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An Analytical Study to Estimate Water Footprint and Its Economic Effects for Wheat Crop in Egypt

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ABSTRACT: Wheat is the most important strategic grain crops in Egypt. The average area with wheat in Egypt is about 3.144 million Feddans (2000-2018). Wheat cultivated area comprises about 45.2% of the total area of the winter crops during (2016 – 2018), which is about 6.953 million Feddans. Under the condition of limited resources in Egypt, Virtual Waters principle considers importing/exporting crops equivalent to importing/exporting water resources from other countries. Available works used farm-scale experimental data, which didn't add-up to applicable values. In this work, we use data by CAPMS (Central Agency for Public Mobilization and Statistics; Egypt) to evaluate wheat water footprint in Egypt. The objectives of this work are: to estimate the Overall Water Footprint indicators for the wheat crop, and to estimate the food security coefficient, and the strategic stock for the crop. In addition, to evaluate the relative value of contribution from local wheat production, wheat imports and the Egyptian agricultural investment abroad in achieving food security for wheat crop in Egypt. The total quantity of virtual waters acquired from imports and Egyptian agricultural investment abroad to achieve the complete level of food security coefficient (1.0) for wheat was estimated. It ranges between the lowest value of 2.9 billion Cubic meters, and highest value of 11.7 billion cubic meters, valued about 3.7 billion Egyptian Pounds, at 95% degree of confidence. Based on the above results, this work recommends the following: 1) Supporting the research authorities to develop a new wheat crop which require less quantities of irrigation water. 2) implementation of modern irrigation systems that reduce irrigation water losses in agriculture. And 3) Adopting agricultural policy that balances between the local production, trade and the external agricultural investment together with optimization of the return from the water unit used in the agricultural .

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1.Introduction:

Wheat is one of the most important winter strategic grain crops in Egypt where it is used for bread production and many food industries depend on it. The average area cultivated with wheat is about 3.144 million Feddans and this cultivated area comprises about 45.2% of the winter crops during the rotation (2016 – 2018), which is about 6.953 million Feddans. Under the condition of limited water resources in Egypt, Virtual Waters principle considers importing/exporting crops is equivalent importing/exporting water resources from other countries. Increased economic bilateral cooperation between countries makes external agriculture in another country an important necessity, especially if the other country has relatively higher (more plentiful) water resources to land ratio

2.Research Problem

Wheat crop is one of the most important cereals crops in Egypt. Due to the rapid increase in population and the increasing demand for wheat grain, the government has to import large quantities of wheat approximately equal to 51% of the Egyptian annual needs of wheat. Because of the limitation in both water resources and the area that can be cultivated with wheat, we must focus on increasing wheat productivity for the unit of water used. Water footprint is one of the most important methods for this subject. However, the available works on wheat water footprint may not lead to suitable understanding for how to face the resulting needs. This is because few works are available on this subject. Moreover, available works used farm-scale experimental data, which didn't add-up to applicable values when generalized to the national scale. Thus, we are faced by the problem of lack/scarcity of research and studies that estimate water footprint for the crops, especially the cereal crops, and wheat crop in particular. This is also reflected in the financial difficulty in facing the deficiency in fertilizer requirements for wheat, and the resulting increase in wheat imports on the account of other commodities. This participates in an increase in national budget imbalance due to agricultural trade deficit in Egypt. This in turn is negatively reflected on the individuals' incomes. Solving this problem can participate in reduction of deficiency in the national agricultural trade balance, which will be positively reflected on the individuals' and the national incomes.

In this work, we will use the data of CAPMS (Central Agency for Public Mobilization and Statistics; Egypt) to reliably evaluate wheat water footprint in Egypt.

3.Research Objectives:

This research aims to estimate the Overall Water Footprint indicators for the wheat crop, and to estimate the food security coefficient, and the strategic stock for the crop. In addition, we will evaluate the relative value of contribution from local wheat production, wheat imports and the Egyptian agricultural investment abroad in achieving food security for wheat crop in Egypt.

4.Research Methodology & Information/Data Sources

Methodology of this work relies on Qualitative and Quantitative Analysis to estimate overall water footprint indicators and food security equations' coefficients. We will also use the Probability Distribution (Bernoulli distribution) to estimate the standard errors at 95% confidence level. This work relies on published and non-published secondary information issued by various Egyptian authorities. These authorities include the Ministry of Water Resources and Irrigation (MWRI), Ministry of Agriculture and Land Reclamation (MALR), electronic site of the Arab Organization for Agricultural Development, and Food and Agriculture Organization (FAO) for the time duration of (2008-2018).

5,Theoretical Framework

To facilitate understanding of this work, we will review definitions of the following terms:

5-1 Abroad Agricultural Investment:

This is the investment which extends for a long period of time and covers long-lasting bilateral interests between the company in the mother country and another company in another country. The company which has the assets of the foreign investments may or may not belong to the mother country.

This kind of investment is an important indicator for the state economy interaction with the world economies. Abroad agricultural investment may be done by purchase/possession of actually existing agricultural companies, by controlling a group of companies through bond/share purchases of a significant proportion or through direct land/farm investments by ownership or rental of agricultural lands together with the participation in the productive aspects or through buying crops of large water requirements from foreign countries/markets.

5-2 Water Footprint

This term expresses the quantity of the Fresh water which a country uses during multiple stages for production of commodities and services that are consumed by the same country. The internal water print is estimated by subtracting the quantity of exported water by the food commodity exported abroad from total virtual used quantity of water used on the national level. The external water footprint is the estimated quantity of water which would be used to domestically produce the products that are imported from abroad.

5-3 The Concept of Food Security

This term expresses the complete ability of all people at all times to obtain food to satisfy their nutritional needs and to sustain good and healthy life. "Food Security" is defined as: All individuals of all categories of the society can obtain sufficient good quality food at all times. On the state level, the country should have the appropriate facilities for the production and domestic/external trade to satisfy the needs of all the individuals. In addition, a state should work on achieving self-sufficiency with respect to national production, and the ability to face potential risks and crises. Also, a state should maintain sufficient amounts of strategic stocks of food to meet the consumption needs for a certain period of time.

6. The Strategic Stock

The Strategic Stock is the quantity of a certain food commodity stored by the country stores in order to meet its local consumption or its exports needs during a specific period of time.

- **First: The Production Indicators for Wheat Crop in Egypt**

Table (1) (referred to as A-1) presented in the (Appendix) shows the Production Indicators for the Wheat Crop in Egypt during the Period (2018-2020), we deduce the following:

6.1 Development of Total Production of the Wheat Harvest in Egypt:

Table (A-1) shows that Average Total Production of Wheat Crop in Egypt equals approximately 8.03 million Tons. The lowest limit for the Total Production of the crop was approximately 6.26 million ton in Year 2001. This shows a reduction of approximately 22% as compared to the average yearly over the study period. The upper limit for the total production of the crop was approximately 9.61 million tons in Year 2015, i.e. an increase of approximately 19.37% as compared to the general average over the study period. Considering the General Time Trend Equation shown in Table (2), it shows that Total Production of Wheat in Egypt increased yearly during the study period by approximately 0.15 million tons. The statistical significance for the used sample was proved at (0.01 & 0.05) significance levels.

6.2 Development of the Feddan Productivity for Wheat Crop in Egypt:

Table (A-1) in the Appendix, shows that the Average Feddan Productivity for wheat crop in Egypt was 2.72 Ton/Feddan for the duration (2000 – 2018).

The lowest limit for Feddan productivity for the crop was approximately 2.39 Ton/Feddan for the Year 2010 where the reduction was about 12.1% of the General Average over the study period. The upper limit for the Feddan productivity was 2.88 Ton/Feddan for the year 2017 which was about 5.9% of the General Average over the study period. Estimating the General Time Trend Equation in Table (2), it shows that the Feddan productivity for the Egyptian wheat crop increased annually during the study period by about 0.004 Ton/Feddan. However, the significance of this increase isn't proved which means that the Relative Constant for the Feddan Productivity for the Egyptian wheat crop was around the Arithmetic Mean.

6.3 Expansion of the Total Area for Wheat Crop in Egypt

Table (A-1) in the Appendix shows the Average Total Area for wheat crop in Egypt in the study period of (2000-2018) was approximately 2.95 million Feddans. This is a reduction of about 20.7% of this average value over the study period. The highest value of the Total Area of the crop was approximately 3.47 million Feddans in the Year 2015 with an increase of about 17.6% the average value for the study period. Using the estimate of the General Time Trend Equation shown in Table (2), the Total Area of the Egyptian wheat increased annually during the study period (2000-2018) by approximately 0.053 million Feddan/yr. The Statistical Significance for the used sample was proved at the regular significance levels of (0.01, 0.05).

We studied the Partial Correlation between the Total Production of the Egyptian wheat crop and both of its Feddan Productivity and total area. Feddan Productivity and Total Area trend coefficients were approximately (0.4, 0.9), respectively, which shows that the increase in the total production for the Egyptian wheat crop is mainly due to the cultivated area factor and not to the Feddan productivity factor.

7, Estimation of the Water Fingerprint and its Indicators for the Egyptian Wheat Crop:

In this work, Water Fingerprint for the Egyptian Wheat crop is estimated using the quantity of water used in Local Production, and quantity of the water gained from the imports and their lost counterparts as the consequence of exports during the Period (2000-2018). Table (3) shows the local production of the wheat crop and the average water needs for the production of "one Ton". Thus, the average annual quantity of water required for wheat production reached about 4969.3 million cubic meters. The minimum amount of water used in wheat crop production reached approximately 3756 million cubic meters in the Year 2001, which is a reduction of about 24.4% from the average during the study period of (2000-2018). The highest value of the quantity of water required for wheat production during the study period was about 5940.1 million cubic meters in the Year 2014, which was an increase of about 19.5% above the average of the study period (2000-2018). Regarding the quantity of exported water that is used for the production of the exported Egyptian wheat crop, Table (3) shows that the average quantity of the exported water during (2000-2018) was about 2.2 million cubic meters, with the lowest value equals Zero during the same period. The highest value of exported water during the same period was about 6.88 million cubic meters in the Year 2007, which is an increase of about 212.7% from the study period average.

Table (2) shows the Statistical data of the development in the General Time Trend, Productivity and the Production of the Wheat crop over the country (national) level during the Period (2018-2020):

Table (2) shows the Statistical data of the development in the General Time Trend, Productivity and the Production of the Wheat crop over the country (national) level during the Period (2018-2020)

Data	Coefficient (A)	Coefficient (B)	(t) Value	Adjusted R^2	(F) Value	Variability Rate
Total Cultivated Area (Million Feddan)	2.42	0.053	** 6.48	0.70	** 42.0	2.0
Feddan Productivity (Ton/Feddan)	2.68	0.004	0.91	0.01	0.84	---
Total Production (Million Tons)	6.49	0.154	** 6.1	0.66	** 36.6	2.0

(**) Significant at (0.01), (*) Significant at (0.05)
Source: Collected and calculated from Table (1) data in the Appendix

Table (3) shows that the average internal water footprint for the production Egyptian wheat crop was about 4967.1 million cubic meters during the study period (2000-2018). The lowest value was about 3750 million cubic meters in Year 2001, which was a reduction rate about 24.5% of the study period average. The highest value was about 5940.1 million cubic meters in Year 2014, which was an increase of 19.6% above the study period average. The average rate of annual variability was about 1.8%. Investigating the General Time Trend Equation in Table (4), it shows that the internal water footprint increased yearly during the study period by about 89.35 million cubic meters. The Statistical Significance for the used sample was significant at the regular statistical levels (0.05, 0.01).

Table (3) shows that the average external water footprint for imported wheat was about 5472.9 million cubic meters for the study period (2000-2018). The minimum value was about 2925.3 million cubic meters in the Year 2000, which was a reduction of about 46.5% from the study period average. The maximum value for the external water footprint for wheat crop was about 8157.1 million cubic meters, in the Year 2018, which was an increase of about 49% of the study period average. The average variability rate of was about 4.3%.

Exploring the General Time Trend Equation in Table (4), it shows that the external water footprint increases yearly during the study period by about 233.9 million cubic meters. This was found statistically Significant for the Sample used at the regular statistical significance levels of (0.01, 0.05).

Table (3) shows that the Total Water Footprint for wheat crop during the study period (2000-2018) was about 10439.9 million cubic meters. The minimum value was about 6841.6 million cubic meters in the Year 2000, which was a reduction rate of about 14.5% from the Average during the study period. The highest value for the Total Water Footprint for wheat crop was about 30.7% from the Average during the study period. The average variability rate was about 3.1%. Investigating the General Time Direction Trend Equation in Table (4), it shows that the Wheat Crop Total Water Footprint increased yearly during the study period by about 323.3 million cubic meters. This was proven statistically significant for the used sample at the regular significance levels of (0.05, 0.01).

Table (3) that the Average Percent Ratio of Dependence on the external water resources was about 51.5% during the study period. The minimum value was about 42.8% in the Year 2000, which was reduction of about 16.9% from the study period average. The highest value for the percent dependence on external water resources was about 5908% in the Year 2018, i.e., an increase of about 16.1% from the study period average, and the variability rate was about 1.3%. Table (4) shows that the Rate of Dependence on the External Water Resources increases yearly during the study period by about 0.66%, which was proven Statistically Significant for the used Sample at the regular statistical levels of (0.05, 0.01).

Table (3) shows that the Average Percent Ratio of self-dependence on Local Water Resources was about 48.1% during the study period (2000-2018). The lowest value was about 40.2% in the Year 2018, which was a reduction of about 16.4% from the study period average. The highest value for Self-dependence on Local Water Resources was about 57.2% in the Year 2000which was an increase of about 18.9% from the study period average. The average rate of variability was about 1.4%.

Investigating the General Time Trend Equation in Table (4), it shows that the Percent Self-Dependence on Local Water Resources during the study period is reduced yearly by about 0.66%. This was proven Statistically Significant for the sample used at the regular significance levels of (0.05, 0.01).

Table (3): The Development of the External, Internal & Total Water Footprint for Wheat Crop during the Period (2000-2018).

Data	**Internal Water Footprint (million Cubic meters).**			**External Water Footprint (million Cubic Meters)**	**Total Water Footprint (million Cubic Meters)**	**Water Footprint Indicators**	
Year	**Quantity of Water used in the Production**	**Quantity of Exported Water (million Cubic meters)**	**Internal Water Footprint**			**% Dependence on the External Water Imports (%)**	**% Self-sufficiency of Local Water Resources (%)**
2000	39163	0	3916.	2925.	6841.6	42.8	57.2
2001	3756	6.0	3750	3414	7164	47.7	52.3
2002	3944.	6.0	3938.	3920.	7857.3	49.9	50.1
2003	4218.	6.2	4212	3695.	7906.8	46.7	53.3
2004	4363.	0.	4363.	4296.	8658.3	49.6	50.4
2005	4651.	0.	4651.	4480.	9131	49.1	50.9
2006	5599.	0.7	5598.	5145.	10742	47.9	52.1
2007	5072	6.9	5065.	4811.	9875.6	48.7	51.3
2008	5453.	0.7	5452.	5165.	10617.	48.6	51.4
2009	5276.	6.2	5269.	6143.	11411.	53.8	46.2
2010	309.6	3.6	5206	7309.	12414	54.8	41.6
2011	51.4	1.8	5102.	6182.	11283.	54.8	45.2
2012	5194.	0.	5194.	6780.	11974.	56.6	43.4
2013	5310.	0.	5311.	4772.	10082.	47.3	52.7
2014	5490.	0.	5940.	6721.	12661.	53.1	46.9
2015	5697.	0.	5697.	6705.	12401.	54.1	45.9
2016	5479.8	0. 9	5480.	7081.	12560.	56.4	43.6
2017	4739.	0.6	4738.	6286.	11024.	54.	43.
2018	5495.	3.5	5492.	8157.	13648.	59.8	40.2
Avg.	4969.3	2.2	4967.	5473.	10439	51.5	48.1

- Quantity of Exported Water = Quantity of Water used in the Production – Quantity of the Exported Virtual Water.
- Total Water Footprint = Internal Water Footprint + External Water Footprint

- Rate of dependence on the External Water Incomes(%) = (External Water Footprint / Total Water Footprint) * 100
- Rate of Self-Sufficiency from the Local Water Resources (%) = (Internal Water Footprint / Total Water Footprint) * 100
- Coefficient of Food Security = Resultant Change in the Strategic Stock Volume / Yearly Average Local Consumption.

Source:

- International Organization Site for Food & Agriculture (FAO).
- Information stated in Table (2.1) in the Appendix.

8. Estimation of the Food Security Coefficient and the Secure Strategic Stock for the Egyptian Wheat Crop:

8-1 Estimation of the Duration of Consumption Reliance on Local Production:

8-2 Estimation of the Local Consumption Duration that is Covered by the Imports:

Table (5) shows that average duration of wheat local consumption that is covered by the imports is about 194.5 Days during the study period (2000-2018). The lowest value was about 139.6 Days in the Year 2000, and the highest value was about 268.1 Days in the Year 2012.

The above information shows that our reliance on imported wheat is larger than our reliance on our local production. This in turn is not a good indicator for the Egyptian economy, as it negatively participates in increasing the deficit in the national monetary budget. In addition, to the Egyptian food security component for wheat crop is thus vulnerable to potential economic and environmental fluctuations of the international wheat trade market. Moreover, some countries tend monopolize the production of some commodities (including wheat production and trade) and manipulate the market price. These countries may even use it as political tool for enforcing their political will and may even use it in enforcing trade sanctions.

8-3 Estimating the Secure Strategic Stock Size for the Egyptian Wheat Crop:

Table (5) shows that the Strategic Stock Size for the Egyptian Wheat Crop was about 9.5 million Tons during the Period (2000-2018). There was a production surplus of the Egyptian Wheat Crop as compared to the local consumption during the years 2004, 2005, 2006, 2009, 2012, 2013, 2014, 2015, 2016, 2018. The estimated total surplus was 16.123 million tons during the study period (2000-2018). There was a deficit in the Egyptian Wheat crop production during the remaining study years, and the estimated total deficit was about 6.646 million tons during the Study Period (2000-2018).

8-4 Estimation of the Food Security Coefficient:

The Strategic Stock Size was estimated and compared it to the average Local Consumption of the Egyptian Wheat Crop. The Food Security Indicator for wheat crop was estimated at about 0.58 during the Period (2000-2018). Consequently, this necessarily requires to increase the strategic stock for the Egyptian wheat crop for a Period that is not less than nine months according to the Food Security standards.

9, Achievement of Current Level of Food Security for the Egyptian Wheat Crop with the Participation of Current Levels of Local Production and Imports with no Egyptian Agricultural Investment Abroad:

According to Table (6), in case of non-availability of the external Egyptian agricultural investment during the Period (2000-2018), Food Security at current level for the Egyptian wheat crop depends on both the local production and the imports. In view of the food security coefficient of (0.58), percent participation from local production of the wheat crop to achieve food security for the crop is of significant importance. The lowest value of local production participation in food security coefficient is about 14.9%, and the highest value is about 40.9%, at 95% Confidence Level. Table (6) also shows that the percent participation of the Egyptian imports of wheat to achieve security at current level for the same crop is also of significant importance with the lowest value of 17.1% and the highest value of about 43.1%, at 95% confidence level.

Table (4). Statistical Variables for General Time trend for internal, external and total water footprint for wheat crop for Egypt during the study period (2000-2018).

Information	**Coefficient (A)**	**Coefficient (B)**	**(t) Value**	**R square Adjusted**	**(F) Value**	**Rate of Change**
Internal Water Footprint.	4074.	89.35	4.93**	0.56	24.3**	1.8
External Water Footprint.	3134.	233.9	8.05**	0.78	64.9**	4.3
Total Water Footprint.	7207.	323.3	8.25**	0.79	68.02	3.1
Rate of Dependence on the External Water Resources.	45.11	0.66	5.37**	0.61	28.9**	1.3
Rate of Dependence on Local Water Resources.	54.89	-0.66	-5.37**	0.61	28.9**	1.4

(**) Significant at (0.01); (*) Significant at (0.05)
Source: Collected and Calculated from data in Table (3).

Table (5): The development of the Economic Pointers for a Period sufficient for the sufficient production and a period for covering the imports and strategic stock for the Egyptian Wheat Harvest during the Period (2000-2018).

Years	**Local Consumption (1000)**	**Local Production Sufficiency Period & Imports Covering Period and Total of Two Periods (in Days).**			**Change in Strategic Stock for the Egyptian Wheat Harvest.**	
2000	35.1	186.9	139.6	326.5	---	1351.4
2001	35.3	177.3	161.5	338.8	---	934.86
2002	36.4	182.1	181.3	363.4	---	68.24
2003	37.3	183.6	161.1	344.7	---	767.18
2004	38.4	187	184.1	371.1	234.2	---
2005	40.3	202	194.5	396.5	1269.	---
2006	41.9	197.4	181.4	378.8	577.2	---
2007	42.7	172.6	163.9	336.5	---	1227.0
2008	46	73.3	164.1	337.4	---	1270.6
2009	49.6	171.8	200.2	372	337.2	---
2010	48.5	147.6	207.2	354.8	---	499.7
2011	51	164.1	198.8	362.9	---	110.1
2012	42.9	205.4	268.1	473.5	4654.	---
2013	47.2	200.4	180.1	380.5	731.6	---
2014	46.6	199.1	225.3	424.4	2768.	---
2015	50.4	190.7	244.4	415.1	2525.	---
2016	53.2	175.6	226.9	402.5	1994	---
2017	54.8	153.6	203.8	357.4	---	417.48
2018	54	154	229.6	384.2	1031.	---
Avg.	44.8	180.3	194.	374.8		
Strategic Stock					9476.8	
Food Security Coefficient					0.58	

Period of Sufficient Production for Consumption = Total Local Production / Local Consumption (Daily).
Period for covering the Imports for Consumption = Total Imports / Local Consumption (Daily).

Surplus Quantity in Consumption = ((Total Periods of Production & Imports – 35) * (Daily Consumption) – Exports.

Deficient Quantity in Consumption = ((365 – Sum of Production & Imports Periods) * Daily Consumption) – Exports.
Strategic Stock = Total Surplus Quantity in the Consumption – Total Quantity of Deficiency in the Consumption.
Source: Collected and Calculated from:
Ministry of Agriculture and Lands Exclamation, Economic Affairs Sector, Agricultural Statistics Bulletin.
Arabic Organization for Agricultural Development (www.aoad.org).

10. Achievement of Food Security at Different Levels for the Egyptian Wheat Crop with the Participation of Current Levels of Local Production and Imports, with Additional Participation of Agricultural Investment Abroad:

Information in Table (7) shows the achievement of different levels of food security for the Egyptian wheat crop in case of adding agricultural investment abroad, with current levels of both local production and imports. In case of targeted achievement of security level of (0.6), the percent participation of local production (at current production level) will be of significant importance with lowest value of about 14.8%, and the highest value of about 41%, at 95% significance level. In case of targeted achievement of food security level of 1.0, the participation of local production (at current production level) will also be of significant importance, with the lowest percent value of 7.7%, and the highest percent value of 48.1%, at 95% confidence level.

Table (6): Achieving the Food Security for the Egyptian Wheat Crop with the contribution of the Local Production, Import and the Egyptian Agricultural Investment abroad during the Period (2000-2018).

Information	Strategic Stock in (Thousand Tons)	Food Security Coefficient	Local Production	Imports
2000-2018	9476.8	0.58	27.9%	30.1%
Probability of contribution in achieving Food Security.			0.29	0.30
Probability of non-contributing in achieving Food Security.			0.30	0.28
Standard Error for Probability of contribution in achieving food security (Virtual).			0.05	0.05
Standard Error at 95% Confidence Level (1).			0.13	0.13
Probability of Contribution in achieving Food Security at 95% significance level.			0.28 ± 0.13	0.30 ± 0.13
Percent Ratio of contribution in achieving Food Security at 95% confidence level. **Highest Value: -----------------------------------** **Lowest Value: ------------------------------------**			40.9% 14.9%	43.1% 17.1%

Probability Distribution (Bernoulli Distribution) at 95% Confidence Level.
Source: Collected and calculated from Table (5) information.

11. Achievement of Different levels of Food Security for the Egyptian Wheat Crop with Variable Participation of Imports, under current levels of Local Production and Agricultural Investments abroad.

Table (8) shows that in order to achieve (0.6) level for food security for wheat crop, the participation percent ratio of imports of wheat will have the lowest value of about 16.1% and highest value of about 43.6% at 95% degree of confidence. In case of achieving the complete level of the Food

Security Coefficient (1.0), the imports' percent ratio participation will have a lowest value of 9.5% and a highest value of about 50.7% at 95% Degree of Confidence. Achievement of different security levels between 0.6 and 1.0 will have variable values between these two levels as shown in Table (8).

Table (7): Achievement of different levels of Food Security for the Egyptian wheat crop with the participation of current levels of Local Production and imports, with additional agricultural investment abroad (for the study period: 2000-2018).

Food Security Levels	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
Information (2000-2018)	**Local Production needed to achieve various Levels of the Food Security**				
Probability of Participation in achieving Food Security.	0.28	0.28	0.28	0.28	0.28
Probability of non-Participation in achieving Food Security.	032	0.42	0.52	0.62	0.72
Standard Error for Probability of Participation in achieving Food Security.	0.08	0.08	0.09	0.10	0.10
Standard Error at 95% Degree of Confidence.	0.13	0.16	0.17	0.19	0.22
Probability of Participation in achieving Food Security at 95% Degree of Confidence.	0.28 ± 0.13	0.28± 0.16	0.28 ± 0.17	0.28 ± 0.19	0.28 ± 0.20
Percent Ratio of Participation in achieving Food Security at 95% Degree of Confidence. **Highest Value: ---------------------------------** **Lowest Value: ---------------------------------**	**41%** **14.8%**	**43.4%** **12.4%**	**45%** **10.8%**	**45.5%** **9.3%**	**48.1%** **7.7%**

Source: Collected and Calculated from Table (5) Information.

Table (8): Achievement of different levels of Food Security for the Egyptian Wheat Crop with the participation of variable levels of Imports under the current levels of Local Production and Agricultural Investment abroad.

Information	Imports to Achieve Various Levels of Food Security				
Probability of Participation of Imports in achieving Food Security.	0.6	0.7	0.8	0.9	1.0
Probability of not Participation of Imports in achieving Food Security.	0.30	0.30	0.30	0.30	0.30
Standard Error for probability of participation of Imports in achieving Food Security.	0.3	0.4	0.5	0.6	0.7
Standard Error at 95% Degree of Confidence.	0.14	0.15	0.17	0.19	0.21
Probability of Participation of Imports in achieving Food Security at 95% Degree of Confidence.	0.30 ± 0.14	0.30 ± 0.15	0.30 ± 0.17	0.30 ± 0.19	0.30 ± 0.21
Percent Ratio of Participation of Imports in achieving Food Security at 95% Degree of Confidence.					
Highest Value: ----------------------	43.6%	45.4%	47.5%	49.1%	50.7%
Lowest Value: -------------------------	16.6%	14.8%	12.7%	11.1%	9.5%

Source: Collected and Calculated from Table (5) Information.

12. <u>Achievement of Food Security for the Egyptian Wheat Crop with the Participation of the external agricultural investment under current levels of Local Production and Imports:</u>

Table (9) shows that in case of achieving (0.6) level for food security coefficient for wheat crop, the participation of external agricultural investment will have a lowest value of 2.9% and a highest value of 6.9% at 95% Degree of confidence. In order to achieve the complete level of the food security coefficient (1.0), the external agricultural investment participation will have the lowest value of 19.9% and the highest value of 64.1% at 0.95% Degree of Confidence. Achieving different security levels between these two values will have other values of external agricultural investment between these mentioned values as shown in Table (9).

13) <u>Estimating the Quantity & Monetary Value of Virtual Waters Acquired by Assuming Different Values for Imports and Egyptian Agricultural Investments Abroad to Achieve Higher Food Security Coefficient Values for Wheat Crop Average Local Consumption During The Time Period (2000-2018):</u>

Table (10) shows that the quantity of imported wheat to achieve the complete level (1.0) of Food Security ranges between the Lowest value of 1.5 million Tons and highest value of 8.3 million at 95% Degree of Confidence. The quantity of wheat from the Egyptian agricultural investment needed to achieve the complete level of food security ranges between lowest value of 3.2 million tons and highest value of 10.5 million tons at 95% degree of confidence. The estimated average water needs for producing a one-ton unit is about 620.2 cubic meters/ton (Ministry of Irrigation and Water Resources, Yearly Report for the Research Institute in Administering the Waters & Methods of Irrigations" average over period; 2000-2018). Data shown in Table (10) also shows that the quantity of virtual waters acquired from importing the wheat to achieve the complete level (1.0) for Food Security ranges between lowest value of 930.3 million cubic meters, which worth 293 million Egyptian Pounds, and a highest value of 5.1 billion cubic meters, which worth 1.6 billion Egyptian Pounds, at 95% Degree of Confidence. The quantity of the virtual waters acquired from recommended Egyptian agricultural investment abroad to achieve the complete level of food security (1.0) for wheat varies between the lowest value of 1.9 billion cubic meters at a value of 625.1 million Egyptian Pounds and a highest value of 6.5 billion cubic meters at a value of 2.1 billion Egyptian Pounds, at 95% confidence level. In view of above results, in order to achieve the complete level of food security for wheat, the total quantity of the virtual waters acquired from imports and from Egyptian agricultural investment abroad ranges between the lowest value of 2.9 billion cubic meters at value of 918.1 million Egyptian Pounds, and a highest value of 11.7 billion cubic meters at a value of 3.7 billion Egyptian Pounds, at 95% Confidence Level.

Table (10) also shows the highest and lowest values for quantities of wheat, and virtual waters acquired from the imports and the external agricultural investment abroad to achieve different levels of food security of wheat crop according to the average local consumption during the Period (2000-2018).

Table (9) Achievement of Food Security for the Egyptian Wheat Crop with the Participation of different levels of external agricultural investment under the current levels of Local Production and Imports.

Information	**Variable Levels of Food Security for the Egyptian Wheat Crop with Participation of Variable Levels of External Agricultural Investment Under Current Levels of Local Production & Imports**				
	0.6	0.7	0.8	0.9	1.0
Probability of Participation of External Agricultural Investment in achieving Food Security.	0.02	0.12	0.22	0.32	0.42
Probability of not Participation of External Agricultural Investment in achieving Food Security	0.58	0.58	0.58	0.58	0.58
Standard Error for Possibility of Participation in achieving Food Security.	0.03	0.06	0.08	0.10	0.11
Standard Error at 95% Degree of Confidence.	0.05	0.12	0.16	0.19	0.22
Probability of Participation of External Agricultural Investment in achieving Food Security at 95% Degree of Confidence.	0.02 ± 0.049	0.12 ± 0.12	0.22 ± 0.16	0.32 ± 0.19	0.42 ± 0.22
Percent Ratio of Participation of External Agricultural Investment in achieving Food Security at 95% Degree of Confidence. **Highest Value: ----------------------------** **Lowest Value: -------------------**	6.9 % 2.9 %	23.8% 0.02%	38.1% 5.9%	51.4% 12.6%	64.1% 19.9%

Source: Collected and Calculated from Table (5) Information.

14) Summary and Recommendations

Wheat Crop is one of the most important main cereal crops in Egypt because of its nutritional value, use in bread production and use in many food industries. Due to the scarcity of water resources and the timely decreasing average individual's annual share of water in Egypt, this work aimed at studying the total indicators of water fingerprint for the Egyptian wheat crop. In addition, we estimated the needed participation percent ratios of local production and imports and the Egyptian agricultural investment abroad in order to achieve national security for the crop.

Using farm level measured data in estimating the crop water footprint on the national level results in significant errors. Thus, we used officially published data on the national level in estimating wheat water footprint on the national scale. By estimating the total water footprint for the wheat crop, it was estimated that the annual average total water footprint is about 10439.9 million cubic meters during the Period (2000-2018). The general time trend for the annual total water footprint increases by (323.3) million cubic meters, with proven statistical significance for the used sample. The time trend equation for the percent ratio of reliance on the external water resources shows yearly increase of (0.66%) during the study period. with proven statistical significance for the used sample. The time trend equation for the percent ration of sufficiency of annual local water resources shows yearly reduction rate of (0.66%), with proven statistical significance of the used sample.

The strategic stock volume for the Egyptian wheat crop is estimated about 9.5 million tons, during the Period (2000-2018). The estimate by the food security coefficient for the wheat crop during the study period is about (0.58). This work also estimated the quantity of virtual waters acquired from importing wheat to achieve the complete level of food security coefficient (1.0). It ranges between the lowest value of 930.3 million cubic meters valued at 293 million Egyptian Pounds, and highest value of 5.1 billion cubic meters valued at 1.6 billion Egyptian Pounds, at 95% Level of Confidence.

The virtual quantity of acquired waters from the Egyptian agricultural investment abroad to achieve the complete level of food security coefficient (1.0) for wheat was also estimated. It ranges between the lowest value of

1.9 billion cubic meters valued at 625.1 million Egyptian Pounds, and highest value of 6.5 billion cubic meters, valued at about 2.1 billion Egyptian Pounds, at 95% degree of confidence. Consequently, the total quantity of virtual waters acquired from imports and Egyptian agricultural investment abroad to achieve the complete level of food security coefficient (1.0) for wheat was also estimated. It ranges between the lowest value of 2.9 billion Cubic meters, and highest value of 11.7 billion cubic meters, valued about 3.7 billion Egyptian Pounds, at 95% degree of confidence.

Based on the above results, this work recommends the following:

- Supporting the Egyptian research authorities to develop new species of Egyptian wheat crop which require less quantities of irrigation water.
- Large-scale implementation of modern irrigation systems that reduce irrigation water losses in agriculture, instead of current flood irrigation in old lands in the Nile Valley and the Nile Delta.
- Adopting integrated national agricultural policy that balances between the local production, trade and the external agricultural investment together with focus on optimization of the return from the water unit used in the agricultural production.

Table (10) also shows the highest and lowest values for quantities of wheat, and virtual waters acquired from the imports and the external agricultural investment abroad to achieve different levels of food security of wheat crop according to the average local consumption during the Period (2000-2018).

Information	**Food Security Levels for Wheat Crop**				
	0.6	**0.7**	**0.8**	**0.9**	**1.0**
Volume of Stock in (million Tons).	9.82	11.5	13.1	14.7	16.36
Average Local Consumption in (million Tons).	16.36	16.36	16.36	16.36	16.36
Quantity of Imported Wheat in (million Tons). **Highest Value:** --------------------------------- **Lowest Value:** ---------------------------------	4.28 1.6	5.2 1.6	6.2 1.7	7.2 1.6	8.3 1.5
Quantity of Wheat from the external agricultural investment in (million tons). **Highest Value:** --------------------------------- **Lowest Value:** ---------------------------------	0.68 ---	2.7 0.002	4.9 0.77	10.5 3.2	
Quantity of Virtual Waters Acquired from Imports in million Cubic meters. **Highest Value:** --------------------------------- **Lowest Value:** ---------------------------------	2654.5 992.3	3225 1054.3	3845.2 1054.3	4465.4 992.3	5147.7 930.3
Value of Virtual Waters Acquired from Imports in **million Egyptian Pounds**. **Highest Value:** --------------------------------- **Lowest Value:** ---------------------------------	**836.2** **312.6**	**1015.9** **332.1**	**1211.2** **332.1**	**1406.6** **312.6**	**1621.5** **293**
Quantity of Virtual Waters Quantity Acquired from the Outside Agricultural Investment in **million cubic meters**. **Highest Value:** --------------------------------- **Lowest Value:** ---------------------------------	421.7 ---	1674.5 1.24	3039 477.6	4714 1116.4	6512.1 1984.6
Value of Virtual Waters Acquired from the Outside Agricultural Investment in million **Egyptian Pounds**. **Highest Value:** --------------------------------- **Lowest Value:** ---------------------------------	**132.8** **-----**	**527.5** **0.391**	**957.3** **150.4**	**1485** **351.7**	**2051.3** **625.1**
Total Quantity of Virtual Waters Acquired from Imports and external agricultural investments in million cubic meters. **Highest Value:** --------------------------------- **Lowest Value:** ---------------------------------	3076.2 992.3	4899.5 1055.5	6884.2 1531.9	9179.4 2108.7	1659.8 2914.9
Total Value of Virtual Waters Acquired from Imports and the external agricultural investments in million Egyptian Pounds. **Highest Value:** --------------------------------- **Lowest Value:** ---------------------------------	969 312.6	1543.4 332.5	2168.5 482.5	2891.6 664.3	3672.8 918.1

** The Average Unit Price of the Irrigation Water is estimated at approximately 0.315 Egyptian Pound per m^3 of water, based on Reference Number (4) as it was collected and calculated from Tables (5, 8, 9) mentioned above in this work.

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Appendices

Table (A-1): The development of the Total and Productive Faddan Area and the Total Production for the Wheat Product in Egypt during the Period (2000-2018).

Years	Total Area (Million Faddan)	Faddan Production	Total Production (Million Ton)
2000	2.46	2.67	6.56
2001	2.34	2.67	6.26
2002	2.45	2.7	6.63
2003	2.5	2.73	6.85
2004	2.6	2.76	7.18
2005	2.98	2.73	8.14
2006	3.06	2.7	8.27
2007	2.71	2.72	7.37
2008	2.92	2.73	7.97
2009	3.14	2.71	8.52
2010	3	2.39	7.16
2011	3.04	2.75	8.37
2012	3.16	2.78	8.81
2013	3.37	2.8	9.46
2014	3.39	2.74	9.28
2015	3.47	2.77	9.61
2016	3.35	2.79	9.34
2017	2.92	2.88	8.24
2018	3.2	2.61	8.03
Average :	**2.95**	**2.72**	**8.03**

Source: Ministry of Agriculture and Land Reformation, Economic Affairs Sector, Central Administration for Agricultural Economy, Yearly Bulletin for the Agricultural Statistics.

Table (A-2): Development of both the Quantity of the Imports and Local Consumption Quantity in thousand tons and the water rationed and the water needs for the ton for the Egyptian wheat harvest during the Period (2000-2018).

Years	Quantity of Consumption (thousand tons)	Quantity of Imports (thousand tons)	Water Rationed for the Harvest (Cubic meters/Faddan)	Water needs for Ton for Harvest (cubic meters/Faddan).
2000	11125	4.9	1594	597
2001	9821	5.7	1602	600
2002	11628	6.6	1606	594.8
2003	10936	6.01	1681	615.8
2004	11754	7.07	1677	607.6
2005	13353	7.84	1560	571.4
2006	14257	7.6	1828	677
2007	13773	7	1872	688.2
2008	14546	7.55	1868	684.2
2009	14592	9.93	1678	619.2
2010	14978	10.05	1739	727.6
2011	16878	16878	10.14	1677
2012	15657	11.5	1639	589.6
2013	17210	8.5	1572	561.4
2014	17025	8.5	1572	561.4
2015	18411	11.31	1642	592.8
2016	19410	12.07	1637	586.7
2017	20019	11.17	1621	562.8
2018	19714	12.4	1744	658.1
Avg.	**15004.6**	**8.8**	**1683.7**	**620.2**

Source:

- Ministry of Irrigation and water resources, Yearly statistical report for the Institute of Research of Water Management and Irrigation Methods.
- Ministry of Agriculture & Land Reforms, Economic Affairs Sector, Yearly Bulletin for Agricultural Statistics.
- Arabic Organization for Agricultural Development, Statistical Yearly Book (www.aoad.org).