ASSESSING CROP WATER REQUIREMENT METHODS USING REMOTELY SENSED DATA FOR ANNUAL PLANNING OF WATER ALLOCATION IN IRRIGATED AGRICULTURE

EVALUATION DES BESOINS EN EAU AGRICOLE PAR LES DONNEES DE TELEDETECTION POUR PLANIFICATION ANNUELLE DE L'ALLOCATION D'EAU DE L'AGRICULTURE IRRIGUEE

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ABSTRACT

Potential use of remote sensing in water resource and in particular in irrigation management has been widely acknowledged. However, in reality, operational applications of remote sensing in irrigation management are few. In this study, the applicability of the main available remote sensing based techniques used in the assessment of Crop Water Requirement is evaluated and used in planning for annual water allocation in irrigated agriculture.

Key words: *Water allocation planning, Crop coefficient, DEMETER, SEBS, SPI drought index, Irrigation management.*

RESUME

L'utilisation potentielle de la télédétection dans les ressources en eau et en particulier dans la gestion de l'irrigation a été largement reconnue. Cependant, en réalité, les applications opérationnelles de la télédétection dans la gestion de l'irrigation sont rares. Dans cette étude, l'applicabilité de la principale disposition de la télédétection des techniques basées utilisées dans l'évaluation des besoins en eau des cultures est évaluée et utilisée dans la planification pour l'allocation annuelle d'eau dans l'agriculture irriguée.

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Mots clés: *Planification de l'allocation d'eau, coefficient cultural, DEMETER, SEBS, index de sécheresse SPI, gestion d'irrigation.*

1. INTRODUCTION

The continuing growth of world population places hard pressure on water resources every day, especially in the dry and semi-arid regions. Improved management and planning of water resources are needed to ensure proper use and distribution of water among competing users. Fortunately, there are opportunities for conservation and significantly more effective use of water use by the world's largest user "agriculture". Accurate planning and delivery of the necessary amount of water in time and space can conserve water (Bos et al., 2009). In this context, methods to quantify accurate irrigation water requirement play a key role in the conservation and management of water resources. Planning and management of water use by agriculture are especially important in an arid and a semi-arid climate. Understanding the Crop Water Requirement "CWR", use and consumption in irrigated agriculture is a prerequisite for better management and conservation of agricultural water.

Iran is located in arid region and lack of proper planning and management on water resources has caused the country to face water crises. Agriculture is the main user, which consumes water through evapotranspiration (ET). In 1996 the Iranian government developed the Iranian Water Directive "IWD" which is supposed to guide water allocation in all the basins (632 Plains) in the Iranian territory. In this document the CRW calculation is based on the average meteorological data and some standard FAO parameters (Alizadeh and Kamali, 2007). Unfortunately, the CWR as presented in the IWD Document could not be implemented due to its low accuracy, reliability and other shortcomings (Aghdasi, et al 2010).

Considering the large area of the country, in practice (on farm) correction and improving accuracy of IWD is difficult and expensive. Remote sensing technology is a promising tool to overcome these problems. However, timely access to high resolution images in this country is difficult and expensive. In this context this paper summarises the finding of a research which was carried out to find a reliable and practical method to determine crop water requirement based on remote sensing techniques for water allocation planning. This paper starts with brief introduction to the pilot area, followed by material and methods, results of the experimentation and finally some concluding remarks.

2. STUDY AREA

The study area is the Ghazvin basin in Iran (Fig. 1), which is an irrigation network of 60,000 ha composed of 170 gate-units "Water User Associations" (WUA). The network is making use of a reservoir and over 3000 tube wells.

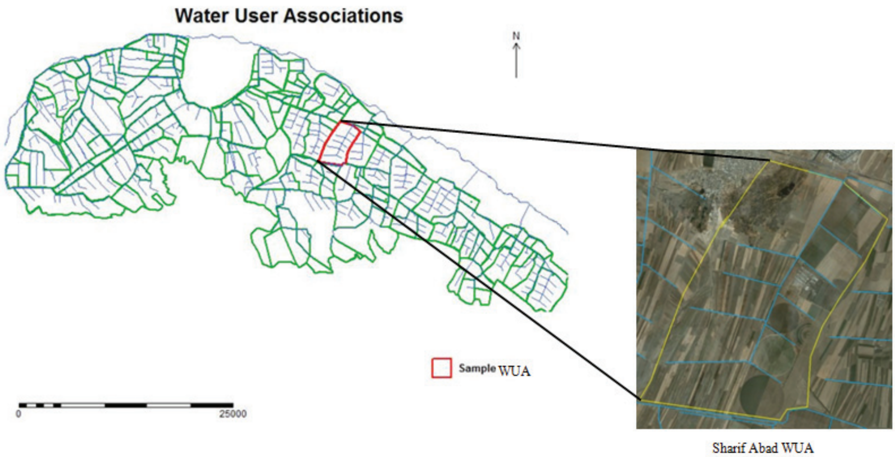

Fig. 1. An overall view of the network and the selected Water User Association “pilot area”

The major issue in the area is the water shortage and excessive groundwater extraction, leading to a lowering of the groundwater table at a rate of around 1 meter per year. The current water allocation planning is subject to a number of difficulties, e.g., outdated method of calculating CWR, not taking into account the specific local conditions (soil and water quality, canal network efficiency, cropping pattern) and variations in time (average of 30 years reference evapotranspiration “ET0”). As a result, the allocated water from reservoir and allowable volume of water extraction from the tube-wells are not observed, furthermore in such water scarce environment, over irrigation is frequently observed.

3. MARTIALS AND METHODS

This research aims at developing a method to estimate accurately the CWR of various crops in Ghazvin basin, suitable for annual water allocation planning. To achieve this, it intends to make use of the state of the arts technology in the application of remote sensing for assessment of CWR. Figure 2 presents overall structure of the methodology.

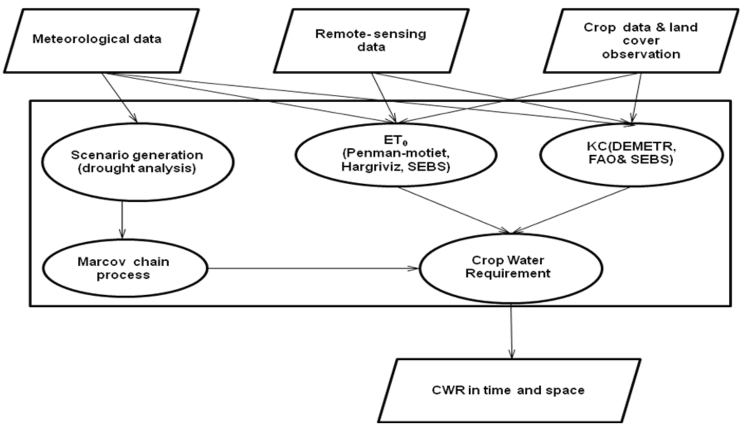

Fig. 2 Overall structure of the methodology

A total of 40 years of historical weather data were classified into wet, normal, and dry years using a Standardised Precipitation Index (SPI). For each of these three classes the average CWR was calculated. Next, by applying Markov Chain Process to the time series of precipitation, the expected CWR for the forthcoming planning year was estimated. Using proper interpolation techniques the expected CWR at each station was converted to CWR map of the area, which was then used for annual water allocation planning.

3.1 Crop Water Requirements

To estimate the CWR Four methods of estimating crop coefficients were used: DEMETER Kc-NDVI, “DEMonstration of Earth observation Technologies in Routine irrigation advisory services” (D’Urso et al., 2007),DEMETER Kc analytical, FAO-56 and Surface Energy Balance System “SEBS” algorithm (Su, 2002). These were produced considering the procedure presented in Fig. 3. Results were compared with lysimeter experiments. In this process use was made of both ASTER and MODIS images to determine crop water requirement at local and regional scales. For planning, considering the current status of climate (2003), using Markov Chain Process, the expected climatic status of the forthcoming year (2004) was derived. This information together with the maps of ET0 and Kc of various crop was used to derive the CWR of each Water User Association for the forthcoming year. Quality assessment of the whole process was carried out by comparisons of the estimated CWR through planning process with the actual CWR (estimated through actual data) as well as other existing sources (Aghdasi 2010).

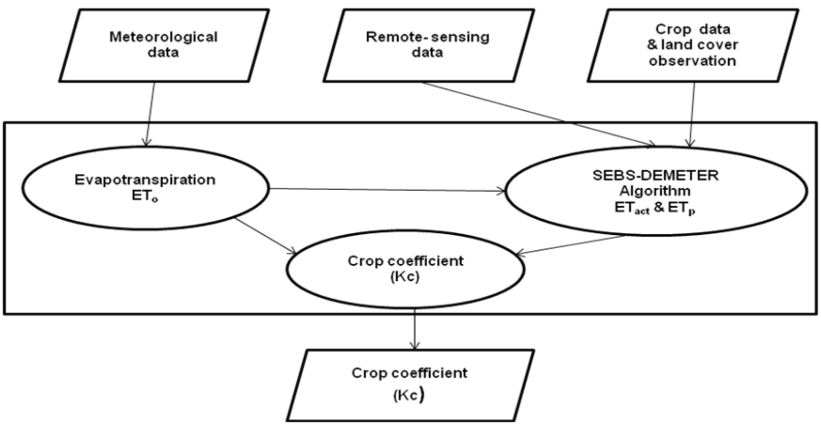

Fig. 3 Stages of Crop coefficient estimation

Furthermore a “regional crop coefficient” which is an average crop coefficient of the pilot area based on remote sensing techniques was estimated based on DEMETER method and SEBS algorithm using MODIS and ASTER images. Average Kc of a mixture of crops in the pilot area “Sharif-Abad” was defined here as regional crop coefficient. The derived regional Kc using MODIS and ASTER images were then compared (Fig. 4). This approach deserves more attention because indications are growing that tabulated Kc values give biased crop potential evapotranspiration estimates for large areas, such as heterogeneous areas (Bastiaanssen, 1998). Michael and Bastiaanssen (2000) investigated calculation of regional scale Kc from remote sensing data based on the Priestly and Taylor equation for ETc.

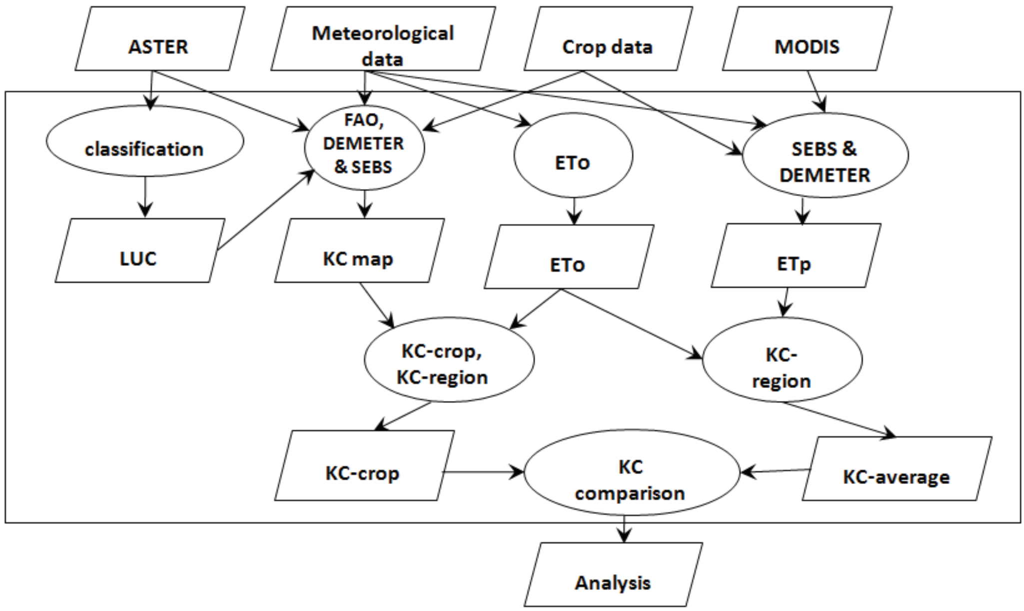

Figure 4. Crop coefficient analysis process

The Potential Evapotranspiration "ET_p" which is the evapotranspiration if enough water is available to meet the sum of evaporation and transpiration. There are several methods for estimation of ET_p, including ground based and remote sensing based methods. In this research the SEBS algorithm as remote sensing based group and FAO-56 Penman-Montieth method as ground based group were used.

The sensitivity of ET_0 with respect to various crop and climatic variables such crop height, Leaf Area Index, Relative Humidity, temperature, incoming short wave radiation, and wind speed was determined. This was carried out by keeping all variables constant and allowing one to gradually change. In this way the effect of one variable on the values of K_c was studied.

3.2 Annual Water Allocation Planning

Currently, in the actual operation, every year at the beginning of the season the crop water requirement of the irrigation network is estimated and sent to the water supply agency (Regional Water and Energy authorities, within the Iranian Ministry of Energy). This estimate is based on a standard table which provides a fixed monthly crop water requirement for the whole basin and in any type of year.

In this study an attempt is made to improve the situation through improved method of estimation of crop water requirement (localized crop coefficient) and considering probability of having different scenarios (wet, normal and dry year). A Markov Chain Process is used for estimating the expected ET_0 at each forthcoming year. Figure 5 shows the process of annual crop water requirement planning.

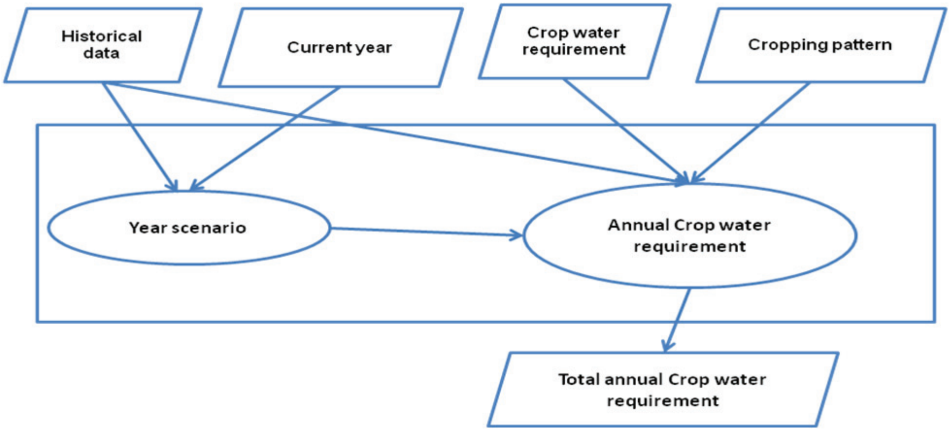

Fig. 5. Process of planning for annual crop water requirement

4. RESULTS

Climatic scenarios: Classification of historical monthly precipitation in three climatic scenarios is presented in Figure 6. As it can be seen, the average ET_0 and evaporation values of pan class "A" for different scenarios are different; in dry years ET_0 is higher than in average and normal years.

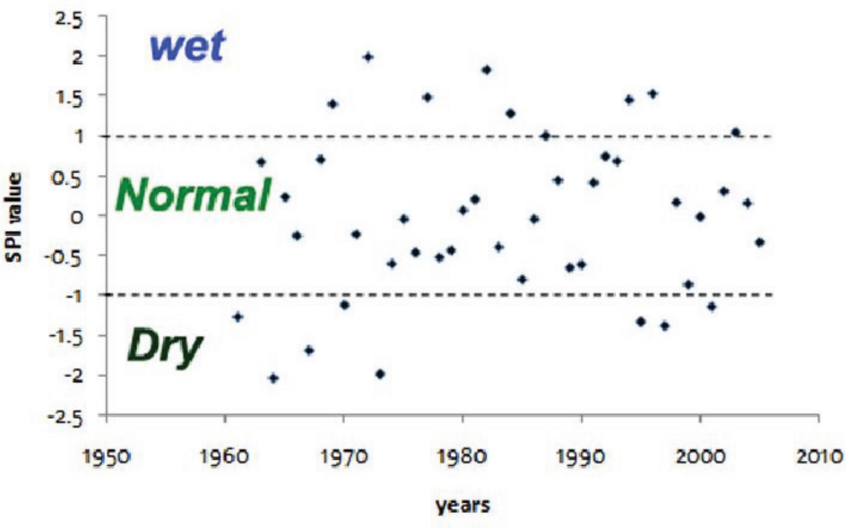

Fig. 6. Presentation of various climatic scenarios

Crop coefficient: Comparisons of four different methods of estimating Kc with lysimateric data (Table 1), show that DEMETER (analytical approach) and FAO methods are producing better results (lower RMSE). The Kc Map of the pilot area derived from the analytical DEMETR approach is presented in Fig. 7.

Table 1. Crop coefficient derived through various methods

Crop	Stage	K_{C} FAO-56 Table	K_{C} FAO-56 adj	K_{C} DEMETER		K_{C} SEBS	K_{C} Lysimeter
				Analytical	K_{C}-NDVI		
Wheat	Init	0.40	***	***	***	***	***
	Mid	1.15	1.23	1.27	1.23	1.27	***
	End	0.40	0.48	0.47	0.78	1.23	***
Canola	Init	0.35	***	***	***	***	***
	Mid	1.15	1.26	1.30	1.19	1.45	***
	End	0.35	0.60	0.57	0.60	1.31	***
Sorghum	Init	0.30	***	0.60	0.62	1.10	***
	Mid	1.20	1.41	1.42	1.34	1.50	***
	End	1.05	1.15	1.14	0.64	1.36	***
Alfalfa	Init	0.40	0.87	0.82	0.37	1.20	0.80
	Mid	1.20	1.25	1.09	1.16	1.23	1.21
	End	1.15	1.19	1.00	0.69	139.00	1.17

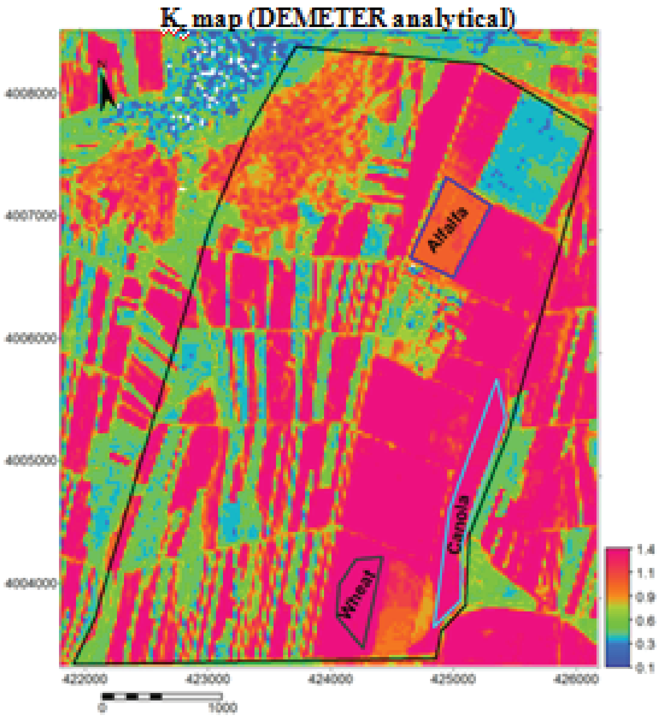

Fig. 7. Kc Map derived from the analytical DEMETR approach

Regional crop coefficient: The regional Kc of the pilot area was derived using Medium and high resolution satellite data and compared. The use of ASTER and MODIS images as shown in Table 2, did not result in significantly different regional Kc at α =0.05. This is promising, as it implies that MODIS can be used for determination of CWR at regional scale "WUA".

Table 2. Comparison of regional Kc Derived from ASTER and MODIS data sets

Date	Regional K_c Sharif Abad WUA		
	ASTER (30m)	MODIS (1km)	MODIS (500m)
24-May	0.85	0.92	0.89
27-May	1.07	1.09	1.06
13-Jul	0.96	1.07	1.06
26-Aug	1.03	1.18	1.05
27-Sep	0.96	1.08	1.02

Sensitivity analysis: Results of sensitivity analysis of Kc with respect to various variables is presented in Fig. 8. Results show that, crop coefficient is more sensitive to temperature, leaf area index, incoming shortwave radiation, relative humidity, wind speed and crop height, in that order.

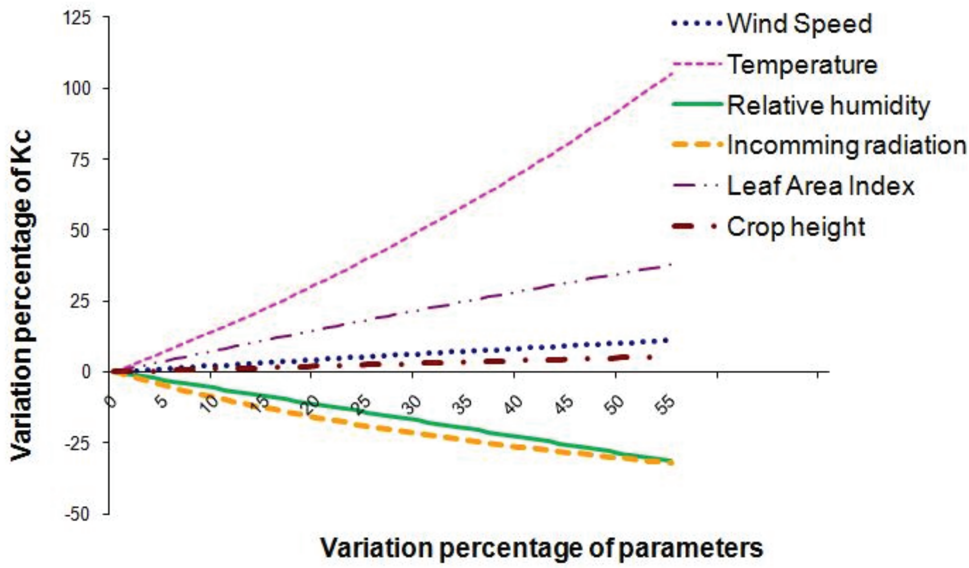

Fig. 8. Sensitivity of Kc with respect to various parameters

Water allocation planning: The proposed method of planning for water allocation showed significant improvement. Comparison between the planned values of crop water requirement and the realised values in 2004 as presented in Table 3 were not significantly different (α =0.05).

Table 3. Comparisons of Crop water requirements of year 2004 based on various methods

Crop Water Requirement values (mm/ha)

Crop	CWR planning	Iranian Water directive	Soil and water research institute	Consultants PANDAM	Current planning	Actual 2004 CWR
Canola	648	***	***	466	700	645
Wheat	696	421	587	546	700	695
Alfalfa	1302	990	1230	1357	1650	1283
Sorghum	858	689	772	650	1100	880

5. CONCLUSIONS

Average daily reference evapotranspiration was found to be different in various scenarios (dry, normal and wet year). This implies that the irrigation requirements should be differentiated according to scenarios. Advanced remotely sensed based methods such as DEMETER has great potential and application in water allocation planning. This was proved to be the case by using the high resolution as well as the medium and low resolution satellite data. In particular this research proved that MODIS data and products which are publicly available can operationally be applied in water allocation planning in irrigation networks. This can be implemented at each individual gates (water user association) as well as large networks.

REFERENCES

Aghdasi, F., Sharifi, M.A., and van der Tol, C. 2010. Assessment of Crop Water Requirement Methods for Annual Agricultural Water Allocation Planning, presented in the European Geosciences Union General Assembly on 2-7 May 2010, Vienna, EGU2010-15604.

Aghdasi, F., 2010. Crop water requirement assessment and annual planning of water allocation, Thesis for mater Sciences in International Institute for Geoinformattion Science and Earth Observation ITC, Netherlands, 68 pp.

Alizadeh, A. and Kamali, G., 2007. Crops Water Requirement in IRAN. Emam Reza University

Bastiaanssen, W., 1998. Remote sensing in water resources management: The state of theart, International Water Management Institute, Colombo, Sri Lanka.

Bos, M.G., Kselik, R.A.L., Allen, G.R. and Molden, D., 2009. Water Requirments for Irrigation and the Environment. Springer, 172 pp.

D'Urso, G. et al., 2007. Portfolio/ Library of harmonized EO methodology.Work Package 3: "EO technology for irrigation water control & management"Project deliverable D10a. Draft v 2.1.

Michael, M.G. and Bastiaanssen, W.G.M., 2000. A new method to determine crop coefficients for water allocation planning from satellites: results from Kenya. Irrigation and Drainage Systems, 14: 237-256.

Su, Z., 2002. The Surface Energy Balance System (SEBS) for estimation of turbulent heat fluxes, Hydrology and Earth System Sciences, pp. 85-99.