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VIRTUAL WATER BALANCE ESTIMATION IN AN IRRIGATED AREA IN NORTH-EASTERN TUNISIA

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Abstract

The virtual water concept, defined by Allan (1997), as the amount of water needed to generate a product of both natural and artificial origin, this concept establish a similarity between product marketing and water trade. Virtual Water trade can alleviate, in arid countries, the problem of water scarcity, increasing imports of products with high virtual water content and so, it can allocate scarce resources to higher priority uses.
Given the influence of water in food production, virtual water studies focus generally on food products. At a global scale, the influence of these product's markets with water management was not seen. Influence has appreciated only by analyzing water-scarce countries, but at the detail level, should be increased, as most studies consider a country as a single geographical point, leading to considerable inaccuracies. For this reason, we consider the value of exploring virtual water strategy at smaller scales such as an irrigated area.
The main objective of this work is the estimation of virtual water balance of strategic irrigated crops (fruit trees and vegetables) in Semi-arid area in Tunisia to determine their influence on the water resources management and to establish patterns for improving it. The virtual water balance was performed basing on farmer's surveys, crop and meteorological data, irrigation management and regional statistics.
Keywords: *Virtual Water, North-Eastern Tunisia, Irrigated Crops, Water Management.*

Introduction

To confront water scarcity and support food security, the concept of virtual water is used. As defined by Allan (1997) virtual water is “the water embedded in key water-intensive commodities such as wheat” or “the water required for the production of commodities”. The importance of this concept is related to its potential contribution for saving water, especially in water short regions like Tunisia. This research study tries to evaluate the strategic importance of polluted or gray water (Loiseau, 2010), which is a component of virtual water with green and blue ones. Reduction of virtual water for strategic agricultural products can be obtained by reduction of gray water. The latter is defined as “water required to dilute polluted water to reach the normalized quality, different with countries”. Water pollution is especially related to use of chemical products (fertilizers, pesticides, etc.) for some crops like vegetables. Besides having a lower opportunity cost, the use of green water for the production of crops has generally less negative environmental externalities than the use of blue water (irrigation with water abstracted from ground or surface water systems). Tunisia exports some crops and gray water volumes in exports have rarely been estimated. Thus, estimation of gray water plays a role in ensuring water and water-dependent food security and avoiding further potential damage to the water environments in both importing and exporting countries.

In this context, Tunisian semi-arid region is chosen because of presence of dry and shiny period, occurring after a cold and rainy one, useful for vegetables crops and family food security. The aim of this study is to present methodologies which can be used to reduce virtual water for some strategic crops in Tunisian semi-arid region, based on improve of irrigation techniques and control of runoff and leaching water;

Material and methods

To estimate the virtual water for different crops, several models were used with the objective to determine the water consumed by the plant. In this study, net irrigation requirements for studied crops and regions were computed following the FAO56 method (Allen et al, 1998) from meteorological data available.

Crop evapotranspiration (ETM, equation 1) was estimated from reference evapotranspiration (ET_0) and the appropriate crop coefficients (K_c).

$$ETM = K_c \; ET_0 \tag{1}$$

Reference evapotranspiration (ET_0) was computed using the Penman-Monteith method (Smith 1993). The crop coefficients values at the initial, medium and end of the crop stages ($K_{c\ ini}$, $K_{c\ med}$ and $K_{c\ end}$), the general lengths (L) for the different growth stages (L_{ini}, L_{dev}, L_{mid} and L_{late}) and the total growing period for the main crops. Net Irrigation requirements (NIR, equation 2) were calculated using the standard FAO procedures, as described by Allen et al. (1998). Effective precipitation (EP) was calculated using the empirical USDA method (Cuenca, 1989). Following these procedures, reference evapotranspiration (ET_0), crop coefficients (K_c), crop evapotranspiration (ET_c), effective precipitation (EP) and net irrigation requirements (NIR) were estimated for the main crops in the AID in 2011.

$$NIR = \left(K_c \; ET_0\right) - EP \tag{2}$$

Net irrigation requirements calculations are based on the soil moisture regime and the phenological stage of the crop, while keeping the other variables at the optimal production level. On this basis, we can calculate crop coefficients for a given location. It is also possible to construct the mathematical function that connects the crop water consumption to the desired crop yield.

The choice of a model depends on the objectives of the study. When the most important is the relationship between water and crop production, which is the case, FAO models (AQUACROP and CROPWAT) are frequently used. CROPWAT is the simplest, based on empirical relationships between water availability and production.

In this study, virtual water consumed by crops was calculated as green (water provided by rain) and blue (water provided by irrigation) water. The present study estimates the green and blue water footprint of 1 kilogram of studied crops produced in semi-arid area in Tunisia following the method described by Hoekstra et al. (2009).

In the study, vegetable production in the different Tunisian semi-arid regions was considered, distinguishing production throughout the year as well as between growing systems. The study focuses on the production stage, that is, the cultivation of the product, from sowing to harvest. The crop virtual water was calculated for each year distinguishing the green and blue water components.

The virtual water of studied crops (rainfed or irrigated) has been calculated distinguishing the green and blue water components Within the CROPWAT model (FAO, 2009)., the ‘irrigation schedule option’ was applied, which includes a dynamic soil water balance and keeps track of the soil moisture content over time. The calculations have been done using climate data from representative meteorological stations located in the major crop-producing regions, selected depending on data availability.

Low virtual water values can be obtained by use of green water and reduction of blue water, based on improve of irrigation techniques and control of runoff and leaching water. For Tunisian semi-arid region, the best seasons for this are spring and autumn.

Vegetable crops generally need a large amount of workers, which can bring agricultural income, especially for women and children and then target food security for them. To perform this, statistical and field analysis of workers (ONAGRI, 2010), for Tunisian semi-arid region, were used.

Results and discussions

Figure 1 presents the net irrigation requirements (NIR) for the vegetables crops and irrigated zones in semi arid area.

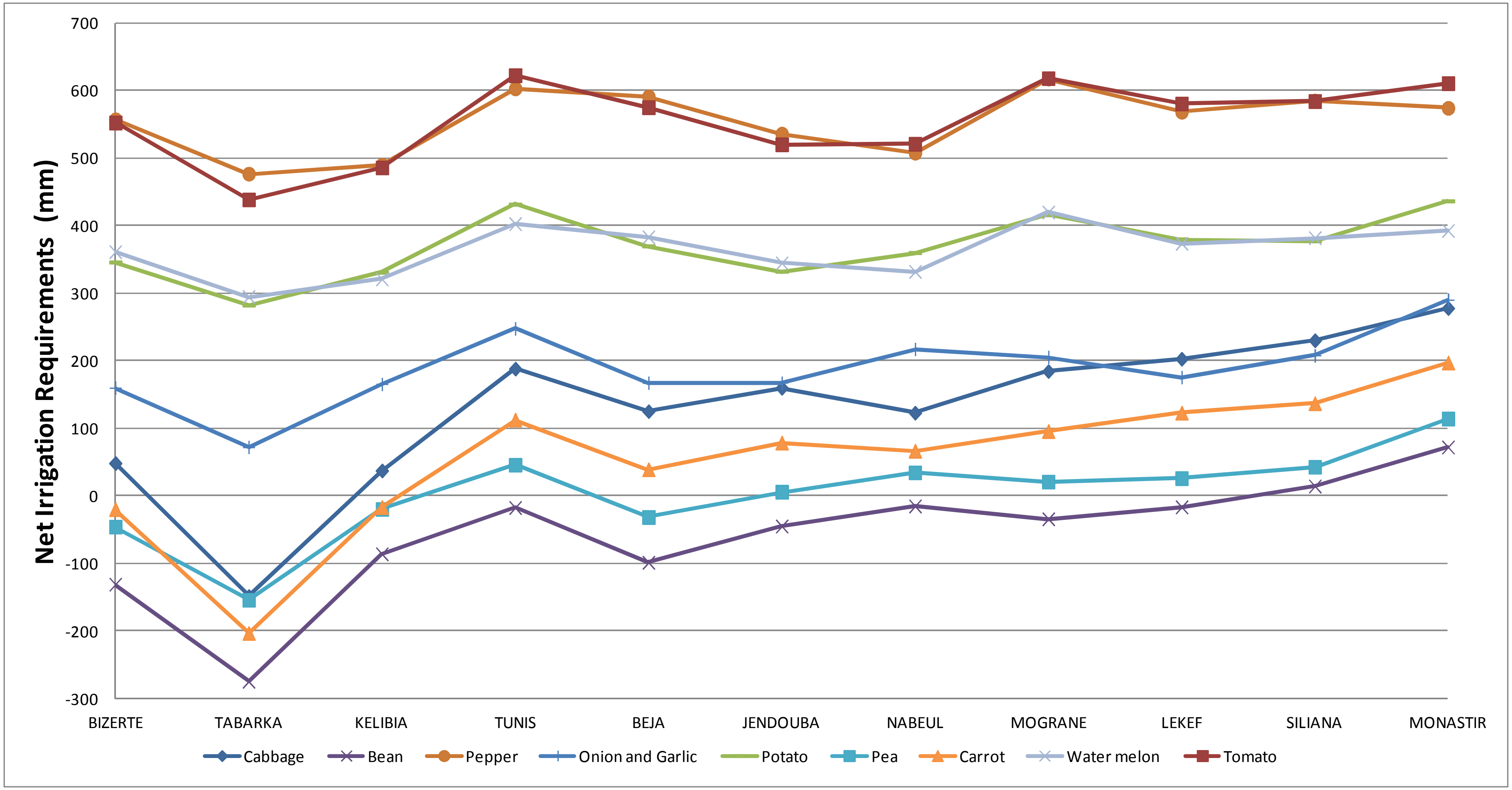

Figure 1. Net irrigation Requirements (mm) for studied vegetables in Tunisian semi arid areas.

NIR slightly increase for all studied crops from the north to the center of Tunisia, this increase is due to that central regions of the country receive less rain. Some vegetables such as pepper, pea and bean do not need irrigation in some regions and have a negative NIR, which means that virtual water consumed by these crops was only provided by the rain or green water. Cultivating these crops in these areas of the country helps minimize irrigation water consumption and thus the virtual water reduction. Summer crops such as tomato and pepper have the highest NIR from 430 mm in Bizerte to 600 mm in Monastir.

Figure 2 presents the net irrigation requirements (NIR) for fruit trees and irrigated zones in semi arid area.

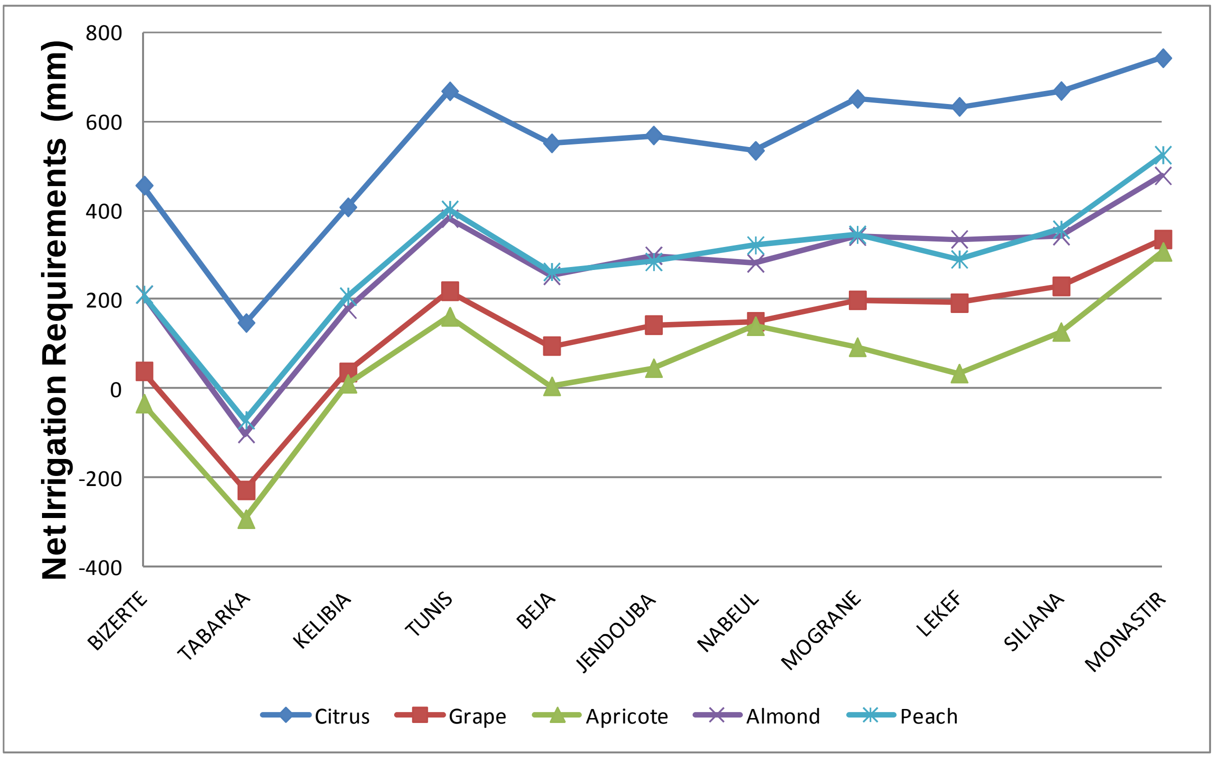

Figure 2. Net irrigation Requirements (mm) for studied fruit trees in Tunisian semi arid areas.

The NIR slightly increase for all studied crops from the north to the center of Tunisia, this increase is due to that central regions of the country receive less rain. Some fruit trees such as citus, Apricote and Almond do not need irrigation in some regions and have a negative NIR, which means that virtual water consumed by these crops was only provided by the rain or green water. Cultivating these crops in these areas of the country helps minimize irrigation water consumption and thus the virtual water reduction. Summer crops such as citusr have the highest NIR from 180 mm in Tabarka to 780 mm in Monastir.

Awareness of the farmer to managing water resources is related to knowing the real crop water requirements at different stages of crop development although he manages well the irrigation scheduling. Over irrigation as infra-irrigation, have a negative impact on crop productivity. Finally, the virtual water concept, contextualized in space and time can provide useful information for benchmarking, indentifying best practices and achieving a more integrated water resource management. Nevertheless, to obtain a comprehensive picture, not only the (eco) efficiency in terms of m^3/ton should be considered, but also the context-specific total cumulative virtual water.

Conclusions

The use of the virtual water concept to confront water scarcity and support food security, in Tunisian semi-arid region showed that:

- Spring and autumn vegetable crops present low virtual water and are thus recommended for this region;
- vegetables are one of the most important agricultural activities in the country contributing to food security needs in water are relatively high compared to other agricultural products;
- Citrus present the high virtual water in the studied regions;
- Reduction of virtual water for these vegetables crops in Tunisian semi-arid region, can be obtained by improve of irrigation techniques and control of runoff and leaching water, using drip, localized and underground irrigations ;
- The virtual water estimation by using a model that gives enough information to perform the value of consumed water each crop and the water wasted by the farmer can help to guide agricultural policy for better water management;
- The concept of virtual water should be treated with caution in trying to both manage water resources according to speculation and ensure food security;
- It seems clear that integrated water allocation, planning and management is needed in the Tunisian semi-arid regions, considering the environmental water requirements together with the blue (surface and ground) and green virtual water, to achieve a more compatible agricultural production.

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