Impact of Crop Replacement Concept as a Solution for Water Scarcity Problem

Marwa M. Aly, Hayam F. Ahmed, F. A. Abd El Motelb

Abstract: Water scarcity is one of the important global risks causing a great dispute around the world. How to obtain a suitable water quantity or quality that affects the economy of the world. Egypt is a country suffering from water scarcity due to the high rates of population growth with a fixed share of the Nile water which is considered as the main Egyptian water resource. The present work aims to apply the concept of virtual water on the agricultural products to suggest the replacement of crops having relatively high water consumption and low prices with other crops having low water consumption and high prices. The impacts of the replacement process was achieved through the classification of selected 22 crops and grouped into four groups based on their Specific Water Demand (SWD) and their world prices, then the crops contained in the group of the lowest water consumption and the highest price will be proposed to be exported and the crops in the group of the highest water consumption with the lowest price will be proposed to be imported. The effect of crop replacement within the 22 crops was measured by calculating the Relative Specific Water Demand (RSWD), the Relative Area (RA) saved and consequently the relative cash return. A Matlab program was constructed and calibrated through comparing its results with the CropWat model of FAO database to calculate the SWD of the selected crops cultivated in Egypt. Regarding the results, "Barley" was the best crop proposed to be imported and replaced by Tomato where the RSWD reaches 15.70 m^3/ton, the relative area saved reaches 10.138 ha/ton and the relative cash return reaches 5691 (1000$/ton). On the other hand, the process of replacement gives a complete vision to the decision makers to decide the priority of the imported crops according to the local market needs taking into consideration the economic situation in the country.

Keywords*: *Crop replacement, water scarcity, Matlab, virtual water trade.

I. INTRODUCTION

Regarding food security and the implications of virtual water trade policy, the national level food security has been achieved and maintained in Egypt by increasing the crops and livestock production within the country and by importing food and fodder from other nations. Food consumption per capita had increased substantially in recent decades, even though population had increased by more than 100% since 1962. Egypt's population was about 70 million in 2003 and is expected to reach 110 million in 2020, while the land and water resources available for agriculture remain fixed. Hence, further improvements in agricultural production and even greater reliance on international trade may be needed in the future to maintain current levels of food consumption and economic growth.

Revised Manuscript Received on January 15, 2020

***** Correspondence Author

Marwa Mohamed Aly*, Faculty of Engineering, Matareya, Helwan University, Egypt. High Institute of Engineering and Technology- El Obour, Egypt. Email: marwaaly3@gmail.com

Hayam Farouk Ahmed, Post Graduate Student, Faculty of Engineering, Helwan University. Email: hfaroukak@gmail.com.

Fakhry Abd Elhamid Abd Elmotelb, Faculty of Engineering, Matareya Helwan University, Egypt. Higher institute of Engineering, 15th of May City. Email: fakhry_ah2006@yahoo.com.

On the other hand the government started to educate and inform the farmers about the water scarcity problem and that Egypt has limited water resources, to ensure that water is used efficiently in domestic production and to motivate production of high-valued crops for export. As well as focusing on the production activities in which Egypt has a comparative advantage that will increase with increasing resources scarcity. The inputs - outputs decisions on farm-level will be consistent with national goals and reflect the relative scarcity of the resources.

Virtual water is the hidden flow of water in the commodities. Trade of agriculture-based products are about 80% of international virtual water [1]. The adjustment of the virtual water trade rate can save water and money as the necessary crops are imported and the commercial crops that require less water are exported. Different research works have been proposed to study the effect of virtual water on the national income as well as saving water by adjusting the amount of exported crops. The analysis of the water use and the water resources management on virtual water point of view in the economic zones of Vietnam were studied [2]. It was found that, the water footprint in major agricultural products demonstrated the diversity in different regions and different products, also the water consumption was analyzed from both direct and indirect water use. The effect of food habits on virtual water in the context of china and how to use this approach to improve water security at local scale were studied by proposing a non-dimensional virtual water scarcity index (NVIRTUAL WATERSI) that is composed of four basic parameters: population of the country, average virtual water per capita, area of the country, and average rainfall in the country [3]. Furthermore, an input–output model was built and the impact of water consumption efficiency variation on the virtual water trade structure with the water resource data, and input–output table of China was tested empirically, in 2007. The final water consumption coefficient and the direct water consumption coefficient were defined as the measurement of water consumption. It was found that the study of these coefficients could be used to improve the virtual water. Finally, it was concluded that, China is net importer in industries of agriculture, mining, petrochemicals while virtual water is net exporter [4]. In Maghreb countries, they studied how the suitable virtual water trade and the achievement of water desalination could solve the water scarcity. It was concluded that, Maghreb exported a large amount of water via agricultural products and imported a smaller amount of water that, should be adjusted to save the water [5]. The problem of priority and independency related to food in Egypt was studied by [6] assuming that, the virtual water as a strategy option is needed to be studied as Egypt is counted among water-poor countries.

Therefore, investigations, and feasibility evaluation should be performed to improve the water scarcity in Egypt. It was concluded that, the water problems in Egypt can be solved if water resources weren't used in production of low-value and water intensive crops such as cotton or rice; however, it was used in high-value crops such as horticulture. The role of virtual water for optimizing the water resources management in Jordan was defined [7] where the water consumption, costs of production, and virtual water were determined. Subsequently, net return from unit volume of irrigation water wasdetermined. The analysis indicated that, water management could be improved if cropping patterns were decided on the basis of maximizing net return per unit volume of irrigation water and minimizing water requirement to produce unit mass of crop yield, this analysis can be applied only on few crop cases. For example, they suggested importing more virtual water especially that embedded in cereal, meat, oil, live animals and sugar.

The virtual water concept could be used to enhance the water scarcity problems. From the previous works it was concluded that the study of virtual water usually requires studying the crops' water consumption and their prices. However, the replacement of the crops with each other based on saving water could be used to increase the imported virtual water with low cost.

Therefore, it is needed to clarify the relationship between crops needs, high crop water and low crop water requirements according to the productivity per hectare and world prices in order to help the decision-maker to improve the situation of water availability and increase the water per capita values so as to reach the highest possible benefit by reducing the area cultivated with crops that need high crop water requirements. These areas could be replaced by crops that need low crop water requirements. On the other hand, few crops of high prices are exported.

II. METHODOLOGY

In this research, 22 crops were studied and classified based on the water consumption and prices to investigate the crops with high water consumption and low prices to be imported. The saved areas and water will be used to cultivate the crops that have high prices and low water consumption in order to overcome the Egyptian water scarcity problem and the national income. The water consumption in crops harvesting is a function of different factors such as climate, where the crop grown in a hot and sunny climate needs more water than the same crop grown in cooler and cloudy climate. On the other hand, the crops' prices are depending on the crops water needs not on the water consumed to harvest the crop. For example, the water footprint unit for 1kg of eggs and milk are 3265 and 1020, respectively, which means that the price of eggs is higher than that of milk by more than three times.

The introduced approach is described in the flow chart represented in Fig.1. Based on [1], based on the virtual water concept, the water consumption of the studied crops were quantified where the Evapotranspiration (Et) is estimated according to the Penman-Monteith equation. This equation is applied using the meteorological data where ClimWat program is used to get the climatic data of Egypt [8], such as air temperature, and wind speed as illustrated in equation (1).

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)} \quad (1)$$

Where:

ET_o, is the reference evapotranspiration [mm/ day],
R_n, is the net radiation at the crop surface [MJ/ m^2 day],
G, is the soil heat flux density [MJ/ m^2 day],
T, is the air temperature at 2m height [°C],
u_2, is the wind speed at 2m height [m/ s],
e_s, is the saturation vapour pressure [kPa],
e_a, is the actual vapour pressure [kPa],
$e_s - e_a$, is the saturation vapour pressure deficit [kPa],
Δ, is the slope vapour pressure curve [kPa °/C] and
γ, is the psychrometric constant [kPa °/C].

Then, the crop coefficient of each studied crop (Kc) was taken from the Cropwat program on the FAO's web site. The crop evapotranspiration (Etc) is calculated according to equation (2).

$$Et_c = k_c \times Et_o \quad (2)$$

Finally, the Specific Water Demand (SWD) in (m^3/ton) of the studied crop (n) is computed using equation (3).

$$SWD[n] = \frac{CWR[n]}{CY\,[n]} \quad (3)$$

Where:

CWR, is the Crop Water Requirement in (m^3/ha) and calculated from the accumulated crop evapotranspiration Etc (mm/day) over the complete growing period and

CY, is the Crop Yield in (ton/ha) and is taken from the FAO database.

The SWD is computed using the steps described in Fig.1 for the 22 crops, and the studied crops were sorted according to both the (SWD) and their prices in four groups. The required data of virtual water content of the selected 22 crops have been retrieved from FAO databases (CropWat, ClimWat, and FAOSTAT).

The used data included; crop water requirements and climatic data as well as the crop parameters for the 22 crops with the crop coefficients in different crop development stages (initial, middle and late stage), the length of each crop in each development stage and the root depth etc.

The obtained data were used as input data in the constructed model based on Matlab software and the net virtual water in Egypt. The model is calibrated through comparing its results with the FAO CropWat model. The interface of the Matlab model is shown in Fig. 2.

Boundary conditions for Matlab model for the calculation of evapotranspiration and wind speed measured at 2m above the surface are required. The FAO Penman-Monteith equation and the mean daily air temperature (T_{mean}) are used to calculate the slope of the saturation vapour pressure curves (D). The impact of mean air density (Pa) as the effect of temperature variations on the value of the climatic parameter is small in these cases.

The value of T_{mean} is the average of the two maximum and minimum temperatures (T_{max}) and (T_{min}), respectively. Hypothetical references of the crop are the height of 0.12 m, an albedo of 0.23 a fixed surface resistance of 70 s m^{-1}.

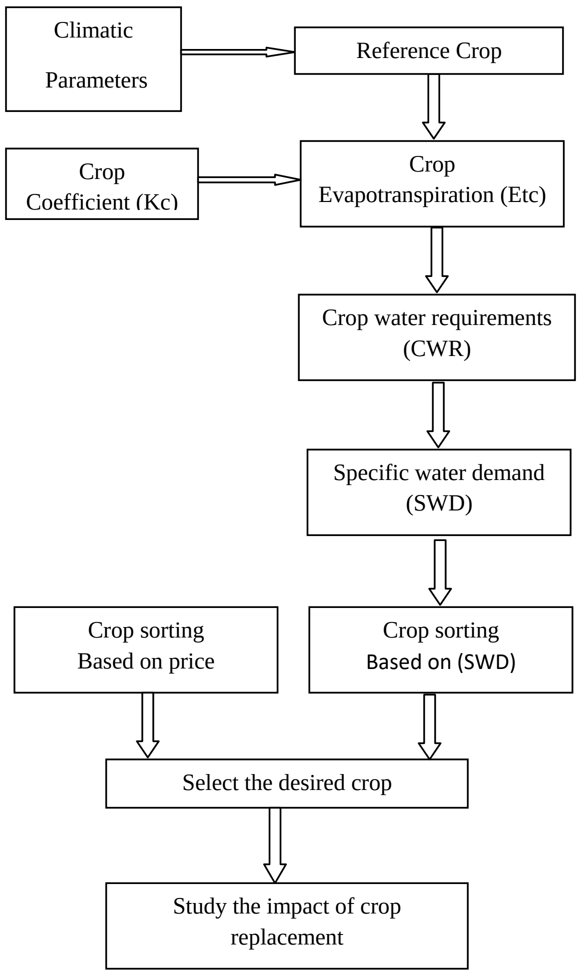

Fig 1: Flowchart of the proposed Matlab mode

The first step to calculate the virtual water is the Evapotranspiration of each crop. Different equations have been used to calculate the ET_o. The Matlab model based on the Penman-Monteith equation was implemented to calculate the ET_o in Egypt through all months of the year. The model was constructed from one interface. The input to the model is the temperature, humidity, wind speed, sunrise time, latitude and the month number.

Model Calibration

In order to calibrate the Matlab model, The absolute error of the difference between ETo values was calculated by the model, and by Cropwat program the results are illustrated in table I. The average percentage of absolute error reaches 3.26%, this value may be due to the truncation in the Penman-Monteith equation.

Then, the crop water requirements (CWR), for the 22 crops, were calculated as illustrated in table II. The average absolute error between CWR of the proposed model and CropWat is 9.6% this value may be attributed to the climatic parameters and location effects.

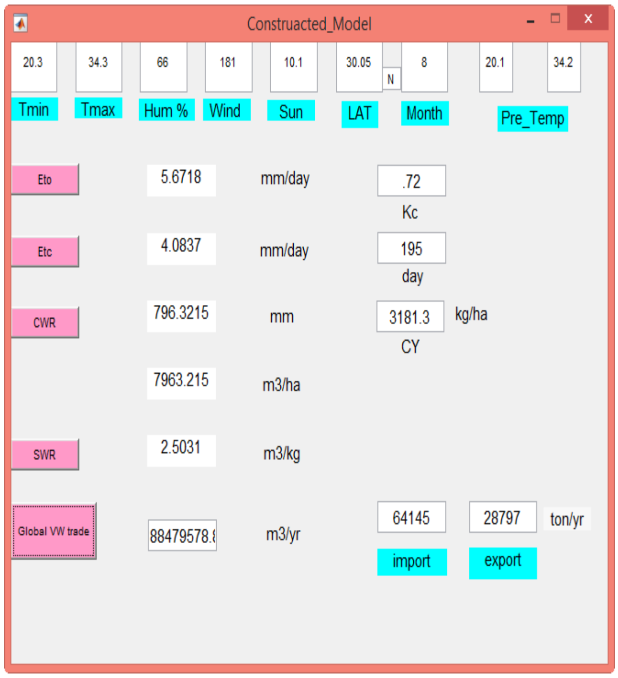

Fig 2: the interface of Matlab model

Table (I): calibration results for ETo values

Error (%)	Cropwat	Model	Month
5.75	2.61	2.46	1
5.12	3.32	3.15	2
4.04	4.45	4.27	3
3.31	5.74	5.55	4
2.76	6.88	6.69	5
2.38	7.56	7.38	6
2.06	7.27	7.12	7
1.91	6.79	6.66	8
1.85	5.95	5.84	9
1.89	4.76	4.67	10
3.02	3.31	3.21	11
5.04	2.58	2.45	12

After the calibration process, the model is applied to calculate the SWD for the 22 selected crops based on equations from 1 to 3; the results are shown in Table III. Then, the crops are classified according to the world price and the SWD into four groups. Group A includes; Maize, Wheat, Soybean, Dry Beans, Potato, Grapes, Cabbage and represents the crops of low price and low water requirements. Group B includes; Tomato, Vegetables, Melon, Artichoke and represents crops of high water and low water requirements. Group C includes Millet, Barely, Grains, Sorghum and represents the crops of low price high water requirements. Finally, group D includes; Pepper, Cotton, Pulses, Mango, Groundnut, Rice, Citrus and represents the crops of high price high water requirements.

Table (II): Calibration results for CWR values

	Model (mm)	Cropwat (mm)	Error (%)
Barely	309.7	295.3	4.89
Cotton	1111.4	1194.2	6.94
Cabbage	695.6	781.2	10.96
Grains	637.6	697.5	8.59
Groundnut	452.4	518	12.66
Maize	730.2	760.4	3.97
Mango	1812.5	1952.8	7.18
Pepper	262.2	389.2	32.62
Citrus	1196.0	1307.1	8.5
Potato	424.7	450.6	5.74
Pulses	652.3	678.6	3.87
Rice	1258.7	1133.1	11.09
Sorghum	648.3	676.6	4.18
Soybean	264.0	356.6	25.97
Vegetables	528.4	571.5	7.55
Tomato	506.5	495.5	2.23
Melon	378.7	393.2	3.68
Grapes	1004.5	1105.9	9.17
Artichoke	1558.7	1647.2	5.37
Dry Beans	339.9	379.9	10.54
Wheat	407.8	462	11.74
Millet	363.8	426.4	14.69

Table (III): SWD for the selected crops based on Matlab model results, World Prices, Crop Yield.

	SWD (m^3/ton)	Price (1000$/ton)	Crop Yield (ton/ha)
Barely	1995.737	362.547771	1548.3
Cotton	3488.591	1500	3181.8
Cabbage	226.2782	1075	30758.6
Grains	1645.579	150	3880.7
Groundnut	1373.526	1415.64113	3290.8
Maize	983.7885	186.896272	7389.8
Mango	1602.422	1176.53802	11295.4
Pepper	52834.1	2378.66109	1593.1
Citrus	1189.006	1500	10042
Potato	155.6306	627.222795	27244
Pulses	2937.35	2304.34783	2213.9
Rice	1341.959	1246.62654	9366.9
Sorghum	1433.628	438.461539	4520.7
Soybean	751.4286	396.71832	3500
Vegetables	382.2169	1340	13774.9
Tomato	127.1443	1333.33333	39773.7
Melon	138.5885	1705.20231	27275
Grapes	437.4144	807.673861	22930.2
Artichoke	822.0408	1740	18928.5
Dry Beans	1023.993	486.131342	3313.5
Wheat	618.9832	195.352629	6575.3
Millet	7532.171	325	481.8

Table (IV). Classification of the 22 crops based on prices and water requirements

High Price	**Group (B)** Tomato, Vegetables, Melon, Artichoke.	**Group (D)** Pepper, Cotton, Pulses, Mango, Groundnut, Rice, Citrus.
Low Price	**Group (A)** Maize, Wheat, Soybean, Dry Beans, Potato, Grapes, Cabbage.	**Group (C)** Millet, Barely, Grains, Sorghum.
	Low Crop Water Requirements	**High Crop Water Requirements**

The impacts of the replacement process will be measured by calculating three governing factors; the first is the virtual water that can be saved, where the RSWD of the crops contained in group B and the 22 crops was calculated based on equation (4). This determines the amount of the virtual water saved in m^3 when replaced by one ton of these crops with the 22 crops, to choose the best crops to be imported instead of being cultivated in Egypt. Then, the RSWD was calculated among the crops contained in group C and the 22 crops to choose the best crops to be exported regarding the amount of virtual water saved, cultivated areas and cash return.

$$RSWD_n = \frac{SWD_n}{SWD_S} \quad (4)$$

Where

$RSWDn$, is the relative specific water demand of crop n,

SWD_n , is the SWD value of crops, n=1, 2, 3 …... 22 and

SWD_S , is the value of the SWD of selected crop.

The second factor was the relative area (RA_n) which was estimated based on $RSWD$ and according to equation (5), as follow:

$$RA_n = \frac{RSWD_n}{cy(n)} * 1000 \quad (5)$$

Where

$cy(n)$, is the Crop yield of the crops in (ton /ha), n=1,2,3,..22.

The third factor was the relative price (RP_n) of all crops with respect to the SWD, it is based on the RSWD calculated from equation (4). The RP calculated from equation (6) is as follows:

$$RP_n = RSWD_n * P_n \quad (6)$$

Where:

RP_n , is the relative price of all crops, n=1,2,3,.......22 and

P_n , is the price of crop (n) in (1000 $).

III. RESULTS AND DISCUSSION

The concept of crop replacement can be achieved by replacing the crops existing in groups (C&D) and use the resulted virtual water and areas saved to cultivate the crops contained in groups (A&B).

As the amount of water saved from the replacement process is appreciable, it is expected to produce large amounts of crops that need low water requirements so the trade balance will be improved.

Based on the classification, the lowest water consumption crops with the highest prices will be suggested to be exported and the highest water consumption crops with lowest prices will be suggested to be imported. That means only crops in group B is suggested to be cultivated in Egypt and then exported while, crops in group C are suggested to be imported. The two suggestions aim to save both the cultivated lands and water, consequently the cash return will increase.

The replacement impact of the 22 crops with the crops contained in group B was studied. The saved RSWD is resulted from cultivating crops contained in this group with respect to the other 22 crops that were calculated from Equation (4) and represented in Table V. On the other hand, the impact of replacement of the crops contained in group C; with the 22 crops was also studied and the relative water saved was calculated. The results are presented in Table VI.

Meanwhile, the impact of crop replacement on the cultivated land was studied by replacing the area cultivated by the 22 crops with group B crops once and by replacing group C crops with the other 22 crops once more to study the imported priority. The RA saved in the two times was calculated from equation (5) and the results are presented in Tables VII&VIII.

Finally, considering the cash return from the crop replacement process based on the average global prices in (1000$/ton) is presented in Table IX, where the RP when replacing one ton of the 22crops with one ton of the crops contained in group B was calculated from equation (6). The RP between crops contained in group C end the 22 crops was represented in Table X in order to take into consideration the economic situation in the country to determine the priority of the imported crops.

Table (V). The impact of crop replacement according to Crop Water Requirements (ton) for export.

	Vegetables	Tomato	Melon	Artichoke
Barely	5.22	15.70	14.40	2.43
Cotton	9.13	27.44	25.17	4.24
Cabbage	0.59	1.78	1.63	0.28
Grains	4.31	12.94	11.87	2.00
Groundnut	3.59	10.80	9.91	1.67
Maize	2.57	7.74	7.10	1.20
Mango	4.19	12.60	11.56	1.95
Pepper	138.23	415.54	381.23	64.27
Citrus	3.11	9.35	8.58	1.45
Potato	0.41	1.22	1.12	0.19
Pulses	7.69	23.10	21.19	3.57
Rice	3.51	10.55	9.68	1.63
Sorghum	3.75	11.28	10.34	1.74
Soybean	1.97	5.91	5.42	0.91
Vegetables	---	3.01	2.76	0.46
Tomato	0.33	---	0.92	0.15
Melon	0.36	1.09	---	0.17
Grapes	1.14	3.44	3.16	0.53
Artichoke	2.15	6.47	5.93	---
Dry Beans	2.68	8.05	7.39	1.25
Wheat	1.62	4.87	4.47	0.75
Millet	19.71	59.24	54.35	9.16

Table (VI). The impact of crop replacement according to Crop Water Requirements (ton) for import.

	Barely	Grains	Sorghum	Millet
Barely	---	1.21	1.39	0.26
Cotton	1.75	2.12	2.43	0.46
Cabbage	0.11	0.14	0.16	0.03
Grains	0.82	---	1.15	0.22
Groundnut	0.69	0.83	0.96	0.18
Maize	0.49	0.60	0.69	0.13
Mango	0.80	0.97	1.12	0.21
Pepper	26.47	32.11	36.85	7.01
Citrus	0.60	0.72	0.83	0.16
Potato	0.08	0.09	0.11	0.02
Pulses	1.47	1.78	2.05	0.39
Rice	0.67	0.82	0.94	0.18
Sorghum	0.72	0.87	---	0.19
Soybean	0.38	0.46	0.52	0.10
Vegetables	0.19	0.23	0.27	0.05
Tomato	0.06	0.08	0.09	0.02
Melon	0.07	0.08	0.10	0.02
Grapes	0.22	0.27	0.31	0.06
Artichoke	0.41	0.50	0.57	0.11
Dry Beans	0.51	0.62	0.71	0.14
Wheat	0.31	0.38	0.43	0.08
Millet	3.77	4.58	5.25	---

Table (VII).Crop replacement impact according to Average Crop Yield (ha) for export

	Vegetables	Tomato	Melon	Artichoke
Barely	3.372	10.138	9.301	1.568
Cotton	2.869	8.623	7.911	1.334
Cabbage	0.019	0.058	0.053	0.009
Grains	1.109	3.335	3.060	0.516
Groundnut	1.092	3.283	3.012	0.508
Maize	0.348	1.047	0.961	0.162
Mango	0.371	1.116	1.024	0.173
Pepper	86.768	260.840	239.301	40.344
Citrus	0.310	0.931	0.854	0.144
Potato	0.015	0.045	0.041	0.007
Pulses	3.471	10.435	9.573	1.614
Rice	0.375	1.127	1.034	0.174
Sorghum	0.830	2.494	2.288	0.386
Soybean	0.562	1.689	1.549	0.261
Vegetables	---	0.218	0.200	0.034
Tomato	0.008	---	0.023	0.004
Melon	0.013	0.040	---	0.006
Grapes	0.050	0.150	0.138	0.023
Artichoke	0.114	0.342	0.313	---
Dry Beans	0.809	2.431	2.230	0.376
Wheat	0.246	0.740	0.679	0.115
Millet	40.902	122.958	112.804	19.018

Table (VIII). Crop replacement impact according to Average Crop Yield (ha for import)

	Barely	Grains	Sorghum	Millet
Barely	---	0.783	0.899	0.171
Cotton	0.549	0.666	0.765	0.146
Cabbage	0.004	0.004	0.005	0.001
Grains	0.212	---	0.296	0.056
Groundnut	0.209	0.254	0.291	0.055
Maize	0.067	0.081	0.093	0.018
Mango	0.071	0.086	0.099	0.019
Pepper	16.618	20.154	23.133	4.403
Citrus	0.059	0.072	0.083	0.016
Potato	0.003	0.003	0.004	0.001
Pulses	0.665	0.806	0.925	0.176
Rice	0.072	0.087	0.100	0.019
Sorghum	0.159	0.193	---	0.042
Soybean	0.108	0.130	0.150	0.029
Vegetables	0.014	0.017	0.019	0.004
Tomato	0.002	0.002	0.002	0.000
Melon	0.003	0.003	0.004	0.001
Grapes	0.010	0.012	0.013	0.003
Artichoke	0.022	0.026	0.030	0.006
Dry Beans	0.155	0.188	0.216	0.041
Wheat	0.047	0.057	0.066	0.012
Millet	7.833	9.500	10.905	---

Table (IX). Crop replacement impact according to Average Global Prices (1000$) for export

	Vegetables	Tomato	Melon	Artichoke
Barely	1893	5691	5221	880
Cotton	13691	41157	37758	6366
Cabbage	636	1913	1755	296
Grains	646	1941	1781	300
Groundnut	5087	15293	14030	2365
Maize	481	1446	1327	224
Mango	4933	14828	13604	2293
Pepper	328804	988439	906817	152881
Citrus	4666	14027	12869	2170
Potato	255	768	704	119
Pulses	17709	53236	48840	8234
Rice	4377	13158	12071	2035
Sorghum	1645	4944	4536	765
Soybean	780	2345	2151	363
Vegetables	---	4028	3696	623
Tomato	444	---	1223	206
Melon	618	1859	---	287
Grapes	924	2779	2549	430
Artichoke	3742	11250	10321	---
Dry Beans	1302	3915	3592	606
Wheat	316	951	873	147
Millet	6405	19253	17663	2978

Table (X). Crop replacement impact according to Average Global Prices (1000$) for import

	Barely	Grains	Sorghum	Millet
Barely	---	440	505	96
Cotton	2622	3180	3650	695
Cabbage	122	148	170	32
Grains	124	---	172	33
Groundnut	974	1182	1356	258
Maize	92	112	128	24
Mango	945	1146	1315	250
Pepper	62971	76371	87662	16685
Citrus	894	1084	1244	237
Potato	49	59	68	13
Pulses	3392	4113	4721	899
Rice	838	1017	1167	222
Sorghum	315	382	---	83
Soybean	149	181	208	40
Vegetables	257	311	357	68
Tomato	85	103	118	23
Melon	118	144	165	31
Grapes	177	215	246	47
Artichoke	717	869	998	190
Dry Beans	249	303	347	66
Wheat	61	73	84	16
Millet	1227	1488	1708	---

From Tables V, VII and IX, it is expected that the crops in group D will have the greatest values regarding the Saved SWD, the cultivated areas and the cash return based on their pre classification of the high prices and high water requirements crops. These crops are omitted from the replacement process according to their strategic and economic values as well as their good reputation all over the world. Regardless these crops, it was obvious that, the common crops suggested to be imported instead of being cultivated in Egypt are (Millet, Barley, Grains and Sorghum). Then, using their areas to cultivate Vegetables, Tomato, Melon and Artichoke which will be exported., Millet is the best choice for replacement but it is not a familiar crop in Egypt so the second choice was for Barely. Concerning the RSWD, the relative area saved and the relative cash return, the greatest effect occurred when replacing Barely with Tomato which saved about 15.70 m^3/ton, 10.138 ha/ton and 5691 (1000$/ton), respectively. On the other hand, less effect occurred when replacing Barely with Artichoke that saved 2.43 m^3/ton, 1.568 ha/ton and 880 (1000$/ton), respectively. From Tables V, VII and IX, it was obvious that, the crops having the priority for import are (Barley, Grains, Sorghum and Millet). The effect of replacement of these crops with other crops was studied to give complete vision to the decision makers to decide the priority of the imported crops according to the local market needs taking into consideration the economic situation in the country.

IV. CONCLUSION

The water scarcity in Egypt can be covered by the crop replacement. However, this replacement should be in line with the food habits and the strategic views of the country. Barley achieves the aim of this study, its price is low and it consumes a high amount of water. The impact of crop replacement shows that, if Barley is replaced with Tomato the relative water saved reached 15.70m^3/ton and the relative area saved reached 10.138ha/ton. On the other hand, this process of replacement will have a positive effect on the national income of Egypt as the relative cash return between Tomato and Barely reaches 5691 (1000$/ton). From this study concerning the imported crops, the relation between the 22 mentioned crops and the lowest prices, highest water consumption crops were studied to aid the decision makers to determine the priority of import according to the local market needs taking into consideration the economic situation in the Country.

REFERENCES

1. A.Y. oekstra,"Virtual water: measuring flows around the world", in Encyclopedia of Water Science. 2007, Taylor & Francis.
2. T.T.Ngo, et al., "Water scarcity in Vietnam": A point of view on virtual water perspective. Water resources management, 2018. 32(11): p. 3579-3593.
3. H.Tiwari, et al., "Mapping of virtual water from wheat and rice consumption for India". Sustainable Water Resources Management, 2017. 3(3): p. 227-239.
4. G. Deng, L. Wang, and Y. Song, "Effect of variation of water-use efficiency on structure of virtual water trade-analysis based on input–output model". Water Resources Management, 2015. 29(8): p. 2947-2965.
5. M. Sebri, "Bridging the Maghreb's water gap: from rationalizing the virtual water trade to enhancing the renewable energy desalination". Environment, development and sustainability, 2017. 19(5): p. 1673-1684.
6. A. El-Sadek, "Virtual water trade as a solution for water scarcity in Egypt". Water Resources Management, 2010. 24(11): p. 2437-2448.
7. T.M. Abu-Sharar, E.K. Al-Karablieh and M.J. Haddadin, "Role of virtual water in optimizing water resources management in Jordan". Water resources management, 2012. 26(14): p. 3977-3993.
8. R.G. Allen et al., "Crop evapotranspiration-Guidelines for computing crop water requirements"-FAO Irrigation and drainage paper 56. Fao, Rome, 1998. 300(9): p. D05109

AUTHORS PROFILE

Dr. Marwa Mohamed Aly, assistant professor in Helwan University. She has 19-years' experience in applied research of Hydrology, water management processes, and mathematical modeling of the Engineering problems. She jointly supervised a number of Master's and Ph.D. thesis, where this research was extracted from one of them. She attended number of National, regional and International conferences. She has a number of publications in national and international journals.

Eng. Hayam Ahmed Farouk, post graduate student in Helwan University. She is a civil Engineer, interested in water resources engineering and virtual water. She had finished her Master thesis entitled "Adopting Water Trade Operations to Solve Water Scarcity Problems in Egypt and Nile Basin Countries" which is still unpublished.

Dr. Fakhry Abd Elhamid Abd Elmotelb, assistant professor in Helwan University. He has 25-years' experience in applied research of Hydrology, water management processes. He jointly supervised a number of Master's and Ph.D. thesis, where this research was extracted from one of them. He attended a number of National, regional and International conferences. He has a number of publications in national and international journals.