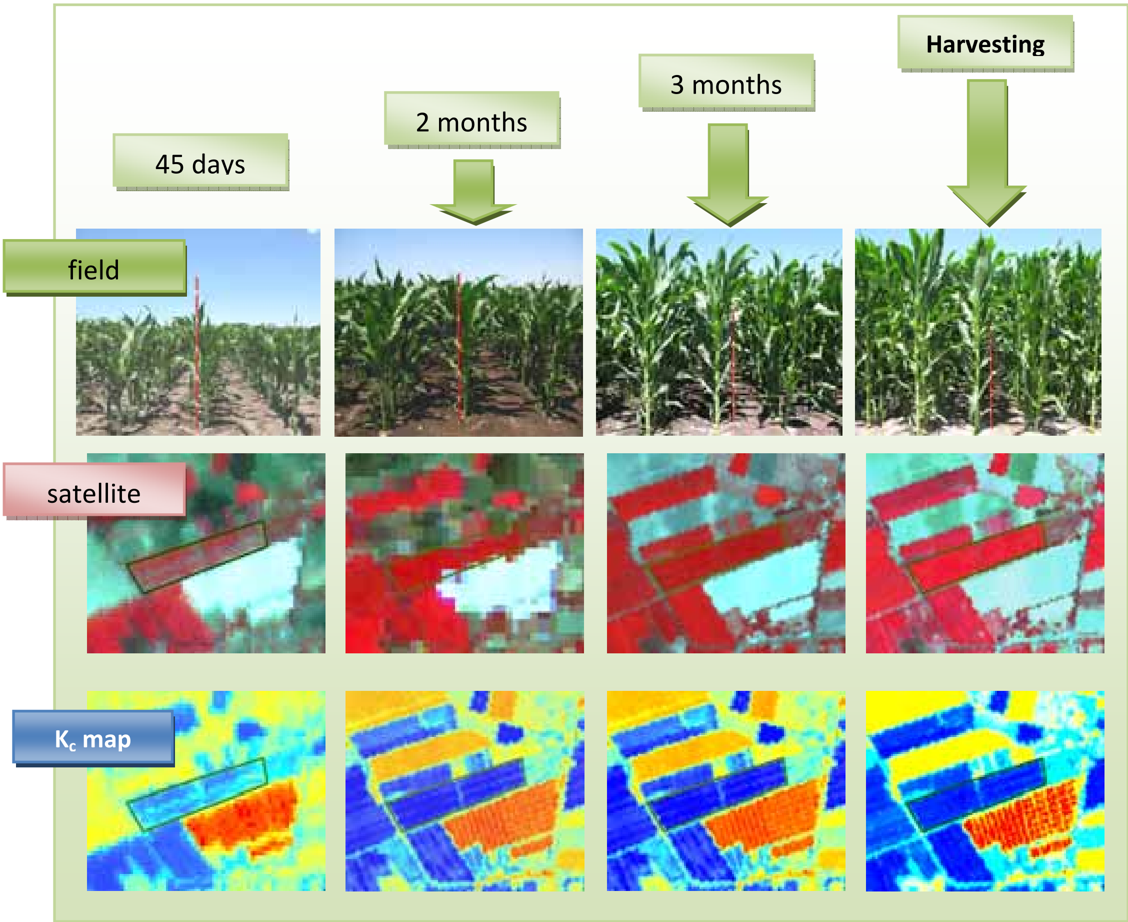

Figure 1: corn rows observed in field, from satellite and in a K_c map. Temporal evolution, from left to right: at 45 days from the sowing date, at 2 months, at 3 months and before harvesting.

C0010
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2. DELIVERY OF INFORMATION TO FINAL USERS

The maps and irrigation suggested volume applications are 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 window is organised in two FRAMES: MAP and DATA.
In the MAP frame (left, Fig.3) the user will find:

- Tools for browsing and quering maps;
- Boundaries of the irrigated plots.

In the DATA frame (right panel, Fig.3), instead:

- the plot details (crop, irrigation method)
- the temporal series of ETp, effective rainfall and crop water requirements.

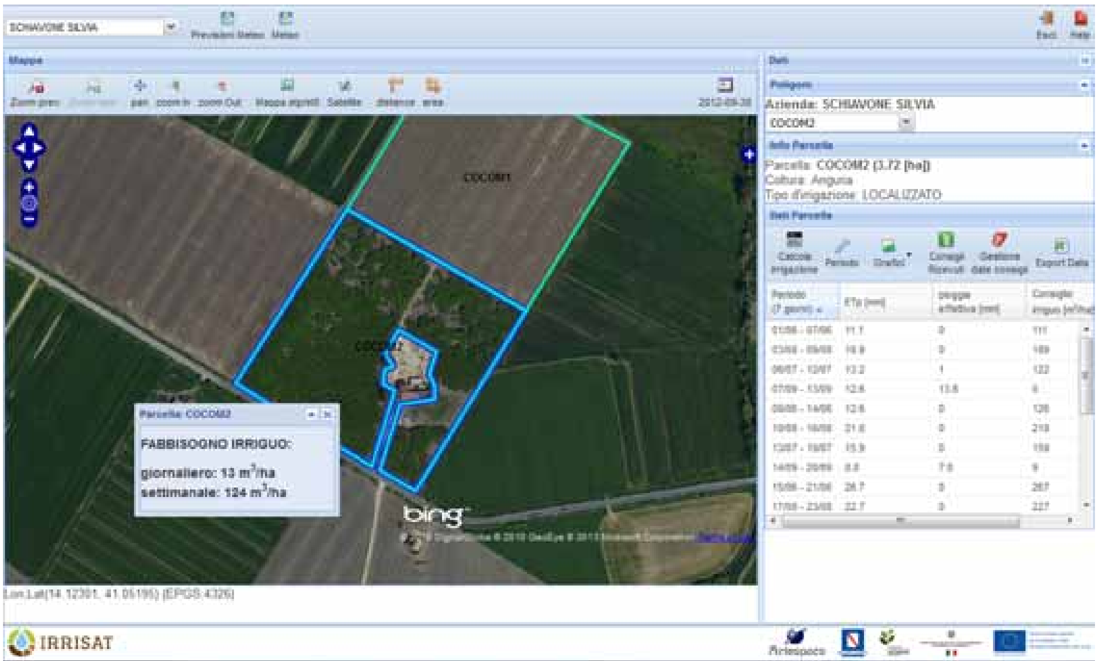

Figure 2: IRRISAT dedicated webGIS interface for the farmers.

The standard background is a Google or Bing satellite image, but the user can overlay the satellite image acquired on a given date by selecting “Satellite” from the tool bar in the map frame.
The image is displayed in false colours where the intensity of red is proportional to the crop vigor (Fig.3). In addition, the user can visualize the crop coefficient map (highest values with blue tonalities) for the same date, which can highlight the growth uniformity within the selected plot (Fig.4).

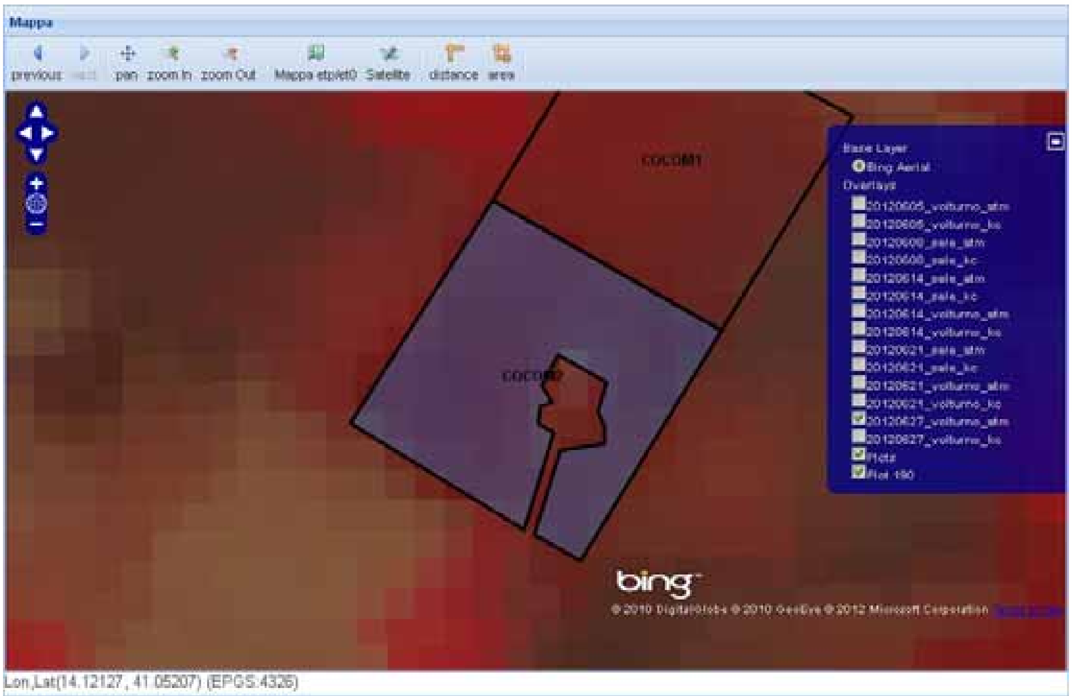

Figure 3: Satellite image overlay in false colors.

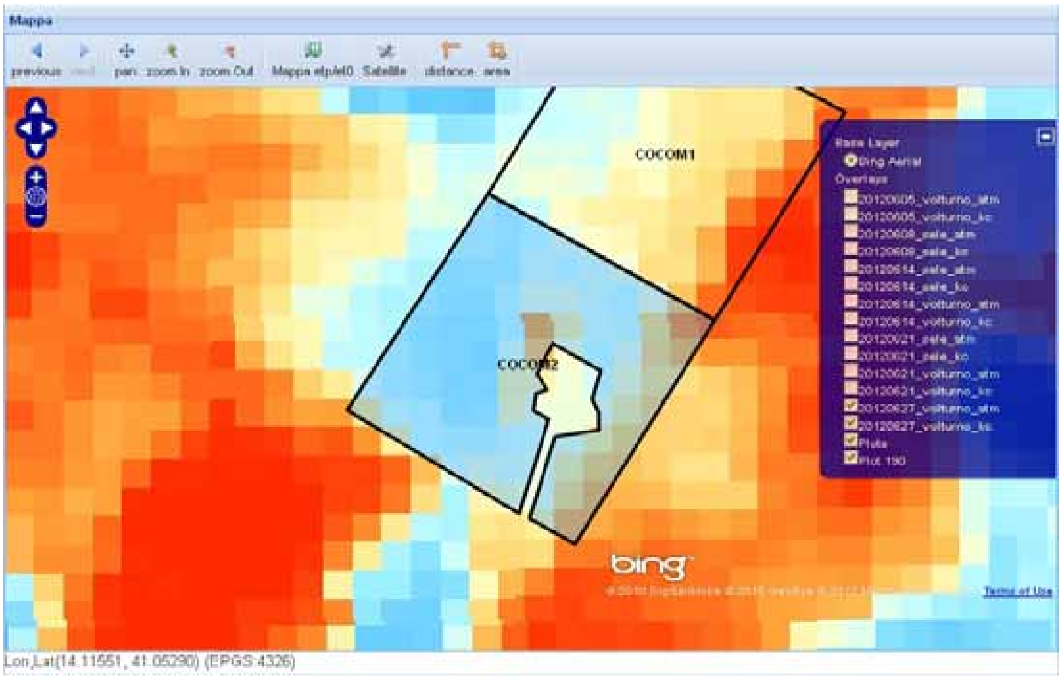

Figure 4: Crop coefficient map overlay (red tones: low values).

C0010
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Average values for each plot are calculated by the system and they can be displayed in graphical form from the Data panel of the user interface (right, Fig.2).

Figure 5: Graphs of the temporal evolution of average values of Crop coefficient, ETp, rainfall and crop water requirements for the selected plot.

The information in the data panel is also sent via SMS to the farmer; a summary sheet is sent by e-mail. However, more and more farmers appreciated the dedicated webGIS interface, due to its intuitive use and richness of information.
A similar interface has been developed for the Irrigation Consortia and Water User associations. The tool allows for evaluating crop water requirements aggregated at district level, for a more efficient management of the conveyance and distribution network. The GIS tools are going to be further expanded to link the financial management of the irrigation fees at farm level to the crop water requirements.

2.1 Validation

The validation procedure in IRRISAT is performed at two different levels:

a) accuracy estimation of canopy parameters based on field measurements;
b) comparison between suggested and actually applied irrigation volumes, at both farm and district level.

The first level of validation is performed in coincidence of the satellite acquisition in selected plot with different crops. A portable LAI digital meter (Licor LAI-2000) is used to estimate the value of LAI in the field; successively, this georeferenced measurement is compared with the value resulting in the LAI map derived by analyzing the satellite image; an example of this comparison in a corn field is given in Fig.6.

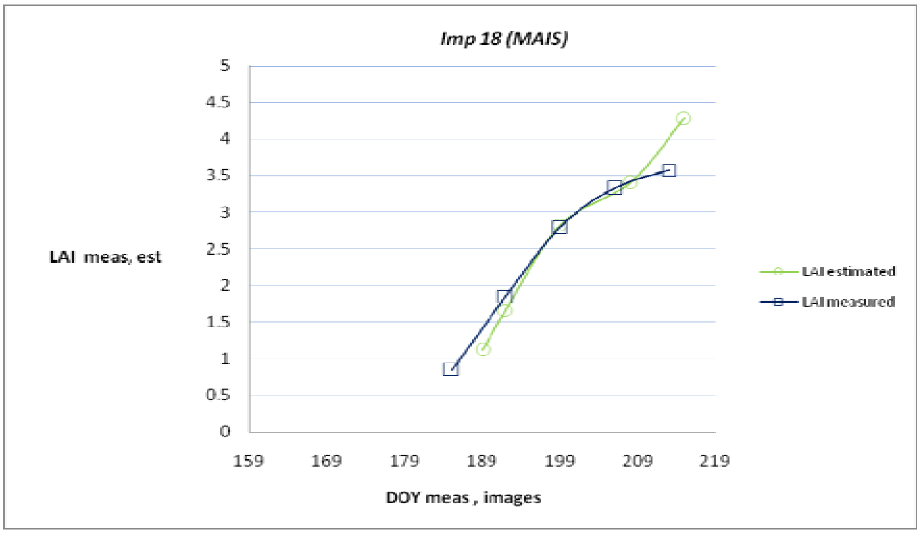

Fig.6. Validation of LAI estimated from satellite image analysis and from coincident field measurements.

The second level of validation is more difficult due to the scarce availability of irrigation applications at farm level. Where automatic registrations of water withdrawals from the distribution network are available, it is possible to evaluate the correspondence between the volumes indicated by IRRISAT and those applied by the farmers (Fig.7). The collection and elaboration of these data set for the irrigation season 2012 is still on the way.

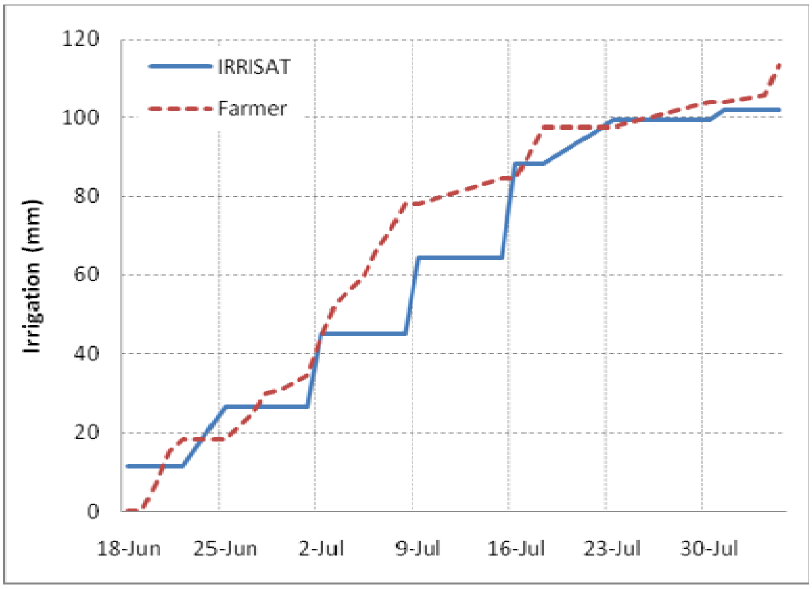

Figure 7. Cumulative irrigation depth suggested by IRRISAT and applied by a farmer in a corn field of 7.7 ha during 2012.

C0010
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3. CONCLUDING REMARKS

The satellite-based crop water requirement procedure adopted in IRRISAT implicitly takes into account the presence of variability of crop development at plot level, due to different soil conditions and agronomic practices. Consequently, IRRISAT gives a site-specific evaluation of irrigation volumes, with substantial advantages either on the rationale use of water and energy at basin and farm levels, either on the final quality of production. The intuitive web-interface gives the growers to monitor the canopy development at plot level in near-real time; in addition, an evaluation of net precipitation, thanks to a better calculation of canopy interception based from satellite LAI values, may reduce the irrigation application.

The cost of the proposed service IRRISAT to final users is strongly dependent on the extension of irrigated area within each satellite image, i.e. above 3000 ha the final cost is estimated around 10 €/ha for the entire irrigation season. Further expected reductions of market prices of satellite images will certainly make the IRRISAT service even more cost-effective in the near future.

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