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Proposed economic guidance for watermelon production and its impact on water consumption in Saudi agriculture

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Abstract
Given the scarcity of water and the concentration of watermelon cultivation in areas with low productivity and high-water requirements, this research aimed to develop an economic plan for watermelon production using linear programming. This study revealed that watermelon production was concentrated in the Makkah region at 70.42%, followed by Riyadh at 13.98%. Watermelon productivity also varied between regions, with most regions exceeding the estimated productivity of the Jazan region, ranging from a minimum of 3.3% for the Najran region to a maximum of 37.1% for the Eastern Province. The total water used for watermelon production amounted to 274.12 million m3, representing 2.58% of the average amount of water used for agricultural purposes, which amounted to 10.62 billion m3 during the period 2019-2023. The proposed plan includes cultivating the same area of 25.53 thousand hectares, of which 21.23 thousand hectares are allocated to the Eastern Province, followed by Riyadh with an area of 3.47 thousand hectares, then Medina, Tabuk, and Hail with areas of 595.1, 154.4, and 81.1 hectares, respectively. The proposed economic orientation requires the use of 213.56 million m3 of water for watermelon production, representing 77.91% of the available water amount of 274.12 million m3. This leaves a water resource surplus of 60.56 million m3, representing 22.09% of the available water amount. Total watermelon production amounts to 701.05 thousand tons. Therefore, production under the proposed economic orientation increases by 90.7 thousand tons compared to its current counterpart, an increase of 14.86%. Finally, this study recommends the need to reconsider the agricultural policy for watermelon production, with the aim of increasing production and rationalizing water consumption.

Keywords: Watermelon production, linear programming, water resources, productivity index, Saudi agriculture.

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1. Introduction

Watermelon is one of the most important vegetables in Saudi agriculture, with a cultivated area of 25.2 thousand hectares, representing 28.4% of the total area cultivated with open-grown vegetables, which amounts to 88.74 thousand hectares. Watermelon production reached 612.7 thousand tons, representing 24.21% of the total open-grown vegetable production in 2023 (General Authority for Statistics, 2023). Given the importance of watermelon, the Ministry of Environment, Water and Agriculture, through the Rural Development Initiative, has been keen to achieve self-sufficiency, reaching 98.1% in 2023 (Ministry of Environment, Water and Agriculture, 2023). It is well known that the Kingdom of Saudi Arabia suffers from water scarcity, as the non-renewable groundwater used for agricultural purposes in the alluvial shelf areas (Riyadh, Eastern Province, Qassim, Al-Jawf, Hail, Tabuk, and the Northern Borders) amounted to 9.36 billion m3, representing 79.5% of the total water used in the agricultural sector, which amounts to 11.77 billion m3, while the amount of renewable groundwater used for agricultural purposes in the Arabian Shield areas (Makkah, Madinah, Asir, Jazan, Al-Baha, and Najran) amounted to 2.41 billion m3, representing 20.5% of the total water used in the agricultural sector in 2023 (Ministry of Environment, Water and Agriculture, 2023). Undoubtedly, the problem of water scarcity affects agricultural economic development. A study by Alrwis et al. (2021) showed that a 10% change in the amount of available water leads to a 5.1% change in the same direction in the cropped area. A 10% change in the estimated cropped area leads to a 1.5% change in the same direction in the total agricultural output. A 10% change in the estimated total agricultural output leads to a 2.9% change in the same direction in the gross domestic product. From the above, it is clear that water scarcity reduces the cultivated area and negatively impacts the value of agricultural output, thus affecting the gross domestic product. To conserve water resources, it is necessary to halt the export of virtual water, especially for water-depleting products, and to include water in the framework of economic accounting.

To rationalize water consumption, Resolution (335) was issued in 2007, which included a ban on the export of crops grown in open fields. Despite the issuance of the resolution, the country exported quantities of watermelons that decreased from 31.25 thousand tons, valued at $7.57 million in 2007, to 181.8 tons, valued at $112.0 thousand in 2023 (Food and Agriculture Organization, 2023). Watermelon cultivation is concentrated in the Makkah region, with an average of 18.05 thousand hectares, representing 70.69% of the total average area cultivated with watermelons, which amounts to 25.53 thousand hectares. This is followed by the Riyadh region with 13.59%, and then the Jazan region with 3.82% during the period 2019-2023 (Ministry of Environment, Water and Agriculture, 2023). Watermelon productivity increased in certain regions such as the Eastern Province (28.02 tons/ha), Medina (25.5 tons/ha), Hail (24.6 tons/ha), and Riyadh (24.57 tons/ha), while watermelon productivity decreased in several regions, most notably Asir (21.92 tons/ha), the Northern Borders (21.19 tons/ha), Najran (21.11 tons/ha), and Jazan (20.44 tons/ha) during the period 2019-2023 (General Authority for Statistics, 2023).

Although watermelon cultivation is concentrated in the Makkah region, its productivity is lower than that achieved in the Eastern Province, Madinah, Hail, Riyadh, and Tabuk. It is well known that low productivity does not achieve a comparative advantage in production, due to the increased loss of agricultural resources used, which consequently increases watermelon production costs in areas with low productivity. In this regard, the study poses the following question: Is it possible to increase watermelon production while maintaining the same cultivated area on the one hand and reducing the amount of water used in watermelon production on the other?

In light of the study's questions, it assumes the following:

Economic management of agricultural resources (land and water resources) leads to rationalization of water consumption and increased agricultural production, given the potential to leverage the productive characteristics of different regions.

Some economic studies have addressed the production strategy for certain agricultural crops and the allocation of water resources. Al-Qunaibit et al. (2014) examined the economic allocation of water resources available to Saudi agriculture to maximize the economic return per unit of water. This study revealed that Saudi agriculture has achieved high levels of self-sufficiency for crops with low productivity per unit of water. The continued implementation of this policy has led to the waste of relatively scarce water resources, and a decline in the relative share of the agricultural sector in the gross domestic product (GDP), which fell from 5.8% in 1999 to 4.4% in 2011. Given the 8 billion m3 of water resources available annually to the agricultural sector, the cropped area has reached 487,000 hectares, an expected decrease in the proposed cropping pattern by 44.53%. The total economic return on water resources in the proposed cropping pattern amounts to SAR 17.96 billion, 3.13% lower than the estimated equivalent for the current cropping pattern.

Cereals rank first in the proposed cropping structure, representing 39.41% of the cropped area of 486,660 hectares, while fruits rank second, representing 31.86%, followed by vegetables at 28.73%. In light of the results of this study, it recommends the need to restructure the cropping structure, taking into account the priority of crops in the proposed cropping structure and allocating crop cultivation to areas with high productivity, thus maximizing the economic return per unit of water and ensuring that the self-sufficiency rate for agricultural commodities does not exceed 100%. The proposed cropping structure can be implemented by reconsidering agricultural subsidies and implementing the National Fodder Plan. Ghanem et al. (2019) developed an economic plan to increase potato production and reduce the amount of water used in water-stressed areas. This study revealed that the proposed plan includes increasing potato production by 30.64% and reducing the amount of water used in water-stressed alluvial shelf areas by 70.48%. The proposed plan also leads to an increase in the self-sufficiency rate for potatoes from 89.45% to 116.85%. This study recommended the need to reconsider potato production policy by focusing potato cultivation on areas with high and medium productivity, according to regional priorities and the proposed economic direction of the land and water resources used. A study by Al Nashwan et al. (2019) focused on developing a strategy for maize production in the Kingdom of Saudi Arabia. The

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study revealed that the economic allocation of land resources, amounting to 17,840 hectares, leads to a 37.7% decrease in water use, a 79.95% increase in maize production, a 1.9% decrease in imports, and an increase in the self-sufficiency rate from 2.32% to 4.16%. Finally, the study recommended the need to reconsider the maize production policy by focusing maize cultivation on areas with high and medium productivity, according to regional priorities and the economic allocation of land resources used in maize production. Ndanitsa et al. (2021) examined the economic analysis and technical efficiency of watermelon production in Niger State, Nigeria. The study revealed that watermelon production suffers from several problems, most notably insufficient capital investment, high and unavailable input costs, small farm size, poor market integration and product pricing, low rainfall, and the risk of pest infestation. Watermelon cultivation was also found to be profitable, and local production could be increased if more land were cultivated, farmers accessed production inputs, and infrastructure was provided. Finally, the study recommended the need to raise technical efficiency and maintain watermelon production through the provision of credit facilities and the implementation of agricultural development programs in the state. Tegen et al. (2024) also indicated that watermelon is a commercial crop and that its cultivation is profitable in Bora and Lomé districts in the Awash River Basin. There is also variation in watermelon production and farmers' income, which is attributed to the applied agricultural practices and farmers' knowledge and skills in watermelon production. The study by (Ghanem et al., 2025) aimed to develop an economic plan to increase wheat production and reduce the amount of water used in water-stressed alluvial shelf areas, using quantitative economic analysis represented by the point estimation method and linear programming. This study revealed that wheat production is concentrated in alluvial shelf areas, where the total relative importance of alluvial shelf production reached 84.69%, while the contribution of the Arabian Shield regions did not exceed 15.31% during the period 2018-2023. There is variation in wheat productivity between regions, as productivity ranged from a minimum of 4.09 tons/ha in the Jazan region to a maximum of 7.89 tons/ha in the Tabuk region. The study also revealed that the priority areas for wheat cultivation are Al-Jouf, Tabuk, Qassim, Hail, Riyadh, and the Eastern Province. The proposed economic plan includes restricting wheat cultivation to Al-Jouf, Tabuk, Hail, and Makkah Al-Mukarramah. This would increase wheat production by 11.2% and reduce the amount of water used in alluvial shelf areas by 6.27 million m3. The proposed plan would also increase the self-sufficiency rate for wheat from 25.3% to 28.1%. Finally, this study recommends reconsidering the wheat production policy, focusing its cultivation on high-productivity areas (Tabuk, Al-Jouf, and Hail) and excluding low-productivity areas (Madinah and Jazan). It is clear from the above that despite the economic and nutritional importance of watermelon, no economic study has been conducted on the watermelon crop in the Kingdom of Saudi Arabia to date.

Research Objectives

This research aimed to develop a proposed economic plan for watermelon production in the Kingdom of Saudi Arabia, based on data from the period 2019-2023. This study aims to examine the following objectives:

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1. The current status of watermelon production and the extent of variation between production regions.
2. Estimating the quantity and value of water used in watermelon production and its ratio to water used for agricultural purposes.
3. Proposed economic guidance for increasing production and reducing the amount of water used in watermelon production.
4. Sensitivity analysis of changes in productivity and specific resource constraints for the watermelon production map in the Kingdom of Saudi Arabia.

2. Materials and Methods

To achieve its objectives, this study relied on data issued by the General Authority for Statistics and the Ministry of Environment, Water and Agriculture, in addition to a survey and determination of the crop composition of the Kingdom of Saudi Arabia's governorates according to the environmental systems of each governorate (Ministry of Environment, Water and Agriculture, 2020). This study also relied on quantitative economic analysis, including:
(a) The productivity index can be expressed using the following equation (United Nations Economic and Social Commission for Western Asia, 2003):
Productivity index = (comparison area productivity ÷ base area productivity) × 100.
The watermelon productivity index was calculated based on the region with the lowest productivity, which represents the base area's productivity, i.e., it equals 100. However, if the productivity of regions is compared to the average productivity at the national level, the average productivity at the national level equals 100. It is known that the productivity index is an economic indicator that measures the relative changes in the productivity of different regions compared to the productivity of the base region (Al-Ghazali, 2003).
(b) The economic direction of agricultural resources used in watermelon production, using the linear programming model. The Linear programming is a mathematical method widely used in operations research and decision-making related to solving problems. The linear programming model consists of: (1) the objective function, which is represented by maximizing the local production of watermelon crop in the various production regions, which number 13 regions, (2) resource constraints (land and water resources), in addition to the non-negativity constraint of production (Bector and Chandra, 2005):

$$
\begin{aligned}
&Max\ Z = C\,X \\
&s.t: \\
&A\,X \leq b \\
&X \geq 0
\end{aligned}
$$

Where: Z represents the value of the objective function to be maximized, which is to maximize local watermelon production in light of resource constraints, most importantly land and water resources. C represents an (nx1) vector of land unit productivity (hectare), while X represents an (nx1) vector of the 13 production regions. A represents the (m x n) matrix of technical coefficients. A sensitivity

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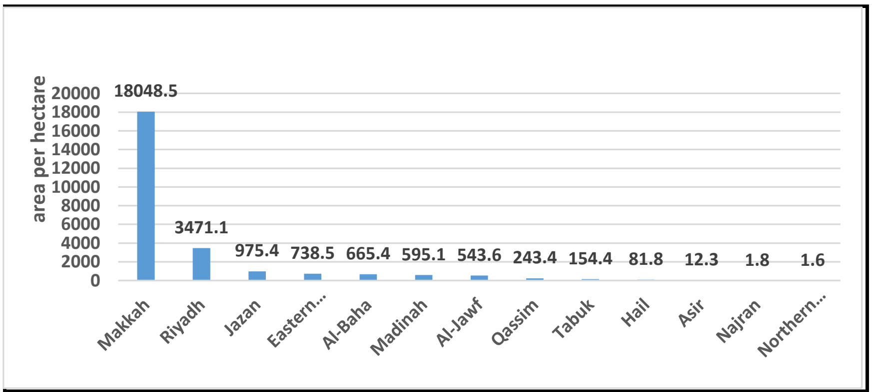
analysis, called post-optimality analysis, was conducted to determine the degree of response of the optimal solution or the flexibility of the proposed production regions to meet the expected changes in land unit productivity (hectare) and resource constraints.

3. Results and Discussion

3.1 The Current Status of Watermelon Production in the Kingdom of Saudi Arabia

By examining the current status of watermelon production in various regions of the Kingdom of Saudi Arabia, the data presented in Figures (1& 2) show that the average area planted with watermelon reached 25.53 thousand hectares, and the average watermelon production reached 610.35 thousand tons during the period 2019-2023. Watermelon production is concentrated in the Makkah region, accounting for 70.42%, followed by the Riyadh region with 13.98%. The Eastern Province ranked third in watermelon production, contributing 3.39%, followed by the Jazan, Al-Baha, Madinah, and Al-Jawf regions, with percentages of 3.27%, 2.52%, 2.49%, and 2.02%, respectively.

Figure (1): Average area planted with watermelon during the period 2019-2023.



Source: (1) General Authority for Statistics, Agricultural Statistics, period 2019-2023, (2) General Authority for Statistics, Agricultural Production Survey Bulletin, period 2019-2023, (3) Ministry of Environment, Water and Agriculture, Statistical Book, period 2019-2023.

The data in Figure (3) show that watermelon productivity ranged from a minimum of 20.44 tons/ha in Jazan region to a maximum of 28.02 tons/ha in the Eastern Region, with an estimated average of approximately 23.9 tons/ha during the period 2019-2023. By examining the extent of variation in watermelon productivity between regions, using the productivity index, the data in Table (1) show that most regions' productivity exceeds its estimated counterpart for Jazan region, with a rate

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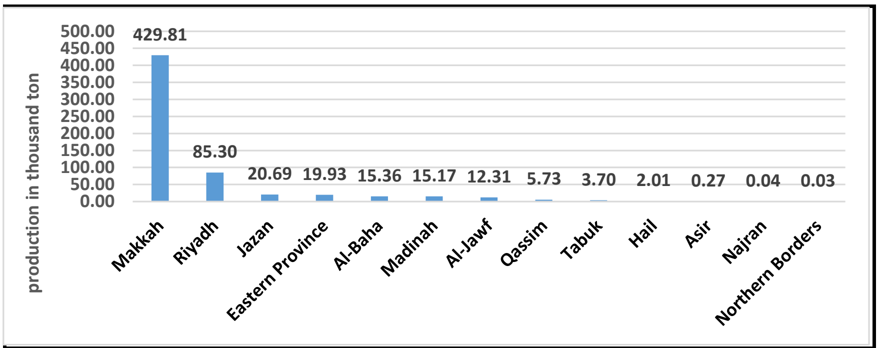
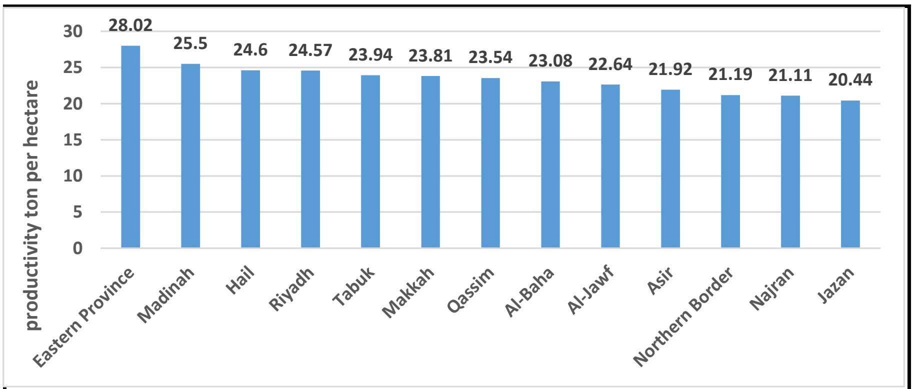
ranging from a minimum of 3.3% for Najran region to a maximum of 37.1% for the Eastern Region. Comparing the productivity of regions with the average productivity at the Kingdom level, it becomes clear that the productivity of the Eastern Region, Madinah, Hail, Riyadh, and Tabuk exceeds the average productivity at the Kingdom level by rates of 17.2%, 6.7%, 2.9%, 2.8%, and 0.2%, respectively. The remaining regions also fell below the national average, with rates ranging from a low of 0.4% in Makkah to a high of 14.5% in Jazan. The disparity in watermelon productivity between regions is attributed to differences in the fertility of agricultural land and the quality of water used for irrigation, in addition to variations in temperature, humidity, rainfall rates, and the experience of watermelon farmers.

Figure (2): Average watermelon production during the period 2019-2023.



Source: (1) General Authority for Statistics, Agricultural Statistics, period 2019-2023, (2) General Authority for Statistics, Agricultural Production Survey Bulletin, period 2019-2023, (3) Ministry of Environment, Water and Agriculture, Statistical Book, period 2019-2023.

Figure (3): Average productivity per hectare of watermelon crop during the period 2019-2023.



Source: Data contained in Figures (1, 2).

Table (1): The amount of variation in the average watermelon productivity for different regions during the period 2019-2023.

region	Jazan region productivity index = 100	Rate of change in productivity %	Kingdom's productivity index = 100	Rate of change in productivity %
Eastern Province	137.1	37.1	117.2	17.2
Madinah	124.8	24.8	106.7	6.7
Hail	120.4	20.4	102.9	2.9
Riyadh	120.2	20.2	102.8	2.8
Tabuk	117.1	17.1	100.2	0.2
Makkah	116.5	16.5	99.6	-0.4
Qassim	115.2	15.2	98.5	-1.5
Al-Baha	112.9	12.9	96.6	-3.4
Al-Jawf	110.8	10.8	94.7	-5.3
Asir	107.2	7.2	91.7	-8.3
Northern Border	103.7	3.7	88.7	-11.3
Najran	103.3	3.3	88.3	-11.7
Jazan	100.0	-	85.5	-14.5
Kingdom	116.9	16.9	100	-

Source: Data contained in Figure (3).

3.2 Estimating the Quantity and Value of Water Used in Watermelon Production

The quantity of water used in watermelon production was estimated based on the average cultivated area and water requirements for the watermelon crop, which ranged from a minimum of 7.14 thousand m3/ha in the Hail region to a maximum of 11.75 thousand m3/ha in the Makkah region, with an average of 8.64 thousand m3/ha (Ministry of Environment, Water and Agriculture, 2020). The data in Table (2) shows that the average amount of water used in watermelon production ranged from a minimum of 0.01 million m3 in the Northern Borders region to a maximum of 212.02 million m3 in the Makkah region, with a total of 274.12 million m3, representing 2.58% of the average amount of water used for agricultural purposes, which amounted to 10.62 billion m3 during the period 2019-2023. In light of the average cost of extracting groundwater, which amounted to 0.48 riyals/m3 (Alnashwan et al., 2016), the value of water used in watermelon production ranged from a minimum of 0.01 million riyals in the Northern Borders region to a maximum of 101.77 million riyals in the Makkah region, with an annual total of 131.58 million riyals during the period 2019-2023.

Table (2): Average quantity and value of water used in watermelon production and its percentage to the total water consumption for agricultural purposes during the period 2019-2023.

region	Cultivated area in hectares	Water requirements m3/hectare	Water quantity million m3	Water value: million riyals
Makkah	18048.5	11747.1	212.02	101.77
Riyadh	3471.1	7185.9	24.94	11.97
Jazan	975.4	11464.2	11.18	5.37
Eastern Province	738.5	8513.3	6.29	3.02
Al-Baha	665.4	8500	5.66	2.71
Madinah	595.1	10287.5	6.12	2.94
Al-Jawf	543.6	7690.4	4.18	2.01
Qassim	243.4	7584.8	1.85	0.89
Tabuk	154.4	7560.8	1.17	0.56
Hail	81.8	7136.7	0.58	0.28
Asir	12.3	8500	0.10	0.05
Najran	1.8	8500	0.02	0.01
Northern Border	1.6	7699.2	0.01	0.01
Total	25532.9	-	274.12	131.58
Average amount of water used for agricultural purposes in million m3			10618	-
%of water used in watermelon production			2.58	-

Source: (1) Data contained in Figure (1), (2) Ministry of Environment, Water and Agriculture (2020). Survey study and determination of the crop composition of the governorates of the Kingdom of Saudi Arabia according to the environmental systems of each governorate.

3.3 Proposed Economic Guidance for Watermelon Production Using Linear Programming

The economic guidance of land and water resources was conducted using a linear programming model consisting of an objective function that maximizes watermelon production under the following resource constraints: (1) Available land resources, expressed by seven constraints. The first concerns the stability of the area planted with watermelon at the Kingdom level. Constraints two to six concern the possibility of increasing the area planted with watermelon in high-productivity regions (Riyadh, Eastern Province, Medina, Tabuk, Hail). The seventh constraint concerns the possibility of limiting watermelon cultivation in low-productivity regions (Al-Jawf, Asir, Northern Borders, Najran, Jazan). (2) Available water resources, expressed by the eighth constraint, aim to reduce the amount of water used in watermelon production. The linear programming model used was formulated in the following equations:

$\boldsymbol{Max}: 23.81X_1 + 24.57X_2 + 20.44X_3 + 28.02X_4 + 23.08X_5 + 25.50X_6 + 22.64X_7 + 23.54X_8 + 23.94X_9 + 24.60X_{10} + 21.92X_{11} + 21.11X_{12} +21.19X_{13}$		
S. t.:		
$X_1 + X_2 + X_3 \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots + X_{13}$	$=$	25532.9
X_2	$\geq$	3471.1
X_4	$\geq$	738.5
X_6	$\geq$	595.1
X_9	$\geq$	154.4
X_{10}	$\geq$	81.1
$X_3 + X_7 + X_{11} + X_{12} + X_{13}$	$\leq$	1534.7
$11.75X_1 + 7.19X_2 + 11.46X_3 + 8.51X_4 + 8.50X_5 + 10.29X_6 + 7.69X_7 + 7.58X_8 + 7.56X_9 + 7.14X_{10} + 8.50X_{11} + 8.50X_{12} + 7.70X1_{13}$	$\leq$	274.12
$X_1, X_2, X_3 \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots$	$\geq$	0

The linear programming results in Table (3) show that the proposed area for watermelon cultivation is 25.53 thousand hectares, of which 21.23 thousand hectares are allocated to the Eastern Region, followed by the Riyadh Region with an area of 3.47 thousand hectares, then the Medina Region with an area of 595.1 hectares, followed by the Tabuk and Hail Regions with an area of 154.4 and 81.1 thousand hectares each, respectively. The proposed economic guidance requires the use of a quantity of water in watermelon production amounting to 213.56 million m3, representing 77.91% of the available water amount of 274.12 million m3, thus leaving a surplus of water resources amounting to 60.56 million m3, representing 22.09% of the available water amount. Total watermelon production under the proposed economic guidance is 701,050 tons. Therefore, total production under the

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proposed economic guidance is 90,700 tons higher than in the current situation, an increase of 14.86%. In light of the proposed economic guidance, the average yield per hectare across the Kingdom is estimated at approximately 27.46 tons, compared to 23.90 tons/hectare under the current situation. Consequently, the average yield per hectare for watermelon crops under the proposed economic guidance is 3.56 tons/hectare higher than under the current situation. Given the local consumption of watermelon at 624,550 tons, implementing the proposed plan will lead to an increase in the self-sufficiency rate for watermelon from 98.1% in 2023 to 112.25%, given the proposed plan's production increase of 90,700 tons.

Table (3): Cultivated area, production, and sensitivity analysis of productivity changes in the proposed direction.

region	Productivity per ton	Cultivated area per hectare		Local production-thousand ton		Range of productivity change	
		current	proposed	current	proposed	Lower limit	Upper limit
Makkah	23.81	18048.5	-	429.81	-	-	28.02
Riyadh	24.57	3471.1	3471.1	85.30	85.30	-	28.02
Jazan	20.44	975.4	-	19.93	-	-	28.02
Eastern Province	28.02	738.5	21231.2	20.69	594.90	25.5	-
Al-Baha	23.08	665.4	-	15.36	-	-	28.02
Madinah	25.50	595.1	595.1	15.17	15.18	-	28.02
Al-Jawf	22.64	543.6	-	12.31	-	-	28.02
Qassim	23.54	243.4	-	5.73	-	-	28.02
Tabuk	23.94	154.4	154.4	3.70	3.70	-	28.02
Hail	24.60	81.8	81.1	2.01	2.01	-	28.02
Asir	21.92	12.3	-	0.27	-	-	28.02
Najran	21.11	1.8	-	0.04	-	-	28.02
Northern Border	21.19	1.6	-	0.03	-	-	28.02
Total	-	25533	25533	610.35	701.05	-	-

Source: Linear programming results using Linear Interactive and Discrete Optimizer (Lindo).

By conducting a sensitivity analysis of the linear programming model to determine the sensitivity of the solution to changes in both productivity and resource determinants, and to what extent these changes can be addressed without the need to change the proposed economic routing pattern or the optimal solution of the linear programming model. Regarding the changes that may occur in the productivity of the land unit (hectare), it is clear from the data in Table (3) that the productivity of the land unit (hectare) in the Eastern Region can be reduced to 25.5 tons/hectare, while the productivity of the remaining regions can be increased within a maximum limit of 28.02 tons/hectare without changing the proposed routing pattern.

As for the changes that may occur in the resource determinants, it is clear from the data in Table (4) that the total area planted with watermelon can be changed within minimum and maximum limits, while the remaining determinants related to the area of watermelon in each of the regions of Riyadh, the Eastern Province, Medina, Tabuk, and Hail can be increased within maximum limits only. Finally, with regard to the water resources determinant, it was shown that the quantities used can be reduced within minimum limits only without the need to change the proposed guidance pattern.

Table (4): The amount of available and used resources and sensitivity analysis to changes in resource determinants in the proposed directive.

Resource determinants	available	used	Surplus and deficit	Range of resource change	
				Lower limit	Upper limit
Total area per hectare	25532.9	25532.9	0	5040.2	32655.74
Area in Riyadh	3471.1	3471.1	0	0	23963.8
Area in the Eastern Province	738.5	21231.2	-20492.7	-	21231.2
Area in Madinah	595.1	595.1	0	0	21087.8
Area in Tabuk	154.4	154.4	0	0	20647.1
Area in Hail	81.1	81.1	0	0	20573.8
Area of low productivity areas	1534.7	0	1534.7	0	-
Water resources in million m3	274.12	213.56	60.56	213.50	-

Source: Linear programming results using Linear Interactive and Discrete Optimizer (Lindo).

4. Conclusion

The study examined the current status of watermelon cultivation and production during the period 2019-2023, then developed an economic plan to increase production and rationalize water consumption using linear programming. By redirecting land and water resources used in watermelon production, domestic watermelon production could be increased from 610,350 tons to 701,050 tons on the same available area of 25,530 hectares, i.e., production could increase by 14.86%. Water consumption can also be rationalized by limiting watermelon cultivation in areas with high water needs. The proposed plan reduces water consumption from 274.12 million m3 to 213.56 million m3, a 22.09% reduction. The proposed plan also increases watermelon self-sufficiency from 98.1% in 2023 to 112.25%, due to an increase in local production of 90.7 thousand tons. To implement the proposed plan, the Ministry of Environment, Water and Agriculture will need to review its agricultural policy for watermelon production, through the proposed economic guidance of land and water resources used in watermelon production across various production areas. The results of this study were consistent with the findings of previous studies, the most important of which are the study (Ghanem et al., 2019) conducted on potato crops, the study (Alnashwan et al., 1019) conducted on maize crops, and the study (Ghanem et al., 2025) conducted on wheat crops in the Kingdom of Saudi Arabia.

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