Irrigation decision support system assisted by satellite. Alqueva irrigation scheme case study

Maia J., Boteta L., Fabião M., Santos M., Calera A., Campos I.

in

Erena M. (coord.), López-Francos A. (coord.), Montesinos S. (coord.), Berthoumieu J.-P. (coord.).
The use of remote sensing and geographic information systems for irrigation management in Southwest Europe

Zaragoza : CIHEAM / IMIDA / SUDOE Interreg IVB (EU-ERDF)
Options Méditerranéennes : Série B. Etudes et Recherches; n. 67

2012
pages 195-201

Irrigation Decision Support System assisted by satellite. Alqueva irrigation scheme case study

J. Maia*, L. Boteta*, M. Fabião*, M. Santos*, A. Calera and I. Campos****

*Irrigation Technology Centre – COTR, Quinta da Saúde, apartado 354, 7801-904 Beja (Portugal)
**Sección de Teledetección y SIG. Instituto de Desarrollo Regional, Universidad de Castilla-La Mancha
Campus Universitario s/n, 02071, Albacete (Spain)

Abstract. In irrigated farming systems is important to increase the processes for the rational use of water improvement, to achieve water maximum productivity, respecting the environment. For that, the Irrigation Advisory Services (IAS), included in the Irrigation Extension Services (IES) must be considered a regular instrument for the best irrigation management. To increase the IES efficiency, COTR proposed, firstly, with the development of the AQUASTAR–Alqueva project, and now within the TELERIEG project, to apply the irrigation scheduling methodology developed in the DEMETER project (Calera *et al*., 2005) to the Alqueva irrigation area (EFMA, Portugal), and based on that, develop the IES, based on Earth observation technologies and other information and communication technologies, which allows near real time to estimates the real crop water use at a large scale. In this work we intend to show the results and the operational side of the irrigation decision support system developed for the Alqueva irrigation scheme.

Keywords. Earth observation – Water management – NDVI.

Système d'aide à la décision d'irrigation assisté par satellite. Cas d'étude du périmètre irrigué d'Alqueva

Résumé. *Dans une exploitation avec un système d'irrigation, il est important d'augmenter les processus pour l'amélioration de l'utilisation rationnelle de l'eau, pour atteindre un maximum de productivité de l'eau, tout en respectant l'environnement. Pour ça, le service personnalisé de recommandation d'irrigation, contenu dans un service de recommandation agricole, doit être considéré comme un instrument régulier pour une meilleure gestion de l'irrigation. A fin de pouvoir améliorer le service de recommandation extensive d'irrigation, le Centre Opératif et de Technologie d'Irrigation (COTR) a proposé premièrement, avec le développement du projet AQUASTAR–Alqueva, et maintenant avec le projet TELERIEG, d'appliquer le calendrier d'irrigation développé par les méthodologies du projet DEMETER (Calera* et al.*, 2005) pour la zone de irrigation du Alqueva (EFMA, Portugal). Basé sur les technologies d'observation de la Terre et sur d'autres technologies de l'information et de la communication, le système permet d'obtenir en temps réel des estimations des besoins d'eau pour les cultures à grande échelle. Dans ce travail nous montrons les résultats et le fonctionnement du système d'aide à la décision pour l'irrigation dans le périmètre d'irrigation de Alqueva.*

Mots-clés. *Observation de la Terre – Gestion de l'eau – NDVI.*

I – Introduction

The irrigation farming is now a days full of challenges and pressures. If it is the main responsible for the food needs fulfil, it also the main responsible for the fresh water use. Based on that, the irrigated agriculture is under a tremendous pressure and in direct competition with other users.

In these conditions, to increase the irrigation farming protection, it is very important that the rational water use, requesting for it, the restricted volume of water need, in the right moment, must become a common reality. This way it is supposed to achieve the maximum water productivity, in economical and environmental terms.

To respond to these needs, the Irrigation Extension Services (IES) must use the Irrigation Advisory Services (IAS), based on technical tools, as a natural water management resource, that allow a more rational water use by the farmers, reducing the water use based on the real water needs, in a way to maximize the production and the cost benefit relation (Allen *et al.*, 1998).

These IAS must be structured based on the end users needs, as technical reports deliverables, sent in real time, or near real time, using as much as possible the information and communication technologies facilities. The crop water use models must use field data, like soils and crops information, fitted to the region.

This strategy has not been considered in the south of Portugal, which leads during the end of the last century to the lack of technical support to help farmers to use these concepts in their farms, using water as a valuable input.

The implementation of the Irrigation Technology Centre (COTR), with the target to transfer the knowledge and the technology to the farmers, gave the opportunity to reduce the lack of technical support in this field. This was possible with the establishment of the IES near the farmers, in their own professional associations, adapted to each local reality.

This IES use, as base resource, the information obtained from the IAS. The IAS follow the FAO (Allen *et. al.*, 1998) methodology, known as the K_c-ETo methodology, where K_c is crop coefficient and the ETo is the reference evapotranspiration.

To increase the efficiency of the IAS an ultimate effort has been made by COTR with the development of the AQUASTAR-Alqueva Project, whose results achieved were improved during the TELERIEG project with the use of Earth observation and communication technologies, to estimate, in near real time, the real crop water demands over large areas, with a spatial distribution, that allows to analyze the different crop behaviours or even in the same field the differences due to different grow conditions, for example, due to the lack of uniformity in water distribution. Consequently, this allows acting during the field campaign to reduce the negative impact in the crop.

All the work results in an adaptation, to the Alqueva irrigated area, of the methodology developed during the DEMETER project (Cuesta *et al.*, 2002).

II – Materials and methods

1. Location

All the work was developed in the Alentejo region, in the South of Portugal, in the Alqueva Irrigation Scheme (www.edia.pt) (Fig. 1) and in some others plots near the influence area, as a way of use as much as possible, the spatial distribution and differences from the region, which will allow, to validate the system at the farmer level, irrigation scheme level or at the river basin level.

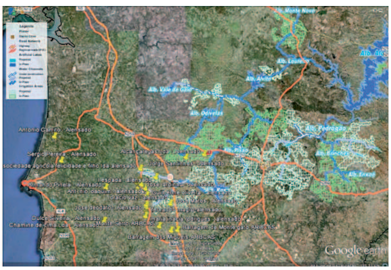

Fig. 1. 2011 farmers location.

2. Automatic weather stations network

The decision support system uses, as main information, the weather data obtained from the regional automatic weather stations network SAGRA (www.cotr.pt/sagra.asp), implemented for regional irrigation water demand decision. The SAGRA system is based in fourteen automatic weather stations (Fig. 2) with a single data base of different atmospheric parameters which allow the reference evapotranspiration determination following the FAO Penman-Monteith methodology (Allen *et al*., 1998).

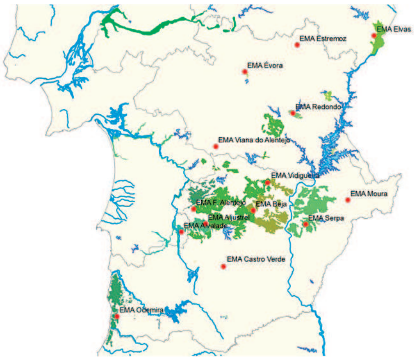

Fig. 2. Automatic Weather Station location.

3. Satellite imagery and processing

The pre-processing of remotely sensed image consists on geometric and radiometric characteristics analysis. By realizing these features, it is possible to correct image distortion and improve the image quality and readability. Radiometric analysis refers to mainly the atmosphere effect and its corresponding ground feature's reflection, while geometric analysis refers to the image geometry with respect to sensor system.

DEMETER's multi-temporal approach requires images of different dates. The use of a temporal images sequence is very demanding over a precise geometric correction because it needs overlay products from different dates and different sensors.

A. Geometric correction

Geometric correction of satellite images involves establishing a mathematical relationship between the image and ground coordinate systems. The rectification method used consist on second order polynomials that model the positional relationship between points on a satellite image and ground control points (GCP) obtained from a georeferenced image (source: EDIA and "Associação de Municipios do Alentejo"). The output images are resampled to the standard pixel size of products (30 m).

Also, as these polynomials only correct locally at GCPs, a high number of GCPs is required to adequately model the distortions in an image. For this reason, about 100 GCPs are used, which are accepted as a valid one if the root mean square error (RMSE) of the polynomial residuals is less than 0.5 pixels (i.e. 15 m).

The adjustment is made interactively using standard image processing software Erdas™.

B. *Reflectivity and NDVI determination*

The Normalized Difference Vegetation Index (NDVI) is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum (NDVI = (NIR-red)/(NIR+red)), and is adopted to analyze remote sensing measurements and assess whether the target under observation contains live green vegetation or not. NDVI has found a wide application in vegetative studies as it has been used to estimate crop yields, pasture performance, and rangeland carrying capacities among others. It is often directly related to other ground parameters such as percent of ground cover, plant photosynthetic activity, surface water, leaf area index and the amount of biomass. NDVI was first used by Rouse *et al*. (1973) and nowadays is the one most often used.

The determination of the NDVI is done with DEMETER (2002) Atmospheric Correction Module 1.0. This module has been designed for the atmospheric correction of the LANDSAT images. The algorithm works retrieving the atmospheric parameters from the multispectral data provided by LANDSAT in the six bands covering the solar spectrum, 1^{st}-5^{th} and 7^{th}, by means of a multiparameter inversion of the Top-of-Atmosphere (TOA) radiances of five reference pixels Once the atmospheric reflectance and transmission functions are calculated, the algorithm decouples the surface and atmospheric radiative effects and calculate de Bottom-of-Atmosfere (BOA) NDVI.

C. *KC-NDVI determination*

The similarity between the temporal evolution of NDVI and crop coefficient during the crop growth cycle has been repeatedly observed. The crop coefficients obtained from the spectral response of vegetation cover represent a real crop coefficient obtained in real time. It doesn't require the planting date for calculation procedure and but it detect the beginning and end of the different stages that express the evolution of Kc.

Experiences in this direction were carried out in Spain, Italy and Portugal in the DEMETER project (Calera *et al*., 2003) and Aquastar-ALQUEVA (COTR).

For Landsat sensors, the following expression is used:

$$Kc\text{-}NDVI = 1.15\ NDVI(BOA) + 0.17 \qquad \text{(Equation 1)}$$

Kc-NDVI: crop coefficients obtained from the spectral response of vegetation cover;

NDVI(BOA): Normalized Difference Vegetation Index at the Bottom-of-Atmosphere.

D. *Web service information system*

All the information obtained is available on SPIDER platform, developed by the PLEIADES project (www.pleiades.es). This information is the result of the methodology described previously and includes not only the charts, but also the tabular results obtained through the Earth observation platforms, using the algorithms that allow the crop coefficients determination.

III – Results

1. Web service platform

The web service platform (Fig. 3) allows the end user to access, in a personalized session, to all the information from his influence area, with the information of the crop water needs (Fig. 4). The system DB allows the access to files from previous years or different crops, and also allows the access to different information sources, like other spatial data. Such flexibility turns it into a powerful service to the end user with much more information access.

Fig. 3. Web service access.

After the upload of the information required, it becomes to be possible the access, by the user, to the evolution of Kc, NDVI and ETc, and with base on that make the best irrigation scheduling.

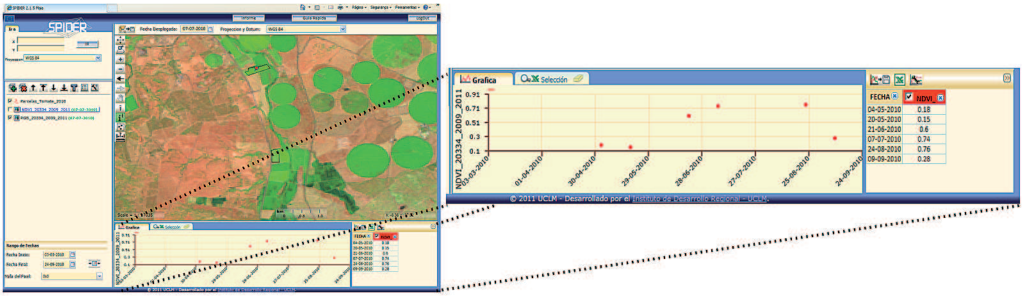

Fig. 4. Tomato water needs evolution.

On Fig. 4, it's possible to see the picture with the green areas that reflect the green vegetation, actively growing, mainly, center-pivots with maize and smaller plots with tomato. Below the picture, it is possible to identify the NDVI evolution of the selected plot of tomato that by equation 1 application, gives the Kc evolution.

With the information obtained, and based on the evapotranspiration determined by the SAGRA network, produces at the time, the real crop water need.

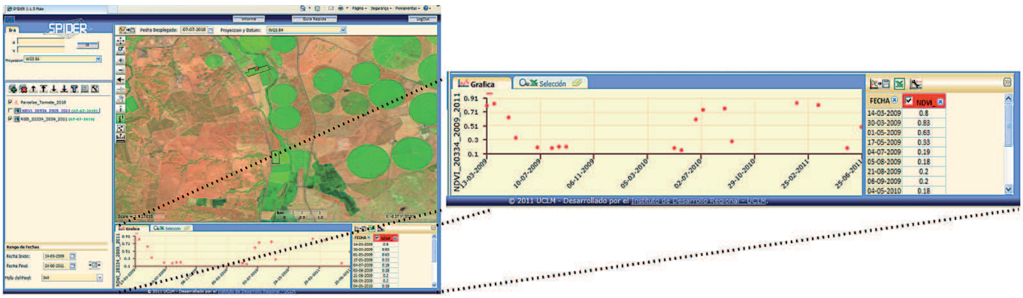

Fig. 5. Water needs evolution over large period of time.

As shown on Fig. 5, the system has the potential to store data from several years, in this case between 2009 and 2011, and also over large areas. Such potential will allow a quick analysis over a large area, as a river basin, for a long period of time, important for water needs planning.

2. e-IAS development

The IES development is a high consumer of human resources, which makes it an expensive activity, because of the intensive field data uptake and analysis, and the timely information deliver to the user.

To increase the efficiency of such services, based on the referred tools to uptake and analyse the data and deliver the information, it was developed the IAS based on the Earth observation techniques and information and communication technologies (e-IAS), that in real or near real time allows the uptake, process and deliver the results to the end user.

The information delivery process usually includes the web service, but nowadays it is possible to supply through the last generation of cellular phones all the information to the user, even if it is pictures, maps or graphic analysis (Fig. 6).

Fig. 6. Information access through last cellular phones generation.

IV – Conclusions and remarks

The Earth observation technologies are a very important jump on the level of information that is possible to collect and deliver to the farmer as an information end user. With it is possible to get step ahead on the irrigation scheduling and the rational water use, as it is possible to correct immediately any decision on the water use, for example, the lack of uniformity in water distribution due to clogging of the sprayers.

The decision support system based on the e-IAS, allow the irrigation manager to access real information about his crops water demands, in a particular period. It is usually referred that the farmers are not a frequent web services users, mainly, in the south of Portugal, but they are a very frequent use of mobile communications. In that sense, the e-IAS allows the cellular phone as way to deliver the information, and allows a quick decision.

The main challenge of the e-IAS is to give the step ahead of include all the irrigation farms of a specific region and, based on that, decide the water distribution from a water source in a particular year or situation.

Acknowledgments

This work was supported by the project "Telerieg" from the Interreg IV B Sudoe Programme (project no. SOE1/P2/E082). The authors are particularly grateful to the Alensado tomato growers association (www.alensado.pt) for its help and collaboration during the data collection.

References

Allen R.G., Pereira L.S., Raes D. and Smith M., 1998. Crop evapotranspiration. Guidelines for computing crop water requeriments. *FAO Irrigation and Drainage* 56. FAO, Rome 300 pp.

Calera A., 2003. Space-assisted irrigation management: Towards user-friendly products. In: *Use of remote sensing of crop evapotranspiration for large regions*, R.G. Allen and W.G. Bastiaansen, (eds). Montpellier, France: ICID-CIID.

Calera A. and Martín de Santa Olalla F., 2005. Uso de la Teledetección em el Seguimiento de los Cultivos de Regadío. In: *Agua y Agronomía*, Cap. XIV, Santa Olalla, López and Calera (eds). Madrid: Ed. Mundiprensa.

Cuesta A., Montoro A., Jochum A.M., López P. and Calera A., 2002. Metodología operativa para la obtención del coeficiente de cultivo desde imágenes de satélite. In: *ITEA,* 101 (2), p. 91-100.

DEMETER, 2002. Demonstration of Earth observation Technologies in Routine irrigation advisory services. VI Framework Program, European Commission. www.demeter-ec.net

Moreno-Rivera J.M., Osann A. and Calera A., 2009. SPIDER - An Open GIS application use case. In: First Open Source GIS UK Conference, Nottingham.

Rouse J.W., Hass R.H., Schell J.A. and Deering D.W., 1973. Monitoring Vegetation Systems in the Great Plains with ETRS. In: Proceedings of the third ERTS Symposium, p. 309-317.