EVALUATING IRRIGATION EFFICIENCY AND ISO-EFFICIENCY MAPS IN IRAN

EVALUATION DE L'EFFICIENCE D'IRRIGATION ET EFFICIENCE DE LA CARTOGRAPHIE ISO EN IRAN

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ABSTRACT

Irrigation efficiency is a basic engineering term used in irrigation science to characterize irrigation performance, evaluate irrigation water use, and to promote better or improved use of water resources, particularly in agriculture. The enhanced understanding of irrigation efficiency can improve the beneficial use of limited and declining water resources needed to enhance crop and food production from irrigated lands. This research is aimed to: 1) collect and build up a databank regarding irrigation efficiencies in Iran 2) determine the irrigation application, conveyance, and total efficiencies 3) estimate spatial and temporal variation of irrigation efficiencies and 4) produce comprehensive irrigation iso-efficiency maps for decision makers in Iran. The analysis was based on the results from a large number of irrigation events on a range of soils, crops, irrigation systems and networks obtained from about 100 field scale studies carried out in different irrigated areas including about 1000 measured irrigation events across the country from 1973 to 2009. All irrigation events conducted under usual farmer management were analysed in this study. The findings showed that the irrigation application efficiency (E_a) widely ranged between 23.9 and 82.1%, the mean being about 54%. Irrigation conveyance efficiency was 83.7% and 75.9% for modern and traditional irrigation networks, respectively. Total irrigation efficiency (E_t) varied from 40 to 46% (assuming 85% for conveyance irrigation efficiency). This indicates nearly 1% annually promotion in total irrigation efficiency since 1999. The latter is consistent with the forecast value of the 4th national development program. Among different pressurized irrigation systems, center pivot, wheel move, and drip irrigation systems resulted in higher application efficiency, average being 71.0, 66.9, and 66.7%, respectively. These values were 53.6%, 48.6% and 45.1% for basin, furrow, and border irrigation systems, respectively. Iso-irrigation efficiency maps were produced using geo-statistical methods. Irrigation efficiencies were somewhat higher in the east of the country, the area where water shortage and groundwater level is more critical. This study also briefly raises the problems and gives suggestions to improve irrigation efficiencies in Iran.

Keywords: *Irrigation efficiencies, Iso-irrigation map, water productivity, Iran*

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RESUME

L'efficience d'irrigation est un terme technique de base utilisé dans la science d'irrigation pour caractériser la performance de l'irrigation, évaluer l'utilisation de l'eau d'irrigation et promouvoir la meilleure utilisation des ressources en eau, particulièrement en agriculture. Une meilleure compréhension en cette matière permettra d'utiliser de manière efficiente les ressources en eau qui diminuent de plus en plus pour production culturale. Les recherches menées en cette matière visent à : 1) recueillir une base de données concernant l'efficience d'irrigation en Iran 2) déterminer l'application, le transport et l'efficience totale d'irrigation 3) évaluer la variation d'efficience d'irrigation dans le temps et dans l'espace et 4) préparer une cartographie détaillée de l'efficience ISO pour les responsables de décision en Iran.

Cette analyse a été fondée sur les résultats d'un grand nombre d'expérimentations d'irrigation menées sur differents types de sols, cultures, systèmes d'irrigation et réseaux depuis les années 1973 jusqu'à 2009. Les résultats montrent que l'efficience d'application d'irrigation (E_a) varie largement de 23,9 à 82,1%, la moyenne étant de 54%. L'efficience de transport d'irrigation est 83,7% et 75.9 % respectivement pour les réseaux d'irrigation modernes et traditionnels.

L'efficience d'irrigation totale (E_t) varie de 40 à 46% (85% pour l'efficience de transport d'irrigation). Cela signifie presque 1% d'augmentation annuelle dans l'efficience d'irrigation totale constatée depuis 1999. Le dernier est en accord avec la valeur de prévision du 4ème programme du développement national. Parmi les différents systèmes d'irrigation à pression, le pivot, le mouvement de roue et les systèmes d'irrigation goutte à goutte donnent la plus haute efficience d'application, la moyenne étant 71,0, 66,9 et 66,7%, respectivement. Pour les systèmes d'irrigation par bassin, sillon et planches, ces valeurs étaient de 53,6%, 48,6% et 45,1%, respectivement. Les cartes ISO de l'efficience d'irrigation ont été réalisées utilisant les méthodes géo-statistiques. Le niveau de l'efficience d'irrigation est plus élevé dans la région orientale du pays où est constatée la situation de la pénurie d'eau et des eaux souterrainnes plus critique. Cette étude traite brièvement les problèmes et donne des propositions pour améliorer l'efficience d'irrigation en Iran.

Mots-clés: *Efficience d'irrigation, carte d'Irrigation ISO, productivité de l'eau, Iran*

1. INTRODUCTION

Agriculture plays a key role in the economy of Iran. It accounts for 18% of the Gross Domestic Product (GDP), one-fourth of employment, more than 85% of food requirements, 25% of non-oil exports, and 90% of raw materials for industries. Out of the 165 million ha (Mha)of the country's land area, about 37 Mha are suitable for irrigation and dry-land agriculture including: 20 Mha irrigated, 17 Mha dry-land. About 18.5 Mha are currently devoted to horticulture and field crops production. This total cultivated is distributed as follows: 6.4 Mha are under annual irrigated crops, 2 Mha horticultural crops and about 6.2 million ha are under annual dry-land crops and the remaining 3.9 Mha are fallow.

Islamic Republic of Iran (IRI) falls within the arid and semi-arid regions of the world. The average annual precipitation is 252 mm (one-third of the world average). However, 179 mm of

rainfall is directly lost through evaporation. In other words, 71% of precipitation is lost due to evaporation, while annual potential evaporation varies between 1500 to 2000 mm. However, in the past 6 years, some parts of the country suffered from severe drought.

Due to inefficiency of traditional irrigation methods and poor efficiency of water conveying systems; about 60% of the valuable water is lost and in practice only 40% of available water is utilized in agricultural production. A common perception is that irrigation efficiency in the Asian and Pacific regions is fairly low, at about 30%. More than 60% of the world's irrigated areas are in Asia, two thirds of it in India and China. From the early 1960s to the end of the 1990s, the irrigated area doubled in size, worldwide. The issues shaping the development of agriculture include water scarcity, over exploitation of groundwater, increasingly severe environmental problems, and a decline in the contribution from agriculture to rural incomes. The need to produce more food and other agricultural products with less water and to enhance the efficiency of consumed water are becoming the major factors affecting the water use efficiency. The overall irrigation efficiency in Iran varies between 31 to 57% for the different provinces (Abbasi et al., 2006). It is lower than the average of the world irrigation efficiency, being 45% for developing countries and 60% for developed countries.

Irrigation efficiency is a critical measure of irrigation performance in terms of the water required to irrigate a field. The value of irrigation efficiency and its definition are important to the societal views of irrigated agriculture. Irrigation efficiency is defined in terms of: 1) the irrigation system performance, 2) the uniformity of the water application, and 3) the response of the crop to irrigation. Each of these irrigation efficiency measures is interrelated and will vary with scale and time. Irrigation efficiency affects the economics of irrigation, the amount of water needed to irrigate a specific land area, the spatial uniformity of the crop and its yield, the amount of water that might percolate beneath the crop root zone, the amount of water that can return to surface sources for downstream uses or to groundwater aquifers that might supply other water uses, and the amount of water lost to unrecoverable sources (salt sink, saline aquifer, ocean, or unsaturated vadose zone). Irrigation efficiency is an important engineering term that involves understanding soil and agronomic sciences to achieve the maximum benefit from irrigation. The enhanced understanding of irrigation efficiency can improve the beneficial use of limited and declining water resources needed to enhance crop and food production from irrigated lands.

In this study, the results from a large number of irrigation events on a range of soils, crops, irrigation systems and networks were collected to build up a databank regarding irrigation efficiencies in Iran, to evaluate irrigation efficiencies and to estimate spatial and temporal variation of irrigation efficiencies in Iran as well as producing iso-efficiency maps.

2. MATERIALS AND METHODS

A large number of field scale data on evaluating irrigation efficiencies from different regions of Iran were collected and analyzed. The data were from a large number of irrigation events on a range of soils, crops, irrigation systems and networks (modern and conventional) obtained from about 100 field scale studies carried out in different irrigated areas including about 1000 measured irrigation events across the country from 1973 to 2009. All irrigation events conducted under usual farmer management were analyzed in this study. The data were collected from various sources, i.e. library of research institutes, universities, consultive

companies, and Ministries of Energy and Jihad-e. Keshavarzy. The data were analyzed using the statistical methods and relevant softwares.

3. RESULTS AND DISCUSSION

Frequency of the studied irrigation systems for the period of 1973-2009 is presented in Fig.1. As shown, most of measurements have been carried out on traditional surface irrigation methods and less on pressurized irrigation systems.

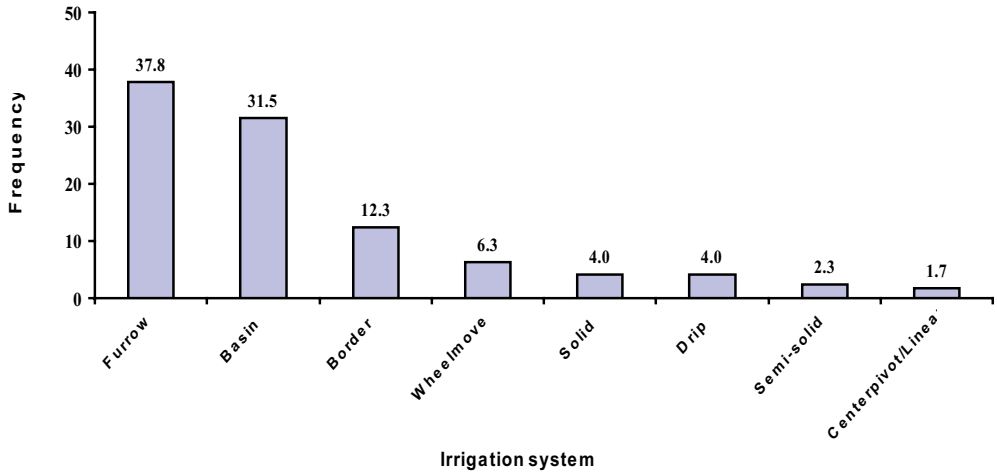

Fig.1. Frequency of the studied irrigation systems in the period of 1973-2009

Irrigation application efficiency (E_a) in various irrigation systems is given in Fig. 2. Naturally, the lowest application efficiency was reported in traditional surface irrigation systems. Among the surface irrigation systems, basins provided higher application efficiency followed by furrows and borders. Mean of E_a for basins and borders were 53.6 and 45.1%, respectively. Among the sprinklers irrigations systems, center pivot and linear systems provided higher E_a being 71% and solid systems provided lower E_a being about 50%. E_a in drip irrigation systems was 66.6%. Overall, E_a in surface and pressurized irrigation systems was 49.1 and 62.4%, respectively. In general, E_a in Iran varied between 23.9 and 82.1%, the average being 54.3%. Results showed that mean of E_a in Iran was 50.1 and 59.1% for the last two decades. This means nearly 1% annually enhancement in E_a. Comparisons also showed that the average of E_a from surface and groundwater resources was 53% and 56.1%, respectively.

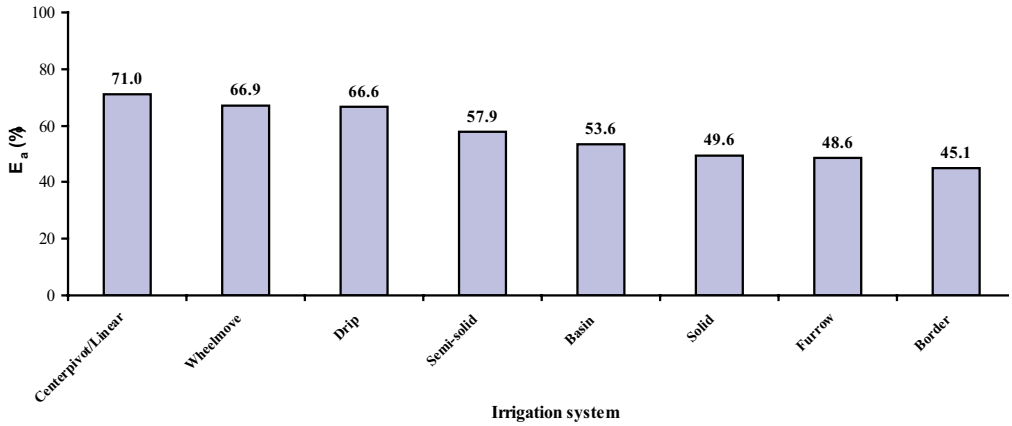

Fig. 2. Irrigation application efficiency of different irrigation systems in Iran

Application iso-efficiency map in Iran is shown in Fig.4. According to this map, E_a in central regions of Iran is lower than northern and western parts of the country.

Results also showed that E_a in Fars, West-Azerbaijan, Ardebil, Kohgilouyeh-BoyerAahmad and Gazvin provinces were higher than other provinces. Due to lack of data, more researches should be conducted in Ilam, Boushehr, North and South Khorasan, Sistan-Balouchestan, Ghom, Kordestan, Lorestan, and Hormozgan provinces for evaluating irrigation efficiencies. Average of irrigation application efficiency for wheat, alfalfa, maize, sugar beet, barley, sugar, rice, silage corn, cotton, tomato, soya, potato, sesame, pistachio, citrus, gardens and cereals was also estimated to be 48.3, 57.8, 60.5, 55.4, 39.6, 58.8, 54.5, 54.7, 45.6, 67, 52.4, 50.5, 59.1, 65, 53.5, 69.2 and 31.4%, respectively.

In Fig. 3 irrigation distribution uniformity (DU) is shown for different irrigation systems. Among the surface irrigation systems, furrow irrigation resulted in higher Du values followed by border irrigation being 75.7 and 63%, respectively. Among the sprinkler irrigation systems, center pivot and linear systems provided higher DU values in which DU was 58.8%. Unexpectedly, there was a minor difference between DU values in surface and pressurized irrigation systems. Mean of DU values was 67.7 and 69.7% for surface and pressurized irrigation, respectively. Results also showed that in 30% of the measurements, DU was less than 70%.

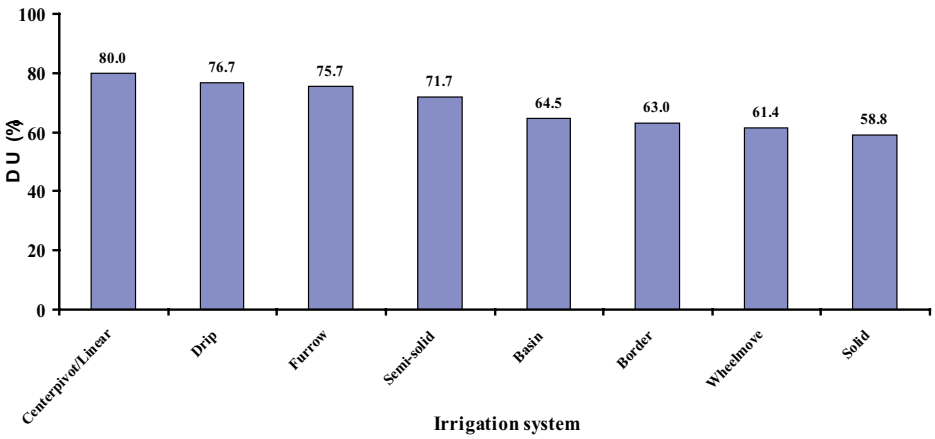

Fig. 3. Irrigation distribution uniformity of different irrigation systems

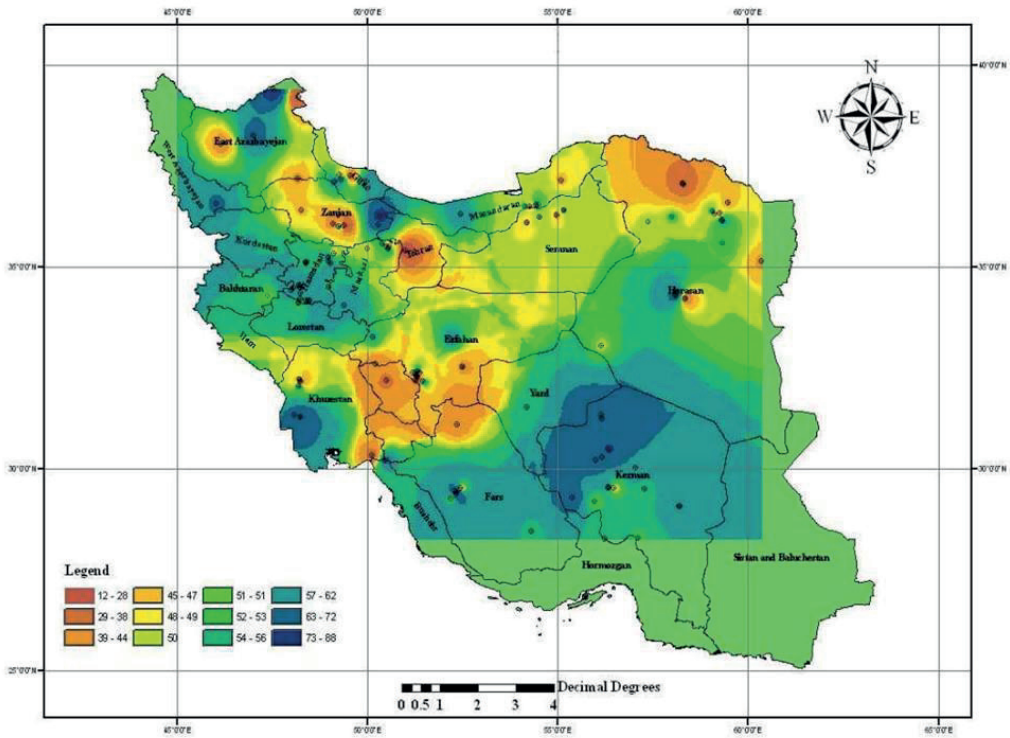

Fig. 4. Application iso-efficiency in Iran

According to the survey, average of irrigation conveyance efficiency (Ec) was about 80%. The latter was 75.9 and 83.7%, for traditional and modern irrigation networks, respectively. Total irrigation efficiency (Et) was estimated to be about 45% (assuming 83.7% for Ec). Et

was about 41% for Ec of 75.9%. Again, this shows a positive trend in irrigation efficiency and well consistent with the national development program in Iran.

The International Water Management Institute (IWMI) has reported that the average net irrigation requirement in Iran for cereal and field crops is 5,100 and 8,100 M^3/ha, respectively. Ministry of Energy, which is in charge of water allocation in Iran estimated the average amount of irrigation requirement to be 5,200 M^3/ha. The average of the figures, which has been published by different consulting engineers, is 5,900 M^3/ha. Considering these figures, the overall irrigation efficiency in Iran would be something between 48 to 55% which is somewhat different than the values presented in this study. This is mainly due to deficit irrigation that farmers practice naturally due to water limitations.

Total iso-efficiency map of Iran is also shown in Fig. 5. This indicates that total efficiency was higher in the north west and east of the country and lower in the central and sought parts.

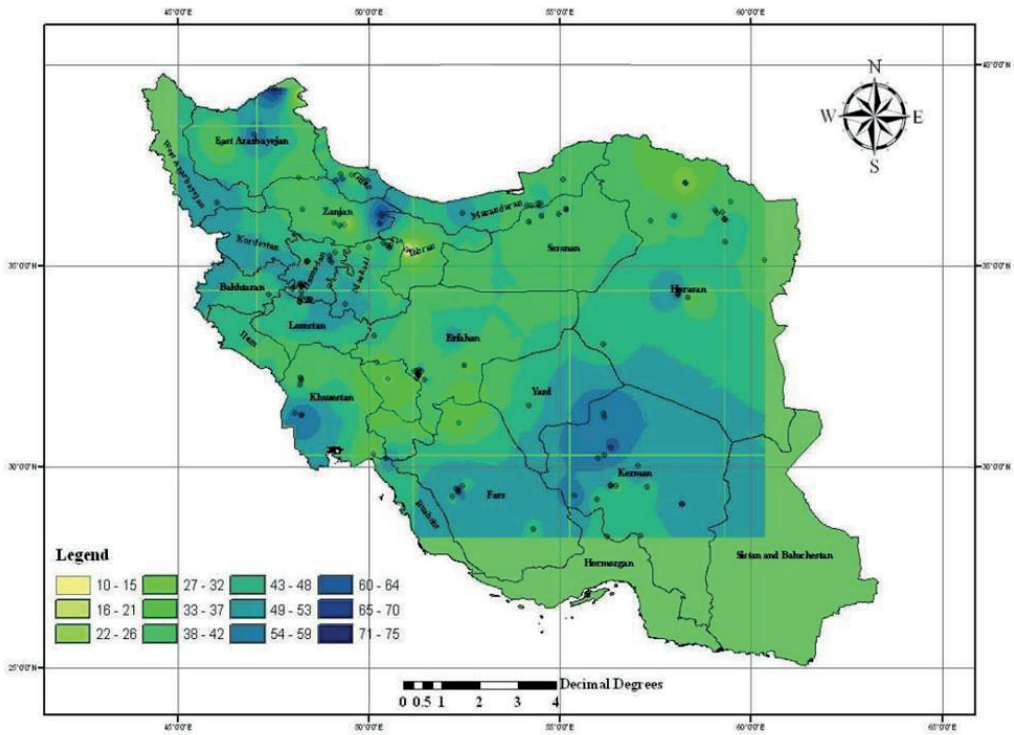

Fig. 5. Total iso-efficiency of Iran

Water use efficiency (WUE) is simply defined as the amount of production per unit of water. Obtaining more production with the same amount of water will increase WUE. A key to mitigate the problem of water scarcity in Iran would be increasing the WUE. High values of WUE in irrigation has not mainly been from a certain irrigation system but from increased crop yields due to better management. By proper water management, converting traditional irrigation

systems to modern systems, and completion of irrigation networks; the irrigation efficiency is expected to be increased up to 50 to 60%. In this case the area of the irrigation networks may increase from 2.5 million ha to 3.5-4.3 million ha.

Overall, WUE in Iran was estimated to be 0.8 kg/M^3 in year 2000 and currently is somewhat higher being about 1 kg/M^3.

Results also indicated that water productivity (WP) for wheat, alfalfa, maize, sugar beet (sugar), barley, sugarcane (sugar), silage corn, cotton, tomato, soya, potato and pistachio was 0.6, 0.6, 0.8, 2.3, 0.6, 1.6, 3.2, 0.9, 3, 0.9, 1.8, 0.5 kg/m^3, respectively. Overall, WP was estimated to be 1.4 kg/m^3 in the country.

In order to fulfill food requirements, WUE should be increased to about 1.6 kg/M^3 in the next decade. This implies that the institution, structure and procedures of water allocation in agriculture sector should be modified. This would call for emphases on special prioritization, policies, modernization, and productivity management.

4. CONCLUSIONS

The major threatening issues concerning irrigation efficiency and water use efficiency include frequent droughts and decreasing water supply to agricultural sector, improper allocation and non-optimum use of available water, and problems arising from the weak implementation of policies, as well as the rather slow adoption of available technologies to improve irrigation efficiency and water use efficiency. Results of the surveys indicate that the trend of irrigation efficiency over the last two decades in Iran is positive. In conclusion, major causes of low irrigation efficiency include poor management, low water prices, and fragmentation of responsibilities among different governmental agencies and inadequate training of farmers.

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