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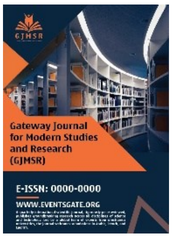

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Current and Future Changes in Water Quotas for the Most Important Strategic Agricultural Crops in Egypt

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Abstract: In recent years, it has become clear that there have been clear changes in water quotas. The research problem is to study and analyze water for the most important winter and summer agricultural crops in Egypt. The research relied on descriptive and quantitative analysis, and the most prominent results were that the water quota during the period (2010-2021) for wheat, sugar beet, beans, clover, and onions increased at an annual growth rate of about 1.7%, 1.5%, 2%, 2.2%, and 1%. It is expected to increase statistically significantly for each of them in the year 2025 by about 17.51%, 21.51%, 19.29%, 33.39%, and 15.2%, respectively. It also became clear that the water quota for winter vegetables decreased at a statistically significant annual rate of about 0.9%, and it is expected to decline by about 13.87% in the year 2025., while the water quota for each of maize, sorghum, cotton, sugarcane, and green fodder increased at a rate of Statistically significant annual growth rates were recorded at approximately 1.8%, 2.4%, 0.97%, 1.4%, and 0.79% for each, respectively. the water quota for each expected to increase by approximately 19.2%, 39.1%, 14.05%, 21.2%, and 11.87% by 2025. The statistical significance of the development of water quotas for rice and summer vegetables has not been proven. The study recommends the need to review the current varieties of the most important summer and winter crops and develop a map of crops that can be expanded and others that can be reduced to preserve Egypt's water capacity.

Keywords: Agriculture, Water, Ration, Crops, Resources.

1. Introduction:

Agriculture is one of the key economic sectors in Egypt. The country relies heavily on this sector to achieve agricultural development goals and meet the demands of a growing population, despite the limited availability of land and water resources. In 2022, Egypt's cultivated land area reached approximately 9.8 million feddans, while its annual share of Nile water remained fixed at about 55.5 billion cubic. Land and water resources are among the most critical components for achieving food security, which underscores the importance of improving their utilization efficiency.Water scarcity is one of the major constraints to economic development in general and agricultural development in particular. The annual per capita share of available water has dropped to less than 630 cubic meters, in addition to Egypt's reliance on virtual water through agricultural imports to bridge the food gap—estimated at around 30 billion cubic meters annually (Annual Bulletin of Irrigation and Water Resources Statistics, 2023).

In recent years, noticeable changes have occurred in crop water requirements, with significant increases for certain crops, placing further pressure on Egypt's water resources. This highlights the

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urgent need to develop new crop varieties with lower water demands. Therefore, analyzing current and future changes in crop water requirements for major winter and summer crops is essential to anticipate future challenges and formulate appropriate responses.

2. Research Problem:

Egypt is among the countries facing a significant water deficit. Agriculture is the most water-consuming sector across all economic activities, and available water resources are the primary input for producing various crops, especially strategic food crops. This directly affects the availability of agricultural production and its ability to meet rising domestic consumption. crop water requirements are among the most critical variables used to determine cultivated areas. Agricultural policies are shaped by what can be planted and produced based on these requirements. However, crop water requirements have undergone substantial changes due to factors such as crop varieties and climatic conditions. Thus, analyzing current and future crop water requirements is vital to understand their evolution and assess their alignment with Egypt's water scarcity challenges.This study focuses on analyzing the crop water requirements of key winter crops—namely wheat, sugar beet, fava beans, early-cut berseem, multi-cut berseem, onions, and winter vegetables—and major summer crops including rice, maize, sorghum, cotton, sugarcane, green fodder, and summer vegetables.

3. Research Objectives:

The main objective of this study is to analyze the development of crop water requirements for Egypt's major agricultural crops during the period (2010–2021). This timeframe was selected due to the significant changes observed in the water requirements of strategic crops. The study also aims to forecast crop water requirements for the year 2025, based on historical trends, to assess future implications for Egypt's water needs and capacities.

To achieve this main goal, the study outlines the following sub-objectives:

1. Examine the evolution of per capita land and water availability in Egypt.
2. Analyze the development of cultivated land area, per capita land share, and per capita water share.
3. Study and analyze the crop water requirements of major winter crops in Egypt—wheat, sugar beet, fava beans, early-cut berseem, multi-cut berseem, onions, and winter vegetables—during the period (2010–2021), and forecast their values for 2025.
4. Study and analyze the changes in crop water requirements for major summer crops in Egypt—rice, maize, sorghum, cotton, sugarcane, green fodder, and summer vegetables—during the period (2010–2021), and forecast their values for 2025.
5. Propose practical solutions and recommendations to address the issue of water scarcity.

4. Research Methodology:

The research relied on both descriptive and quantitative analysis to achieve its objectives. This included the use of general time trend equations to identify the development and growth of the study variables, where temporal development and growth rates were estimated during the period (2010–2021). Since the water statistical bulletin is issued every two years, the latest published data were used. These data were then employed to forecast the water requirements of the most important winter and summer crops in Egypt for the year 2025. This aims to monitor their development and attempt to analyze the results during the study period.

5. Data Sources:

The study relies on secondary data published by the Ministry of Agriculture and Land Reclamation and the Ministry of Water Resources and Irrigation. Key sources include bulletins from the Central Agency for Public Mobilization and Statistics, the Annual Bulletin of Irrigation and Water Resources Statistics, as well as data available through online platforms and other relevant institutions that provide information related to the study topic.

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5. Research results and discussion

1. Evolution of Per Capita Agricultural Land and Water Resources in Egypt:

The following section presents a study and analysis of the development of per capita agricultural land and water resources in Egypt during the period from 2010 to 2021. This aims to assess their trends and growth rates over time, as detailed below:

(1-1) Evolution of Per Capita Agricultural Land in Egypt

Per capita access to land and water resources is considered one of the most critical factors affecting food security. Based on the analysis of data from Table No. (1), Egypt's population during the period (2010–2021) ranged from a minimum of approximately 80.44 million in 2010 to a maximum of about 102.06 million in 2021, with an average of about 92.98 million people.

An analysis of population growth in Egypt during the period (2010–2022) reveals a statistically significant upward trend, with an annual increase of approximately 1.98 million people, representing about 2.14% of the average population. During the same period, the area of agricultural land in Egypt ranged from a minimum of about 8.62 million feddans in 2011 to a maximum of about 9.40 million feddans in 2021, with an annual average of approximately 9.1 million feddans. Estimating the general time trend equation for agricultural land area during this period shows a statistically significant upward trend of about 0.075 million feddans per year, indicating an annual growth rate of approximately 0.76% relative to the average land area during the study period.

Furthermore, the per capita share of agricultural land in Egypt during the same period ranged from a minimum of about 2.15 qirat in 2018 to a maximum of approximately 2.61 qirat in 2010, with an annual average of around 2.37 qirat. Estimating the general time trend equation for per capita agricultural land during this period reveals a statistically significant downward trend of about 0.032 qirat per year, representing a decline of approximately 1.35% from the annual average.

This decline in per capita agricultural land is attributed to the population increasing at a faster rate than the expansion of agricultural land area.

Table (1): The development of population, agricultural land area and per capita annual share of agricultural land and water in Egypt during the period (2010-2022).

capita share of water (m³)	capita share of agricultural land (Kirat)	agricultural land area (million acres)	population (million people)	Statement years
689.93	2.61	8.74	80.44	2010
673.46	2.51	8.62	82.41	2011
657.44	2.50	8.80	84.42	2012
641.92	2.49	8.95	86.46	2013
626.91	2.42	8.92	88.53	2014
612.42	2.41	9.10	90.62	2015
598.47	2.36	9.10	92.74	2016
582.96	2.30	9.13	95.20	2017
571.30	2.15	8.69	97.15	2018
561.16	2.26	9.33	98.90	2019
551.60	2.25	9.45	100.62	2020
543.79	2.21	9.40	102.06	2021
604.84	2.37	9.10	92.48	Average

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Source: Compiled and calculated from the Central Agency for Public Mobilization and Statistics, Population Bulletin and Agriculture and Land Reclamation Bulletin, various issues (2010-2021).

(1-2) Evolution of Per Capita Water Resources in Egypt

As shown in Table No. (1), the per capita share of water in Egypt during the study period ranged from a minimum of approximately 543.79 cubic meters in 2021 to a maximum of about 689.93 cubic meters in 2010, with an average of around 604.84 cubic meters.

Based on the estimation of the general time trend equation for per capita water availability in Egypt, as presented in Table No. (2), it was found to follow a statistically significant downward trend, with an annual decline rate of approximately 2.2%.

This decline poses a major challenge to Egypt's food security, as the country falls within the category of water-poor nations—defined as those with less than 1,000 cubic meters of water per capita annually—and is approaching the threshold of water scarcity, which is defined as less than 500 cubic meters per capita per year.

Table (2): Equations of the general time trend for the development of population, agricultural land area, per capita share of agricultural land and water in Egypt during the period (2010-2021).

F	R^2	Rate of change %	Equation	Statement
*(3775.01)	0.997	2.14	$\hat{Y}_t = 78.65 + 1.98\,\hat{X}t$ (16.88)* (61.43)*	**population (million people)**
*(27.02)	0.711	0.76	$\hat{Y}_t = 8.55 + 0.075\,\hat{X}t$ (55.78)* (5.196)*	**Agricultural land area (Million acres)**
*(55.35)	0.834	1.35	$\hat{Y}_t = 2.59 - 0.032\,\hat{X}t$ (33.01)* (7.416)*	**Per capita share of agricultural land (Kirat)**
* (1683.43)	0.994	2.2	$\log \hat{Y}_t = 699.75 - 0.022\hat{X}t$ (21.99)* (41.012)*	**per capita share of water (m^3)**

Source**:** Compiled and calculated from Table No. (1).
$\hat{Y}_t$: The estimated value of the dependent variable in year *t*.
$\hat{X}t$: The time element in years, where *t* = 1, 2, 3, 4, …, 12. Values in parentheses represent the calculated *t*-statistic.

- Significant at the level 0.01. ** Significant at the level 0.05.

(2) Current and Future Changes in Water Requirements for Major Crops in Egypt:

This section presents a study and analysis of the changes in water requirements for Egypt's major winter and summer crops during the period (2020–2021), along with projections for the year 2025, as outlined below:

(2-1) Current and Future Changes in Water Requirements for Major Winter Crops in Egypt

The following section presents a study and analysis of the changes in water requirements for Egypt's major winter crops, which include: wheat, sugar beet, fava beans, berseem (early-cut), berseem (multi-cut), onions, and winter vegetables, during the period (2010–2021), along with projections for the year 2025.

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(2-1-1) Current and Future Changes in Water Requirements for Wheat in Egypt

Based on the analysis of data in Table No. (3), the water requirement for wheat during the study period ranged from a minimum of approximately 1,560 cubic meters per feddan in 2005 to a maximum of about 2,309 cubic meters per feddan in 2016, with an annual average of around 1,885 cubic meters per feddan.

Table (3): The development of water requirements for the most important winter agricultural crops in Egypt during the period (2000-2021).

winter vegetables	onions	Berseem (Multi-Cut)	Berseem (Early-Cut)	beans	sugar beet	wheat	Statement years
1907	1783	2639	921	1181	1965	1595	2000
1904	1758	2621	931	1191	1905	1602	2001
1905	1764	2634	929	1190	1915	1606	2002
2002	1853	2768	968	1250	2004	1681	2003
2003	1862	2773	964	1271	2007	1677	2004
2011	1709	2519	942	1197	1858	1560	2005
2194	2011	3004	1061	1382	2211	1828	2006
2231	2072	3099	1160	1409	2272	1872	2007
2247	2060	3087	1330	1403	2415	1868	2008
1999	1822	2788	975	1257	2071	1678	2009
2051	1841	2876	1006	1295	2126	1734	2010
1475	1809	2505	852	1097	2126	1667	2011
1349	1700	2401	863	1490	1976	1726	2012
1558	1967	2889	935	1826	2399	2085	2013
1521	1978	2951	948	1854	2441	2135	2014
1491	1935	2928	938	1834	2408	2113	2015
2334	2064	3315	1034	1690	2572	2309	2016
1871	2039	2724	1058	1556	2579	2035	2017
2018	2066	2264	1409	1998	2899	2085	2018
1674	2625	2656	2085	1491	3860	2205	2019
1536	2073	2670	2151	1691	2565	2039	2020
1744	2196	2536	1278	1542	2546	2272	2021
1863	1971	2759	1156	1466	2368	1885	Average

Source: Compiled and calculated from the Central Agency for Public Mobilization and Statistics, Annual Bulletin of Irrigation and Water Resources Statistics, various issues (2010-2021).

By estimating the general time trend equation for wheat's water requirement in Egypt using linear, quadratic, and exponential models—and selecting the best-fitting model based on the lowest mean squared error—it was found that the exponential form best represented this relationship. The trend showed a statistically significant upward direction, with an annual growth rate of approximately 1.7%.

Table (4): Equations of the general time trend for the development of water requirements per feddan in cubic meters for the most important winter crops in Egypt during the period (2000-2021).

F	R^2	Rate of % change	The equation	Model type	Statement crop

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** 59,211	0.748	1.7	$\hat{Y}_{t}$= 7 0.01 + 1532.69 $\hat{X}t$ **(2.932) *(12.23)	**Wheat**
** 32.93	0.622	1.5	$\hat{Y}_{t}$= 1806.68 + 0.0 21$\hat{X}t$ **(3.321) *(10.112)	**Sugar Beet**
** 25.76	6 0.5	2	$\hat{Y}_{t}$= 1140.21 + 0.02$\hat{X}t$ **(2.876) (0.123)	**beans**
**9.76	0.328	2.2	$\hat{Y}_{t}$= 839.41+ 0.022$\hat{X}t$ **(2.883) *(6.6)	**Berseem (Early-Cut)**
**8.09	0.430	-	$\hat{Y}_{t}$= 2.56 - 2786.16 $\hat{X}t$ **(3.321) *(22.23)	**Berseem (Multi-Cut)**
*16.09	0.445	1	$\hat{Y}_{t}$= 1 0.0 + 1729.72 $\hat{X}t$ *(4.456) *(10.98)	**onions**
**8.64	0.154	0.9	$\hat{Y}_{t}$= 0.009 -2055.78 $\hat{X}t$ **(2.889) *(8.809)	**winter vegetables**

Source: Compiled and calculated from Table No. (3).$\hat{Y}t$: The estimated value of the dependent variable in year t.
$\hat{X}t$:The time element in years, where t = 1, 2, 3, 4, …, 12. Values in parentheses represent the calculated t-statistic.

- **Significant at the level 0.01. ** Significant at the level 0.05.**

By applying a forecast using the exponential model, the expected change in wheat's water requirement in Egypt by the year 2025 is estimated to reach approximately 2,390 cubic meters per feddan. This represents an increase of about 17.51% compared to the average value during the study period, which may exert significant pressure on water resources and pose a major challenge to food security. (See Figure No. 1)

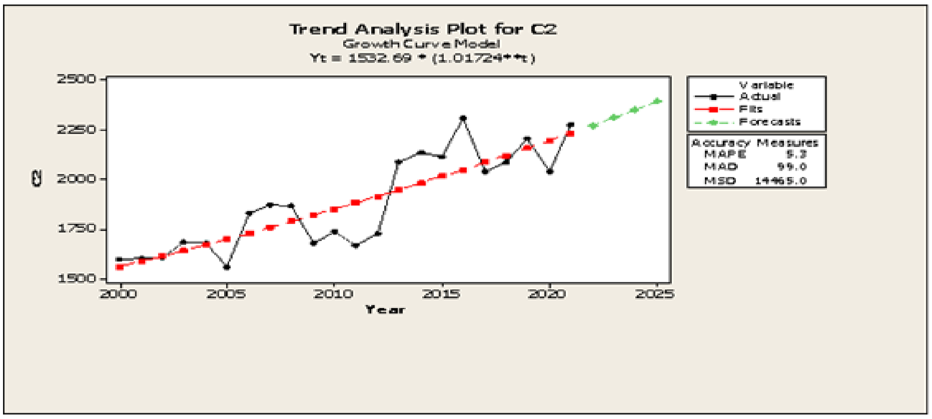

Figure (1): Changes Current and the future in The legislator Watery For the crop wheat in Egypt

Source: Data from Table No. (3, 4).

(2-1-2) Current and Future Changes in Water Requirements for Sugar Beet in Egypt

Based on the analysis of water requirements for sugar beet during the study period, as shown in Tables No. (3) and (4), the values ranged from a minimum of approximately 1,858 cubic meters per feddan in 2005 to a maximum of about 3,860 cubic meters in 2019, with an annual average of around 2,368 cubic meters. By estimating the general time trend equation for the development of sugar beet's water requirement in Egypt, it was found that the exponential model best represented

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this relationship. The trend showed a statistically significant upward direction, with an annual growth rate of approximately 1.5%. Using this model to forecast the expected changes in sugar beet's water requirement by the year 2025, it is projected to reach approximately 3,086 cubic meters per feddan—an increase of about 21.42% compared to the average during the study period. (See Figure No. 2)

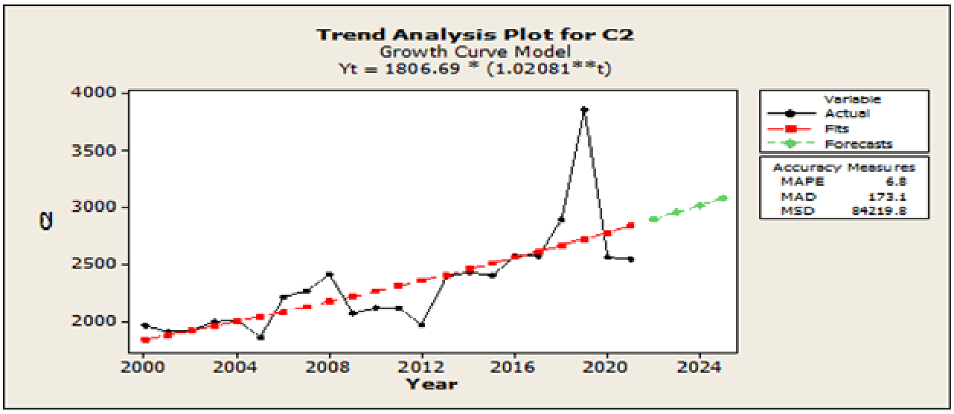

Figure (2): Current and future changes in water requirements for sugar beet crops in Egypt until 2025

Source: Data from Table No. (3, 4).

(2-1-3) Current and Future Changes in Water Requirements for Fava Beans in Egypt

Based on the review and analysis of data in Tables No. (3) and (4), the water requirement for fava beans during the study period ranged from a minimum of approximately 1,097 cubic meters per feddan in 2011 to a maximum of about 1,998 cubic meters in 2018, with an annual average of around 1,466 cubic meters.By estimating the general time trend equation for fava beans' water requirement using the exponential model, the trend was found to be statistically significant and upward, with an annual growth rate of approximately 2%.

Forecasting the expected changes in fava beans' water requirement by the year 2025 using this model suggests it will reach approximately 1,925 cubic meters per feddan—an increase of about 19.29% compared to the average during the study period. This increase may place considerable pressure on water resources and pose a significant challenge to food security. (See Figure No. 3)

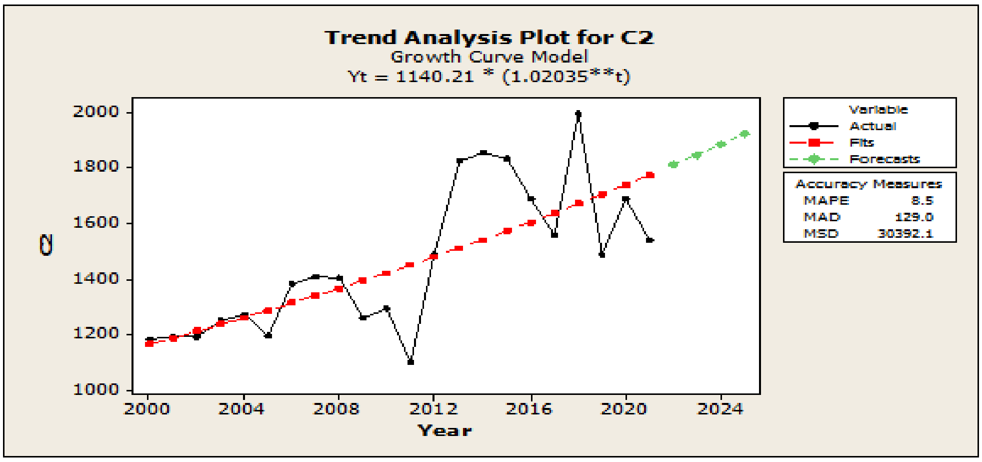

Figure (3): Current and future changes in water quotas for fava bean crops in Egypt until

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2025

Source: Data from Table No. (3, 4).

(2-1-4) Current and Future Changes in Water Requirements for Berseem (Early-Cut) in Egypt

Based on the analysis of data in Tables No. (3) and (4), the water requirement for early-cut berseem during the study period ranged from a minimum of approximately 852 cubic meters per feddan in 2011 to a maximum of about 2,151 cubic meters in 2020, with an average of around 1,156 cubic meters. By estimating the general time trend equation for early-cut berseem's water requirement using the exponential model, the trend was found to be statistically significant and upward, with an annual growth rate of approximately 2.2%.

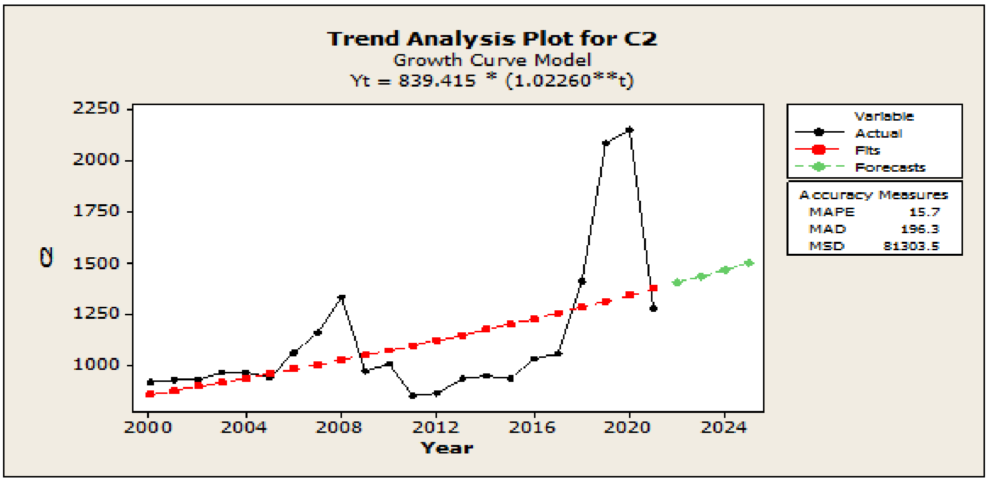

Figure (4): Current and future changes in the water requirement of berseem crop in Egypt until 2025

Source: Data from Table No. (3, 4).

Forecasting the expected changes in water requirements for early-cut berseem by the year 2025 using this model suggests it will reach approximately 1,500 cubic meters per feddan—an increase of about 33.39% compared to the average during the study period. This rise may place considerable pressure on water resources and pose a significant challenge to food security. (See Figure No. 4)

(1-2-5) Current and Future Changes in Water Requirements for Berseem (Multi-Cut) in Egypt

Based on the review and analysis of data in Table No. (3), the water requirement for multi-cut berseem during the study period ranged from a minimum of approximately 2,264 cubic meters per feddan in 2018 to a maximum of about 3,315 cubic meters in 2016, with an average of around 2,759 cubic meters. By estimating the general time trend equation for multi-cut berseem's water requirement using the linear model, the trend appeared to be downward but statistically insignificant.

(1-2-6) Current and Future Changes in Water Requirements for Onions in Egypt

Based on the review and analysis of data in Tables No. (3) and (4), the water requirement for onions ranged from a minimum of approximately 1,700 cubic meters per feddan in 2012 to a maximum of about 2,625 cubic meters in 2019, with an average of around 1,971 cubic meters during the study period. By estimating the general time trend equation for onion's water

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requirement using the exponential model, the trend was found to be statistically significant and upward, with an annual growth rate of approximately 1%. Forecasting the expected changes in onion's water requirement by the year 2025 using this model suggests it will reach approximately 2,253 cubic meters per feddan—an increase of about 15.3% compared to the average during the study period. This increase may place considerable pressure on water resources and pose a significant challenge to food security. (See Figure No. 4)

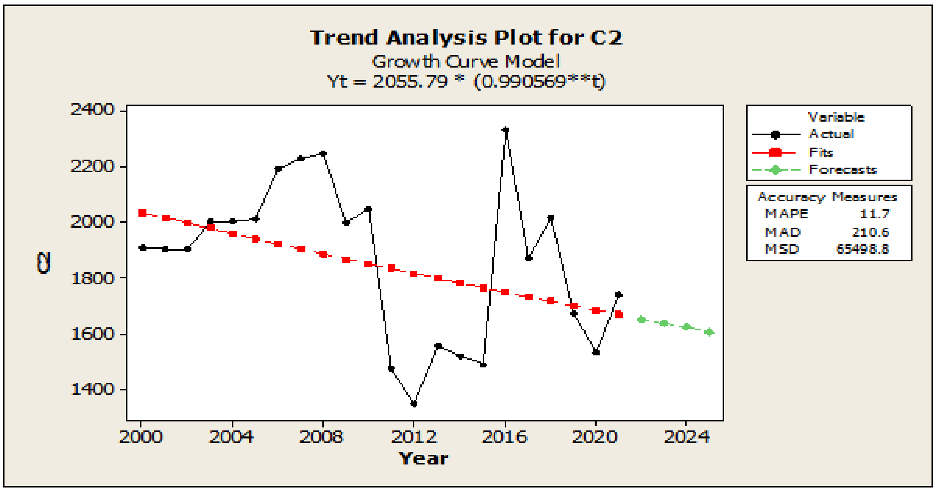

Figure (5): Current and future changes in water quotas for onion crops in Egypt until 2025

Source : Data table Number No. (3, 4).

(1-2-7) Current and Future Changes in Water Requirements for Winter Vegetables in Egypt

Based on the review and analysis of data in Tables No. (3) and (4), the water requirement for winter vegetables during the study period ranged from a minimum of approximately 1,349 cubic meters per feddan in 2012 to a maximum of about 2,334 cubic meters in 2016, with an annual average of around 1,863 cubic meters. By estimating the general time trend equation for winter vegetables' water requirement using the exponential model, the trend was found to be statistically significant and downward, with an annual decline rate of approximately 0.9%.

Forecasting the expected changes in water requirements for winter vegetables by the year 2025 using this model suggests it will reach approximately 1,606 cubic meters per feddan—a decrease of about 13.87% compared to the average during the study period. (See Figure No. 6)

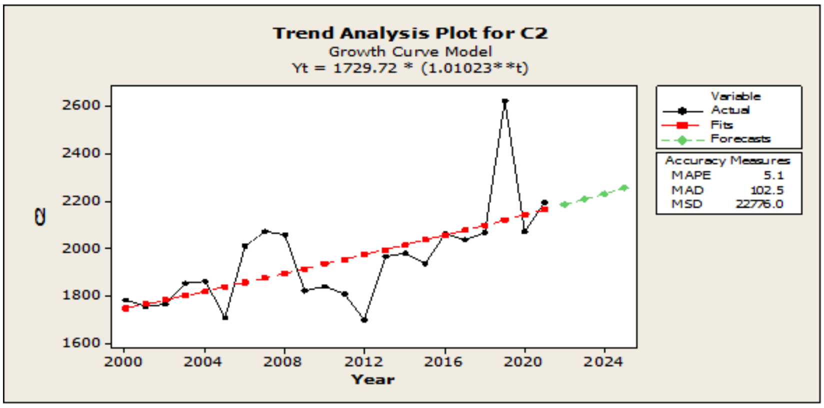

Figure (6): Current and future changes in water rationing For winter vegetables in Egypt until 2025

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Source: Data from Table No. (3, 4).

(2-2) Current and Future Changes in Water Requirements for Major Summer Crops in Egypt

The following section presents the changes in water requirements for Egypt's major summer crops, which include: rice, maize (yellow corn), sorghum, cotton, sugarcane, green fodder, and summer vegetables, during the period (2010–2021), along with projections for the year 2025.

(2-2-1) Current and Future Changes in Water Requirements for Rice in Egypt

Based on the review and analysis of data in Tables No. (5) and (6), the water requirement for rice ranged from a minimum of approximately 3,959 cubic meters per feddan in 2012 to a maximum of about 6,668 cubic meters in 2010, with an average of around 5,843 cubic meters during the study period. By estimating the general time trend equation for rice's water requirement using the linear model, the trend appeared to be upward but statistically insignificant, despite significant efforts to develop varieties with lower water needs. This situation continues to exert considerable pressure on water resources and poses a major challenge to food security.

(2-2-2) Current and Future Changes in Water Requirements for Maize in Egypt

Based on the review and analysis of data in Tables No. (5) and (6), the water requirement for maize ranged from a minimum of approximately 2,634 cubic meters per feddan in 2005 to a maximum of about 4,104 cubic meters in 2016, with an average of around 3,254 cubic meters during the study period. By estimating the general time trend equation for maize's water requirement using the exponential model, the trend was found to be statistically significant and upward, with an annual growth rate of approximately 1.8%.

Forecasting the expected changes in maize's water requirement by the year 2025 using this model suggests it will reach approximately 4,161 cubic meters per feddan—an increase of about 19.12% compared to the average during the study period. This increase may place considerable pressure on water resources and pose a significant challenge to food security. (See Figure No. 7)

Table (5): The development of water requirements in cubic meters for the most important summer crops in Egypt during the period (2010-2021).

vegetables	green fodder	sugar-cane	cotton	sorghum	corn	rice	crop years
2748	3249	8458	2667	2844	2763	5550	2000
2725	3273	8441	2965	2846	2758	5540	2001
2740	3271	8363	2957	2841	2776	5548	2002
2877	3296	8833	3107	2984	2912	5547	2003
2861	3418	8851	3102	2980	2914	5821	2004
2843	3383	7809	2822	2697	2634	5189	2005
3144	3827	9678	3392	3258	3201	6360	2006
3189	3816	9875	3494	3319	3281	6551	2007
3128	3674	9683	3370	3248	3224	6369	2008
2901	3274	8914	3118	2976	2976	5852	2009
3245	3762	10121	3467	3402	3336	6668	2010
2919	2320	9149	3571	2932	2904	4373	2011
2807	2335	10434	3562	3464	2855	3959	2012
3031	2669	10808	3914	3548	2989	6501	2013
3071	2554	11032	3998	3592	3050	6632	2014
3040	2503	10929	4033	3563	3003	5301	2015
3723	3159	12,000	4891	4597	4104	5501	2016
2287	3194	10688	3661	4473	4037	6459	2017

2649	3456	10164	3224	4170	3614	6457	2018
2689	2860	10973	2136	4338	4087	6563	2019
2626	2905	10428	3497	4371	3962	6294	2020
2374	2906	9993	3467	4248	3973	6566	2021
2901	3135	9810	3393	3499	3254	5843	Average

Source: Compiled and calculated from the Central Agency for Public Mobilization and Statistics, Annual Bulletin of Irrigation and Water Resources Statistics, various issues (2010-2021).

Table (6): Equations of the general time trend for the development of water requirements per feddan in cubic meters for the most important summer crops in Egypt during the period (2000-2021).

F	R^2	% rate of change	The equation	Model type	Statement crop
** (8.05)	0.342	-	$\hat{Y}_t = 5488.2 + 35.01\ \hat{X}t$ **(4.231) *(4.006)	**linear**	**rice**
*(35.63)	0.641	1.8	$\hat{Y}_{t=}$ 18 0.0 + 2612.53$\hat{X}$t *(3.987) *(7.098)	**sorrow**	**corn**
*(87.84)	0.815	2.4	log$\hat{Y}_t$= 2612.53+0.018 log$\hat{X}$t **(3.125) (2.654)	**sorrow**	**sorghum**
**(3.5)	0.146	0.97	$\hat{Y}_{t=}$ 18 32.85 + 3004.67$\hat{X}$t **(4.456) *(10.112)	**linear**	**cotton**
*(34.09)	0.630	1.4	log$\hat{Y}_t$= 8325.9 + 0.014 log$\hat{X}$t **(11.345) *(4.092)	**sorrow**	**sugar-cane**
* * (7.6)	0.310	0.97	$\hat{Y}_{t=}$ = 3492.98- 30.6 $\hat{X}$t *(2.981) (0.65)	**linear**	**green fodder**
(7.974) **	0.324	-	log$\hat{Y}_t$= 2994.59- 0.004 log$\hat{X}$t **(2.904) *(24.34)	**sorrow**	**summer vegetables**

Source: Compiled and calculated from Table No. (5).
$\hat{Y}$t: The estimated value of the dependent variable in year t.
$\hat{X}$t:The time element in years, where t = 1, 2, 3, 4, …, 12. Values in parentheses represent the calculated t-statistic. • Significant at the level 0.01. ** Significant at the level 0.05.

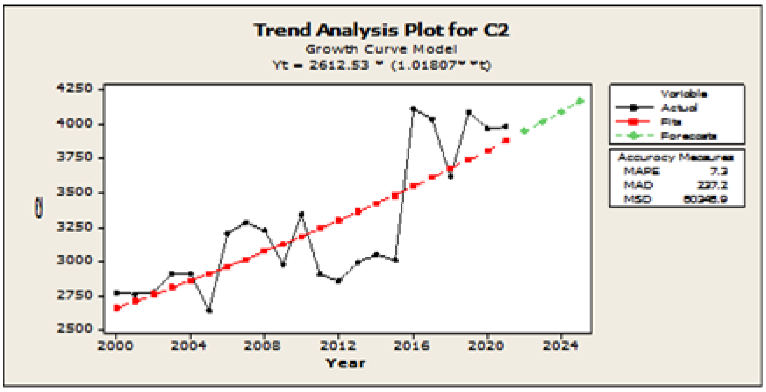

Figure (7): Current and future changes in water rationing For corn in Egypt until 2025

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(2-2-3) Current and Future Changes in Water Requirements for Sorghum in Egypt

Based on the review and analysis of data in Tables No. (5) and (6), the water requirement for sorghum during the study period ranged from a minimum of approximately 2,697 cubic meters per feddan in 2005 to a maximum of about 4,597 cubic meters in 2016, with an average of around 3,499 cubic meters. By estimating the general time trend equation for sorghum's water requirement using the exponential model, the trend was found to be statistically significant and upward, with an annual growth rate of approximately 2.4%.

Forecasting the expected changes in sorghum's water requirement by the year 2025 using this model suggests it will reach approximately 4,849 cubic meters per feddan—an increase of about 39.1% compared to the average during the study period. This increase may place considerable pressure on water resources and pose a significant challenge to food security. (See Figure No. 8)

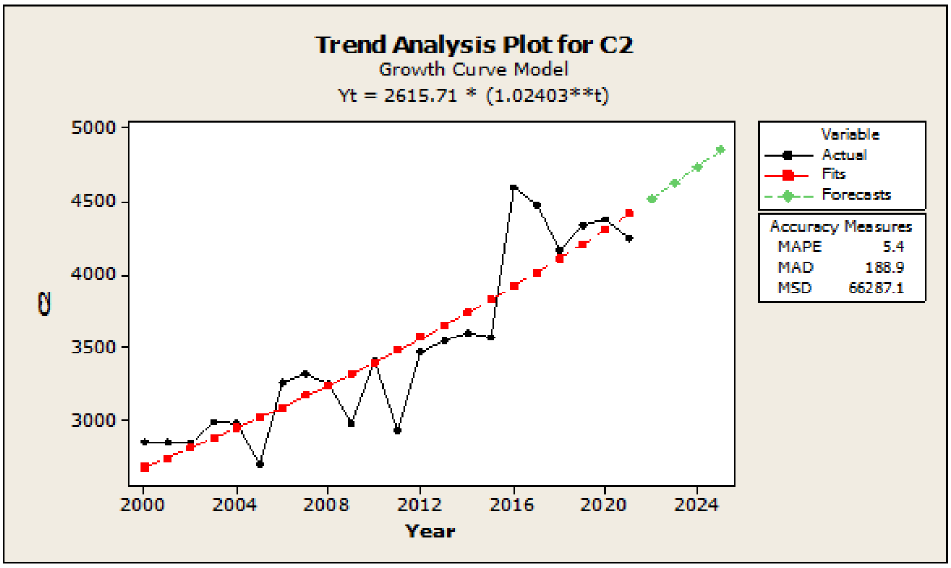

Figure (8): Current and future changes in water rationing For sorghum in Egypt until 2025
Source: Data from Table No. (5, 6).

(2-2-4) Current and Future Changes in Water Requirements for Cotton in Egypt

Based on the review and analysis of data in Tables No. (5) and (6), the water requirement for cotton ranged from a minimum of approximately 2,136 cubic meters per feddan in 2019 to a maximum of about 4,891 cubic meters in 2016, with an annual average of around 3,393 cubic meters during the study period.

By estimating the general time trend equation for cotton's water requirement using the linear model, the trend was found to be statistically significant and upward, representing approximately 0.97% of the average value during the study period.

Forecasting the expected changes in cotton's water requirement by the year 2025 using this model suggests it will reach approximately 3,858 cubic meters per feddan—an increase of about 14.05% compared to the average during the study period. This increase may place considerable pressure on water resources and pose a significant challenge to food security. (See Figure No. 9)

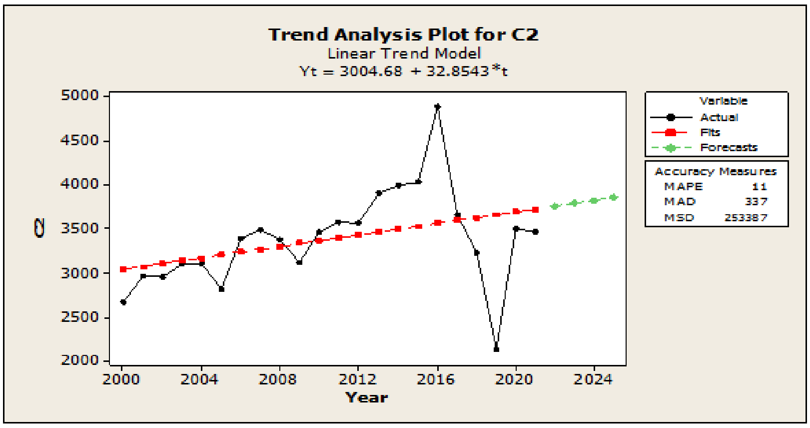

Figure (9): Current and future changes in water rationing For cotton in Egypt until 2025
Source: Data from Table No. (5, 6).

(2-2-5) Current and Future Changes in Water Requirements for Sugarcane in Egypt

Based on the review and analysis of data in Tables No. (5) and (6), the water requirement for sugarcane ranged from a minimum of approximately 7,809 cubic meters per feddan in 2005 to a maximum of about 12,000 cubic meters in 2016, with an average of around 9,810 cubic meters during the study period. By estimating the general time trend equation for sugarcane's water requirement using the exponential model, the trend was found to be statistically significant and upward, with an annual growth rate of approximately 1.4%.

Forecasting the expected changes in sugarcane's water requirement by the year 2025 using this model suggests it will reach approximately 11,879 cubic meters per feddan—an increase of about 21.2% compared to the average during the study period. This increase may place considerable pressure on water resources and pose a significant challenge to food security. (See Figure No. 10)

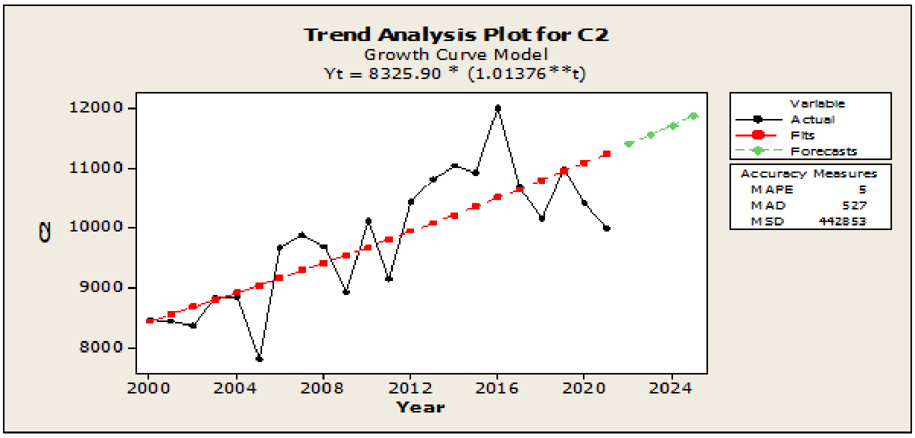

Figure (10): Current and future changes in water rationing Sugarcane in Egypt until 2025
Source: Data from Table No. (5, 6).

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(2-2-6) Current and Future Changes in Water Requirements for Green Fodder in Egypt

Based on the review and analysis of data in Tables No. (5) and (6), the water requirement for green fodder ranged from a minimum of approximately 2,320 cubic meters per feddan in 2011 to a maximum of about 3,827 cubic meters in 2006, with an annual average of around 3,135 cubic meters during the study period. By estimating the general time trend equation for green fodder's water requirement using the linear model, the trend appeared to be downward, representing a decline of approximately 1.4% from the average value during the study period.

Forecasting the expected changes in green fodder's water requirement by the year 2025 using this model suggests it will reach approximately 2,771 cubic meters per feddan—a decrease of about 11.78% compared to the average during the study period. This reduction may help alleviate pressure on water resources. (See Figure No. 11)

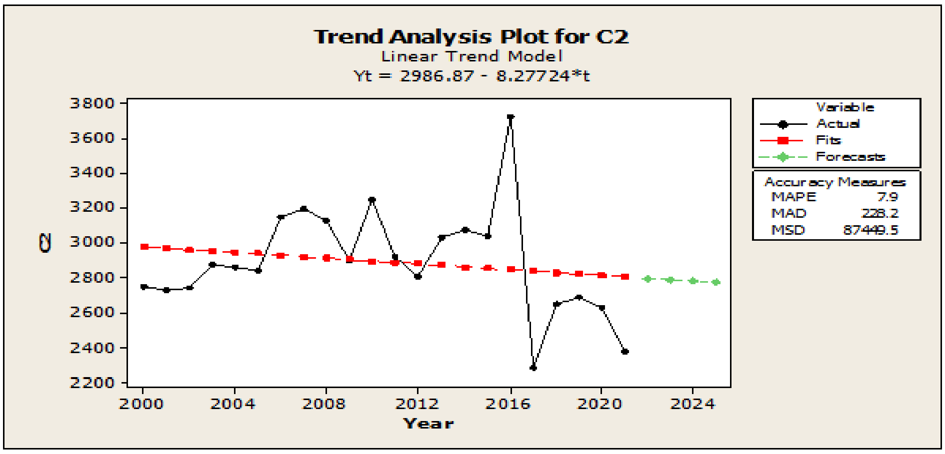

Figure (11): Current and future changes in water rationing For green fodder in Egypt until 2025

Source: Data from Table No. (5, 6).

(2-2-7) Current and Future Changes in Water Requirements for Summer Vegetables in Egypt

Based on the review and analysis of data in Tables No. (5) and (6), the water requirement for summer vegetables ranged from a minimum of approximately 2,287 cubic meters per feddan in 2017 to a maximum of about 3,723 cubic meters in 2016, with an average of around 2,901 cubic meters during the study period. By estimating the general time trend equation for summer vegetables' water requirement using the exponential model, the trend appeared to be downward but statistically insignificant, despite ongoing efforts to develop varieties with lower water needs. This situation continues to exert considerable pressure on water resources and poses a major challenge to food security.

(3): Solutions and Recommendations to Address Water Scarcity

Efforts are being coordinated and activated to provide a suitable environment for implementing five proposed pillars aimed at rationalizing water use and preserving water resources, while fostering collaboration among all stakeholders in water management. These pillars include:

1. **Expanding the modernization of field irrigation systems** in the Delta and Nile Valley to reduce irrigation water losses by 10–15%.
2. **Adopting modern irrigation techniques** such as drip and sprinkler systems for fruit trees and vegetable crops in old lands, and sugarcane in the Nile Valley, while expanding their use in newly reclaimed lands to reduce irrigation losses by up to 20%.

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3. **Improving water use efficiency in agriculture** by applying good agricultural practices to reduce irrigation losses by 25–30%.
4. **Utilizing non-conventional water sources** and reducing agricultural pollution loads by developing the use of agricultural drainage water mixed with freshwater, and expanding the use of tertiary-treated wastewater—such as the Bahr El-Baqar treatment project, which provides over 4.5 billion m³ annually—to meet irrigation needs in reclaimed lands in Sinai.
5. **Developing rain-fed agriculture** and optimizing the use of available water resources from rainfall, flash floods, and groundwater.

Additional recommendations include:

- Integrating water security with social, economic, environmental, and health considerations, with special attention to food security and the water-energy nexus—especially renewable energy sources used in groundwater development, such as solar energy as an alternative to electricity and fossil fuels.
- Accounting for climate change impacts when formulating policies and estimating crop water requirements.
- Maximizing agricultural productivity and water-use efficiency per unit of land and water.
- Transitioning from a culture of water abundance to one of water scarcity, which is now a reality, and enhancing water-use efficiency.
- Empowering all water users—especially farmers and citizens—in managing and rationalizing water consumption.

The five proposed pillars aim to:

1. Ensure equitable distribution of irrigation water among farmers, addressing the challenges faced by fields located at the ends of canals and watercourses.
2. Increase per-feddan productivity by approximately 20% in areas where irrigation systems are modernized.
3. Raise the average income of smallholder farmers—who represent 85–90% of farmers in targeted areas—by 15–20% compared to current levels.
4. Improve farmers' health by reducing exposure to endemic diseases, as modern irrigation systems help cover open water channels and reduce direct contact with water, creating healthier rural environments.
5. Boost investment opportunities in manufacturing irrigation equipment and materials, enhance farmers' awareness, and create new job opportunities in agricultural services and industries related to modern irrigation systems.
6. Rehabilitate and upgrade private field canal infrastructure in coordination with the Ministry of Water Resources and Irrigation.
7. Improve water distribution systems and develop water accounting mechanisms to measure irrigation usage.
8. Encourage innovation and scientific research to optimize every drop of water in the agricultural sector.
9. Align food and water security strategies with assessments of food balance and trade policies, including the concept of virtual water, in coordination with the Ministry of Water Resources and Irrigation.
10. Define optimal crop patterns that promote drought- and salinity-tolerant crops with lower water requirements and higher economic returns, while limiting the cultivation of water-intensive crops such as sugarcane, berseem, rice, and bananas.
11. Promote irrigation and farming systems that allow water recycling and reduce water use per feddan, helping meet water demands and protect water resources from pollution and degradation.

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12. Ensure safe and sustainable use of agricultural and municipal wastewater in crop production, and develop rain-fed agriculture along Egypt's northeastern and northwestern coasts, including infrastructure rehabilitation in these regions.
13. Strengthen fertilizer and pesticide monitoring systems, and expand the use of greenhouses, hydroponics, and organic farming.

6.Recommendations

The study proposes several key recommendations as follows:

1. **Reevaluate the current varieties of major summer and winter crops**, as most have shown increasing water requirements in recent years, placing additional strain on Egypt's available water resources.
2. **Develop new crop varieties** that consume less water than existing ones and are better aligned with Egypt's water resource capabilities.
3. **Establish a strategic crop map** identifying which crops can be expanded and which should be reduced to preserve Egypt's water capacity.
4. **Study international experiences** in addressing water scarcity related to crop water requirements and explore the applicability of these approaches in Egypt.
5. **Create a favorable environment for private investment** and open opportunities in the agricultural sector, which is highly productive and can benefit from private sector contributions.
6. **Explore modern technological solutions** to manage the increasing water requirements of agricultural crops and leverage these innovations to mitigate water scarcity.

7.Conclusion

By studying and analyzing the water requirements for the most important winter and summer crops in Egypt, it became clear that the water requirement for wheat, sugar beet, beans, and clover in Egypt increased, while the water requirement for winter vegetables decreased, while the water requirement for maize, sorghum, and cotton increased, and the water requirement for green fodder decreased. Therefore, the current varieties of the most important summer and winter crops should be reconsidered, and a map should be drawn of the crops that can be expanded in cultivation and others that should be reduced in order to preserve Egypt's water resources.

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