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The Water Footprint of Sugar Cane And Sugar Beet Cultivated in Egypt

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ABSTRACT

Sugar cane is the main source for refined sugar and the sole source for the molasses industry in Egypt. However, it consumes huge amount of water that could be used to produce other high value crops. Sugar beet might be a good alternative to sugar cane. Yet, due to limited water sources in Egypt, it is important to conduct an integrated water management for both crops. Therefore, in this study, water footprint was estimated to enhance water use efficiency and overcome water scarcity problems. Water footprint (WF) and virtual water trade were estimated, during the period from 2012 to 2016, to select the best crop to produce sugar that reduces the gap between production and consumption of sweetens and achieves high income for farmers. Results showed that the average total water footprint for sugar cane and sugar beet were 428.69 and 232.53 m^3/ton, respectively. The energetic and economic water productivity for sugar cane were 1354.18 kcal/$m^3$and 1.48 \$/m^3; while for sugar beet they were 3338.33 kcal/$m^3$and 3.67 \$/m^3, respectively. Therefore, it is recommended to increase the cultivated area of sugar beet in Egypt. On the other hand, sugar cane had an imported energetic water productivity of 1812.3 kcal/m^3 that was lower than the exported one (2304.94 kcal/m^3). This suggests that exporting sugar cane is beneficial for Egypt than importing it. However, importing sugar beet is preferable than exporting it because it had a lower exported energetic water productivity (2557.25 kcal/m^3) and exported economic water productivity (2.81 \$/m^3) than imported ones.

Keywords: Sugarcane, sugar beet, water footprint, green water footprint, blue water footprint, total water footprint, water scarcity.

INTRODUCTION

Water footprint accounting , as proposed by the Water Footprint Network (WFN), can potentially provide important information for water resource management, especially in water scarce countries relying on irrigation to secure food requirements for their population (Ghandour, 2018). Sugar is a strategic commodity in many parts of the World. It is mainly produced from sugar cane and sugar beet. Sugar contents in sugar beet and sugar cane is approximately 16% and 12.5%, respectively. Extraction rate of sugar from sugar beet juice ranging from 40% to 80% and from 30% to 100% from sugar cane juice (Hussain *et al*., 2016).

The mean of sugarcane production for the time period 1994-2016 was 15532.49 thousand ton while for the sugar beet production was 4987.03 thousand ton. The mean of sugarcane area is 133.54 thousand hectare and for sugar beet area is 99.60 thousand hectares (Elasraag, 2019).

Raw sugar production from beet and cane in 2012/2013 was at 1,083 TMT and 917 TMT, respectively compared to 850 TMT and 950 in 2011/2012. Sugar consumption was at 2,950 TMT for the 2012/2013 compared to 2,900 TMT for the 2011/2012. However, sugar consumption was increased to 3000 TMT in 2013/2014 (Gressel and Al-habbal, 2014).

Total raw sugar production was increased in 2015/2016 by 3 percent at 2.127 MMT compared to 2.067 MMT in 2014/2015. This growth was attributed to the increase in raw beet sugar production by 0.060 MMT for a total of 1.210 MMT versus 1.150 MMT in the previous year. Raw cane sugar production was remained stable at 0.917 MMT. On the other hand, total raw sugar consumption 2015/2016 was increased by 2.5 percent at 3 MMT compared to 2.930 MMT in the previous year. Sugar consumption was driven by Egypt's population growth rate of 2.4 percent (Verdonk, 2016).

In 2016/2017 sugar production was increased by 60,000 MT to reach 2.185 MMT from 2015/2016 production of 2.125 MMT. Of total 2016/2017 sugar production, 915 TMT of sugar derived from cane and 1.270 MMT of sugar from beet. Total sugar consumption to increase by roughly 2 percent to reach 3 MMT in 2016/2017. Domestic consumption was at 2.950 MMT in 2015/2016. The increase in consumption was due to the increase in total population by at least 2 percent annually (Hamza and Verdonk, 2016).

Egypt is bridging the gap between consumption and production through imports. Total imports decreased in 2012/2013 at 930 TMT compared to 1179 TMT in the previous year (Gressel and Al-habbal, 2014). However, total raw sugar imports in 2015/2016 to drop by 300,000 MT to 1 MMT. Raw sugar imports in 2014/2015 are revised upward to 1.300 MMT from USDA's estimate of 1.190 MMT (Verdonk, 2016). In 2016/2017 total raw sugar imports to drop by 6 percent at 800,000 MT. Imports were at 850,000 MT in 2015/2016 down by 450,000 MT from 2014/2015 imports (Hamza and Verdonk, 2016).

At a global scale, substantial water volumes are consumed and polluted in the industrial and domestic

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sectors. However, there is a lot of water used in agricultural production (WWAP, 2009). Therefore, managing and conserving water resources is vitally important specially in water scarce countries (Felix, 2012). In these countries, some sectors and issues would be linked together using water footprint and virtual water analysis, an appropriate framework provides the best management of water resources (Aldaya *et al*., 2009). A worksheet to analyze the link between the globes freshwater and human consumption is provided by water footprint. The total volume of freshwater that is used to produce a product is defined as the water footprint (Hoekstra *et al*., 2009).

To reduce the pressure putting on fresh water resources, assessment of blue, green, and grey water footprint would be conducted. A spatially and temporally explicit water footprint analysis is also required by the variability of water resources in space and time (Mekonnen, 2011). Gerbens-Leenes and Hoekstra (2009) assess the green, blue and grey water footprint (WF) of sugar, High Fructose Maize Syrup and ethanol in the main producing countries (Brazil, United States, China, and India). In addition, an impact assessment was carried out for sugar cane and sugar beet production in three large river basins: the Dnepr, Indus and Ganges basins. Chapagain and Hoekstra (2004) calculated the WFs of sugar and starch crops for all producing countries. However, no attempt was made to distinguish between green, blue and grey water. Moreover, ethanol production was not taken into account.

To our knowledge, no studies have been conducted to estimate the water footprint of sugar cane and sugar beet cultivated in Egypt, and to determine the best sugar crop that could be cultivated to provide the vast increasing population that is coincides with water scarcity. Therefore, the objectives of this research were to: 1) estimate the total water footprint and virtual water trade, for Sugar cane and Sugar beet in Egypt over the period 2012 to 2016, which helps in selecting the best governorate for water use efficiency to cultivate each crop and taking a trade decision for these crops; and 2) calculate energetic and economic water productivity, over the same period. This will help in determining the more efficient and economical conditions to produce sugar in Egypt.

MATERIALS AND METHODS

Methodology

The total water footprint of sugar cane and sugar beet was estimated in Egypt in the period from 2012 to 2014. The footprint included the green, blue and grey water components. This was carried out for each governorate in Egypt. Moreover, the total virtual water trade for each crop was estimated to indicate whether to import or export each crop. This will help to decide the most beneficial crop for Egypt.

The virtual water and water footprint were calculated using the methodology developed by Hoekstra and Hung (2002; 2005) and Chapagain and Hoekstra (2003). To achieve the objectives of this study, the following steps were performed:

1- Calculate the green and blue crop water requirement

Average monthly evapotranspiration data were obtained from www.wunderground.com website at provincial level processed in the CROPWAT model. For calculating green and blue crop water requirements, evapotranspiration must be estimated (Allen *et al*, 1998).

Figure1 shows CROPWAT 8.0 model outputs which produce the following:

The total water evapotranspired (ET_a) = actual water use by crop in the model output.

The blue water evapotranspired (ET_{blue}) = the minimum value from 'total net irrigation' or 'actual irrigation requirement'.

The green water evapotranspired (ET_{green}) = the total water evapotranspired (ET_a) minus the blue water evapotranspired (ET_{blue}) Chapagain and Hoekstra (2003).

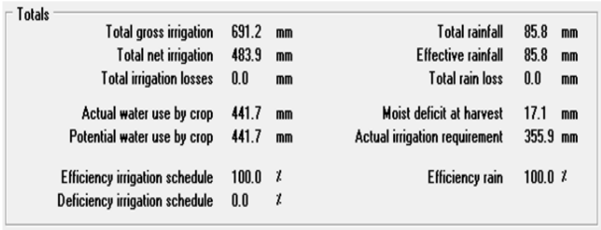

Figure 1. The CROPWAT model output for the case study of sugar beet crop in Gharbia (2013)

The green and blue components in crop water requirement (CWR, m^3/ha) were calculated using Equations (1) and (2) as follows Hoekstra *et al*., (2011):

$$\mathbf{CWU_{green}(m^3/ha) = 10\sum_{d=1}^{1gp} ET_{green}} \dots\dots\dots\dots\dots\dots (1)$$

$$\mathbf{CWU_{blue}\ (m^3/ha) = 10\sum_{d=1}^{1gp} ET_{blue}} \dots\dots\dots\dots\dots\dots\dots (2)$$

Where:

CWR = Crop water requirement (either green or blue) in m^3/ha; and
ET = Daily evapotranspiration (either green or blue) in mm.
gp = Stands for length of growing period in days.
The factor 10 is intended to convert water depth values from mm into m3/ha.

Estimated green and blue water footprint

The green water footprint of a primary crop (WF_{green}, m^3/ton) was calculated as the green crop water requirement (m^3/ha) divided by the crop yield (*Y*, ton/ha) using Equations (3) as follows:

$$\mathbf{WF_{green}\ (m^3/ton) = \frac{CWR_{green}}{Y}} \dots\dots\dots\dots\dots\dots (3)$$

$$\mathbf{WF_{green}\ (m^3/ton) = \frac{CWR_{green}}{Y}} \dots\dots\dots\dots\dots\dots (3)$$

In parallel, the blue water component was calculated as blue crop water requirement divided by per ton sugar as shown in Equation (4):

$$\mathbf{WF_{blue}\ (m^3/ton) = \frac{CWR_{blue}}{Y}} \dots\dots\dots\dots\dots\dots (4)$$

2- Estimated grey water footprint

The grey water component in the water footprint was estimated as a fraction of the applied chemicals that enter the water system. It could be estimated by using simple or more advanced models by dividing the pollutant load by the difference between the maximum acceptable concentration for that pollutant of water and its natural concentration in the receiving water body. This value was divided by the crop yield. Equation (5) indicates the simplest model to assume grey water footprint (Mekonnen and Hoekstra, 2011):

$$\mathbf{WF_{grey}(m^3/ton) = [\frac{\propto * Appl}{c_{max} - c_{nat}}]/Y} \text{ ……………….. } (5)$$

Where:

WF_{grey} = The grey water footprint in (m^3/ton);
Appl = The application rate of chemicals to the field per hectare in (kg/ha);
c_{max} = The maximum acceptable concentration of Nitrogen in (kg/m^3);
c_{nat} = The natural concentration of Nitrogen in (kg/m^3); and
α = The leaching-run-off fraction.

3- Calculate the total water footprint

The total water footprint was estimated as the sum of green, blue and grey water footprint of crop as shown in the following Equation:

$$\mathbf{WF_{Tot}(m^3/ton) = WF_{green} + WF_{blue} + WF_{grey}} \text{ ……………… } (6)$$

4- Energetic water productivity

For the amount of energy produced by a unit mass of a crop fixed, the static indicator of the energy water productivity consumed or transported across different products for different countries were determined. The energetic water productivity was calculated as follows:

$$\mathbf{En_g = \frac{En_{output}}{WF_{Tot}}} \text{ ………………………………… } (7)$$

Where:

En_g = Energetic water productivity in (kcal/m^3); and
En_{output} = Energy output of the crop in (kcal/ton) Pimentel and Hall (1984).

5- Economic water productivity

The economic water productivity analysis can be very useful in order to identify possible water uses not justified in economic efficiency terms and achieve an efficient allocation of water resources (Aldaya and Llamas (2008). Water economic productivity was calculated as follows:

$$\mathbf{C.W.P = En_g * P_{EN}} \text{ ……………………………… } (8)$$

Where:

C.W.P = The economic water productivity in (\$/m^3); and
P_{EN} = Energy price in (\$/kcal) World Bank (2016).

6- Virtual water trade flows and the national virtual water trade balance

Virtual water trade flows between nations was calculated by multiplying international crop trade flows by their associated virtual water content. The volume of virtual water imported into Egypt (m^3/year) was calculated as follows:

$$\mathbf{V.W.I = T_{crop} * WF_{import\ country}} \text{ ……………………. } (9)$$

Where:

V.W.I = Virtual water imported (m^3/year);
T_{crop} = Crop trade (ton/year); and
$WF_{import\ country}$ = The virtual water content (m^3/ton).

However the volume of virtual water exported from Egypt (m^3/year) was calculated as:

$$\mathbf{V.W.X = T_{crop} * WF_{Exported\ country}} \text{ ……………………… } (10)$$

Where:

V.W.X = Virtual water exported (m^3/year);
$WF_{Exported\ country}$ = The export quantity by the average virtual water content of the crop (m^3/ton).

Moreover, the net virtual water import was calculated by subtracting the gross virtual water import from the gross virtual water export.

RESULTS AND DISCUSSION

1- Cropping area

Table 1 and Figure 2 show the total area planted with sugar cane and sugar beet in (2012-2016) for Egypt governorate. Figure 2 shows the areas for each governorate. It is clear that the sugar cane cultivated area in Qena and Aswan was the greatest area among other governorates. However, the smallest cultivated sugar cane area was in Alexandria. Although the sugar beet cultivated area in Kafer El sheikh and Dakahlia was the greatest area among other governorates. However, the smallest cultivated sugar beet area was in New Valley. As can be seen in Figure 2, sugar cane was planted in Upper Egypt while sugar beet was planted in Lower Egypt. The total area planted with sugar cane was 0.136 million ha in 2012 and increased in 2013 and 2014. Then, total area decreased in 2015 and 2016. On the other hand, sugar beet planted area was increased over the period from 2012 to 2016. This is a general trend in Egypt, where the Egyptian government takes great efforts to achieve self-sufficiency and stop import of sugar.

2- Water requirements for sugar cane and sugar beet

Crop water requirements refer to the water needed for evapotranspiration under ideal growth conditions, measured from planting to harvest. As shown in Figure 3, sugarcane had a higher water requirement than sugar beet in all governorates. Aswan, Qena, and Suhag governorates had the highest sugarcane water requirements over the period from 2012 to 2016. On the other hand, new valley and Assuit had the highest sugar beet water requirements in the same period due to climatic conditions as shown in figure 4.

Table 1. The total planted area (hectare) for sugar cane and sugar beet in (2012-2014) in Egypt.

Area (hectare)		
Year	**Sugar cane**	**Sugar beet**
2012	136809	177837
2013	138241	193400
2014	139449	211800
2015	137807	233080
2016	136880	235004
Average	137837	210224.2

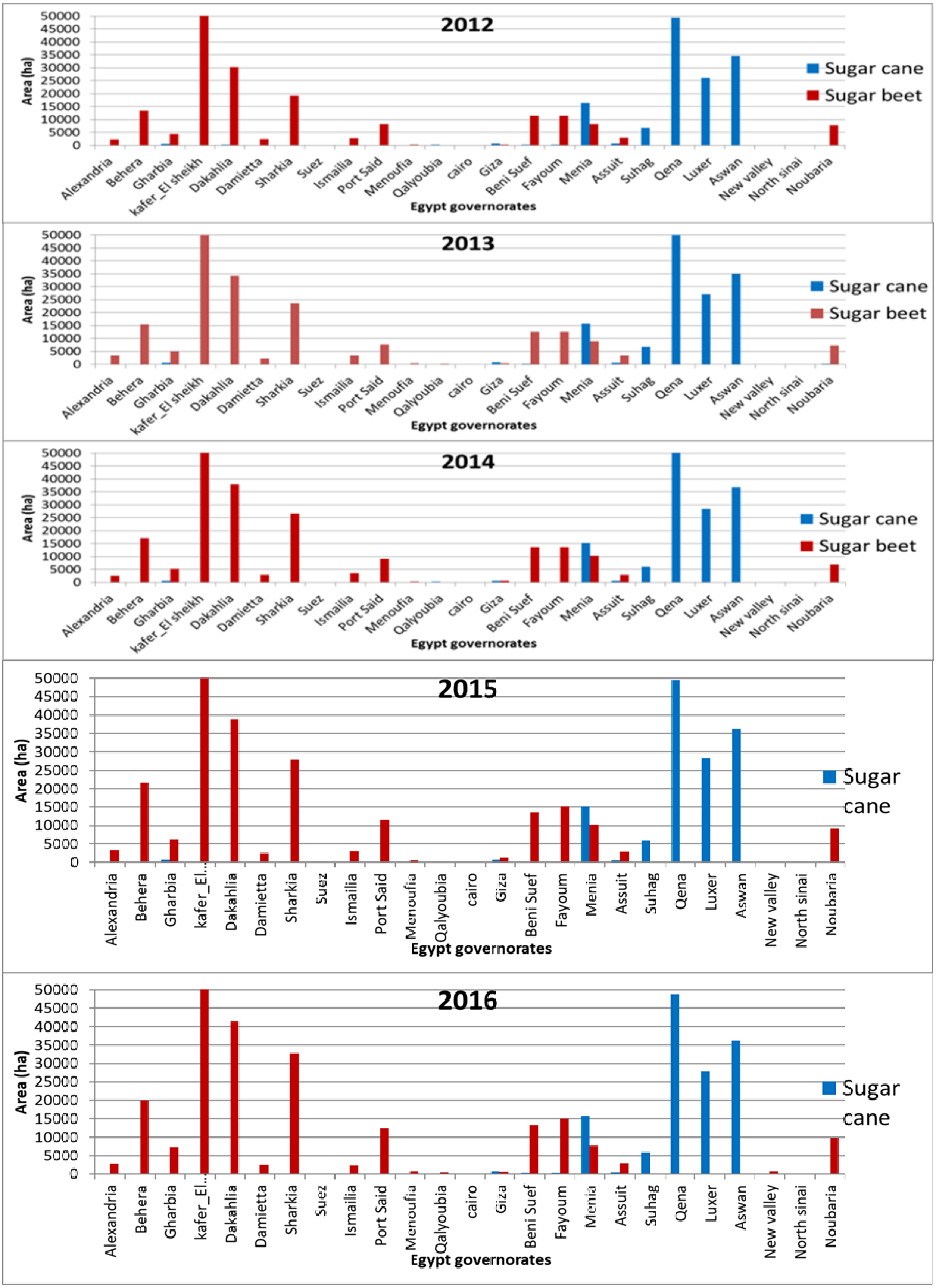

Figure 2. The total planted area for sugar cane and sugar beet in different governorates in the period 2012-2016 .

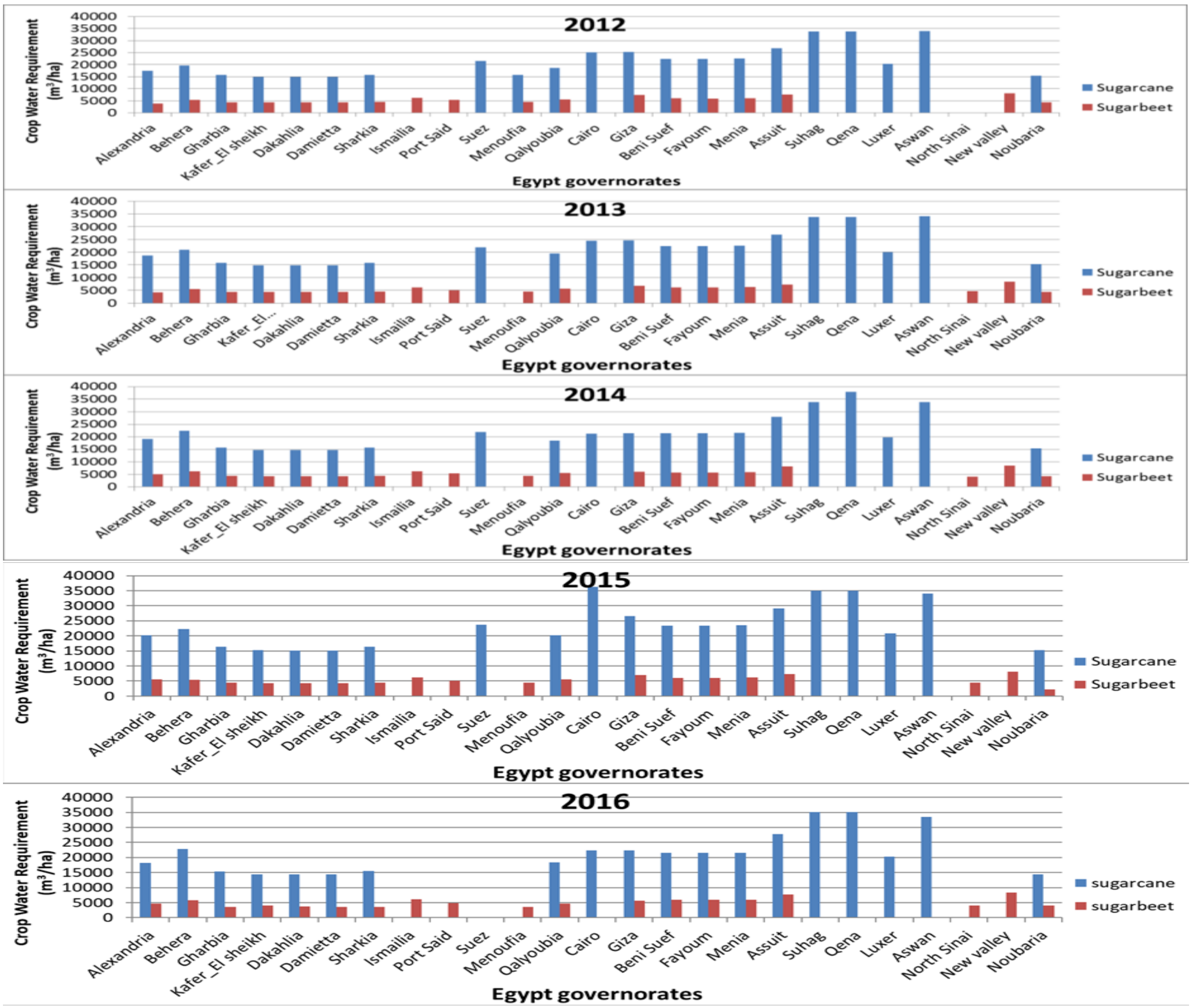

Figure 3. Crop water requirements for sugarcane and sugar beet in each governorate.

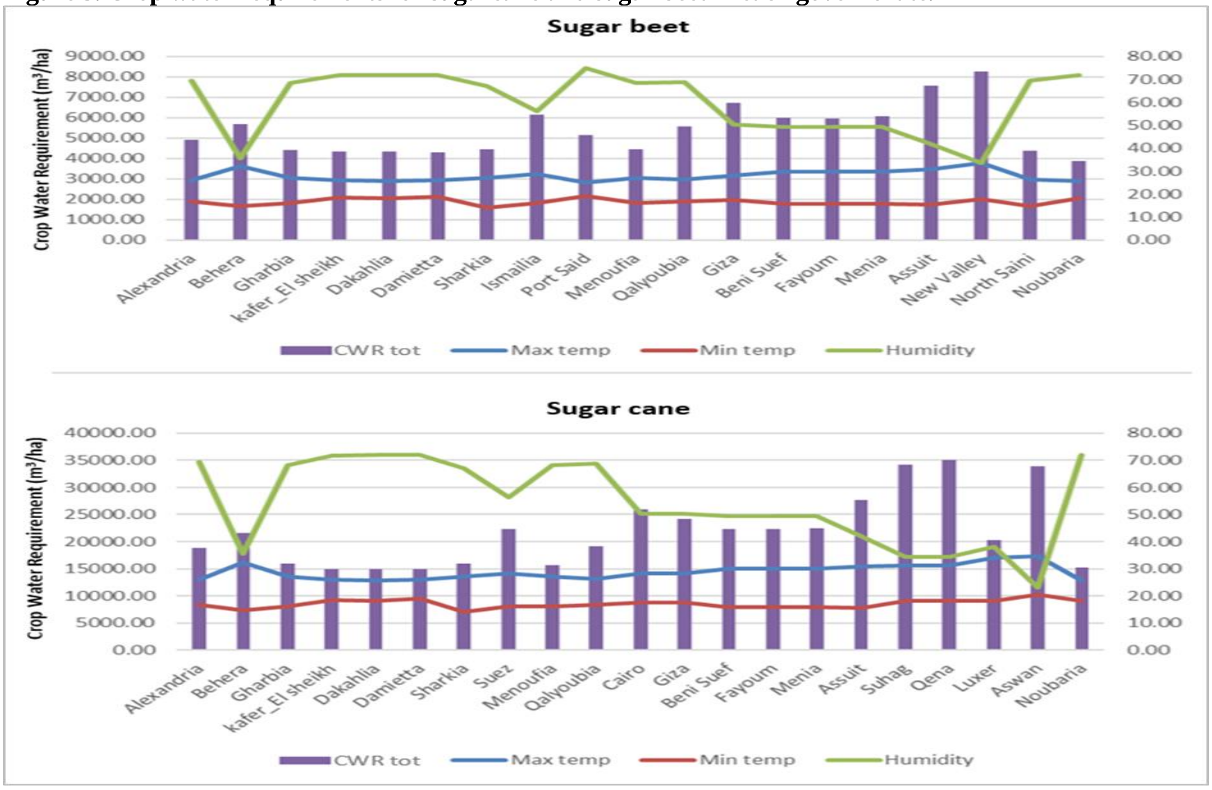

Figure 4. Water requirements change for sugarcane and sugar beet in each governorate due to climatic conditions in the period 2012-2016 .

3- Green, blue, and grey water footprint for sugar cane and sugar beet

The blue water footprint for sugar cane was higher than the green and grey water footprint. The blue water footprint for sugarcane was 358.4 m^3/ton in the period of 2012-2016. On the other hand, the green water footprint for sugarcane was approximately 18.5 m^3/ton over the same period. In addition, the grey water footprint for sugarcane was 47.6 m^3/ton, due to the application of nitrogen during growing seasons. The blue water footprint for sugar beet was 195.87 m^3/ton and the green water footprint for sugar beet was 5.94 m^3/ton over the period 2012-2016. While the grey water footprint for sugar beet was 107.43 m^3/ton.

Over the period of 2012-2016, Kafer-El Shiekh and Gharbia had the lowest blue water footprint for sugar cane of 141.581 and 154.67 m^3/ton, respectively (Figure 5). However the lowest blue water footprint values of 60.4 and 61.8 m^3/ton were calculated for Gharbia and Dakhlia, respectively. The highest blue water footprint for sugar cane and sugar beet were calculated in Noubaria (631 m^3/ton) and New valley (411.7 m^3/ton), respectively. The differences in the blue water footprint could be attributed to the differences in soil type and climate conditions. The lowest sugar cane yield caused the highest grey water footprint in Noubaria, while the lowest grey water footprint in Menoufia was due to the highest sugar cane yield. However, the green water footprint depends on the rain in each governorate.

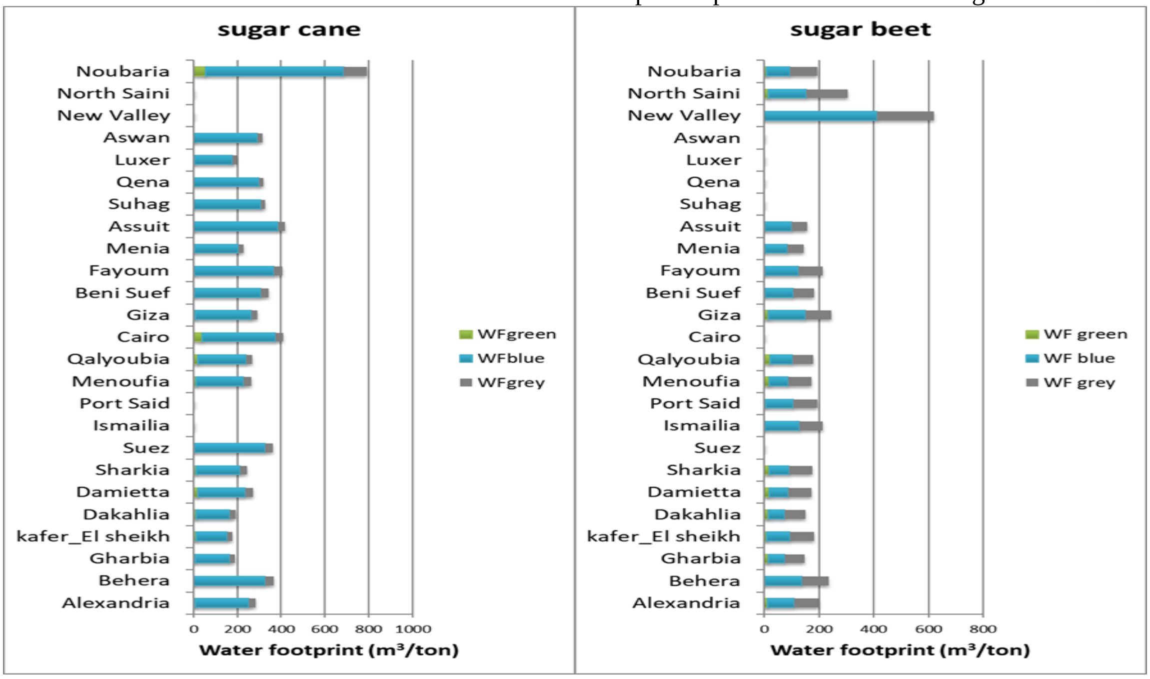

Figure 5. Green, blue and grey water footprint for sugar cane and sugar beet in each governorate in the period 2012-2016.

4- Total water footprint for Sugar cane and Sugar beet

Figure 6 shows average total water footprint for sugar cane and sugar beet for each governorate in the period 2012 to 2016. For sugar cane, Noubaria had the lowest sugar can yield and the greatest total water footprint that could be due to hot climate. However, Kafer El-Sheikh had the lowest total water footprint due to high yield. On the other hand, for sugar beet, the highest and lowest total water footprint were found in New Valley and Menia, respectively. It can be seen from Figure 6 that Alexandria had a higher total water footprint for sugar cane than that for sugar beet. Therefore, sugar beet is more preferable for producing sugar in this governorate. Contrary to that, It is recommended to reduce the cultivated area of sugarcane in Alexandria.

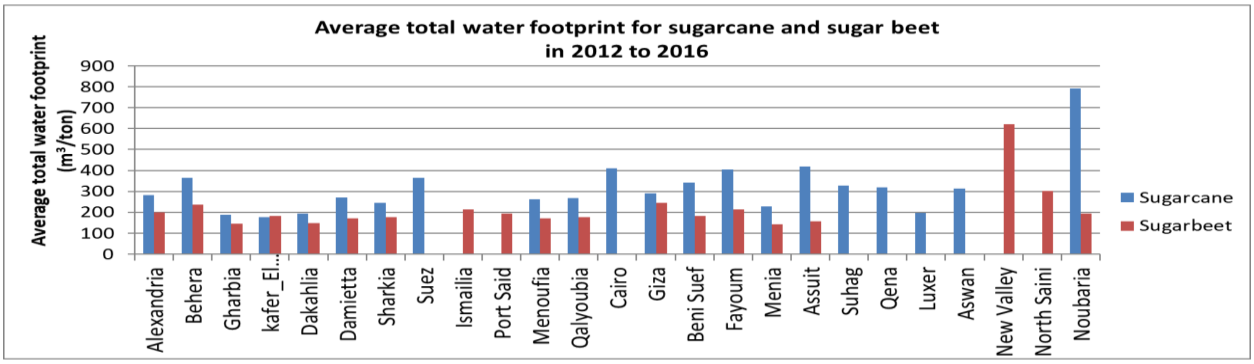

Figure 6. The Average total water footprint for sugar cane and sugar beet in each governorate.

5- Energetic and economic water productivity for sugar cane and sugar beet

Energetic and economic water productivity for sugar cane and sugar beet was estimated over the period 2012-2016 (Figure 7). The average water energetic and economic productivity for sugar cane were 1354.2 kcal/m^3 and 1.45 \$/m^3, the corresponding values for sugar beet were 3338.3 kcal/m^3 and 3.67 \$/m^3, respectively.

As shown in Figure 6, water footprint for sugar cane was higher than sugar beet. Moreover, energetic and economic water productivity for sugar cane was lower than sugar beet. These results may be attributed to the highest water footprint had the lowest energetic and economic water productivity. Therefore, it is highly recommended to cultivate sugar beet rather than sugar cane because it consumed less water per ton than sugar cane.

Figure 8 shows energetic and economic water productivity for sugar cane and sugar beet in the different governorates during the period from 2012 to 2016. As illustrated in Figure 7, Kafer El-Sheikh had the highest energetic and economic productivity for sugar cane that were 2134.44 kcal/m^3 and 2.35 \$/m^3, respectively. While, for Menia, the highest energetic and economic productivity for sugar beet were 4454.78 kcal/m^3 and 4.9 \$/m^3, respectively. However, new valley had the lowest energetic and economic water productivity for sugar beet.

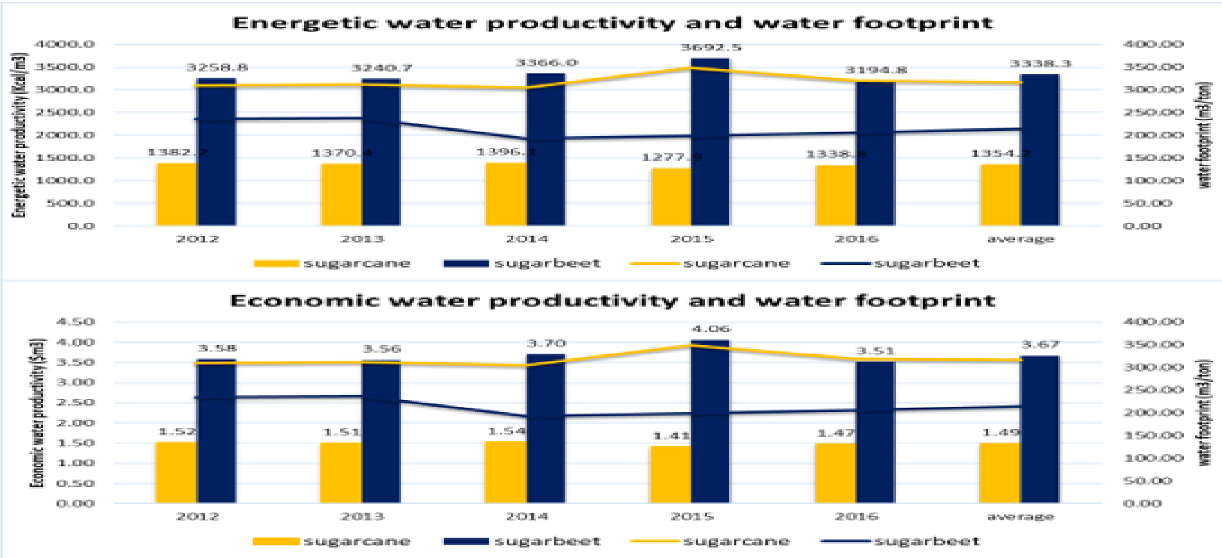

Figure 7. Average total water footprint, energetic water productivity and economic water productivity for sugar cane and sugar beet over the period 2012-2016

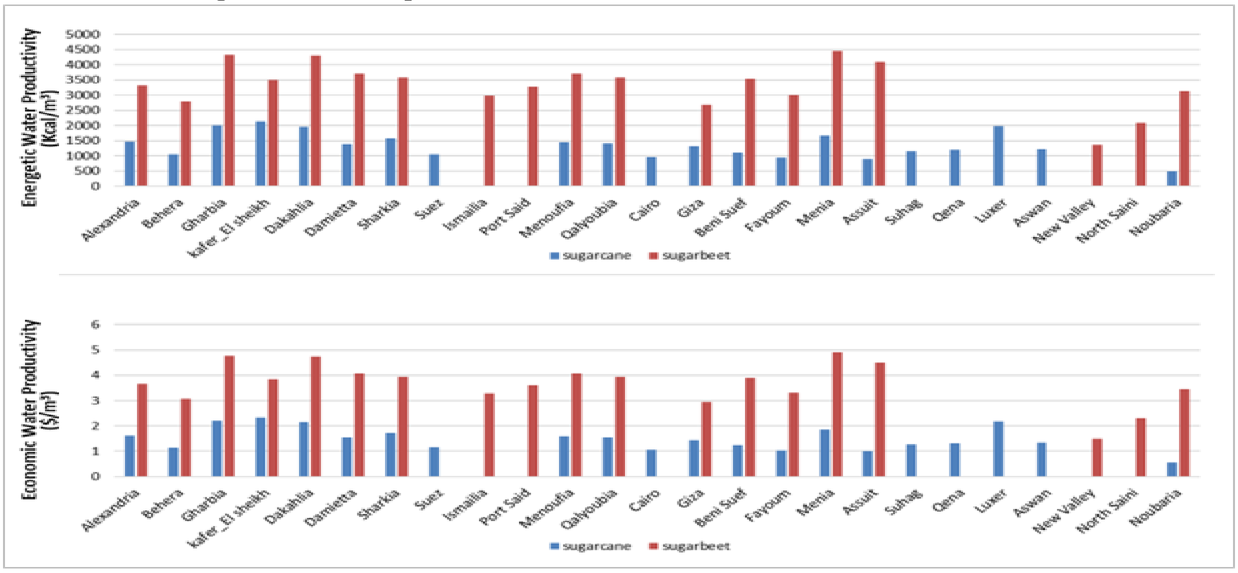

Figure 8. Average energetic water productivity and economic water productivity for sugar cane and sugar beet for each governorate in the period 2012-2016

6- Virtual water trade flows and the national virtual water trade balance for sugar cane and sugar beet

Egypt has net imported virtual water for sugarcane and sugar beet so it is an importer country for both crops (Gressel and Al-habbal, 2014). Table 2 illustrates the gross sugarcane and sugar beet trade from 2012 to 2016. During this period for sugarcane, total crop exported from Egypt was 0.26 million ton. However, the total net crop imported to Egypt was 2.22 million ton. The virtual water export or import could be estimated by multiplying international crop trade flows by their associated virtual water content of processed crop.

Table 2. The gross sugar cane and sugar beet trade (ton) over the period of 2012-2016

Crop	Sugar cane			Sugar beet		
Year	**Import**	**Export**	**net**	**import**	**export**	**net**
2012	4808918.00	17775.00	4791143.00	282996.30	982.30	282014.01
2013	1653576.00	304409.00	1349167.00	110141.10	6608.00	103533.10
2014	1031598.00	328576.00	703022.00	63166.46	3349.40	59817.06
2015	1244238.00	314293.10	929944.90	145653.30	2003.03	143650.27
2016	3822330.00	336165.00	3486165.00	200360.80	5403.00	194957.80
Mean	2512132.00	260243.62	2251888.38	160463.59	3669.15	156794.45

Source: General Organization for Export and Import control (GOEIC)

According to Table 3, Egypt has net virtual water import 3.58 trillion m^3/year over the period of 2012-2016. It can be seen from Table 3 that the imported virtual water flow in sugarcane was higher than the exported virtual water flow in sugar cane. This is because the imported sugar cane trade was greater than the exported one. Moreover, Egypt has net virtual water import for sugar beet 0.0939 trillion m^3/year over the period 2012-2016.

Table 3. The imported and exported virtual water trade in sugar cane and sugar beet over the of period 2012-2016.

Virtual water trade (m^3*10^9)						
crop	**Sugar cane**			**Sugar beet**		
year	**Import**	**Export**	**Net**	**Import**	**Export**	**Net**
2012	6.700	0.07	6.63	0.0443	0.001062	0.0432
2013	2.470	0.12	2.35	0.0170	0.000739	0.0163
2014	1.546	0.13	1.416	0.0099	0.000362	0.0095
2015	1.864	0.125	1.739	0.3700	0.000217	0.3698
2016	5.450	0.134	5.316	0.0315	0.000604	0.0309
mean	3.606	0.1158	3.4902	0.0945	0.000597	0.0939

From results illustrated in Figure 9, if we consider the energetic and economic water productivity, it is suggested to export sugarcane and not to import it. Because sugarcane had higher exported economic water productivity which means that one cubic meter of water used in producing it gives higher price of sugarcane. So, it is quite clear that the exported water economic productivity is lower than imported water productivity.

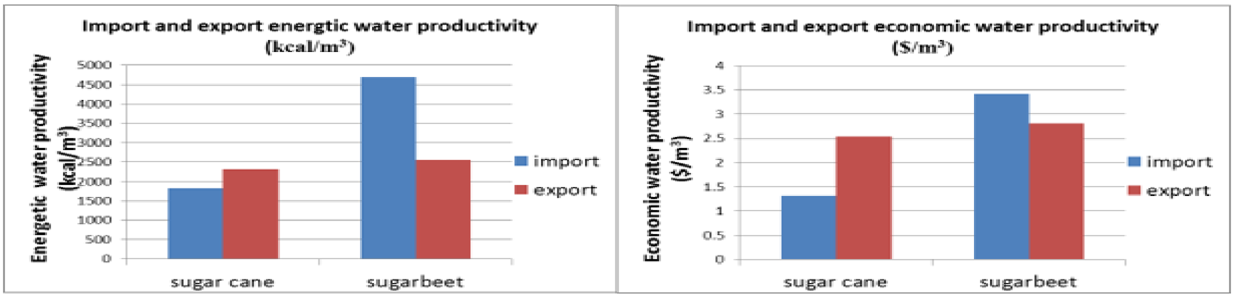

Figure 9. Average imported and exported energetic water productivity and imported and exported economic water productivity for sugar cane and sugar beet

CONCLUSION

In the present work, water footprint and virtual water trade for sugar cane and sugar beet were estimated over the period 2012-2016. This could help decision makers to manage irrigation water for both crops.

The water footprint of sugar cane was 59.09 million m^3/year during 2012-2016 with contents of 6.6%, 82.4%, and 11% for green, blue, and grey water footprint, respectively. However, the water footprint of sugar beet was 48.88 million m^3/year 1.15%, 62.14%, and 36.71% for green, blue, and grey water footprint, respectively. The energetic and economic water productivity for sugar cane (1354.18 kcal/m^3 and 1.48 \$/m^3, respectively) was lower than that of sugar beet (3338.33 kcal/m^3 and 3.67 \$/m^3, respectively).

The results indicated that, Noubaria has the highest water footprint (791.9682 m^3/ton) while the least water footprint for sugar cane was found in Kafer El-shiekh (178.1268 m^3/ton). On the other hand, for sugar beet, New valley has the highest total water footprint (621.834 m^3/ton) for sugar beet while the least total water footprint was found in Menia (143.6 m^3/ton).

The net imported virtual water trade for sugarcane was 349.02 million m^3/year. While it was 93.9 million m^3/year for sugar beet. The exported economic water productivity for sugar cane (2.54 \$/m^3) was higher than imported which was (1.32 \$/m^3). For the sugar beet the exported economic water productivity (2.81 \$/m^3) was lower than imported one (3.42 \$/m^3).

From examining results, it could be recommended that:

- Planting sugar beet is more preferable than sugar cane because sugar beet had the least water footprint and highest energetic and economic water productivity.
- Planting sugar cane could be focused in Kafer El-Sheikh because it had the least total water footprint in 2012-2016. As well as it is preferred to plant sugar beet in Menia due to lower water footprint.
- Reduce the amount of nitrogen applied to sugar beet in order to reduce grey water footprint.
- If, the cultivated area with sugar cane was planted with sugar beet over the period 2012 to 2016, sugar production would be decreased to 820459.87 ton sugar. To compensate for this decrement of sugar, the cultivated area with sugar beet will be increased about 172296.573 ha. This scenario will save about 1.334 billion cubic meter of water.

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البصمة المائية لقصب السكر و بنجر السكر في مصر

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السكر واحد من اهم المنتجات في مصر وعلى مستوى العالم ويعتمد انتاج السكر في مصر على محصولي قصب السكر وبنجر السكر ومع ذلك فإن مصر دولة مستورده للسكر وذلك للفجوة الموجودة بين الإنتاج والاستهلاك المحلى. وبالرغم من الانتاجية العالية لمحصول قصب السكر في مصر الا ان انتاجه يواجه العديد من الصعوبات. ومن اهم المشكلات التي تواجه محصول قصب السكر هي مياه الري المحدودة وزيادة الاحتياجات المائية للمحصول المصاحبة لارتفاع دراجات الحرارة. في هذا البحث تم تقدير البصمة المائية لمحصولي قصب السكر وبنجر السكر وذلك خلال خمس سنوات في الفترة من 2012 الى 2016 حيث أن البصمة المائية هي اداة من ادوات الادارة المتكاملة للمياه. ومن خلال هذه الدراسة تمكنا من معرفة مقدار البصمة المائية لكل محصول من المحاصيل داخل كل محافظه تمت زراعة هذا المحصول بها وايضا من خلال مقدار البصمة المائية تمكنا من معرفة افضل محافظة لزراعة كل محصول من المحاصيل تحت الدراسة داخل مصر ومن النتائج وجد ان انتاج السكر من محصول بنجر السكر اكثر كفاءة من انتاجه من قصب السكر وذلك في الظروف المناخية والجغرافية والمساحة المتاحة التي يمكن ان تزرع ببنجر السكر وكذلك العجز في المياه. ووجد أنه بالنسبة لمحصول قصب السكر ان افضل محافظة لزراعته هي محافظة كفر الشيخ حيث انها تستهلك اقل بصمة مائية حوالى 178.13 م^3/طن مقارنة بالمحافظات الاخرى. بينما اكثر محافظة في استهلاك المياه اثناء زراعة قصب السكر بها هي محافظة النوبارية وكانت البصمة المائية بها حوالى 791.9682 م^3/طن. بينما نلاحظ ان اقل محافظة في استهلاك البصمة المائية لمحصول بنجر السكر كانت المنيا وبالتالي يفضل زراعته بها. وكان متوسط البصمة المائية لكل من قصب السكر وبنجر السكر في مصر خلال الفترة من 2012 الى 2016 كالاتي 4.95 و 2.45 تريليون م3 لكل سنة على التوالي. وكانت النسب المئوية لكل من البصمة المائية الخضراء والزرقاء والرمادية لمحصول قصب السكر كما يلى 6.6٪ و 82.4٪ و 11٪ على التوالي. بينما كانت تلك النسب لمحصول بنجر السكر حوالى 1.15٪ و 62.14٪ و 36.71٪ على التوالي. ومما سبق يمكننا القول ان البصمة المائية لمحصول قصب السكر اعلى منها لمحصول بنجر السكر. وايضا من النتائج السابقة يمكننا ملاحظة ان البصمة المائية الرمادية في محصول بنجر السكر تمثل نسبة اكبر منها في محصول قصب السكر وذلك يرجع الى معدل التسميد النيتروجيني. وقد وجد أن سعر المتر المكعب المستخدم في إنتاج محصول قصب السكر داخل مصر يعادل 2.54 دولار/ م^3 بينما سعر المتر المكعب ماء لقصب السكر الذى يتم استيراده يعادل 1.32 دولار/ م^3. ومما سبق فإنه من غير الاقتصادي تصدير قصب السكر بينما سعر المتر المكعب المستخدم في إنتاج محصول بنجر السكر داخل مصر يعادل 2.81 دولار/ م^3 وهو اقل من سعر المتر المكعب من الماء لبنجر السكر الذى يتم استيراده ويعادل 3.42 دولار/ م^3. وبالتالي فإنه يوصى بالآتي: التوسع في زراعة قصب السكر في المحافظات ذات البصمة المائية المنخفضة خاصة محافظة كفر الشيخ وذلك لأنها تحتوى على اقل بصمة مائية له ولنفس السبب ينصح بزراعة محصول بنجر السكر في المنيا. خفض كمية التسميد النيتروجيني لمحصول بنجر السكر وذلك حتى تنخفض البصمة المائة الرمادية له ولكن بنسبه لا نؤثر على الانتاجيةحسب البيانات السابقة يفضل زراعة بنجر السكر بدلا من قصب السكر نظرا لانخفاض البصمة المائية له. وبفرض استبدال المساحة المزروعة بمحصول قصب السكر ببنجر السكر خلال الفترة من 2012 إلى 2016 سيتم توفير حوالي 1.334 مليار متر مكعب من المياه. وسينخفض إنتاج السكر بنحو 820459.87 طن سكر. ولتعويض النقص في كمية السكر يتم زيادة المساحة المزروعة بمحصول بنجر السكر بنحو 172296.573 هكتار.