DEMAND MANAGEMENT FOR INCREASING WATER PRODUCTIVITY IN AGRICULTURE

GESTION DE LA DEMANDE POUR AUGMENTER LA PRODUCTIVITE DE L'EAU EN AGRICULTURE

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ABSTRACT

This paper discusses developing methodologies and their related supports for the Qazvin irrigation networks to improve water productivity and efficiency in the agricultural sector. Currently, 403 Mm^3 of surface and ground water is used in the Ghazvin Irrigation network. Even 1% increase in irrigation efficiency, will save around 28 Mm^3 irrigation water. This will be worth 3.5 M Euros from the corresponding wheat production. The paper analyzes the water resource management in the agricultural sector in Qazvin Province in terms of crop water requirements, water availability (supply), balance between surface water and groundwater, actual and desirable delivery structures and irrigation efficiency. Analysis is also done of the situation of the agricultural water users and interactions with other stakeholders in the process. The water balance in the irrigated system can in principle calculated by comparing the input and the output of water. The residual will give an estimate of the unlicensed well deliveries to the irrigation systems. The analysis will produce an assessment of water productivity and cropping intensities, besides identifying problem areas within the irrigation system.

Key words: *Irrigation efficiency, Water demand management, Energy balance at ground surface, ASTER images.*

RESUME

Ce document examine le développement des méthodologies et les soutiens qu'elles fournissent aux réseaux d'irrigation Qazvin pour améliorer la productivité et l'efficience de l'eau du secteur agricole. A présent, l'eau de surface et l'eau souterraine de 403 Mm^3 est utilisée par le réseau d'irrigation Ghazvin. Après l'augmentation de l'efficience d'irrigation de 1%, il nous permettra de conserver environ 28 Mm^3 d'eau d'irrigation. Il vaut 3,5 M Euros

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de la production correspondante du blé. Le rapport analyse la gestion des ressources en eau agricole de la province de Qazvin en ce qui concerne les besoins en eau agricole, la disponibilité en eau (approvisionnement), l'équilibre entre l'eau de surface et l'eau souterraine, les structures de distribution actuelle et proposée et l'efficience d'irrigation.

On analyse également la situation des usagers de l'eau agricole et leur interaction avec d'autres parties prenantes. En principe, le bilan d'eau du système d'irrigation peut être calculé par les contributions et les rendements de l'eau. Il nous donne une estimation de la distribution non autorisée des eaux de puits aux systèmes d'irrigation. L'analyse fera une évaluation de la productivité de l'eau et des intensités agricoles, en outre l'identification des problèmes du système d'irrigation.

Mots clés : *Efficience d'irrigation, gestion de la demande en eau, bilan énergétique à la surface du sol, images d'ASTER.*

1. INTRODUCTION

Irrigation efficiency is one of the most important indexes for assessing the status of agricultural water use. This efficiency, surprisingly, has been found lower in Modern Irrigation network than in the traditional farmer-managed irrigation systems.

The reason for low Irrigation efficiency in the modern systems may be attributed to more emphasis on construction of irrigation infrastructure and much less on the management and maintenance of the systems. Lack of basic knowledge on water use efficiency in irrigation would have the following adverse impacts:

- Inequitable distribution of limited water, water loss and low area coverage under irrigation.
- Server drop of ground water consumption (because of inversing population and therefore increasing need to food along with low water use efficiency)
- Water table decline due to over exploitation of groundwater to meet water demand by increasing population and to meet shortfall in the surface water for irrigation. Unpreparedness to meet the challenges posed by frequently occurring droughts.
- Harmful side effects such as rising groundwater table in heavily irrigated areas and development of saline condition.
- High cost of ameliorating waterlogging and salinity.

In design and planning of irrigation networks, followed by their proper operation, management and performance evaluation, the above adverse impacts can be greatly reduced.

In a properly designed network, water losses along its conveyance route is sought to be minimized through scientific design, alignment and also by lining. Thereafter, scientific application of water on the farmland is also important to minimize losses from the water that reaches the crop land from the water source. All these are possible when the current situation on water delivery and use are studied, understood and recognized as the elements that influence irrigation efficiency.

The present 2-year study was undertaken with a Consultant engineer in Gazvin Irrigation and Drainage Network.

2. GOALS OF STUDY

The study has been performed over farmlands and orchards of drainage and impaction network of Gazvin plan with following objects:

Studying water use efficiency for irrigation methods (surface and pressurized)

Investigating water transfer efficiency in farmlands for surface methods.

investigating current problems and their reason in the network.

Development of planning module using Remote Sensing

3. PROBLEM SETTING

3.1 Background

The history of Qazvin starts from 241 B.C. For centuries, the then land lords followed traditional methods of agriculture, including water resource development and use. However in 1963, with the execution of the land reform, controls came to the farmers. Meanwhile, after the catastrophic earthquake of 1962 in Qazvin, the study phase of DPQA was initiated. The objective of this project was to develop water and land resources of Qazvin area. Agricultural development of the Qazvin plain has been started from the decade of 1960 with the aim of optimum use of water and soil resource in a sustainable manner. This 450000 ha fertile plain has a modern and advanced irrigation network in an area of more than 60000 with transferring water from the Shahroud River. The construction of transmission tunnel and diversion dam and 1200 km long network has started from the mid 1960s. The capacity of the network input channel is 30 m^3/s and the network comprises 94 km of grade 1 channel, 220 km of grade 2 channel, 320 km of grade 3 and 560 km of grade 4 channels. During droughts, groundwater is extracted from the 100 wells drilled in this plain.

Following phase 1 and 2 of participatory operation studies, 12 WUAs in 12 villages were formed and their unions were formally established in 1999. Being unsuccessful, these WUAs were dissolved in 2001. The main reasons for dissolution were:

- Their mismatching with water users
- Lack of water users participation in decision making
- Government could not provide necessary technical and financial supports

Following such experiences, the ministry of Energy gave special attention to PIM and transfer of irrigation management to water users. A total of 158 new WUAs were established within the period of 2002-2005. WUAs under a specific canal formed a union of WUAs; where 8 unions were established throughout the plain being confederated in to the irrigation unions center (IUC). According to the contract issued between IUC and the operation company, IUC together with WUAs is responsible for supply as well as transfer of water and maintenance of the system.

Creation of IUC and WUAs have had many positive effects on transfer of irrigation management to competent members which is the main goal of PIM. Some of these positive socio economic effects are:

- Employment generation among young professionals,
- Saving the time required for water demand and supply,
- Lesser cases of destructing equipments/structures,
- Lower distribution costs and fewer problems faced water distribution,

Some components of Qazvin Irrigation System are given in Table 1, 2 and 3.

Table 1. Reservoirs and water distribution works

Structure	Unit	Remarks
Talegan Reservoir Dam Capacity	Million m^3	450
Main canal Length	km	94
Main canal Capacity	m^3	30-3
Laterals Length	km	204
Laterals Capacity	m^3	7.4-0.6
Tertiary and Quaternary canals Length	km	749
Tertiary and Quaternary canals Capacity	m^3	0.170-0.100

Table 2. Qazvin's Cropping Pattern

Land Use	Cultivated Area (ha)	%
Gardens and vineyard	2947	4
Wheat and Barley	33855	43
Con forage, Alfalfa, Beet, Summer crops	21460	27
Rotation Cultivation	17204	22
Canola	3133	4
Total	78599	100

Table 3. Water resources in the last 3 decades (mm^3/ann)

Water resources	Designed plan	Average operation in 3 decades	Talghan Dam future potential in normal situation
Talghan Water transferred for Agriculture	279	142.2	279
Talghan Water transferred for Artificial recharge of aquifers	60	19.8	20
Aquifer water extraction for agriculture, industry and drinking	194.4	433.8	334.5
Water supply from local rivers	6.7	16	16
Total	480.1	611.8	629.5

3.2 Objectives and description

A better understanding of the functioning of the irrigation system forms the base for the work related to planning and operations. It is proposed to study the period from 2000-2008 through water balance approach because MODIS (medium resolution) and ASTER (high resolution) images are available from 2000 onwards. In addition use will be made of AVHRR and LANDSAT imagery. The residual of the water balance after accounting for surface input, input from leagal groundwater extraction structures, and output will give an estimate of the unlicensed well deliveries to the irrigation systems. Furthermore, the analysis will produce an assessment of water productivity and cropping intensities. The analysis will also identify problem areas inside the irrigation system.

4. CONCLUSIONS

The energy balance is given by:

$$R_n = G + H + \lambda ET$$

where, R_n is pure radiation, G soil heat flow, H perceptible heat flow and λET is hidden heat flow. All units are as W/m^2.

Most of plants use less than 1% of solar light for photosynthesis process during their life. Sumi and Tanner (1958) found that in 3m tall maize that had produced 17t/ha of maize, the maximum heat storage would be 1% of total heat balance. Therefore photosynthesis and heat storage of plants are two negligible components in the energy balance equation.

Horizontal heat component indicates pure energy exchanged by plant horizontally. In arid climate, this component could be considered as equal with pure radiation, and be eliminated due to lack of simple method for its evaluation, although it is important. By eliminating these three components, the energy balance equation was solved. Relation between visible spectrum energy and heat infra red radiation in region with high hydrologic contrast is the base for models arrangement which evaluate plant evapo-transpiration rate by applying energy balance equation. Figure 1 presents a conceptual model for aforementioned model arrangement.

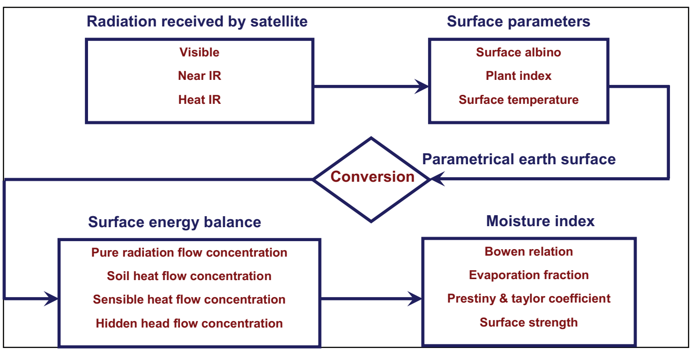

Fig. 1. Conceptual model for ET estimation (Modèle conceptuel de la méthode de disposition des modèles d'estimation pour l'usine Evapo transpiration)

Algorithms for actual ET determination using satellite images: Remote sensing is capable to present physical quantities of energy balance components and facilitate estimating spatial distribution of actual ET. Satellite data are used for estimating partial vegetation, superficial Albido, active and descending sun radiation with respect to photosynthesis, partial cloud coverage, weather temperature and partial water vapor pressure. Precipitation is obtained by means of integrating satellite and isometropia observations. Biophysical parameters of the model (such as hydrological features of soil and maximum leaf carbon absorption) are obtained from collected data and region ground coverage.

In order to determine actual ET of energy balance algorithm, Bastiaanssen, et al (1998) developed SEBAL model and compared the model output with field data. They found that in 85% of cases, results of SEBAL algorithm were consistent with field data, even without any calibration. SEBAL has some strong and weak points related to other algorithms which limit its application to special condition as followed:

Benefits

- Quantitative field data required
- Has a physical concept which makes it applicable for various climates
- No need to land use mapping
- No need to intervene required data for hydrologic models.
- In case of high resolution data, it is possible to make probability density function and alterations graphs which are of high importance.
- This method is suitable for all visible, near IR, thermal IR bands but could be applied for several spatial and resolution ability, and it does not means which there are high capability for various resolution and scale combination.
- For high resolution images, results may be verified by point flow and soil moisture measurements.

Disadvantages

- No-cloud condition is required
- Coincident dry and damp lands are needed
- Definition of surface roughness is not clear
- Results in uneven areas have less accuracy

4.1 Result of applying this model for MODLS Images

Evaluation results of actual Evapo transpiration in several periods for Qazvin plain range in agricultural annum (2000-2001) as a dry year and (2002-2003) as a wet year and (2004-2205) as normal year are presented in tables 4 to 6 respectively.

Table 4. Results of actual ET estimation in Qazvin plain for agricultural year (2000-2001:dry season) (résultats de l'estimation évapotranspiration réelle dans la plaine de Qazvin pour an agricoles (2000-2001: saison sèche))

Data	Day	Referrers Period(day)	Real Daily Evaporation and Transpiration(mm in day)	Real Period Evaporation and Transpiration(mm)
27.4.2001	117	6	0.6	3.9
30.4.2001	120	8	0.5	4.3
13.5.2001	133	10	0.9	8.9
20.5.2001	140	5	0.7	3.5
23.5.2001	143	3	0.6	1.9
27.5.2001	147	3	0.9	2.6
29.5.2001	149	4	0.8	3.4
5.6.2001	156	19	1.2	23.3
7.7.2001	188	19	0.8	15
14.7.2001	195	5	0.7	3.6
19.7.2001	199	9	0.5	4.8
8.1.2001	213	8	1.1	8.6
4.8.2001	216	9	0.9	8.4
20.8.2001	232	10	1.2	12.3
24.8.2001	236	5	0.8	4
31.8.2001	242	9	1.1	9.5
12.9.2001	255	6	0.8	4.6

Table 5. Results of actual ET estimation in Qazvin plain for agricultural year (2002-2003: wet season) (résultats de l'estimation de la transpiration réelle dans la plaine de Qazvin Evapo pour an agricoles (2002-2003: saison des pluies))

Data	Day	Referrers Period(day)	Real Daily Evaporation and Transpiration(mm in day)	Real Period Evaporation and Transpiration(mm)
26.9.2002	269	12	1.3	15.3
7.10.2002	280	13	1.1	14.7
23.10.2002	296	10	0.6	5.5
28.10.2002	301	6	1.1	6.6
4.11.2002	308	6	0.5	2.9
10.11.2002	314	6	0.5	3
17.11.2002	321	5	0.2	1.2
20.11.2002	324	2	0.3	0.6
22.11.2002	326	6	0.3	1.6
14.3.2003	73	20	0.2	4.2
24.4.2003	114	26	0.8	19.6
6.5.2003	126	7	1.6	11.4
8.5.2003	128	9	0.6	5.5
24.5.2003	144	15	1	15.7
7.6.2003	158	8	1.1	8.7
9.6.2003	160	4	1.5	6
16.6.2003	167	8	1.6	12.7
26.6.2003	177	8	1.4	11.5
2.7.2003	183	19	1.6	31.2
3.8.2003	215	19	1.7	31.4
10.8.2003	222	8	2.2	17.6
19.8.2003	231	12	1.6	19.6
4.9.2003	247	19	1.9	36.9

Table 6. Results of actual ET estimation in Qazvin plain for Agricultural year (2003-2004: normal season) (results of real Evapo transpiration estimation in Qazvin plain for agricultural annum (2003-2004: normal season))

Data	Day	Referrers Period(day)	Real Daily Evaporation and Transpiration(mm in day)	Real Period Evaporation and Transpiration(mm)
27.9.2003	270	13	1	13
1.10.2003	274	4	1	4.2
6.10.2003	279	4	1.1	4.4
10.10.2003	283	8	1.3	10.1
22.10.2003	295	18	1.1	20.6
16.11.2003	320	16	0.1	1.8
23.11.2003	327	11	0.1	0.8
9.12.2003	343	8	0.2	1.5
28.1.2004	28	26	0.1	1.4
21.3.2004	81	27	0.1	3.6
23.3.2004	83	8	0.5	3.7
6.4.2004	97	8	0.2	1.2
8.4.2004	99	2	0.4	0.9
10.4.2004	101	3	0.6	1.8
15.4.2004	106	14	1	14.4
8.5.2004	129	12	0.8	10
10.5.2004	131	3	1	2.9
15.5.2004	136	8	0.5	3.9
26.5.2004	147	9	1.2	10.7
2.6.2004	154	7	1.8	12.3
9.6.2004	161	5	1.5	7.3
13.6.2004	165	5	1.2	5.9
20.6.2004	172	6	1.6	9.6
25.6.2004	177	9	1.6	14.8
8.7.2004	190	10	1.4	14.3
15.7.2004	197	5	1.4	7
18.7.2004	200	6	1.5	9
27.7.2004	209	7	1.4	9.8
2.8.2004	215	4	1.3	5.2
5.8.2004	218	3	1.4	4.1
9.8.2004	222	5	1.5	7.5
16.8.2004	229	6	1.4	8.4
21.8.2004	234	6	2.2	13.2
28.8.2004	241	5	1.3	6.3
1.9.2004	245	3	1.6	4.9
3.9.2004	247	4	2.4	9.5
10.9.2004	254	9	2	17.9

4.2 Investigation of Evapotranspiration changes in normal, dry and wet year

According to the Tables 1 - 3, ET rate in Qazvin plain is influenced by various meteorological condition, in the years of 2003-2004 when normal condition prevailed, the average ET rate was 1.10 mm/day during the year; while for farming year 2000-2001, which was a dry year, the ET was 0.84 mm/day, i.e., a 24% reduction in the ET rate. In the farming year 2002-2003, which was a wet year, the ET rate was 1.80 mm/day. Figure 2 shows trends ET of Qazvin plain for dry, normal and wet years.

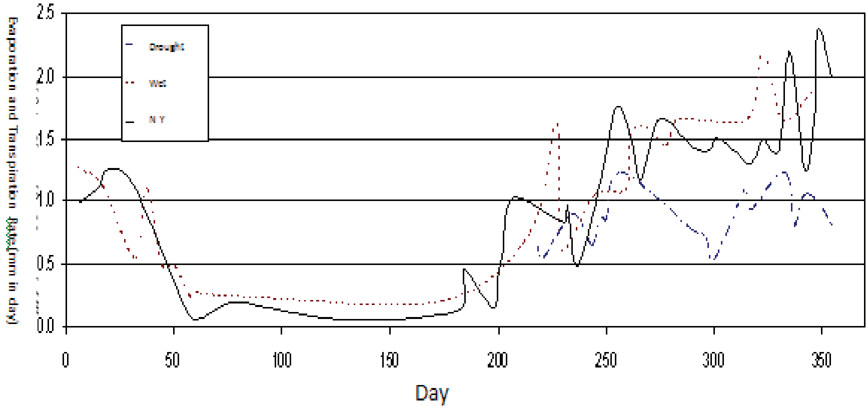

Fig. 2. Changes trend of real Evapo transpiration of Qazvin plain for dry, normal and wet (tendance à des changements de la transpiration évapo réelle de la plaine de Qazvin pour les peaux sèches, normales et humide)

4.3 Evaluation of ET obtained from ASTER and MODIS Images

Images with low spatial resolution have high time resolution and are more affordable to use. The Relative difference between ASTER and MODIS images is low and this indicates that MODIS images could be used in spite of its large pixels. The relation between ET estimated by ASTER and MODIS is shown in Fig. 3. Several clear points from both photos were selected and were evaluated for ET estimate quantity.

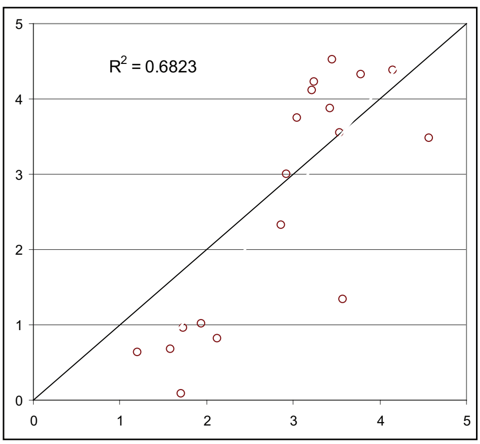

Fig. 3. Indicates that 0.68 correlation between estimated daily Evapo – transpiration by ASTER and MODIS.(indique que la corrélation entre 0,68 estimé l'évapotranspiration quotidiennement par ASTER et MODIS)

4.4. Analysis of groundwaters Systems and issues

Activities will have to be aimed at building on the existing databases (Arc GIS) of the Ministries of Agriculture and Energy. The available time series of ground-water levels will be analyzed and a compilation of pizometric levels for the last 8 years will be made. The analysis of level changes combined with specific yield values will make it possible to carry out a spatial and temporal analysis of the levels (locations and hydrographs). An analysis of both government and private well abstractions and water use will be made, based on available records.

4.5. Analysis of canal water deliveries

The water deliveries at primary and secondary level will be taken as representative for the total inflow into the command area and the main irrigation units. The data will be used as recorded by the Ministry of Energy.

4.6. Data collection on meteorology and climate

Spatial and temporal data will be collected on meteorology and climate as needed to determine the evapotranspiration and the irrigation demand.

4.7. Determination ET supported by Remote Sensing

The spatial and temporal precipitation patterns will be studied on daily, decadal and monthly basis. The meteorological data will be used to calculate the Penman-Monteith ET_0 values and compare these with the existing analysis. The quality of the meteorological data is crucial for the analysis and especially important for the modeling and forecasting proposed. For this reason it is recommended to install a small automatic weather station with soil moisture sensors inside the irrigated area in Qazvin. This station will produce data at 5 minute intervals and will be operated by the Qazvin Agricultural Office. The reference crop evaporation ET_0 will be determined by the Penman-Monteith method. Since weather stations are only available in a few locations it is difficult to obtain spatially representative values. However, a bulk resistance RS map can be made during satellite overpasses. This map will then be used to apply Penman-Monteith on a spatial scale during days when there is no satellite overpass. The actual ET maps will be calculated with one of the well-known methods SEBS or SEBAL.

4.8. Determination crop water productivity maps

From the actual ET other parameters will then be determined such as soil moisture and biomass growth. Maps of cropping intensity and water productivity will be prepared on a monthly scale for the entire command area. Spatial and temporal aspects of these parameters will be refined in other sections. Other parameters such as LAI, NDVI and irrigated area will also be determined by the remote sensing techniques. Finally, a supervised crop classification will be made with the available LANDSAT and ASTER images for the two growing seasons.

4.9. Development methodology and software

The methodology for overall assessment of the networks, based on the analysis of this section, will be synthesized in a computer system for general use.

5. RESULTS AND DISCUSSION

In order to determine ET, most literature and researches suggest using Penman Montheith method. In this method, potential evapo-transpiration has been calculated for reference plant by use of meteorological data and was determined by use of plant coefficient experimentally .real evapo-transpiration were estimated for each plant. Due to insufficient density of meteorological stations in the country, high cost of data collection and approximation in estimating plant coefficient for each region, aforementioned method using satellite data have following benefits:

- Low cost of data collecting compared with field methods.
- Real time data collection
- No need to land use map

Among the present algorithms for actual ET calculation, SEBAL algorithm has various capabilities and could be used as the appropriate model. The main goal of this study is to determine plant water requirement and actual ET of plant. In SEBAL algorithm, the actual ET for any crop is estimated at fixed time steps. This method does not require crop coefficient values.

It is concluded that the currently used estimates for crop water requirement are in general not correct and that the resulting water demands are not realistic. This makes the water allocation problematic and the timely delivery of water questionable. The present planning and operation procedures are based more on historical figures and expert judgments. Moreover, the participation of the users (farmers) in planning and implementation is rather synthetic and could be improved. Given the limited supply of water, this all together makes the overall situation far from what ideal.

6. SUMMARY

Iran is a water scarce country with limited rainfall in many places and irrigation is widely used to support the agricultural activities in the country. Present irrigation techniques are characterized by low water productivity due to losses in the system and inefficient water allocation schemes. The National Water Document (NWD) has been adopted as a directive on how to manage irrigation systems and is supposed to improve the situation. However, this document faces various technical and operational problems and it is hardly applied, if at all. Technical issues in NWD relate to insufficient attention for local conditions related to soils, crops, average weather data and spatial differentiated canal efficiencies. As a result of this it appears that the demand for irrigation requirement according to the NWD differs substantially from the real demand and that appropriate delivery in time and space does not take place. Still the law requires that the NWD should be implemented.

The main objective is to improve the water productivity and allocation efficiency of the irrigation systems in Iran. It will do this by updating the NWD and the operationalization of this document by providing the responsible agencies with approaches and tools for planning and operational management.

The Project will analyze the water resource management in the agricultural sector in Qazvin Province with specific attention to crop water requirements, water availability (supply), balance between surface water and groundwater, actual and desirable delivery structures, irrigation efficiency. Furthermore, an analysis will be made of the situation of the agricultural water users and interactions with other stakeholders in the process. Use will be made of modern GIS and RS techniques.

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