FOOD SECURITY AND IMPROVEMENT OF FARMERS LIVELIHOOD WITH APPLICATION OF VIRTUAL WATER

MOYENS DE SUBSISTANCE ALIMENTAIRE ET L'AMÉLIORATION DES AGRICULTEURS AVEC APPLICATION DE L'EAU VIRTUELLE

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ABSTRACT

Iran agriculture's is dependent on irrigation water as well. About 90 percent of agricultural raw outputs are produced by "blue water" which puts stressful pressure on Iran water resources and in some cases brings about environmental problems. In this paper, hydrological balance of "blue water" and "green water" in Iran, as well as, existing policies on water resources management are analyzed. Then, by using virtual water theory, procedures of enhancing food security, improving farmer's livelihood, and protecting environment in Iran are presented such as the cases as follows:

- Considering further use of "green water" to produce food such as rainfed agriculture, pastures, etc;
- Concentrating on economic comparative advantages by using "blue water" for agricultural and nonagricultural products with high economic value;
- Decreasing wastes in the agricultural sector and reusing the agricultural wastes for food production;
- Increasing food production by applying the methods without using fresh water, such as fishery development;
- Using modern biotechnological methods for producing food products resistant against salinity and dryness, as well as, producing food with methods such as tissue cultivation;
- Observing crop pattern with less virtual water;
- Changing Food Diet.

Virtual water trade as a policy option requires a comprehensive understanding of its impacts not only related to international trade regimes and dependencies but also on the local, social, environmental, economic and cultural situation.

Key words: Green water, Blue water, Virtual water, Food Security

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RÉSUMÉ ET CONCLUSIONS

L'inquiétude actuelle est que si les ressources en eau sont utilisées de la meilleure méthode? Les livraisons de produits agricoles durables à la méthode? Les effets environnementaux sont dus à un usage irrégulier de l'eau surveillés? Comment pouvons-nous engager une procédure de nouvelle (s) au monde de l'eau virtuelle et dans quelle mesure?

Un des points clé dans l'analyse de l'eau virtuelle est absorber l'attention de la population à la nature de l'eau, ainsi que, à l'endroit et l'heure de production. Classification des types d'eau en bleu, vert, et des gris, ainsi que, illustrant les spécifications et les potentialités de chaque type doit contribuer à une meilleure compréhension de la planification et l'organisation. spécifiques de planification et de gestion est requis pour chaque type d'eau bleue, et l'eau verte. La part de l'eau bleue de la production alimentaire mondiale n'est que de 15 pour cent pour laquelle 70 pour cent des prélèvements dans le monde entier l'eau bleue sont utilisés par le secteur agricole.

Il semble que l'Iran se concentre sur l'eau bleue. Par conséquent, la plupart des investissements en capital et les coûts sont alloués à la lutte, réglementer et gérer l'eau bleue.

Comme 85 pour cent de la production alimentaire mondiale est alimenté par l'eau verte, il est recommandé que les décideurs politiques en Iran accent sur l'application de l'eau verte comme une procédure rationnelle pour atténuer la pression sur les eaux de surface et des eaux souterraines du pays. Dans le cas où l'application de l'eau verte en Iran est augmentée par les directions coordonnée, des recherches et des investissements, des pressions supplémentaires sur les prélèvements d'eau des aquifères de base essentielles à diminuer.

À l'heure actuelle, l'utilisation de l'eau verte de la sécurité alimentaire de l'Iran est insignifiante, mais les agriculteurs appliquait auparavant durable méthodes locales, en application de l'eau verte pour l'agriculture pluviale et l'élevage ainsi que dans de nombreux domaine.

Après avoir commencé le développement technologique par le secteur public, l'Iran davantage concentrées sur des types d'eau en bleu au lieu d'engager la technologie appropriée dans les eaux vertes. Par conséquent, les possibilités de l'eau verte et les capacités progressivement obtenu un état d'abandon.

Plus de déca - milliards de m3 d'eau verte est chaque année publié et évaporée inutilement. Gestion et l'utilisation de l'eau verte en Iran peut être réellement efficace sur la fourniture de la sécurité alimentaire et de faire face la pénurie d'eau.

ressources en eau l'Iran sont sérieusement limitées. Par conséquent, la gestion de quitter unilatérale dans laquelle les ressources en eau sont affectées à différentes exigences devrait être changé dans la gestion globale de l'eau d'approvisionnement, la production et la consommation.

Identifier la quantité d'eau virtuelle utilisée dans divers biens et produits alimentaires est un guide pour l'élaboration des politiques de gestion macro - économiques pertinentes pour les ressources en eau de l'Iran. La perte d'eau sous diverses formes telles que les déchets de biens et de produits alimentaires devrait être étudiée et contrôlée.

1- INTRODUCTION

The rugged mountain chains surrounding several basins are collectively known as the Central Plateau. Having less than one third of the world’s average precipitation (253 mm), Iran is one of the arid countries of the world. Besides, unequal availability of precipitation throughout the country has brought about improper water resources in Iran's various regions. Hence, the country may be divided in two regions. The first one, is the north, west, western south and south areas (that is the basins of Caspian Sea, Orumia Lake, Persian Gulf & Oman Sea) covering about 40% of the country area. While the latter region, known as the basins of the Eastern, the Qara Qum, Hamoun Lake & the Central Plateau, covers the remaining 60% of the country area. Iran's main basin division is illustrated in Figure 1, where some related precipitation statistics are presented in table 1.

Table 1. Basin Precipitation Specification in Iran (Spécification des précipitations du bassin en Iran)

Basin	As % of total area	Rainfall (mm/year)	Rainfall (km³/year)	As % of total rainfall
Persian Gulf and Gulf of Oman Sea	26	380	161	39
Orumie Lake	3	347	18	5
Caspian Sea	11	423	74	18
Hamoun Lake	6	107	11	3
Central Plateau	51	166	137	33
Qara-Qum	3	226	10	2

In Figure 2 the annual evaporation in various areas of Iran is illustrated. Iran's average air temperature is about 16 oC and average evaporation is 2556 mm annually.

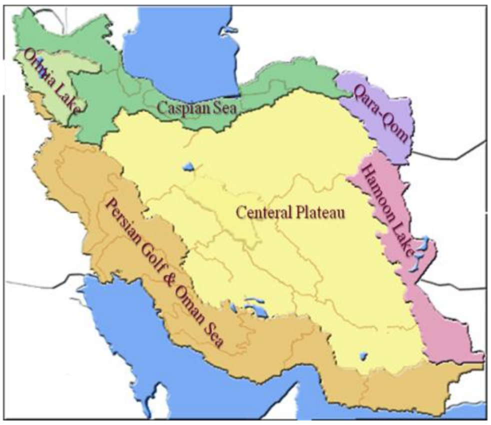

Figure 1. Iran Major Basin Division (Division Iran grand bassin)

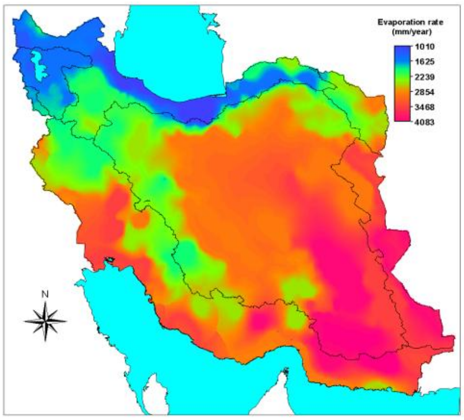

Figure 2. Annual evaporation in Iran (mm) (évaporation annuelle en Iran (mm))

Excess evaporation and lack of surface water resources in the east, southeast and central areas of Iran have extensively made them dependent on ground water resources. Further more the availability of ground water resources in Iran is more equitably allotted than the surface water resources. The index of saline water in most parts of the east, northern east, southern east and central area of the country is about 1,200 mg/l, which is not appropriate compared with the adequate rate of 500 mg/l that is required for potable water.

2- WATER RESOURCES IN IRAN

According to the water comprehensive plan of the country, the total annual precipitation throughout the country as the main water resources in Iran is equal to

413 billion cubic meter, of which 93 billion cubic meter flows as the surface water, 25 billion cubic meter penetrates to the mobile aquifers and the rest becomes unaccessible in the form of evapotranspiration from the surface of the land, forests, pastures & dry farming areas. Besides, water resources supplied through precipitation, about 12 billion cubic meters enters our country via rivers which makes the total surface water resources reach 105 billion cubic meters.

Considering the 25 billion cubic meter of the underground mobile aquifers, the total renewable water resources of the country reaches 130 billion cubic meters.

The studies reveal that about 96 billion cubic meter of the total renewable water resources is used for the sectors of agriculture, industry, mines and home usage as the following:

- 88 billion cubic meters, that is 90 percent for agriculture;
- 7.5 billion cubic meters, that is 7 percent for home usage;
- The rest for the sector of industry and the other ones.

In spite of water resource constraints, and improper locational distribution in the geographical areas of Iran, water productivity and irrigation efficiency is not very high. The analysis of water usage indicators in the agricultural sector illustrates most of water loss can be saved by applying proper and efficient strategies.

3-THE IRRIGATION AND AGRICULTURAL SITUATION IN IRAN

Iran with an area of 165 million hectare has 37 million hectare arable land of which only 8.8 million hectare is irrigated, 6 million hectare is rain-fed, and 4.5 million hectare remain in the form of fallow land.

The agricultural sector plays a vital role in the national economy and food products of Iran. About 27 percent of GNP and 23 percent of Iran labour power are related to this sector. Although equal land areas are allocated for the irrigated and rain-fed farms, the irrigated farming is the basic factor of food production because of the improper locational and periodical precipitation, that is, about 89 percent of the total agricultural products in the last 5 years have been produced from the irrigated cultivation (Figure 3 and 4).

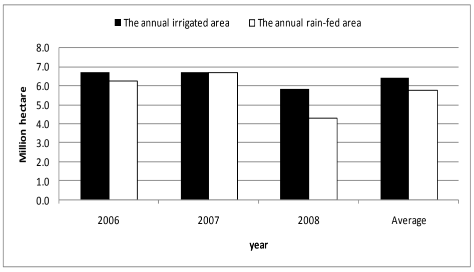

Figure 3. The area under the rain-fed and the irrigated farming in Iran (L'aire sous la pluviale et l'agriculture irriguée en Iran)

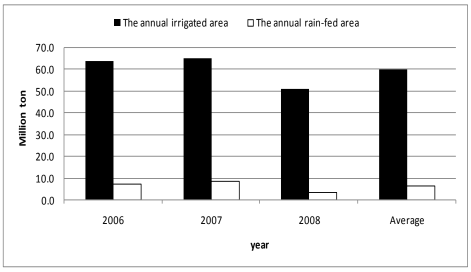

Figure 4. The production share of the rain-fed and the irrigated farming in Iran (La part de production des cultures pluviales et de l'agriculture irriguée en Iran)

The potentiality of Iran agricultural sector compared with the other countries of the world is fairly in a suitable situation. After India, China, US and Pakistan, Iran is ranked the fifth level in the irrigated farming area, however, in the 20th level, relevant the total arable land. Considering 8.8 million hectare of Iran irrigated area, that is about 122 hectare per 1000 persons, compared with 45 hectare of the Average World Irrigated Area (AWIA) per 1000 persons, Iran per capita area of the irrigated farming is about 2.5 times as many as the AWIA.

4-VIRTUAL WATER

Water consumption in so many countries is around 200 liters per person per day. But indeed, we all consume a whole lot more. This amount includes the water we use daily in our homes, but it also includes the amount embedded in what we consume. Water is hidden in anything we see around us, in our cars, our foods, and our books. That kind of water hidden in goods and services is called virtual water.

Virtual water refers to the amount of water required to produce goods from start to finish or it is the volume of freshwater used to produce the product, measured at the place where the product is actually produced. It refers to the sum of water used in various steps of the production chain. For example, about 1300 liters of water is required to produce one kg wheat and 15000 liters for one kg of beef.

While talking about virtual water of various products, one should consider all the various phases of growing, breeding, processing, supplying, marketing, etc.

In general, virtual water of livestock products is definitely more than that of agricultural products (forage, grains & cereals). Because livestock requires water to drink, agricultural products to consume, water to maintain the environment, etc.

Amount of virtual water required for the floras differs in various countries of the world due to climate and geographical conditions, technical issues, crop patterns, cultural standards, etc. For example, producing one kg wheat in Iran takes over 2900 liters of virtual water, while in the world 1300 liters on average, which illustrate a lot of virtual water consumption variations in producing the same crop.

Tomato virtual water and wheat virtual water in 5 provinces of Iran (Khuzestan, Ghazvin, Isfahan, Ardabil, and Fars) has been figured out and compared. The results illustrate that wheat virtual water in Khuzestan is the highest while tomato virtual water in this province is the lowest one (Figure 5).

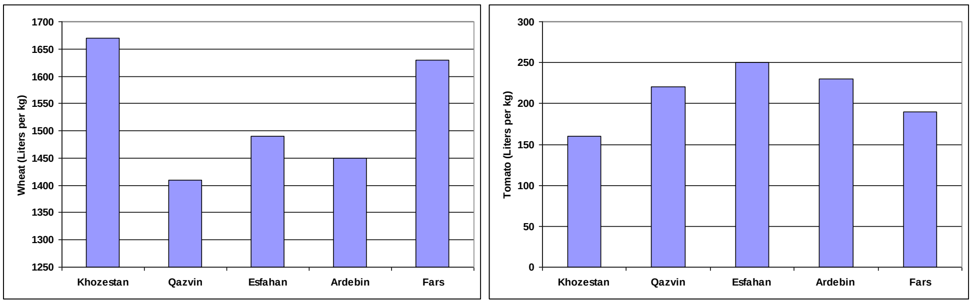

Figure 5. Virtual waters of tomato and wheat in the 5 provinces in Iran
(eaux virtuelle de la tomate et le blé dans les 5 provinces de l'Iran)

5- PROCEDURES TO COPE WITH WATER CRISIS

5-1- Considering further use of "green water" to produce food such as rainfed agricultures, pastures, etc.

Green water supplies 85 percent water demand of total agricultural crops in the world. 40 percent of the world precipitation enters the rivers, lakes, seas and groundwater aquifers, while the remaining 60 percent is absorbed in the soil as moisture. Such hidden moisture is called "green water". Green water is vital for the growth of flora, natural pastures & rainfed lands; without which, water of rivers, seas and groundwater aquifers is certainly not enough to supply the growing demand of the world food security.

Hence, further use of green water is one of the most effective methods for decreasing the pressure on the surface water and groundwater resources. Issues such as climate conditions, as well as, spatial, temporal and amount of precipitation are really important in green water use.

In arid and semi – arid countries, the major burden of producing food products is on "blue water"; however, proper management of green water resources can help us produce more food products. One of the effective methods to withdraw green water is paying more attention to the grazing lands with procedures as follows:

- Providing the required forage of tribal & rural livestock (Figure 6);
- Producing products such as medical plants, gums and resins;
- Applying soil conservation and management; soil erosion prevention, and hydrologic cycle regulation in nature;
- Safeguarding flora and fauna genetic reserves;
- Securing food and shelter for wildlife and birds;
- Providing green environment, as well as, purifying weather and ecotourism.

It is estimated that 40 percent of the required livestock forage, and 30 percent of the red meat (about 250'000 tons) produced in Iran per year are supplied by rainfed agriculture (green water).

Considering 15 m^3 virtual water for producing one kg red meat, one can estimate that 3.75 billion m^3 virtual water is withdrawn from green water. Besides, livestock by – products such as wool, hide, and milk possess a lot of virtual water dispensed with in the above – mentioned estimation. Therefore, it is recommended that arid and semi – arid countries not concentrate all of their activities on "blue water" management (by erecting dams, drilling wells, etc) but supply part of their water demand by producing crops via "green water".

Figure 6. Pasture in Iran (Pâturage en Iran)

5-2- Concentrating on economic comparative advantages by using "blue water" for agricultural and nonagricultural products with high economic value

Non – standard and too much use of water resources with justification of national policy such as "national self–sufficiency" and "employment creation" is prevalent in certain countries. However, sustainable development is not fulfilled by too much pressure on water resources such as fossil water (Figure 7). Widespread output of agricultural products may not have economic comparative advantage in countries with severe water deficit. It is recommended that part of water used in the agricultural sectors be allocated to the other sectors such as Industry.

Figure 7. Withered trees because of drought in Kerman province-Iran
(arbres desséchés à cause de la sécheresse dans la province de Kerman, Iran)

5.3. Decreasing wastes in the agricultural sector and reusing the agricultural wastes for food production

Considering virtual water theory, one can understand that every product contains some water. Therefore, saving and decreasing agricultural and non – agricultural wastes should mean providing extra water for the other uses. Most of goods and products require a lot of water during the production process. Disposal of used goods is ignoring a large part of such virtual water. Gathering and recycling most of the used products such as paper, plastic, metals, etc. shall be very effective in saving water. Two examples shall be presented as follows:

5.3.1. Water loss by disposable wastes

According to FAO statistics, Iran population is one percent of the world population, but consumes 2.5 percent of the whole world wheat. Of course, economic and cultural varieties may cause wheat consumption differences in the world countries; however, such statistics reveals unreasonable high rate of wheat wastes and consumption in Iran. The world annual per capita wheat consumption is about 90 kg, but in Iran it is more than twice as much, that is, 200 kg.

In spite of very high importance of wheat in Iran, the rate of wheat & bread wastes in Iran is high. According to reports of Iran Wheat Site (IWS), wheat wastes rate is 20 - 25 percent and bread wastes rate is 30 – 35 percent. Considering wheat cultivation area of 6.9 million hectare in Iran with 30 – 35 percent wastes, one can assume that products of about 2.2 million hectare of Iran cultivable area with its relevant agricultural inputs are all lost. According to IWS report, about 2 - 2.5 million ton wheat is lost via waste and smuggling in the country.

Therefore, it is estimated that the volume of this amount of wheat virtual water is about 10 billion m^3, that is, one ninth of total annual water allocated for the agricultural sector in Iran.

One of advantages in highlighting virtual water theory is absorbing the attention of the people to the huge volume of water loss through wastes of goods and food products. The relevant cases to be recommended are as follows:

- Relevant communication of news and information to people by mass media should seriously be considered in water resources management;
- Amount of goods virtual water, as well as, their production location should be tagged on the products. Such wise steps shall have positive effects on economizing in the use of virtual water.

5.3.2. Use of agricultural wastes for protein production

There are worthwhile various ways of protein production from agricultural wastes including production of edible fungi from wheat stalks and poultry manures. By this way, it is possible to use the existing virtual water in the agricultural wastes for protein production.

Per capita edible fungus consumption in Iran is about 300 grams while the average per capita consumption in the world is between 1.2 and 1.5 Kg. In case per capita fungus consumption in Iran reaches one Kg, potential fungus production shall be 70'000 Tons. Considering 15 cubic meters water saved per one Kg mushroom for protein production, it is possible to save one billion cubic meters water by using agricultural wastes for food production (Figure 8).

Figure 8. Edible fungus production by using agricultural wastes
(production champignons comestibles en utilisant les déchets agricoles)

5.4. Increasing Food production by applying methods without using fresh water, such as fishery development

Careful observing one's food basket, one can understand that some varieties of foods don't require fresh water. Sea-food such as various fishes, shrimps, lobsters, shells, etc. are creatures which produce protein by using saline water and the other nourishing sea-food. Such a case is really noticeable because protein is one of the most important needs of human beings.

Supply of sea-food protein can substitute for the protein produced from mutton, beef and the other non -sea food which require a lot of virtual fresh water. Besides, synthetic supply of aquatic creatures in the farms is another procedure to produce protein, to diminish pressure on water resources, and to increase employment.

This policy is seriously followed in Iran. In addition to development of fishing in the sea, policy of producing aquatic creatures in irrigation and drainage canals, aquatic farms, etc is persuaded. In the existing conditions, aquatic supply is about 600'000 tons which shall reach one million tons in the near future. Fulfilling the promise of such an amount of fishing, we shall save 15 billion m^3 water for the other uses if we consider 15 m^3 water per Kg protein production.

Furthermore, some of aquatic creatures not directly consumed for human beings nourishment, shall eventually be used as food for animals such as poultry for indirect protein supply (figure 9).

Figure 9. Pool of fish breeding in Iran (Pool de la pisciculture en Iran)

5.5. Using modern biotechnical methods for producing food products resistant against salinity and dryness, as well as, producing food with methods such as tissue cultivation

Modern biotechnical methods have provided very good opportunities for supplying additional food. For example, manipulating the plants genetics, we can further develop species resistant to dryness salinity and pests. We are also able to produce, new species of animals and plants by applying modern methods to supply more outputs with the same existing inputs.

It should be considered that at the present time the amount of agricultural inputs for supplying food products is very high. Thus, a lot of water, energy, labour, fertilizer, poison, etc. are annually required to supply such products. Cultivation in planned areas is one of modern techniques to supply food products.

Planned areas are those in which all or one of growth factors of plants such as light, water, food materials, weather and moisture shall intelligently be planned, controlled, and supervised (Figure 10). The amount of plant used water shall noticeably decrease and the output productivity shall increase a lot in such conditions. In other words, applying the modern techniques, we can produce a lot of agricultural products by using considerable volume of virtual water, but with very much less real water. Therefore, the share of water for residential areas, industry, etc. shall increase.

Figure 10. Tomato production by Hydroponics in Iran
(La production de tomates en hydroponique en Iran)

As another example, water consumption for cucumber and tomato under two conditions of hydroponic cultivation, and farm plantation is noticeable. Production of one kg cucumber under hydroponic method requires 10 liters of water while under farm condition it takes 20 times as much. Water used for one kg tomato in farm is about 10 times as much water required under hydroponic method.

5.6. Observing crop pattern with less virtual water

Genetics specifications of plants, time of cultivation, climate, and the other factors let virtual water of similar agricultural products differ in various regions of Iran. In case each product comparative advantage is identified according to the least use of virtual water in every region, crop pattern shall be arranged according to the relevant comparative advantage of that product to decrease average virtual water of Iran products. Having obtained such data of virtual water, we shall be able to draw the map of agricultural products comparative advantage in Iran.

5.7. Changing Food Diet

A vegetarian diet takes less water in the production cycle compared with a meat-oriented one. With higher per capita income and people's change of diet, additional food and water may be required for supplying food products.

Frankly, one can not make the people be merely vegetarian. A healthy diet should be various and composed of meats, cereals and vegetables. In general, the idea of omitting meat because of requiring a lot of water is neither acceptable nor possible. However, it is rational to make the people aware of the high volume of water requirement of red meat so that they gradually decrease its consumption in the long-run.

We can decrease dependence on importing virtual water, exuberant financial & political costs, as well as, diminish pressure on water resources. By changing food diet. Total change may not occur, however, any change in decreasing per capita water footprint of the society shall save and reserve more water.

CONCLUSIONS

The existing anxiety is that whether water resources are used in the best method? Are the supply of agricultural products sustainable with such method? Are the environmental effects resulted from irregular use of water monitored? How can we initiate new procedure (s) to the world for virtual water and to what extend?

One of the pivotal points in virtual water analysis is absorbing the attention of the people to the kind of water, as well as, to the place and time of production. Classification of water types in blue, green, and grey ones, as well as, illustrating specifications and potentials of each type shall help to the better understanding of the planning and organization. Specific planning and management is required for each kind of blue water, and green water. The share of blue water in the world food production is only 15 percent for which 70 percent of the whole world blue water withdrawals are used via agricultural sector.

It seems that Iran concentrates on blue water. Therefore, most of capital investments and costs are allocated to control, regulate and manage the blue water.

As 85 percent of the world food production is supplied via green water, it is recommended that policy makers in Iran focus on application of green water as a rational procedure to mitigate the pressure on surface water and groundwater resources of the country. In case the application of green water in Iran is increased by coordinated managements, researches and investments, extra pressures on water withdrawals from critical ground aquifers shall decrease.

At present, the use of green water in Iran's food security is insignificant; however farmers formerly applied sustainable local methods in application of green water for rainfed agriculture and livestock breeding as well in many area.

Having started technological development by the public sector, Iran further concentrated on blue water types instead of initiating proper technology in green water ones. Therefore, green water potentials and capacities gradually got a forlorn state.

Over deca – billion m^3 green water is annually released and evaporated uselessly. Management and using of green water in Iran can really be effective on supplying food security and confronting water scarcity.

Iran water resources are seriously limited. Hence, the exiting unilateral management in which water resources are allocated for various demands should be changed into comprehensive water management of supplying, producing, and consuming.

Identifying the amount of virtual water used in various goods and food products shall be a guide for policy making of macro – economics management relevant to Iran water resources. Water loss in various forms such as wastes of goods and food products should be studied and controlled.

REFERENCES

Chapagain, A.K. and A.Y. Hoekstra. 2004. Water Footprints of Nations, vols. 1 and 2. UNESCO-IHE Value of Water Research Report Series No. 16. Available online at www.waterfootprint.org, accessed 24 January 2007.

Ehsani M. 2005. A Vision on Water Resources Situation, Irrigation and Agricultural Production in Iran. ICID 21st European Regional Conference

Ehsani M., Khaledi H. 2004. Water Productivity in Agricultural. Iranian National Committee on Irrigation and Drainage (IRNCID). Tehran. Iran.

Ehsani M., Khaledi H. 2009. Introduction to Virtual Water. Iranian National Committee on Irrigation and Drainage (IRNCID). Tehran. Iran.

Hoekstra, A.Y. 2008. Water Neutral: Reducing and Offsetting the Impacts of Water Footprints. Research Report Series No. 28. UNESCO.

Irrigation in the Middle East region in figures – AQUASTAT Survey 2008

Renault D., 2002. Value of Virtual Water in Food: Principles and Virtues. Food and Agriculture Organization of the United Nations.

Statistical Center of Iran, http://www.sci.org.ir

Web site of Iran wheat analyze, www.iranwheat.ir

Zygmunt J., 2007, Hidden Waters; A Waterwise Briefing, www.waterwise.org.uk, February 2007