Water rationalization in Egypt from the perspective of the virtual water concept

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Abstract. Egypt is located in the hyper arid climatic zone, where rainfall is scarce and the desert covers most of the land. The available water resources in Egypt are restricted to a fixed Nile quota (i.e. 55.5 billion cubic meters) in addition to a deep non-renewable groundwater reservoir and a total annually torrent water of 1.5 BCM. Water demands were multiplied in recent decades as a result of overpopulation, agriculture expansion and industrial and living standard progress. The water shortage is the main constraint and a major limiting factor facing the implementation of the country future economy in industry, several actions are required to rationalize water uses. Recycling of agriculture wastewater and trapping water losses are satisfying the Egyptian water needs, which are 25% higher than the available water resources. Municipal water distribution networks in Egypt have witnessed great expansions during the last three decades in order to cope with the rapid urbanization projects and increased population. In this paper, a vision for the future water status in Egypt is presented. This vision is based on a perception of the current available water resources status. The topics of water usage, water use efficiency, the institutional and legislative frameworks of water management, and the strategies and policies to rationalize water use and to augment water supply are discussed. It was concluded that virtual water concept is an essential tool in calculating the real water use of a country, or its water footprint. Water losses in Egyptian agriculture sector are very large compared with these losses in industrial and domestic uses. So it is very important to take the concept of virtual water in consideration when the issue of water rationalization is discussed.

Keywords. Egypt – Water rationalization – Virtual water – Water use efficiency.

Rationalisation de l'eau en Egypte du point de vue du concept de l'eau virtuelle

Résumé. *L'Egypte est située dans une zone climatique hyper-aride, où les précipitations sont très faibles et le désert couvre la grande partie du territoire. Les ressources en eau disponibles en Egypte sont limitées à une quote-part du Nil établie (à savoir, 55,5 milliards de mètres cubes) en plus d'un réservoir d'eaux souterraines non-renouvelables profondes et d' une quantité d'eau torrentielle annuelle de 1.5 milliards de mètres cubes. Ces dernières décennies, la demande d'eau s'est multipliée à cause du surpeuplement, de l'expansion de l'agriculture et de l'accroissement de l'industrie et de l'élévation du niveau de vie. La pénurie d'eau représente la contrainte majeure et le principal facteur limitant pour le développement de l'économie industrielle du pays. Des actions différentes sont donc nécessaires pour rationaliser l'utilisation de l'eau. Le recyclage des eaux usées en agriculture et la réduction des pertes d'eau contribuent à satisfaire les besoins en eau dans le pays, qui dépassent de 25% les ressources en eau disponibles. En Egypte, les réseaux municipaux de distribution de l'eau ont connu une expansion considérable ces trois dernières décennies afin de faire face aux projets d'urbanisation rapide et à l'accroissement de la population. Dans ce travail, nous allons présenter une vision du statut de l'eau futur en Egypte. Cette vision repose sur une perception du statut actuel des ressources en eau disponibles. L'accent est mis sur des thèmes tels l'utilisation de l'eau, l'efficience d'utilisation de l'eau, le cadre institutionnel et réglementaire de la gestion de l'eau et les stratégies et les politiques pour rationaliser l'utilisation de l'eau et augmenter l'approvisionnement. On en conclut que le concept d'eau virtuelle est un outil essentiel pour le calcul de l'utilisation réelle de l'eau d'un pays ou de son empreinte sur l'eau. Dans le secteur agricole, les pertes d'eau sont très significatives par rapport aux pertes pour l'usage industriel et ménager. Par conséquent, il est très important de considérer le concept d'eau virtuelle dans la débat sur les enjeux de la rationalisation de l'eau.*

Mots-clés. *Egypte – Rationalisation de l'eau – Eau virtuelle – Efficience d'utilisation de l'eau.*

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I – Introduction

Egypt is located in the hyper arid climatic zone, where rainfall is scarce and the desert covers most of the land. In addition to its fixed Nile quota, a deep non-renewable groundwater reservoir may be utilized with a rate of 2.7 BCM/year over a period of 100 years. The higher the exploitation rate, the shorter the period of use will be. Egypt is now capable of satisfying its water needs, which are 25% higher than the available water resources, through recycling of agriculture wastewater and trapping water losses. The water shortage is the main constraint and a major limiting factor facing the implementation of the country future economy.

The water demands were multiplied as a result of population growth, agricultural expansion, industrial development and rising of living standards. In this paper, a vision for the future water status in Egypt is presented. This vision is based on a perception of the current available water resources status. The topics of water usage, water use efficiency, the institutional and legislative frameworks of water management, and the strategies and policies to rationalize water use and to augment water supply are discussed.

Renewable water resources in Egypt are confined to the withdrawal quota from the Nile, the limited amount of rainfall, the shallow groundwater reservoirs in the Nile Valley and Delta and the coastal strip. The deep groundwater in the eastern desert, the western desert and Sinai, are almost non-renewable resources. The non-traditional water resources include reuse of agricultural drainage water and treated wastewater, as well as the desalination of seawater and brackish groundwater. Agriculture in Egypt, as in most developing countries, represents the main usage of water, followed by the residential, industrial and tourist uses. It is worth to mention that these sectors are users, as well as consumers of water, while other sectors like river transport and hydropower generation only use water without real consumption. Most data available on water uses in Egypt are approximate and are not based on field measurement, because there are no measuring devices with acceptable accuracy for the water uses for either irrigation or the municipal and industrial sectors.

II – Water supply in Egypt

There is no effective rainfall in Egypt except on a narrow strip located along the northern coast; agriculture is almost totally dependent on irrigation. The total water resources currently available in Egypt are totally estimated as 73.8 billion cubic meters (BCM) per annum, including the natural and non-traditional resources. Table (1) shows that the present annual use of water is 62.6 BCM. Table (2) shows the distribution of water consumption between the various sectors. The agricultural sector consumes about 81 percent of the total water available. The total torrent water is estimated at 1.5 BCM annually. The Nile is the major source of water in Egypt and agricultural development is closely linked to the Nile River and its management.

A major component of the strategy for agricultural development is the improvement of the efficiency of Nile water use, increasing the productivity per water unit. Total water consumption in the year 1995 was approximately 49 BCM. Water consumption for the proposed cropping pattern for the year 2017 should amount to around 67 BCM for the cultivation of about 9.2 million ha. The additional water is expected to result from reducing the area under rice to 420 000 ha and the cultivation of new varieties with a shorter growth duration and lower water consumption. This should reduce the consumption of irrigation water for rice cultivation by four BCM. A saving in the consumption of water on sugar cane is expected to be almost 0.5 BCM as a result of improving water use efficiency and land leveling by laser of about 42 000 ha. A further saving is expected to result from improving the use of drainage water and the use of nonconventional water resources. The Government has indicated its intent to shift emphasis from its role as the central (or sole) actor in developing and managing water supply systems, towards promoting participatory approaches in which water users will play an active role in the management of irrigation systems and cost sharing. Important institutional and legislative measures have been taken recently to promote the establishment of sustainable participatory irrigation management (PIM) associations. However, despite these measures, the development of water users associations (WUA's) as effective partners in irrigation management remains at an early stage. In the new lands, the concept of PIM is not yet effectively operational for a variety of economic, financial and institutional reasons. While most settlers recognize the importance of WUA's in the equitable distribution of available water, uneven water availability, either due to design shortcomings or to lax enforcement of rules against excess abstraction by front-end water users, has acted as a disincentive to the successful operation of WUAs in many instances (FAO, 2000).

Table 1. Availability and current use of water.

Source	Availability BCM/annum	Percent	Current use BCM/annum	Percent
Nile	55.5	75.2	51.7	82.6
Underground	11.3	15.3	5.2	8.3
Agriculture*	5.0	6.8	3.7	5.9
Waste water	1.5	2.03	1.5	2.4
Rainfall	0.5	0.67	0.5	0.8
Total	73.8	100	62.6	100

*Re-use of drainage water
(Source: FAO, 2003)

Table 2. Distribution of water use by sector.

Sector	Consumption BCM/annum	Percent
Agriculture	50.8	81.1
Industrial and municipal	8.8	14.1
Electricity	2.0	3.2
Navigation & winter closure	1.0	1.6
Total	62.6	100

(Source: FAO, 2003)

III – Policy of water resources in Egypt

In 1929, an agreement between Egypt and the United Kingdom, on behalf of the Sudan, was signed to ratify the historical Nile water rights for each country. The recorded water rights were 48 billion cubic meters (BCM) for Egypt and four BCM for Sudan. In 1933, the Government of Egypt implemented a water policy designed to benefit from the extra storage of the Nile water upstream from the old Aswan reservoir after its second elevation. That policy aimed at cultivating additional 160,000 ha in Lower Egypt and converting 208,000 ha from basin to permanent irrigation, along with the establishment of public open drains in the permanent irrigation areas. In 1948, the Egyptian Government presented a memorandum to the cabinet showing that after 1950 there would be a pressing need to find extra water resources. The memorandum recommended several Upper Nile projects to increase the river flow and to avoid flood hazards. After the 1952 revolution, the High Aswan Dam (HAD) project was presented to the Government and was approved. Its construction was planned for inside Egypt, as compared to the Upper Nile projects.

In 1959, an agreement between Egypt and the Sudan had been reached for the optimal use of Nile Water as an integral part of 1929 agreement. According to the agreement, the quota for Egypt and the Sudan had been increased by 7.5 and 14.5 BCM, respectively. These values were calculated according to the mean annual natural Nile flow at Aswan, Egypt, from the recorded inflows for 70 consecutive years, (i.e. 84 BCM/year). Moreover, it was recommended to trap the Upper Nile water losses and optimally utilize those losses in equal shares. The new quota allowed Egypt to increase its cultivated area to reach 2.4 million ha. In 1975, the Ministry of irrigation established a policy aiming at rebalancing the water status. Rebalancing was proposed through the rationalization of crop water applications, on basis of scientific studies and field experiments. The additional demands were to be satisfied by the reuse of drainage water, expansion of groundwater utilization especially in the Nile Delta region and the optimal use of rainfall on the Northern coast. In 1977, the Ministry of Irrigation began preparing the National Water Master Plan (NWMP) in collaboration with the German Development Bank (KFW) and UNDP. The NWMP aimed at setting plans to satisfy water demands over a period of 20 years (1980–2000). In 1982, the Ministry of irrigation reset its water policy according to the results of the NMWP; the new policy showed that 11.7 BCM of extra water was needed to satisfy future water demands. The policy showed that this additional water could be secured through Egypt share in the first phase of the Jonglie canal (2.0 BCM/year), which was designed to trap a small port on of Nile water losses in the Sudd region, southwest of the Sudan. Ultimately, this plan was intended to increase groundwater utilization up to 4.9 BCM/year and to expand drainage water reuse practices up to 10 BCM/year. In 1994, Ministry of Water resources and irrigation (MWRI) and the General Authority for Land Reclamation prepared a comprehensive and ambitious plan intended to expand the country's agricultural horizon by 1.28 million ha up to the year 2025. This would be achievable by limiting the rice area to 280,000 ha; improving surface irrigation projects; maximizing the drainage water reuse, treated wastewater recycling, and optimizing groundwater utilization, as well as the completion of the first phase of the Jonglie canal. In October 1997, MWRI prepared a draft of "Water resources Strategy of Egypt Until 2017" The strategy also analyzed the projected water balance in the year 2017 for three scenarios: the first is for reclaiming 612,000 ha, the second is for reclaiming 0.9 million ha, and the third for reclaiming 1.36 million ha. Securing the required extra water (about 24 BCM) has to be accomplished through the completion of the first phase of Jonglie canal, an increase in groundwater utilization, water reuse practices, and a reduction of the areas of high water requirement crops (MWRI, 1997).

IV – Water management practices in Egypt

Since the 1970's, water uses in Egypt have exceeded the available resources. Accordingly, the Government has provided additional resources by recycling drainage and wastewater, trapping water losses, and with water use rationalization practices. At present, municipal and industrial uses involve many negative aspects. These include high losses in the distribution networks, misuse of clean drinking water in small factories, workshops, car washing, and in irrigating backyards and public gardens. Other irrational uses include the absence of long-term technical or financial plans for preventive maintenance; and inadequate tariff policy.

Municipal water distribution networks in Egypt have witnessed great expansions during the last three decades in order to cope with the rapid urbanization projects and increased population. The irrigation improvement Project (IIP) in Egypt was launched due to the impetus of a leading research project executed by the National Water Research Center (NWRC) in 1977-1984. The project examined various alternatives capable of improving the on farm water management practices, including laser land leveling, developing mesqa (tertiary canal) and water distribution structures, and forming water users associations (WUAs). This project provided the following benefits;

1. Land saving due to the construction of the improved mesqas and saving about 2% of the total command area of the mesqa for agriculture.
2. Increase of crop yield due to the better conditions of water availability.
3. Equity of water distribution by improving the water allocation between the head and tail of the mesqa.
4. Reduction of 50-60% of irrigation time due to improving the conveyance efficiency and irrigation scheduling.
5. Using the findings of that research project in a large improvement program (1984-1996) implemented by MWRI on an area of 156,000 ha in five Governorates.

Another irrigation improvement project started in 1997 over an area of 100,000 ha. The irrigation and drainage law No. 12 for the year 1984 was amended to recover the relevant improvement cost from farmers at installments over twenty years without interest. There were also pilot projects to establish federations of WUA's and to form water boards to take part in Operation and Maintenance of branch canals. On one hand, the various irrigation improvement projects have several positive impacts (Allam, 1995). On the other hand, there were various difficulties like the slow rate of implementation, high cost of improvement, weak monitoring and follow-up programs, and funding problems for the pumping units for the raised mesqa (MWRI, 1998). The government has imposed modern irrigation methods in the new lands, however the relatively high maintenance costs caused the farmers to remove drippers or sprays and thus convert modern irrigation methods into surface ones. The government is planning to switch the orchards and other fruits farms into drip irrigation to save about 0.75 BCM/year. The main obstacle that faces this program was providing the funds needed for modernization. Farmers have no significant incentive to share the cost, as long as the government provides their water requirements free of charge. The crops of high water requirements are mainly sugarcane, banana and rice. Sugarcane is cultivated in Upper Egypt with a total area of less than 200,000 ha. Although one ha of sugarcane consumes triple the amount of water required for one ha of sugar beets, it is difficult to convert sugarcane agriculture into sugar beets. Firstly, because most of the existing sugar mills are sugarcane mills. Secondly, sugar beet is a winter crop and may not be suitable for the relatively hot climate of Upper Egypt. The solution may be the improvement of the irrigation methods for sugarcane to decrease the losses, as well as a gradual reduction of sugarcane areas. In light of the deregulation of crops prices, rice became one of the most important lucrative crops for farmers. Its grown areas gradually increased from about 280,000 ha by the mid-70's to about 0.8 million ha in 2000. Rice has become one of the most important Egyptian exports in the agricultural sector. The real intentions of the government towards this crop are not yet clear. The banana farms, on the other hand, consume a lot of water; most farms are in the newly reclaimed sandy soils which area characterized by excessive natural drainage.

V – Virtual water concept

Virtual water is the amount of water that is embedded in food or other products needed for its production. For example, to produce one kilogram of wheat we need about 1,000 liters of water (i.e. the virtual water of this kilogram of wheat is 1,000 liters), meat needs about five to ten times more. The per capita consumption of virtual water contained in our diets varies according to the type of diets, from 1m3/day for a survival diet, to 2.6m3/day for a vegetarian diet and over 5m3 for a USA style meat based diet. It is clear that moderating our diets especially in the developed world could make much water available for other purposes.

With the trade of food crops or any commodity, there is a virtual flow of water from producing and exporting countries to countries that consume and import those commodities. At the global level, virtual water trade has geo-political implications: it induces dependencies between countries. Therefore, it can be regarded either as a stimulant for co-operation and peace or a reason for potential conflict. The water consumed in the production process of an agricultural or industrial product has been called the ‘virtual water’ contained in the product (Allan, 1998). If one country exports a water intensive product to another country, it exports water in virtual form. In this way some countries support other countries in their water needs. For water-scarce countries it could be attractive to achieve water security by importing water-intensive products instead of producing all water demanding products domestically. Reversibly, water-rich countries could profit from their abundance of water resources by producing water-intensive products for export. Trade of real water between water-rich and water-poor regions is generally impossible due to the large distances and associated costs, but trade in water-intensive products (virtual water trade) is realistic (Hoekstra and Hung, 2002).

Virtual water trade between nations and even continents could thus ideally be used as an instrument to improve global water use efficiency, to achieve water security in water-poor regions of the world and to alleviate the constraints on the environment by using best suited production sites (Turton, 2000).

VI – Planning water policy using virtual water concept

Virtual water is an essential tool in calculating the real water use of a country, or its water footprint, which is equal to the total domestic use, plus the virtual water import, minus the virtual water export of a country. A nation’s water footprint is a useful indicator of the demand it places on global water resources. At the individual level, the water footprint is equal to the total virtual water content of all products consumed. A meat diet implies a much larger water footprint than a vegetarian one, at an average of 4,000 liters of water per day versus 1,500. Being aware of our individual water footprint can help us to use water more carefully. Virtual Water for Crops (tables 3 & 4); water lost along with loss of different types of food (table 5), Agriculture crop trade balance (table 6 & 7), irrigation efficiency (table 8) and cropping pattern table 8) are the most important elements for obtaining the best water schedule and rationalization.

This information reveals the following:

- Crops are differing widely in their water use efficiency; some crops have low (need more than 2000 m^3/ ton), moderate (need more than 750 m^3/ ton) and high efficiency (need less than 500 m^3/ ton).
- The production of 1 liter from sunflower oil needs to 8000 liter of water, while production of 1 Kg vegetables require only 250 liter of water.
- The crops or food lost means the lost of water, this lost is very high in the case of low water efficiency crops (sugar and oil crops and rice), whereas it is low in the case of high efficiency crops (fruits and vegetables).

Table 3. Virtual Water for Certain Crops in Egypt.

Virtual Water m³/ton	Crop
Low Efficiency Crops	
10000	Soya bean
8000	Sun flower
3500	Cotton
2700	Sugar Cane
2300	Peanuts
2000	Rice
Medium Efficiency Crops	
1330	Banana
1300	Sugar beet
1080	Faba bean
960	Corn
750	Wheat
High Efficiency Crops	
600	Olive
500	Grape
440	Citrus
480	Bean
250	Potato
225	Melons
200	Tomato
130	Onion

Calculated and modified after FAO (2005) and MALR (1994).

Table 4. Virtual water content of certain crops in Egypt and the world.

Virtual water m³ / ton		Crop
World range	**Egypt**	
1000-1700	2700	Sugar cane
900-1450	2000	Rice
700-1100	1300	Sugar beet
250-400	1300	Banana
200-500	500	Citrus
80-100	200	Tomato

Calculated and modified after FAO (2005) and MALR (1994).

The data in table (5) refer the following:

- The loss of one loaf of bread means the loss of 75 liters of water
- The loss of a cup of tea (three cubes of sugar) means the loss of 40 liters of water
- The loss of cup of rice means the loss of 200 liters of water
- The loss of one spoon of sunflower oil means the loss of 80 liters of water

Table 5. Volume of water lost along with loss of different types of food.

Water (liter)	Type & Quantity
75	Loaf of Bread (100gr.Wheat)
54	Broad Bean (50gr)
38	One Potato (150gr)
30	One Tomato (150gr)
66	One Orange (150gr)
400	Cup of Rice (200gr)
200	One Banana (150gr)
13	Cube of Sugar (5gr)
80	Spoon of Sun Flower oil (10ml)

Calculated and modified after FAO (2005) and MALR (1994).

Table 6. Agriculture crop trade balance in Egypt.

Crop	Production $10^9 m^3$	Exports $10^9 m^3$	Imports $10^9 m^3$
Wheat	4.7		4.5
Corn	5.9		4.3
Pulses	0.4		0.3
Sugar	3.8		1.3
Plant oils	0.8		7.2
Meat	10.9		1.6
total	26.5		19.2
Cotton	3.5	0.35	
Rice	7.8	0.80	
Potatoes	0.6	0.08	
Vegetables	3.5	0.09	
Fruits	3.5	0.06	
total	18.9	1.38	

Calculated and modified after FAO (2005) and MALR (1994).

Table 7. Virtual water trade balance in Egypt.

Crop	Production 10^6 ton	Exports 10^6 ton	Imports 10^6 ton
Wheat	6.3		6.0
Corn	6.1		4.5
Sugar	1.4		1.0
Vegetables oils	0.1		0.9
Meat	1.3		0.12
total	15.6		12.82
Cotton	1.0	0.10	
Rice	3.9	0.40	
Potatoes	2.2	0.30	
Vegetables	14.0	0.35	
Fruits	7.0	0.12	
total	28.1	1.27	

Calculated and modified after FAO (2005) and MALR (1994).

The daily Food & water consumption of Egyptian family (5 persons) represented in table (8) show that a loss of 5% means the loss of 2.4 BCM /year (this amount of water is sufficient to cultivate 100,000 ha / year.

Table 8. The Daily Food & water Consumption of Egyptian Family (5 persons).

Water) Liter)	Quantity gr./day	Type
1500	2000	Wheat
770	800	Corn
1110	550	Rice
990	410	Sugar
75	292	Potatoes
120	112	Pulses
250	114	Oil Seeds
1200	150	Vegetable Oil
480	2400	Vegetables
540	1200	Fruits
	310	Meat
	27	Offal
	653	Milk
	29	Egg
	32	Animal Fat
1785	1051	Total (animal Products)
	136	Fish
8820	9215	Total

Calculated and modified after FAO (2005) and MALR (1994).

Table (9) represents the annual loss of water along with the post harvesting processes. The data indicate that the total value of the loss water is satisfied to cultivate 125,000 ha/year also this amount representing 75% of the domestic use of water in Egypt. The data refer to the importance of the use of the virtual water concept in the issue of water rationalization.

Table 9. Quantity of water lost along with post harvest losses.

Wasted Water	Post Harvest Losses		Crop
Mm³	% from Production	1000 Ton	
905	19	1207	Wheat
448	6	224	Rice
809	14	843	Sorghum
71	8	74	Starchy Roots
54	10	214	Sugar Crops
44	1	145	Legumes
37	9	1344	Vegetables
269	10	663	Fruits
47	2.5	21	Oil crops
2976	-	4769	Total

Calculated and modified after FAO (2005) and MALR (1994).

VII – Conclusion

Virtual water (impeded water) is an essential tool in calculating the real water use of a country, or its water footprint, which is equal to the total domestic use, plus the virtual water import, minus the virtual water export of a country. A nation's water footprint is a useful indicator of the demand it places on global water resources. At the individual level, the water footprint is equal to the total virtual water content of all products consumed. A meat diet implies a much larger water footprint than a vegetarian one, at an average of 4,000 liters of water per day versus 1,500. Being aware of our individual water footprint can help us use water more carefully.

In Egypt the water losses in the agriculture sector is very large compared with these losses in industrial and domestic uses. So it is very important to take the concept of virtual water in consideration when the issue of water rationalization is discussed.

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