10.7251/AGSY13031187S

CONTRIBUTION OF VIRTUAL WATER TO IMPROVING WATER SECURITY IN TUNISIA: A CASE STUDY OF WHEAT AND OLIVE GROWING FARMS IN ZAGHOUAN REGION

Asma SOUISSI*, Abdallah BENALAYA, Belhassen ABDELKEFI, Talel STAMBOULI, Lamia GHEZAL, Rabeh BELAID, Youssef NACEUR, Marwa OUESLATI, Saida FEKIH, Saker BENABDALLAH, Aymen FRIJA

Affiliation: ESA Mograne, 1121 Mograne-Zaghouan, Tunisia.
*(Corresponding author e-mail: asma.s@hotmail.com)

Abstract

Virtual water represents all freshwater used in the process of producing a commodity. In the case of agricultural products, many studies have focused on quantifying virtual water flows through international trade products. The concept of virtual water commercialization should be carefully studied as a potential solution for water scarcity, especially in countries facing risks of water shortage in a few years such as in Tunisia.

The main idea of this paper is to optimize water use, by the mean of estimation of virtual water in exported crops which have high water consumption. We also analyze the crops that are imported and therefore, might contribute to save water.

Commonly exported and imported crops are widely cultivated in the region of Zaghouan characterized by diversity of agricultural products. That's why it could represent a good case study from Tunisia. In this study we especially focus on olive oil which is one of the most strategic exported products in Tunisia and on wheat as main imported product.

We attempt to create technical and economic data sheets through monitoring about 40 farmers in this region. These sheets are not only to estimate the gross margin but also to calculate water demand for each crop allowing the estimation of virtual water. We found out that Tunisia may saves 1.13 m^3 of water per kilogram of wheat if we import it instead of producing it domestically. In the case of olive trees, for an average yield of 2339 kg per hectare we exports 2.10 m^3 of virtual water for every kilogram of exported olive.

Results presented in this study are of essential implications for policy making regarding water use optimization and water security enhancement.

Keywords: Tunisia, water scarcity, virtual water, international trade, water security.

Introduction

Agriculture has always occupied an important place in the socio-economic development in Tunisia. The agriculture expansion is heavily relied on available natural resources, especially on water. Because of its geographical location, Tunisia undergoes the influence of two climate types: the Mediterranean type in the north and the Saharan type in the south which are at the origin of space and time variability in water resources. Therefore, the annual rainfall average varies from less than 100 mm in the extreme south to more than 1500 mm in the extreme northern parts of the country. Water resources are evaluated in 2000 to 4825 million m^3, with 2700 million m^3 of surface water and 2,125 million m^3 of ground water. Tunisia is, then, a country with relatively limited renewable water resources (SEMIDE, 2002).

That’s why; taking into consideration the scarcity of water resources in the planning of agricultural policies is necessary to improve the trade balance, to ensure a level of food security, and to enhance the countryside and the environment.
In this context, many countries attempt to reach new alternatives for the management and the sustainable use of water resources in particular. These new approaches have brought about a relatively new idea called virtual water (VW) which tries to give an explanation to water use management (Velázquez, 2007).

Virtual Water Concept

The Concept of virtual water was firstly defined by Allan (1993, 1994) in terms of the water embodied in a certain product, that is, the water necessary for creating a product.
In food products or crops products trading, there is a virtual water flow between producers and exporting countries and countries that consume and import those goods. Zimmer and Renault, (2003) had concluded that it did not make much sense to export goods that required a lot of water in countries with water deficits.
Therefore, countries facing water shortages should tend to import goods whose production requires a lot of water rather than produce these goods. The transaction resulted in actual water savings; it allows the country to not only ease the pressure on water resources, but also to save its available resources to use for other purposes.
According to the Blue Plan (2008), agricultural products’ trading is responsible for nearly 90% of virtual water exchange in the world. It is indeed difficult to carry water, then it is easier to trade agricultural products whose production is a major consumer of water in the world (Fernandez and Thivet, 2008). Thus, food import is equivalent to the import of water condensed form. This is called virtual water import (Allan, 1998).
The virtual water concept has also shown up influence of consumer’s food preferences and agricultural policies in the surplus producing areas to the detriment of water resources (Renault, 2002) and consequently has drawn attention internationally to the issue of the irrigated agricultural activity distribution between different parts of the world and the organization of global food markets.
Quantification of virtual water flows in agriculture allows illustrating interactions between agricultural and water policies and their impact on the use of water resources. Policies to reduce the export of products whose production requires large amounts of water are occasionally adopted by many countries in situation of water shortage. These also tend to increase their imports of agricultural commodities.
Particularly Middle East and North Africa countries, potentially illustrate a virtual water trade strategy to compensate for water shortages and to enhance their food security (Wichelns, 2001).
To ensure food security, Tunisia imports a lot of agricultural products such as wheat, corn and barley. In 2011, wheat imports reached almost 2 million tons (FAOSTAT, 2011). In addition to food security, these imports can ensure better conservation of water resources. Such a strategy is efficient during years in which the world price of grain products is less than the cost of production especially in countries, like Tunisia, with a potential water scarcity. Nevertheless, the export of some food products such as olive oil, citrus, dates, etc., even if it involves the export of huge amounts of virtual water, it remains vital to Tunisian economy. Nearly three-quarters of these products are intended for the European market.

Objectives and structure of this study

To set this work in the right context, it is important to note that is part of a larger study in the framework of a research project about "virtual water and food security in Tunisia: from observation to support to development". This project aims, mainly, to assess the potential and challenges of virtual water in food security strategy in Tunisia and its implications on the economy of water resources.

Regarding this work, goals are more specific. Based on gross margin collected data sheets we will try to assess value of each m3 of water consumed by each studied culture. Next, we will focus on the estimation of virtual water amount needed to produce two strategic crops in Tunisia; Olive growing, since olive oil is one of the most important exported agro-food products with about 100 thousand tons in 2010 and wheat as the most imported product with 1 million tons in 2010 (INS, 2010).

Field work took place in the region of Zaghouan located in the north-east of Tunisia. The choice of this area can be justified by the fact that agricultural activities are focused on cereals and olive growing. Agricultural land is covering two thirds of the region territory with 282,000 ha, (185,000 of arable land and 87 thousand of range and forest) and water resources are mobilized by two large dams and 18 small lakes. The agricultural sector contributes significantly to regional economic growth especially since it provides about 27% of jobs.

This work would provide the basis for any discussion about Tunisian agricultural policies, rational and efficient water management in the field of agricultural production, water resources conservation and food security. The study tries to go one step forward in this field by breaking fresh ground for future research. The paper is organized as follows. After the introduction, we will explain the methodology we have used to create technical and economical data sheet, calculate gross margin and estimate virtual water. Results are analyzed in part 3. Final remarks and conclusion are included in part 4.

Materials and methods

In this work we have been monitoring the management of 22 wheat farmers and 13 olive trees farmers during a full crop season to create technical and economic data sheets, to calculate gross margins and estimate the virtual water for each studied crop. The survey covered various parts such as farmers' identification, acreage, mechanization, labor, seeds, irrigation, fertilization, treatments, yield and selling prices. All questions were about quantities, prices, dates of farming activities, costs and incomes.

Obtained information is used to calculate charges and gains of each farmer and to deduce gross margin.

Gross margin = Total incomes - Total variable charges

Technical and economic data sheets have been developed for each farm then weighted average sheets have been made for each crop. The weighting is based on the farm size.

After that, we attempt to estimate virtual water (m^3/kg) for wheat as an imported product and olive oil as an exported one. As we saw previously, virtual water is the water embodied in products, in other words, the water which is necessary to produce certain goods. Hoekstra (2002, 2003) suggested two branches to the concept to analyze the amount of water that can be saved if we import goods instead of producing them domestically: real virtual water and theoretical virtual water. The first involves the water that is actually used in the domestic production of goods. In turn, the second is the water that would have been used in the country of destination for a same production. In order to estimate the virtual water associated to olive

oil, we will estimate the amount of water actually used to produce olive oil in the studied zone. Actually we will use the concept of real virtual water created by Hoekstra et al. (2003). Conversely, we will employ the concept of theoretical virtual water to estimate the virtual water imported in wheat crops. This means the amount of water that we would have needed if we have not imported wheat but produced it instead. This theoretical concept is more suitable than the concept of real virtual water to estimate imports of virtual water in this case. This amount of water does not have to coincide with the amount we would be using in country we are importing from, on account of the differences in weather conditions, soil texture, evapotranspiration, etc. (Velázquez, 2007).
The first step to calculate virtual water is to estimate the Water Needs of a harvested Crop n (WNCn), expressed in m^3/ t (Chatzimpiros and Barles, 2007).

$$WNCn = ETPN / Rn$$

ETPn is potential evapotranspiration of the plant (mm / period of growth, calculated by the Penman-Monteith method (Allen et al., 1998) and made available by the FAO (Food and Agriculture Organization of the United Nations) and Rn the n crop yield (t / ha) (Agreste, 2006). The potential amount of water (PWn) per crop per year is then calculated by multiplying the harvested production (Pn) by WNCn.

$$PWn\ (m^3) = WNCn\ (m^3 / t) * Pn\ (t)$$

Calculation of water productivity is rather simple: crop water requirements ETa (m^3/ha) are calculated from the climatic demand (ETP) adjusted with crop coefficients (Kc). Software like CROPWAT (FAO, 1992) can be used for this purpose. Water productivity is then obtained by dividing the crop yield Y (kg/ha) by the crop water requirements. Virtual water value (VWV), the inverse of water productivity is then given by the following equation:

$$VWV=Eta / Y$$

So, virtual water of the crop per unit (m3/kg) has been estimated as the ratio of the water consumption (m^3/ha) to the crop yield (kg/ha). The water consumption is obtained by summing up the real water evapotranspiration over the growing period of rainfall and irrigated systems. The water consumption includes the proportion of the water evapotranspiration of each textural class. The virtual water volume in m^3 is calculated multiplying the final water consumption over the growing period and the crop area. The inclusion of water consumption depending on the textural class is an improvement of the method of Hoekstra et al. (2009) made by Salmoral et al. (2010).
Calculations were made with an Excel application elaborated by the project team and checked by the CROPWAT software.

Results and discussion

Conducted field surveys showed us that Tunisian farmers are usually unaware of the water needs of crops. Irrigations doses are made most of the time by the amount of available water and archaic skills based on traditional tools (foliage observation, assessing soil moisture, etc.). Distribution of irrigation doses is set randomly without really recognizing critical stages of plants development. This can be explained by the low level of education of the majority of the interviewed farmers (more than 60%) and their age that usually exceeds 50 years. The age and educational levels of the sample match with national statistics. In fact, according to the survey on the agricultural exploitations structure (2004-2005) carried out by the Ministry of

Agriculture, Water Resources and Fisheries, about 70% of Tunisian farmers are aged over 50, illiterate or with primary school education.
Concerning crops, we can say that average weighted data sheet obtained for wheat farming in the region of Zaghouan shows that for an average yield of 60 quintals/ha, gross margin is about 500 €. The value of one m^3 of irrigation water is estimated at 0.170 €. As for the olive, despite it is a low cost production crop, the average gross margin does not generally exceed 500 €. The olive trees need supplementary irrigation only during the dry period in the studied zone. One m^3 of water used for the irrigation of olive trees leads approximately to a gross margin of 0.5 €. These results are confirmed by the study of Bachta et al. (2001) about competitiveness of exported Tunisian agricultural products and costs in natural resources. This work shows that olive oil exported by Tunisia has a statistically significant explanatory power of competitive performance, contrary to wheat.
Virtual water comprises three components of different colors: the green, blue and grey waters (Allan, 1998). Quantification of virtual water flows for each of the two studied cultures showed that for wheat, volume of virtual water used is equal to 682.5mm which is the sum of the green water (useful rain) with 292 mm and blue water (irrigation water) with 390.4mm.

$$VW = VW1 * 10 / Y = 6825/6018 = 1.13 \ m^3/kg$$

VW: Virtual Water expressed in m^3/kg
VW1: Virtual Water expressed in mm
Y: Yield in kg/ha

In other words Tunisia saves 1.13 m^3 of water per kilogram if we import wheat instead of producing it in the region of Zaghouan. In the case of olive trees, the amount of virtual water used is equal to 493.5 mm or (408.5 mm, 85mm green water and blue water). This means that for an average yield of 2339 kg per hectare, virtual water is about 2.10 m^3/ kg. Consequently, Tunisia exports 2.10 m^3 of water for every kilogram of exported olive. This amount will increase considerably when we involve olive oil processing water consumption.
Importing significant quantities of wheat represent a good strategy especially when the world price is below the cost of local production. As we have already seen, by importing about 1 million tons of wheat per year, Tunisia is saving a huge amount of virtual water. Indeed, wheat is a vital commodity for food security in water scarce importing countries (Yang et al., 2006). It is also important to preserve local production. That’s why; wheat production is still being closely related to agricultural and water policy of the country.
Finally, although farming products’ needs of virtual water amount vary according to crops, varieties themselves, crops managements, etc., the encountered results are comparatively close to those reported by Zimmer and Renault (2003).

Conclusion

Through the two studied crops examples, we intend to contribute to the achievement of a more efficient allocation of water resources, and to making a first step towards a comprehensive analysis of two dimensions of virtual water - agronomic and economic - in a perspective of sustainable development and improved food security.

The challenge is to develop the country’s capacity to produce crops while preserving and enhancing its limited water resources through the choice of crops that use less water and guarantees good returns.

Indeed, in the current context of scarce water resources, farmers should be better encouraged to rationalize water use. Managers should be able to ensure an equitable distribution of available resources based on crop needs. Therefore, we can say that the opportunities to improve water efficiency in the agro-economic level is based primarily on a better planning of land use and a proper management of the limited water resources. Valuing virtual water is also dependent on the establishment of a proper irrigation schedule that provides the plant with its water needs in its vegetative stages. Irrigation system must be revised to increase its efficiency. All that can have a positive impact on limiting water wastage.

Tunisia exports water-extensive high-value economic products adapted to the Mediterranean climate, essentially olive oil. It is true that by exporting olive oil Tunisia loses a significant amount of virtual water, but these exports are very important from an economic and social point of view.

Finally, it is important to say that further analysis will be carried out in the project “virtual water and food security: from observation to support to development”. These studies could provide a transparent and multidisciplinary framework for informing and optimizing water policy decisions, contributing at the same time to the implementation of a national water directive.

References

Allan, J.A., (1993). Fortunately there are substitutes for water otherwise our hydro-political futures would be impossible. ODA, Priorities for Water Resources Allocation and Management. ODA, London, (13-26).

Allan, J.A., (1994). Overall perspectives on countries and regions. In: Rogers, P., Lydon, P. (Eds.), Water in the Arab World: Perspectives and Prognoses. Harvard University Press, Cambridge, Massachusetts, (65-100).

Allan, J.A., (1998). Virtual water: a strategic resource. Global solutions to regional deficits, Ground water, Vol. (36), (545-546).

Bachta M.S., El Abbassi M. and Ferktaji R., (2001). Competitivité des produits agricoles tunisiens exportés et coûts en ressources naturelles. In : Laajimi A. (ed.), Arfa L. (ed.). Le futur des échanges agroalimentaires dans le bassin méditerranéen : Les enjeux de la mondialisation et les défis de la compétitivité. Cahiers Options Méditerranéennes, Zaragoza, Vol. (57), (101-111)

FAO (1992). CROPWAT a computer program for irrigation planning and management. FAO Irrigation and Drainage technical paper n°46.

Fernandez, S. and Thivet, G., (2008). Virtual water: Which perspective for the Mediterranean water management and distribution? Blue Plan Notes, Environment and Development in the Mediterranean, Vol. (8), (1-4).

Hoekstra A.Y., (2003). Virtual water trade. Proceedings of the International Expert Meeting on Virtual Water Trade. Water Research Report Series, vol. 12. IHE, Delft, Holland.

Hoekstra A.Y., Chapagain A.K., Aldaya M.M., Mekonnen M.M., (2009). Water footprint manual: state of the art 2009. Water Footprint Network, Enschede, the Netherlands.

Hoekstra, A.Y. and Hung, P.Q., (2002). Virtual water trade: a quantification of virtual water flows between nations in relation to international crop trade. Value of Water Research Report Series No.11, IHE, the Netherlands.

Institut National de la Statistique (INS), (2010). Statistiques du commerce extérieur 2008-2010, Vol. 41, Tunis.

Renault D. and Wallender W., (2000). Nutritional Water Productivity and Diets: From « Crop per drop » towards « Nutrition per drop ». Agricultural Water Management, Vol. (45), (275-296).

Renault D., (2003). Value of Virtual Water for Food: Principles and features. Expert meeting on Virtual Water, Delft, December.

Renault, D., (2002). La valeur de l'eau virtuelle dans la gestion de l'alimentation humaine. Actes des 27emes journées de la Société Hydrotechnique de France, Eau et Economie, (24-26).

Salmoral G., Aldaya M.M., Chico D., Garrido A and Llamas M.R. (2011). The water footprint of olives and olive oil in Spain. Spanish Journal of Agricultural Research, Vol. 9(4), (1089-1104).

Velázquez, E., (2007). Water trade in Andalusia. Virtual water: An alternative way to manage water use. Ecological economics Vol. (63), (201-208).

Wichelns D, (2001). The role of 'virtual water' in efforts to achieve food security and other national goals, with an example from Egypt. Agricultural water management Vol. (49) (131-151).

Zimmer D. and D. Renault, (2003). Virtual water in food production and global trade: review of methodological issues and preliminary results. In *Virtual water trade: proceedings of the international expert meeting on virtual water trade*, Value of water research report series No.12, Delft (the Netherlands), UNESCO-IHE, (93-107).

Websites:

Agreste, (2006). http://www.agreste.agriculture.gouv.fr/ Accessed on 22/07/2013.

Blue plan, (2008). http://planbleu.org/sites/default/files/publications/4p_eau_virtuelle_uk.pdf Accessed on 13/06/2013

FAOSTAT, (2013). http://faostat.fao.org/ Accessed on 07/06/2013.

National Statistics, (2005). http://www.onagri.tn/STATISTIQUES/ENQUTES% 20STRUCTURES /ESEA%202004-2005.htm Accessed on 20/06/2013

Point Focal Tunisien du SEMIDE, (2002). http://www.semide.tn/english/contressource.htm Accessed on 20/07/2013