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Banana production and export in the light of the water footprintand Virtual water trade

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Abstract: The research aimed to study of the production indicators and the foreign trade of bananas, the estimation of the amount of virtual water in the foreign trade of bananas, and the monetary return of the water unit, the estimation of the amount of the internal and external water footprint and its most important indicators, and the effect of reducing the area Bananas on rationalizing water use and the amount of virtual water. The research reached a number of results, the most important of which are: that the banana area increases by about 1.75 thousand acres annually, it was found that the average amount of virtual water exported during the period study as a result of banana export amounted to about 5.4 million m^3, while the average amount of imported virtual water reached about 4.9 million m^3. It was also found that the average total water footprint of bananas, which represents their total water consumption, amounted to about 388.2 million m^3 and increases by 18.6 million m^3 annually. It was also shown through the scenarios presented in the research that the third scenario represented in reducing the banana area by 30% by the use of modern irrigation methods so that the water ration does not exceed 5000 m^3. It was also found through the scenarios presented in the research that the third scenario represented in reducing the area of bananas by 30% and using modern irrigation methods so that the water ration does not exceed 5000 m^3 according to Ministerial Resolution No. 104 of 2020, is the best scenario where the banana area is reduced by 21, 79 thousand acres compared to 2019, and achieved water savings of about 290 million m^3 as a result of reducing the amount of water used in banana production, and the amount of exports decreased by 10.8 thousand tons, which includes the provision of a virtual amount of water exported that amounted to about 6.34 million m^3, the deficit in the virtual water balance decreased by 5.2 million m^3. As a result of the reduction in exports, the water footprint, this reflected the water consumption of bananas, decreased by 284 million m^3.

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1. Introduction:

Despite Water resources scarcity in many developing countries in the world, including Egypt, are treated as God‘s gift commodity given to humans for use in various human activities away from the calculations of cost and economic return. This has led to an increase in waste and irrational use of water resources, as well as the pollution of its sources. From this standpoint, the importance of virtual water emerged as a concept that imposed itself recently, in order to solve the problem of limited water resources, rationalize their use and raise the efficiency of its use, and later another concept emerged, which is the water footprint.

Virtual water is defined as the water included in the product or commodity, not in the real sense, but in the virtual sense, as it refers to the water needed to produce these products or commodities, while the concept of the water footprint expresses the total amount of fresh water consumed to obtain a commodity or service starting from the stage production until it reaches the final consumer that it is a multi-dimensional indicator that not only indicates the volume of water contained in the commodity, but also shows the location and source of the water used which leads to more efficiency in the use of water, especially in dry areas.

Banana is one of the most important fruit crops in Egypt, ranking fourth in terms of exports after citrus, grapes and mango. it is considered a voracious water-consuming crop due to the high water needs of an acre of it, as an acre consumes about 7.5 thousand m3 according to 2019 data, whereas, this quantity may be directed of water to increase the area planted with some important strategic crops such as wheat and corn, as this amount is sufficient to plant about 3.59 acres of wheat or 2 acres of corn [1].

Therefore, the Egyptian agricultural strategy aimed to limit the high water consumption crops, including bananas, which resulted in the issuance of Joint Ministerial decree No. 104 of 2020 between the Egyptian ministry of Agriculture and the ministry of Water Resources and Irrigation whereas, The first article of it prohibits the cultivation of bananas in new desert lands, regardless of the source of irrigation water, with the exception of the areas actually planted before the issuance of this decision until the end of the periods of their production cycles, with a maximum of three years. The second article of it stipulates the commitment to modify the irrigation system for banana cultivation in the old lands from flood irrigation to modern methods with a water rate of no more than five thousand cubic meters per acre annually. Provided that no fertilizers are disbursed until after changing the irrigation system on these lands, starting from the beginning of the summer season, on the first of May, 2021.

Research problem:

The problem of this research encounters in the expansion of banana cultivation in Egypt, where its area increased to reach about 72.6 thousand acres in 2019, despite being a voracious crop for water use, in the light of the increasing need for expansion in the cultivation of strategic crops with the limited Egyptian water resources and their insufficiency to meet the needs of horizontal agricultural expansion programs.

Research aims:

The main objective of this research is to study the production and export of bananas in the light of the water footprint and the virtual water trade by studying: (1) The indicators of productivity and foreign trade of bananas. (2) The estimation of the amount of virtual water in the foreign trade of bananas and the monetary return of the water unit. (3) The estimation of the amount of the internal and external water footprint and its most important indicators. (4) The reducing effect of the area of bananas on rationalizing water use and the amount of virtual water.

2. Research method and data sources:

In achieving the research objectives, the research relies on the descriptive economic analysis method, in addition to the quantitative economic analysis method, which is represented by the use of some indicators and statistical criteria that can be clarified as follows:

(1) Using the Growth Function to determine the general trend and the change rate of the variables under study.

(2) **Equations used in estimating virtual water, which can be clarified as follows**:

- **Water requirements per ton of the crop** = water ration per acre ÷ productivity per acre of the crop.
- **The amount of virtual water exported** = the amount of crop exports x water requirements per ton.
- **The amount of virtual imported water** = the amount of imports of the crop x the water requirements per ton.
- **Net imports of virtual water (the trade balance of virtual water)** =

The amount of imports of virtual water - the amount of exports of virtual water.

(3) The economic return per unit of exported and imported water, which is one of the criteria that guide the possibility of expanding the production of some crops or devising new varieties of other crops thus increasing their exports or decreasing their imports, where it is equal to the value of exports or imports ÷ virtual water exported or imported.

(4) **Equations used in estimating the water footprint and its indicators**:

- **The amount of water used in production** = the amount of crop production x water requirements per ton.
- **The internal water footprint** = the amount of water used in production - the amount of virtual water exported.
- **External water footprint** = the amount of virtual water imported from abroad - the amount of virtual water that has been re-exported from the imported products.
- **Total water footprint** = internal water footprint + external water footprint.
- **Dependence on external water imports** = (external water footprint ÷ total water footprint) x 100.
- **Self-sufficiency ratio of local water resources** = (internal water footprint ÷ total water footprint) x 100.

The research relied on published and unpublished secondary data issued by the Ministry of the Egyptian Agriculture and Land Reclamation, the Central Agency for Public Mobilization and Statistics, in addition to the United Nations foreign trade database published on the website: **db/comtrade.un.org//http.**

3. Results:

(1) Indicators of productivity and foreign trade of bananas:

Using the data in Table No. (1) studying the fruitful area of bananas in Egypt during the period from 2005 to 2019, it was found that it ranged between a minimum of about 47.3 thousand acres in 2006, and a maximum of about 72.6 thousand acres in 2019, with an annual average reached about 60.4

thousand acres with an annual growth rate of about 2.9%, which is equivalent to about 1.75 thousand acres annually.

By studying the acre productivity of it during the same period, it was found that it ranged between a minimum of about 17.98 tons in 2005, and a maximum of about 20.07 tons in 2010, with an annual average of about 18.9 tons.

A study of the quantity of its production showed that it ranged between a minimum of about 855,000 tons in 2006, and a maximum of about 1,366,000 tons in 2017, with an annual average of about 1,142,000 tons, and an annual growth rate of about 3%, which is equivalent to about 34, 3 thousand tons annually.

It was also found that the water needs of an acre of bananas ranged between a minimum of about 5147 m^3 in 2005 and a maximum of about 7489 m3 in 2019, with an annual average of about 6,373 m^3, and an annual growth rate of about 2%, which is equivalent to about 127.5 m^3 annually.

Table No. (1): Development of production indicators and foreign trade during the period (2005-2019).

Year	**Fruitful area** (acre)	**Productivity** (tons/acre)	**Production** (thousand)	**Water Meter** (m^3/ acre)	**Quantity of Imports** (Thousand Tons)	**Value of exports** (million dollars)	**Quantity of exports** (Thousand ton)	**Imports value** (millions of dollars)
2005	51303	17.98	923	5147	2.84	0.775	10.7	2.18
2006	47344	18.06	855	6357	6.09	1.67	10.47	2.24
2007	51359	18.41	945	5560	4.66	1.21	8.85	2.03
2008	56508	18.8	1062	6314	2.97	2	8.54	2.72
2009	57007	19.66	1121	5843	2.48	2.55	20.11	14.05
2010	53964	20.07	1083	5745	10.14	5.26	16.59	12.96
2011	55941	18.85	1054	5683	25.63	13.82	9.93	8.38
2012	59697	18.93	1130	5511	28.39	22.82	4.5	3.81
2013	60090	19.27	1158	8078	28.76	22.55	10.22	9.02
2014	65510	19.59	1284	6157	26.1	18.32	13.23	11.06
2015	65497	20.06	1314	6702	33.64	54.42	6.87	5.29
2016	66762	18.19	1214	7171	24.69	12.36	10.75	8.73
2017	72044	18.95	1366	7146	3.25	2.38	33.6	19.76
2018	69770	18.53	1293	6697	7.33	3.85	42.19	22.91
2019	72599	18.33	1331	7489	8.34	5.65	24.58	12.67
Average	**60360**	**18.91**	**1142**	**6373**	**14.4**	**11.31**	**15.41**	**9.19**
Growth	**(2.9)****	**(0.1)****	**(3)****	**(2)****	**(9)**$^{n.s}$	**(14)**$^{n.s}$	**(5.7)**$^{n.s}$	**(14)****

Source: Compiled and calculated from:
- Central Agency for Public Mobilization and Statistics, Irrigation and Water Resources Bulletin, miscellaneous issues.
- Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Agricultural Statistics Bulletin, miscellaneous issues.
- United Nations Foreign Trade Database, http://db/comtrade.un.org//.

The quantity of Egypt's imports of bananas ranged between a minimum of about 2,48 thousand tons in 2009, and a maximum of about 33,64 thousand tons in 2015, with an annual average of about 14.4 thousand tons, and the value of imports from it ranged between a minimum of About 775,000 dollars in 2005, and a maximum of about 54.4 million dollars in 2015, with an annual average of about 11.3 million dollars.

The quantity of Egypt's exports of bananas ranged between a minimum of about 4.5 t average of about 15.4 thousand tons, the value of exports ranged between a minimum of housand tons in 2012, and a maximum of about 42,19 thousand tons in 2018, with an annual about$2.03 million in 2007, and a maximum of about $22.9 million in 2018, with an annual average of about $9.19 million. With an annual growth rate of about 14%, this is equivalent to 1.28 million dollars.

(2) Estimated virtual Water Quantity in Banana Foreign Trade and Monetary Return per Unit of Water:

Rationalizing the use of water resources is one of the most important objectives of the agricultural development strategy in Egypt, so it is important to take into account the amount of virtual water exported and imported, especially when evaluating foreign trade returns, where the process of exporting or importing any agricultural commodity is nothing but an export or import process of a quantity Of the water was used in the production of this commodity, and therefore the export of a voracious water crop is considered a depletion of water resources, and by reviewing the data in Table No. (2) it became clear the following:

By studying the needs of the banana ton of water in Egypt during the period from 2005-2019, it was found that they ranged between a minimum of about 286 m3 in 2005, and a maximum of about 409 m^3 in 2019, with an annual average of about 337 m^3, and an annual growth rate of about 1. 9%, this is equivalent to about 8 m^3 annually.

By studying the total amount of water used in banana production in Egypt during the same period, it was found that it ranged between a minimum of about 264 million m^3 in 2005, and a maximum of about 544 million m^3 in 2019, with an annual average of about 389 million m^3, and an annual growth rate of about 4.1%, which is equivalent to 15.9 million m^3.

From a study of the hypothetical amount of water exported as a result of banana export, it was found that it ranged between a minimum of about 1.31 million m^3 in 2012, and a maximum of about 15.25 million m^3 in 2018, with an annual average of about 5.4 million m^3, and a growth rate of about 5.4 million m^3. Annually, it reached about 8.4%, which is equivalent to about 453,000 m^3 annually.

It was also found that the amount of virtual water imported as a result of importing bananas ranged between a minimum of about 737 thousand m3 in 2009, and a maximum of about 12.05 million m^3 in 2013, with an annual average of about 4.9 million m^3.

The value of the water unit exported as a result of the export of bananas ranged between a minimum of about 0.6 dollars in 2006, and a maximum of about 2.9 dollars in 2012, with an annual average of about 1.8 dollars. The value of the unit of imported water as a result of importing bananas ranged between A minimum of about \$0.8 in 2006, and a maximum of about \$4.8 in 2015, with an annual average of about \$2.

Table No. (2): Evolution of the estimated virtual water quantity in the foreign trade of bananas and the monetary return per unit of water during the period (2005-2019)

Year	needs of a ton of water (m^3)	The amount of water used in the production of bananas (million m^3)	The amount of virtual water exported (Million m^3)	The amount of imported virtual water (million m^3)	The value of the exported water unit (dollars)	The value of the imported water unit (dollar)
2005	286	264	3.06	0.81	0.7	1.0
2006	352	301	3.69	2.14	0.6	0.8
2007	302	286	2.67	1.41	0.8	0.9
2008	336	357	2.87	1.00	0.9	2.0
2009	297	333	5.98	0.74	2.4	3.5
2010	286	310	4.75	2.90	2.7	1.8
2011	302	318	2.99	7.73	2.8	1.8
2012	291	329	1.31	8.27	2.9	2.8
2013	419	485	4.28	12.05	2.1	1.9
2014	314	403	4.16	8.20	2.7	2.2
2015	334	439	2.29	11.24	2.3	4.8
2016	394	479	4.24	9.74	2.1	1.3
2017	377	515	12.67	1.23	1.6	1.9
2018	361	467	15.25	2.65	1.5	1.5
2019	409	544	10.04	3.41	1.3	1.7
Average	337	389	5.4	4.90	1.8	2.0
Growth	**(1,9)** **	**(4,1)** **	**(8,4)** **	**(10,9)** n.s	**(5,8)** n.s	**(3,9)** n.s

Source - collected and calculated from: Table No. (1) In the research

From the previous presentation, it was found that the area of bananas increases by about 1.75 thousand acres annually. It was also found that an acre needs on average about 6373 m^3 and it increases annually by 127 m^3, and the production of the ton on average needs about 337 m^3, which increases by about 8 m^3 annually, and the total production needs Bananas average about 389 million m^3, with an annual increase of about 15.9 million m3. This represents a burden on the Egyptian water resources, especially with the increase in the cultivated area.

The average amount of virtual water exported as a result of exporting bananas was about 5.4 million m3, while the average amount of virtual water imported as a result of importing bananas was about 4.9 million m3. This means that it achieved a water deficit in its trade balance of virtual water, and the value of the exported water unit was estimated On average, about $1.8, the average value of the imported water unit was about $2, and accordingly, banana exports should be reduced, and imports from it should be reduced due to the high value of the imported water unit, and the decrease in the value of the exported water unit, especially in light of the limited water resources.

(3) **Estimation of the amount of internal and external water footprint required for banana production and its most important indicators:**

The water footprint is an updated analytical tool to build a comprehensive understanding of water and food security at the local and international levels, which helps decision makers to take the necessary action, to meet the potential expectations of water demand. Since the water footprint expresses the amount of fresh water used in the production of a particular product, directly or indirectly, from the moment of starting the production and processing of the raw materials that make up the product until it reaches the final consumer, this part of the research is concerned with estimating this quantity for the banana crop.

By reviewing the data contained in Table No. (3), it was found that the internal water footprint of bananas ranged between a minimum of about 261 million m^3 in 2005, and a maximum of about 534 million m^3 in 2019, with an annual average of about 383 million m^3, and an annual growth rate of about 4 8%, which is equivalent to about 18.4 million m^3 annually, and the external water footprint of bananas ranged between a minimum of 737 thousand m^3 in 2009, and a maximum of about 12.05 million m^3 in 2013, with an annual average of about 4.9 million m^3. The total water footprint of bananas, which represents their total water consumption, ranged between a minimum of about 261.8 million m 3 in 2005, and a maximum of about 537 million m^3 in 2019, with an annual average of about 388.2 million m^3, and an annual growth rate of about 4, 8%, which is equivalent to about 18.6 million m^3 annually.

It was also found that the percentage of dependence on external water resources for the banana crop ranged between a minimum of about 0.22% in 2009, and a maximum of about 2.51% in 2015 with an average of about 0.8%, while the percentage of self-sufficiency in resources ranged The local water supply for the banana crop ranged between a minimum of about 97.5% in 2012 and a maximum of about 99.8% in 2017, with an average of about 98.8%, meaning that Egypt depends on 98.8% of local water resources for banana production. This confirms the depletion of large amounts of water from the areas planted with bananas in Egypt, which represents a great pressure on water resources due to the high water needs of bananas, especially in light of the Renaissance Dam crisis.

Table No. (3): Estimation of the water footprint and its indicators during the period (2005-2019).

Year	Internal water footprint (million m^3)	External water footprint (million m^3)	Total water footprint (million m^3)	Dependence on external water resources (%)	Percentage of self-sufficiency in local water resources (%)
2005	261	0.81	261.8	0.31	99.7
2006	297	2.14	299.4	0.72	99.3
2007	283	1.41	284.3	0.5	99.5
2008	354	1	354.9	0.28	99.7
2009	327	0.74	327.9	0.22	99.8
2010	305	2.9	308.2	0.94	99.1
2011	315	7.73	322.6	2.4	97.6
2012	328	8.27	335.9	2.46	97.5
2013	481	12.05	493.2	2.44	97.6
2014	399	8.2	407.4	2.01	98
2015	437	11.24	447.9	2.51	97.5
2016	475	9.74	484.2	2.01	98
2017	502	1.23	503.4	0.24	99.8
2018	452	2.65	454.7	0.58	99.4
2019	534	3.41	537	0.63	99.4
Average	383	4.9	388.2	0.8	98.8
Growth rate	(4.8)**	(10.9) n.s	(4.8)**	-	-

Source: Compiled and calculated from: Table No. (1), (2) by research

4) **The effect of reducing the area of bananas on rationalizing water use and the amount of virtual water:**

Three scenarios have been worked out. The first scenario is to reduce the area of bananas by 20%, while the acre needs remain unchanged, while reducing exports by 20% as a result of the decrease in production. The second scenario is to reduce the banana area and use modern irrigation methods to reduce the water needs of the acre by 20%. With a 20% reduction in exports, and the third scenario is a 30% reduction in area while reducing exports by the same percentage, and fixing the water ration according to the ministerial decision so that it does not exceed five thousand cubic meters during the period from 2017-2019.

- **The results of the first scenario:**

It was found from the data in Table No. (4) that if the area planted with bananas decreased from 72,59 thousand acres in 2019 to 58 thousand acres, an estimated decrease of 14,59 thousand acres, with the water needs remaining the same, which would result in a decrease in the amount of water used in the production Bananas from 544 million m3 to 434 million m3, an estimated decrease of 110 million m3, followed by a decrease in exports from 24,58 thousand tons to 19.66 thousand tons, an estimated decrease of 4.92 thousand tons, and a decrease in the amount of virtual water exported from 10, 04 million m^3 to 8 million m^3, an estimated decrease of about 2.04 million m^3, thus achieving a decrease in the trade balance deficit from virtual water, and the same year, from 6.6 million m^3 to 4.6 million m^3, an estimated decrease of about 2 million m^3 as a result of the reduction in exports, which also resulted in a decrease in the total water footprint of the banana crop from 537 million m^3 to 430 million m^3, an estimated decrease of about 107 million m^3. It also results in the percentage of dependence on local water resources in banana production from 99.4% to 99.2%, but it is still high.

- The results of the second scenario:

It was found from the data in Table No. (4) that the planted area with bananas decreased from 72,59 thousand acres in 2019 to 58 thousand acres, and the water ration decreased from 7,489 m^3 to 5,991 m^3 by a decrease of about 1,498 m^3, as a result of which the decrease in the amount of water used In banana production, from 544 million m^3 to 348 million m^3, an estimated decrease of 196 million m^3, and a decrease in exports from 24,58 thousand tons to 19.66 thousand tons, and a decrease in the amount of virtual water exported from 10.04 million m^3 to 6.4 million A decrease in the amount of virtual water, estimated at about 3.6 million m^3, and a decrease in the amount of imported virtual water from 3.41 million m^3 to 2.72 million m^3, resulting in a decrease in the trade balance deficit of virtual water for the same year from 6.6 million m^3 to 3. 68 million m^3 with a decrease estimated at about 2.92 million m^3 as a result of the reduction in exports, which resulted in a decrease in the total water footprint from 537 million m^3 to 344 million m^3 with an estimated decrease of about 193 million m^3, and the percentage of dependence on local water resources in banana production decreased. From 99.4% to 99.2%, but it is still high.

-The results of the third scenario:

It was found from the data in Table No. (4) that the area planted with bananas decreased from 72,59 thousand acres in 2019 to 50.8 thousand acres, with an estimated decrease of about 21,79 thousand acres and the water level decreased from 7489 m^3 to 5000 m^3 by an estimated decrease By about 2489 m^3, and this results in a decrease in the amount of water used in banana production from 544 million m^3 to 254 million m^3, an estimated decrease of about 290 million m^3, and with a decrease in exports from 24,58 thousand tons to 13.8 thousand tons, an estimated decrease of about 10 8 thousand tons, and a decrease in the amount of virtual water exported from 10.04 million m^3 to 3.7 million m^3, an estimated decrease of about 6.34 million m^3, and a decrease in the amount of imported virtual water from 3.41 million m^3 to 2.3 million m^3, The deficit in the trade balance of virtual water for the same year decreased from 6.6 million m^3 to 1.4 million m^3 with a decrease of about 5.2 million m^3 as a result of the reduction in exports, the total water footprint decreased from 537 million m^3 to 253 million m^3, and the percentage of Dependence on local water resources for banana production increased from 99.4% to 99.1%.

Based on the foregoing, the third scenario, which is to reduce banana areas by 30% and use modern irrigation methods so that the water ration does not exceed 5000 m^3 according to Ministerial Resolution No. 104 of 2020, is the best scenario, as the reduction of banana area by 21,79 thousand acres, It achieved a water saving of about 290 million m^3 as a result of reducing the amount of water used in the production of bananas, which also resulted in a decrease in the amount of exports by 10.8 thousand tons, which includes the provision of a virtual amount of water exported that amounted to about 6.34 million m^3, and a decrease in the water balance deficit. As a result of the reduction in exports, the total water footprint, this expresses water consumption of bananas, decreased by 284 million m^3.

Based on the foregoing, the research recommends reducing the areas Crops voracious for water, including bananas, which is inevitable and necessary to provide a measure of water resources, especially in light of its limitations and the Renaissance Dam crisis, which threatens Egypt's water share from the Nile River, the main source of Egyptian water resources.

Table No. (4): The effect of reducing the area of bananas on rationalizing water use and the amount of virtual water during the period (2017-2019).

Year	Area	water meter	The amount of water used in the production of bananas	The amount of virtual water exported	The amount of virtual water imported	External footprint	Internal footprint	Total footprint m^3
	Thousand acre	(m^3)	(million (m^3)	Million (m^3)	Million (m^3)	Million (m^3)	(m^3)	(m^3)
	Actual data from 2017-2019							
2017	72044	7146	515	12.67	1.23	502	1.23	503.4
2018	69770	6697	467	15.25	2.65	452	2.65	454.7
2019	72599	7489	544	10.04	3.41	534	3.41	537
	Results of the first scenario: area reduction 20%, export reduction 20%							
2017	57635	7146	411.9	10.13	1.23	402	1.23	403
2018	55816	6697	373.8	12.19	2.65	362	2.65	364
2019	58079	7489	435	8	3.41	427	3.41	430
	Results of the second scenario: reducing the area by 20%, and reducing the water meter and exports the same percentage							
2017	57635	5717	329.48	8.1	0.98	321.4	0.98	322.4
2018	55816	5358	299.03	9.7	2.11	289.3	2.11	291.4
2019	58079	5991	347.96	6.4	2.72	341.6	2.72	344.3
	Results of the third scenario :reducing the area by 30%: The water meter does not exceed 5000 m^3, and exports are reduced by 30%							
2017	50431	5000	252.18	4.9	0.85	247	0.85	248
2018	48839	5000	244.2	6.4	1.9	238	1.9	240
2019	50819	5000	253.95	3.7	2.3	250	2.3	253

. Source: Compiled and calculated from: Table No. (1), (2) by research

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