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Virtual water balance estimation in Tunisia

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Abstract - The Virtual Water (VW) 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. 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.

The main objective is the virtual water balance estimation of strategic crops in Tunisia (both irrigated and rainfed crops) to determine their influence on water resources management and to establish patterns for improving it. The virtual water balance was performed basing on farmer's surveys and monitoring, crop and meteorological data, irrigation management and regional statistics.

Results show that the majority of farmers realize a waste of the irrigation water especially for the vegetable crops and fruit trees. Thus, a good control of the cultural package may result in lower quantities of water used by crops while ensuring good production with a suitable economic profitability. Then, the virtual water concept integration in the production systems choice and policies affecting the use of water is very useful to save over this scarce resource and to support farmers in their production activities and maintaining the sustainability of farms.

Keywords: Virtual water, water balance, irrigation, Tunisia

1. Introduction

The water in Tunisia is limited and unevenly distributed in the different regions, especially in arid zones. In fact, the annual rainfall average varies from less than 100 mm in the extreme South to over 1500 mm in the extreme North of the country. Currently, the conventional potential of water resources of the country is estimated about 4.84 billion m³ / year of which 2.7 billion cubic meters / year of surface water and 2.14 billion cubic meters / year of groundwater, characterizing a structural shortage for water safety in Tunisia (under 500 m^3/capita/year). With over than 80% of water volumes have been mobilized for agriculture.

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.

The main objectives of this study are:

In the first part we will focus on the problem of water scarcity in Tunisia, the need for irrigation and the impact on food security. We will also address the choice of strategies to cope with water shortages on the findings of some researchers in the field and finally we end the discussion of this part, specifying the situation of agricultural products in Tunisia facing the water scarcity issue.

The second part will focus on the methods used to determine the virtual water balance (blue water, green water and virtual water) at different economic regions of Tunisia.

1.1 Water resources in Tunisia: Limited quantities and uneven spatial distribution

Tunisia, like any Mediterranean country, is subject to the vagaries of the climate with droughts more frequent forcing him to focus on water resources. In fact, it has for decades, public facilities for the storage, transfer and distribution of water, which allowed him a multiyear regulation of water resources and the needs of all economic and social sectors. Surface water intakes from four distinct natural regions by their climatic, hydrological and geomorphological and geological aspects; these are:

- The extreme north: Although its area presents only 3% of the total land area, it provides surface water intakes estimated on average to 960 million m³ / year, 36% of the total potential of the country.
- The North: presented by the basins of the Medjerda Cap Bon and Méliane and provides an average of 1,230 million m³ / year, 46% of the total potential surface water.
- The center: it includes the watersheds Nebhana, Marguellil, Zeroud and Sahel and presents annual resources estimated at an average of 320 million m³ / year, or 12%.
- The South: it content for about 62% of the total land area, it is the poorest region in surface water and has only very irregular resources, assessed at 190 mm³ / year, or 6% of the total potential.

Potential conventional water resources of the country are estimated as 4840 million m³ / year which 2700 million m³ / year in surface water and 2,140 million m³ / year in groundwater (DGRE, 2012). These resources can be divided into three categories: existing resources, exploitable resources, surface water and groundwater.

1.1.1. Available resources

The mobilization rate of the available conventional resources was estimated 88% in 2005. A low volume yet to mobilize during the next decade, mostly from surface water (300 million m³), the rest in the form deep groundwater (80 million m³), and to achieve a rate of 96% of available resources.

1.1.2. Exploitable Resources

Exploitable water resources are estimated at an average of 4.236 billion m³ / year (DGRE, 2012), divided into 2,100 million m³ / year from surface water (available resources), 1.486 billion m³ / year as renewable groundwater resources and 650 million m³ / year of non-renewable groundwater resources.

1.1.3. Surface water

These waters provide an average of 230 mm / year, or 36 billion m³ / year. Rainfall is highly variable in space and time to the monthly and annual basis.

According to DGRE (2012), surface water resources are distributed on average as follows: Tunisian north with 2190 Mm³ / year which 1,800 Mm³ with salinity below 1.5 g / l, the center with 320 million m³ of which 150 million m³ having a salinity of less than 1.5 g / l and the South: 190 mm³ per year including 6 Mm³ having a salinity of less than 1.5 g / l.

1.1.4. Groundwater resources

Most of the groundwater resources come from the south aquifers, the largest of which are fossil deep aquifers. The mean annual groundwater are estimated at 2.1 billion cubic meters of which 1,486 million m³ / year of renewable resources (69.6%) and 650 million m³ / year non-renewable resources (30.4%).

The north of Tunisia has 55% of groundwater resources; the center contains 30% while the south contains only 15%. For deep aquifers, the southern region has 58% of drilling while the central and northern contain 24 and 18% respectively.

The exploitation of these resources for groundwater has reached 780 million m³ (in 2000) and from more than 90,000 surfaces well equipped. The deep groundwater is exploited to 80%, which corresponds to 1100 Mm³ (in 2000), from more than 3,500 wells.

The fossil character of South aquifers, raises the issue of the sustainability of their operations, especially since this region is increasingly seen as a development area by the water. As for surface slicks, they are operating at the limits of their resources; most important, those of central and southern Tunisia; they display exploitation of situations, with all that follows as qualitative and quantitative aspects of water degradation (salt water intrusion and declines in groundwater levels).

The groundwater resources are distributed on the other in 737 million m³ / year from groundwater and 1403 million m³ / year of deep groundwater half of which is non-renewable (DGRE, 2012).

1.2. The irrigation sector in Tunisia

1.2.1. The irrigable potential

The irrigated area is characterized by the variety of exploited water resources (dams, hill dams, boreholes, etc.), which imposes differences in size, configuration, equipment and type of these perimeters management. Similarly, operating modes and agricultural intensification levels are uneven and depend on the weather and regional socio-economic (Louhichi, 1999).

1.2.2. The irrigated sector: the importance and need for water

In Tunisia, despite the reduced area that not exceeding 7% of the total agricultural area, the irrigated sector contributes to 32% of total production and 20% of agricultural exports. It accounts for 95% of vegetable production, 45% of fruit production and 12% of livestock products (Louhichi, 1999).

1.2.2.1. Irrigated areas

Irrigated areas are divided into public schemes whose major works are made entirely by the state, and private schemes based on small hydro and implemented by individual farmers with or without public support.
Private schemes, characterized by small hydro, are concentrated in the irrigated areas of great tradition, or in coastal areas or in central Tunisia, mainly around the shallow wells.
About the nature of the irrigated areas, fruit trees occupy the top spot with 40% of irrigated area are second vegetable crops with 36% (21% reserved tomato and 15% to the potato). Cereals and fodder occupy 17% and 13% respectively perimeters (FAO, 2005). The small irrigated area under cereals is remarkable. In fact, the irrigation of cereals in Tunisia is usually done under the form of supplemental irrigation to offset rainfall deficit. Government incentives for dairy farming caused a shift from irrigation to forage (Laajimi, 2007).
Irrigated areas have been created to enable farmers to cope with erratic rainfall, but also for various other reasons and primarily for the improvement, diversification and intensification of production and stabilize yields from one year to another which reduces the dependence of farmers' incomes climatic factors. The results recorded at the grain yields show that there has been no great improvement in performance. Indeed, it is still of supplementary irrigation where farmers irrigate their crops in case of urgent needs. By cons, priority is given to high-value crops that are generally more sensitive to water stress. The yields of vegetable crops showed improved yields in recent years especially the tomato crops, melon and watermelon (Laajimi, 2007).
To ensure good control of irrigation management, important reforms to technical, economic, organizational and institutional continue to be conducted with the objective of improving the efficiency of irrigation networks, establish adequate pricing of irrigation water system and a more active participation of the users of the water resource. In this context, the state has adopted in 1995 a National Water Saving Irrigation Program (PNEE) whose main objective is to rationalize the use of water in agriculture and is committed to equipping all irrigated by water saving systems in 2009 which allowed to reach 50% of agricultural production in Tunisia and reduce allocations per hectare to a level of 5,000 m3 / ha in 2010 (Laajimi, 2007).

1.2.2.2. Investments and loans in the irrigation sector

The performance of agriculture in Tunisia cannot be attributed only to the constraints imposed by the natural environment and the technicality of farmers, but also to other macroeconomic nature of production factors such as investment and credit policies. Although the volume of investments in the agricultural sector in Tunisia has almost doubled in recent years, the share of investment allocated to agriculture compared to total investments was down slightly (only 12% in 2001) remained roughly in line with the share of agriculture in gross domestic product (Chebbi, 2005).

1.3. water and food security Stress

1.3.1. Water stress

The water security problem is inextricably linked to security objectives and / or food self-sufficiency and its implications on agricultural production. To the question of whether water availability is able to ensure the long-term water security, the answer is not unique: the sufficiency or insufficiency of water

resources can be assessed only against the nutritional requirements; Therefore, with respect to the objectives of the development policy in general and of agricultural policy in particular.
In this context, there is a very important issue that confronts the water in Tunisia; it is the concept of water stress. Indeed, there is water stress when demand for water exceeds the available amount during a certain period or when poor quality restricts its use. Water stress causes deterioration of fresh water resources in terms of quantity (groundwater overexploitation, dry rivers, etc.) and quality (pollution by organic matter, saline intrusion, etc.).
The main risk will be to manage a situation where 100% of the resources have been mobilized, where we will run out in a few years all the technical, regulatory, and institutional to preserve the resource, where the population continues to grow and where Tunisian special needs continue to evolve. How in these conditions continue to ensure water security of the country? The mobilization of surface water is substantially complete; the volumes stored by large dams have even tended to decline over the long term result of siltation deductions. Thus, the construction of hydraulic structures of small and medium size only better spatially distribute the overall resource without increasing the stored volumes. The small lakes and dams are also designed to trap sediment transported which gives them rapid change and a short life span. In addition, the hydraulic infrastructure has become very complex and its management. The presence of a basin of a series of overlapping facilities with different scales of intervention generates a series of impacts to be taken into account. Meanwhile, the Tunisian irrigated agriculture must meet basic strategic goals (food security and export promotion) in a changing environment: a complete openness to foreign markets and complete liberalization of the external market, increasing demand for food products competitive prices, the emergence of new competitors making better use of their water resources, a progressive financial disengagement of the state in favor of collective structures that need to organize.

1.3.2. Food security

Food security is achieved when all members of a society have, in a constant way, physical and economic conditions to have access to sufficient, safe and nutritious food for their needs and food preferences and there to lead an active and healthy life (FAO, 2006).
The concept of food security is different from that of self-sufficiency because it poses no constraint on the location of agricultural production. It focuses instead on the conditions for securing the availability in quantity and quality, stability for all and all the time, physical, economic and social access and sanitary and health conditions of the offer. It also introduces the variety of diets.
Using import in Middle Eastern countries is therefore an indicator of water scarcity they face. These imports also help slow politically unpopular reforms in favor of a water demand management perceived by many governments as a challenge to their ability to secure supplies of water and food (Lysiane and Corinne, 2005).
Based on the concept of virtual water, the authors sought to introduce changes in diets and technical advances that increase the productivity of land and water in the analysis of tensions generated by Food Production Water Resources. These works are so integrated in a broader reflection on the possibilities of action on agriculture to "liberate" water for other uses (Fernandez, 2008).
Water and food security are closely associated. According to FAO (2002), nearly 800 million people suffer from hunger in the world "the world cannot feed everyone," and a large part of them live in areas where water is scarce. Thus, achieving food security in the country will be to ensure quality food in sufficient quantities and without interruption, for the optimum combination of domestic production, import and export - optimization will result in the sustainable balance of the food balance and the development of the food industry.
In this context, we first endeavor to produce in sufficient quantities basic commodities for which Tunisia is competitive. This will increase the products for export, such as olive oil, seafood, citrus, dates and early vegetables crops.

1.3.3. Performance of Tunisia in food and water security

In the area of food safety, Tunisia is considered among the better-off countries in the Middle East and North Africa. Regarding nutritional deficiencies, the prevalence of undernourishment in the total population was less than 2.5% for the period 2002-2004. For the same period and under average

conditions, food consumption according to FAO estimates amounted to 3,280 Kcal / person / day, well above the minimum value energy needs which are estimated at 1,890 Kcal / person / day.
In Tunisia, it is cereal, tomatoes, potatoes, oil, meat, milk and sugar which represent 75% of the human diet and 30% of the family budget (Khaldi , 1997). Moreover, Tunisia has become deficient in these elements. As a result, food security must rest on substantial progress in all areas of production. It also assumes the best advantage of the new opportunities available in foreign markets in order to achieve the balance of trade balance of agricultural products.
Water security is an issue of food security: the vast majority (80%) of mobilized resources (called also "Blue Water") is used in agriculture.
In addition, irrigated agriculture has played a significant role in increasing food production in recent decades but its absolute contribution is still lower than that of rainfed agriculture plays a vital role in food security; it represents 65% of national agricultural production and 80% of agricultural exports.
The vision of rational water management needs to be extended to all of rainfed agriculture (also called green water), which values the most important part of the natural water resources and provides about 70% by value of total agricultural production. This broader perception of agricultural water issue beyond the traditional concept of available resources in large (or blue water) is the richest in opportunities and the best adapted to the Mediterranean context (PSSA, 1994).

2. Material and methods

About 784 farm surveys have been conducted to estimate the amount of water consumed by crops across the country. In this respect, this work is conducted to study the irrigation wastage and deficit water in these regions. The analysis is based on data from surveys about farms using irrigation. A geographic database has been created to facilitate the locations where the culture of the wastage irrigation has been increased. The superposition of these layers of information with those of available water resources in the agricultural map of Tunisia will allow us to prevent against the phenomenon of exploitation of these resources.
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).

$$ETM = K_c \, ET_0$$

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_{cini}, K_{cmed} and K_{cend}), 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.
Monthly actual crop evapotranspiration (ETRi) belongs the month i was estimated using the following equation system:

$$\boldsymbol{ETR_i} = \begin{cases} \mathbf{P\hat{u}_i + I_i + S_{i-1}} & \boldsymbol{if}\ \mathbf{P\hat{u}_i + I_i + S_{i-1} < ETM_i} \\ \mathbf{ETM_i} & \boldsymbol{if}\ \mathbf{P\hat{u}_i + I_i + S_{i-1} \geq ETM_i} \end{cases}$$

With :
$\mathbf{P\hat{u}_i}$**:** Usful P at the month i
$\mathbf{I_i}$**:** Irrigation water at month i
$\mathbf{S_{i-1}}$**:** Available water in the soil at month i-1
ETMi: Maximum Crop evapotranspiration at month i

Thus, total actual evapotranspiration ETR which represents the total amount of water consumed by the crop during the growing season is given by the equation:

$$ETR = \sum_{i=1}^{n} ETR_i$$

With n is the number of the month's season

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). Crop production in the different Tunisian 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.

WU: Water used per hectare (m^3 / ha)

WU = WU (mm) x 10
With:
WU (mm): water used by the crop throughout its growing period (mm)
- For annual crops, the growing period is less than one year
WU: Water used per hectare culture (m^3 / ha)

TWU: Total water used by crop and region
TWU = WU x S
With:
WU: water used per hectare (m^3 / ha)
TWU: Total water used by the crop in the area (m^3)
S: total area (ha) of culture in the area that has approximately the same performance and the same middle data (soil types, rainfall, ETP)

Estimation of virtual water per kg of agricultural product and area
<u>• Agricultural production by crop and by zone:</u>
C = R x S
With:
C: total production in the area (t)
A: crop yield in the area (t / ha)
S: total area of the crop in the zone/area (ha)

• Virtual water used per kg per area VW
VW= TWU / (C x 1000)
With:
VW: Virtual water used per kg (m^3 / kg)
TWU: Total water used by the culture in area (m^3)
The value of the green water is calculated by the model through the following formula:
If P useful <ETM: Green water = P useful
If P useful > ETM: Green water = ETM
Note: The rest will be considered as a waste of irrigation.

Virtual water exported and imported
• VW exported by zone (VWexp)
VWexp = VW xCexp x 1000
Along with
Cexp: Imported Production (t)
• VW imported by zone (VWexp)
VWexp = VW x Cimp x 1000
Along with:
Cimp: Imported Production (t)

3. Results and discussions

The total water resources of Tunisia is estimated as 4.86 billion cubic meters including 2.16 billion cubic meters as groundwater 44.4% and 2.7 billion cubic meters as surface waters or 55.6%. Compared to other Maghreb countries, these resources are low, due to the small size of watersheds and the country; more limited rainfall.
The scarcity of water resources is a key factor in the politics of mobilization, and the role of the state, the main player in the country's water policy. Because of its scarcity, water is therefore a fundamental issue for the present and future development of Tunisia.
Table 1 illustrates the overall water balance per crop for Tunisia. The total area studied is of the order of 2.44 million hectares of cultivated land. The total blue water used by crops is about 2830 million m^3 which shows 31.9% of virtual water used by these cultures (Figure 1). The total amount of irrigation water is 3577 million m^3 of waste with a percentage of about 18%.

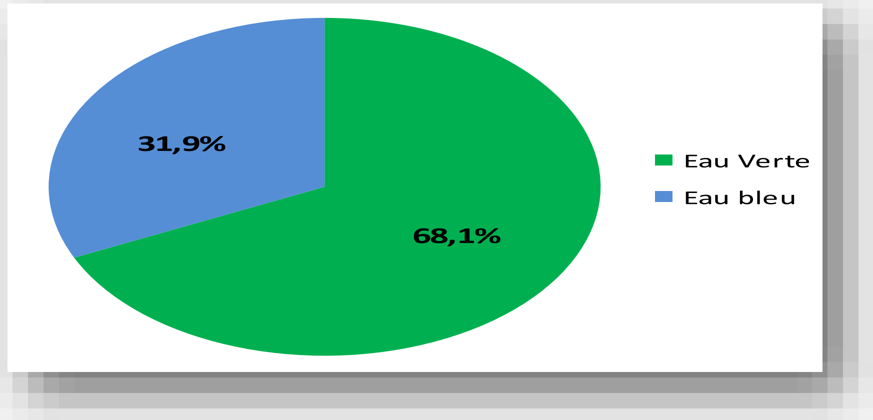

Figure 1. Percentage of green water and blue water of the total Virtual water consumed by all studied crops in Tunisia

Virtual water per kg of agricultural product is low for vegetable crops that do not exceed 0.5 m^3 / kg; these crops are cost effective for a country like Tunisia, which is poor in terms of water resources.
The results show that the amount of virtual water differs from one culture to another. We note while among the studied products, olive oil is classified as an agricultural product in the most demanding water (about 7 m^3/kg). Regarding the primary crops, cereals are the first class in terms of water requirement with an average of 1.5 m^3 / kg. At the date palm cultivation which consumes 3.1 m^3 of water per kg, the amount of virtual water fruit trees other than olive, apple and almond does not exceed 1.6 m^3/kg.

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Table 1: water balance for major crops in Tunisia

Crop	Area (ha)	Water used (m^3/ha)	Total water used (m^3)	Total green water (m^3)	Total bleu water (m^3)	Wast water (m^3)	Irrigated water (m^3)	VW (m^3/kg)
Apricot	1072	3454	3 746 379	3 084 498	661 881	65 216	727 097	1.14
Citrus	19982	9058	164 704 527	71 085 525	93 619 002	35 337 878	128 956 880	0.35
Garlic	935	3888	4 754 467	1 063 988	2 796 779	620 979	3 417 758	2.89
Almond	31228	2296	70 207 955	60 498 129	9 709 826	1 029 696	10 739 522	2.53
Artichoke	1531	8227	15 919 291	5 722 400	10 196 891	2 012 018	12 208 909	0.67
Oat	81765	3482	286 967 777	268 598 254	18 369 523	39 554 157	57 923 680	1.52
Durum wheat	435200	3668	1 655 402 540	1 626 481 664	28 920 876	111 850 313	140 771 190	1.23
Soft Wheat	86400	3682	324 662 227	311 026 827	13 635 400	7 799 933	21 435 333	1.34
Carrot	533	3207	1 700 364	1 430 921	269 443	1 259 344	1 528 787	0.24
Choux	1000	3545	3 545 000	2 640 250	904 750	2 694 000	3 598 750	0.11
Zucchini	460	5126	2 357 960	748 420	1 609 540	805 000	2 414 540	0.16
Bean	14750	1635	24 082 500	24 082 500	0	0	0	0.86
Strawberry	645	4954	2 786 751	1 651 950	1 134 801	1 403 747	2 538 549	0.15
Green bean	35	4040	141 400	47 005	94 395	41 685	136 080	0.51
Melon	954	5495	5 337 990	838 163	4 499 827	1 071 289	5 571 115	0.20
Onion	4638	3484	18 860 740	4 994 114	13 866 625	6 145 293	20 011 918	2.61
Olive	1289289	3332	3 775 717 845	2 375 032 057	1 400 685 789	60 013 562	1 460 699 351	1.39
Barley	262600	3745	1 041 252 400	1 032 480 250	10 745 310	119 320 677	130 065 987	1.68
Barley and wheat	109700	4029	448 686 298	119 249 662	329 436 637	28 062 528	357 499 165	0.94
Dates	39873	18765	733 237 030	25 817 782	707 419 248	46 906 375	754 325 624	3.08
Water melon	2764	4778	13 445 135	2 996 178	10 448 957	4 827 631	15 276 588	0.12
Peach	4762	3367	8 543 238	6 681 947	1 861 291	2 935 287	4 796 579	0.38
Chili Pepper	5442	5448	27 016 962	7 768 419	19 247 063	1 693 790	20 940 853	0.39
Pear	1273	4791	10 593 647	4 051 297	6 542 350	850 084	7 392 434	1.53
Potato	10996	3610	42 121 706	17 865 816	24 255 890	11 192 606	35 448 496	0.22
Apple	8183	5592	65 757 344	17 989 314	48 614 433	6 817 165	55 431 598	6.43
Sorghum	26	2411	62 686	59 566	3 120	0	3 120	1.61
Tomato	12124	5985	72 059 683	18 328 992	53 720 208	18 138 213	71 858 421	0.10
Grape Vine	12242	5556	49 741 070	33 566 993	16 174 077	2 010 513	18 184 589	0.21
General total	**2 443 344**	**4839**	**8 879 256 233**	**6 051 077 832**	**2 830 092 301**	**518 979 490**	**3 349 071 791**	-

3.1. Virtual water Trade

Through the trade in agricultural products, he always had it a virtual water flows from countries exporting goods to countries that import these goods.

3.2. Virtual water export

The products covered by this analysis are as follows: Olive oil dates, citrus, fresh tomato and watermelon.
In 2013, the export of 151,500 tons of olive oil, 108 thousand tons of dates, 22,000 tons of citrus, 2,400 tons of tomatoes and 17 tons of watermelon important source of currency Tunisia has lost respectively 1398 million m3 exported in the form of virtual water.

Table 2. Total exports of major agricultural products in Tunisia

Product	EV3 (m^3/kg)	Quantity (Tonnes)	EV exported (m^3)
Olive oil	6.95	151 500	1 053 247 708
Dates	3.08	108 000	332 490 655
Citrus	0.35	22 000	7 595 576
Tomatos	0.10	2 390	2 390 000
Water melon	0.12	17 126	1 980 000
Total			**1 397 703 939**

3.3. Virtual water import

Because of the lack of data on the water content of some agricultural products, this analysis will be limited to the following crops: durum wheat, winter wheat, barley, maize (culture not practiced in Tunisia) and potatoes.
Following the import of 3,230 tons of cereals and studied 15,700 tons of potato, Tunisia savings 6141 Million m^3 of water resources.

Table 3. Total imports of major agricultural products in Tunisia

Product	EV3 (m^3/kg)	Quantity (Tonnes)	EV imported (m^3)
Durum Wheat	1.23	540000	666 450 002
Soft Wheat	1.34	1100000	1 479 197 233
Barley	1.68	790000	1 328 039 048
Maiz	3.33	800000	2 664 000 000
Potatos	0.22	15700	3 468 435
Total			**6 141 154 717**

According to the theories of international trade, Tunisia interest to export low water intensity agricultural products and import agricultural intensive products like water but to improve the use efficiency water and consequently preserve water resources.
The concept of virtual water turns a tool for analyzing interesting that it allows decreasing pressure on water resources and encourages reflection on the valuation of agricultural water m^3, providing elements of understanding interactions between sectorial policies and effective water management.
Although Tunisia has a significant potential in international trade of agricultural and food products, its ability to consolidate its position in the market is conditioned by its capacity to meet the growing demands of the European market in terms of quality standard. In addition, the scarcity of water resources could reduce their chances to take advantage of the opportunities offered by free trade. The analysis incorporates virtual water in a global vision including all water resources (green, blue, gray, virtual).
In addition, the analysis process all dimensions of virtual water: agronomic, economic, food in a perspective of sustainable development (water resources preservation) and food security improvement. The challenge would, no doubt, to seek to develop, in addition, the country's ability to preserve and enhance its limited resources.

Therefore, we can say that the possibilities to improve water efficiency in agro-economic level are mainly based on better planning of land use, for good management of limited water resources. Tunisia can act only weakly on the diet to reduce the pressure on water resources and improve its trade balance. Indeed, this system largely holds on the capabilities and availability of waters. The only way to harmonize water resources, trade and food security balance is to reorient agricultural production to water-efficient crops whose value covers the actual cost of the resource.
Agricultural and food policy proposes to engage in a farming way of coping with water capabilities, and to get him to take advantage of all its potential and relayed by an agro-food sector performant. It seems that it is cheaper and more profitable for Tunisia to guide agricultural planning as follows:

- Increase irrigated cereal areas in extra high yield areas, where land cannot be allocated to the tree (heavy clay land North of the country) justified by the difference in the equivalent Water and performance between the two cereals production techniques (dry and under extra irrigation). However, the increase in cereal area aims to ensure national food security in cereals. The valuation of virtual water then remains strongly linked to the proper management of the plot and the development of a good irrigation plan that can help us reduce waste water while maintaining a desirable performance for the culture. Therefore cereal crops remains strongly linked to the agricultural policy of the country, through which one can explain the high import content of cereals. And which can be reduces by a global effort and extensive awareness and outreach especially for different modes of irrigations. All his will may be required to improve the country's economic balance and ensure food security.
- Increase the areas of dry olive trees justified by the fact that fully value the olive m^3 of water exported. On the other hand, the main reason it seems that it is more efficient and more profitable economically, to increase the oil production is that the export product covers both the real value of water resources that it uses.
- The increase in the area of peppers, tomatoes and citrus justified by the fact that these cultures value the better m^3 of water for export (EV3 $<0.5m^3$ / kg).
- Increase the areas of dry fodder: this can be explained by the fact that the effective exploitation of water resources by breeding for milk and meat are still unknown, because of steps further processed from water to forage and fodder to milk and meat. This production functions require different analyzes crossing disciplines such as hydraulics, agronomy, animal science and economics.
- Indeed, this new planning ensures alignment between water efficiency in agriculture, environmental conservation, increased efficiency in the use of rainwater (olive) and valuations of irrigation water (irrigation cereal, tomatoes, peppers and citrus fruits).

4. Conclusions

The use of the virtual water concept to confront water scarcity and support food security, in Tunisian regions 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 regions can be obtained improving the irrigation techniques and the control of runoff and leaching water.
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. Moreover, the virtual water concept should be treated with caution in trying to both manage water resources according to speculation and ensure the 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 water and ground water) and green virtual water, to achieve a more compatible agricultural production.

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