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Study of the current and proposed status of wheat cultivation and production in the Kingdom of Saudi Arabia

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دراسة الوضع الراهن والمقترح لزراعة وإنتاج القمح في المملكة العربية السعودية

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Abstract:
The research 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 showed 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 does not exceed 15.31% during the period 2018-2023. There is a disparity in wheat productivity between regions, as productivity ranged between a minimum of 4.09 tons/ha for the Jazan region and a maximum of 7.89 tons/ha for the Tabuk region. It was also shown that the priority areas for productive wheat cultivation are Al-Jouf, Tabuk, Qassim, Hail, Riyadh, and the Eastern Province. The proposed economic plan includes limiting wheat cultivation to Al-Jouf, Tabuk, Hail, and Makkah Al-Mukarramah regions. Accordingly, wheat production can be increased by 11.2% and the amount of water used in the alluvial shelf areas can be reduced by 6.27 million m3. The proposed plan also leads to an increase in the self-sufficiency rate for wheat from 25.3% to 28.1%. Finally, this study recommends the need to reconsider the wheat production policy, so that its cultivation is concentrated in areas with high productivity (Tabuk, Al-Jouf, Hail), and not in areas with low productivity (Madinah and Jazan).

Keywords: wheat, priority areas, linear programming, proposed plan, Saudi Arabia.

الملخص
استهدف البحث وضع خطة اقتصادية لزيادة إنتاج القمح وتقليل كمية المياه المستخدمة في مناطق الرف الرسوبي المجهدة مائياً، باستخدام التحليل الاقتصادي الكمي المتمثل في طريقة التقدير النقطي والبرمجة الخطية. وتبين من هذه الدراسة أن إنتاج القمح يتركز في مناطق الرف الرسوبي، حيث بلغت جملة الأهمية النسبية لإنتاج مناطق الرف الرسوبي 84.69%، في حين لا تزيد مساهمة مناطق الدرع العربي عن 15.31% خلال الفترة 2018- 2023. ويوجد تفاوت في إنتاجية القمح بين المناطق، حيث تراوحت الإنتاجية بين حد أدنى بلغ 4.09 طن/ هكتار لمنطقة جازان وحد أعلى بلغ 7.89 طن/ هكتار

لمنطقة تبوك. كما تبين أن أولوية المناطق الإنتاجية في زراعة القمح، تتمثل في كل من منطقة الجوف، تبوك، القصيم، حائل، الرياض، الشرقية. والخطة الاقتصادية المقترحة تتضمن قصر زراعة القمح على كل من منطقة الجوف وتبوك وحائل ومكة المكرمة، وبالتالي يمكن زيادة إنتاج القمح بمعدل 11.2% وتقليل كمية المياه المستخدمة في مناطق الرف الرسوبي بمقدار 6.27 مليون م3، كما أن الخطة المقترحة تؤدي إلى زيادة نسبة الاكتفاء الذاتي للقمح من 25.3% إلى 28.1%. وأخيراً توصي هذه الدراسة بضرورة إعادة النظر في سياسة إنتاج القمح، بحيث تتركز زراعته في المناطق ذات الإنتاجية المرتفعة (تبوك، الجوف، حائل)، وعدم زراعته في المناطق ذات الإنتاجية المنخفضة (المدينة المنورة وجازان).

الكلمات المفتاحية: القمح، أولوية المناطق، البرمجة الخطية، الخطة المقترحة، المملكة العربية السعودية.

Introduction

Wheat is a strategic crop grown in the winter season, requiring less water than other crops (sorghum, maize, millet, sesame, exposed potatoes, dates, citrus fruits, clover, and other fodder). It is known that the Kingdom of Saudi Arabia suffers from water scarcity, and therefore Resolution (335) was issued to rationalize water consumption. The resolution included stopping the purchase of locally produced wheat for a period not exceeding eight years, at a rate of 12.5% annually, and thus the area planted with wheat decreased from 450.33 thousand hectares in 2007 to 84.7 thousand hectares in 2019, then increased to reach 210.1 thousand hectares in 2023. Local wheat production also decreased from 2.56 million tons in 2007 to 500.2 thousand tons in 2019, then increased to 1.31 million tons in 2023 (Figure 1). In light of local consumption needs, the self-sufficiency rate for wheat decreased from 103.0% in 2007 to 14.9% in 2019, then increased to 28.9% in 2023 (Ministry of Environment, Water and Agriculture, 2023).

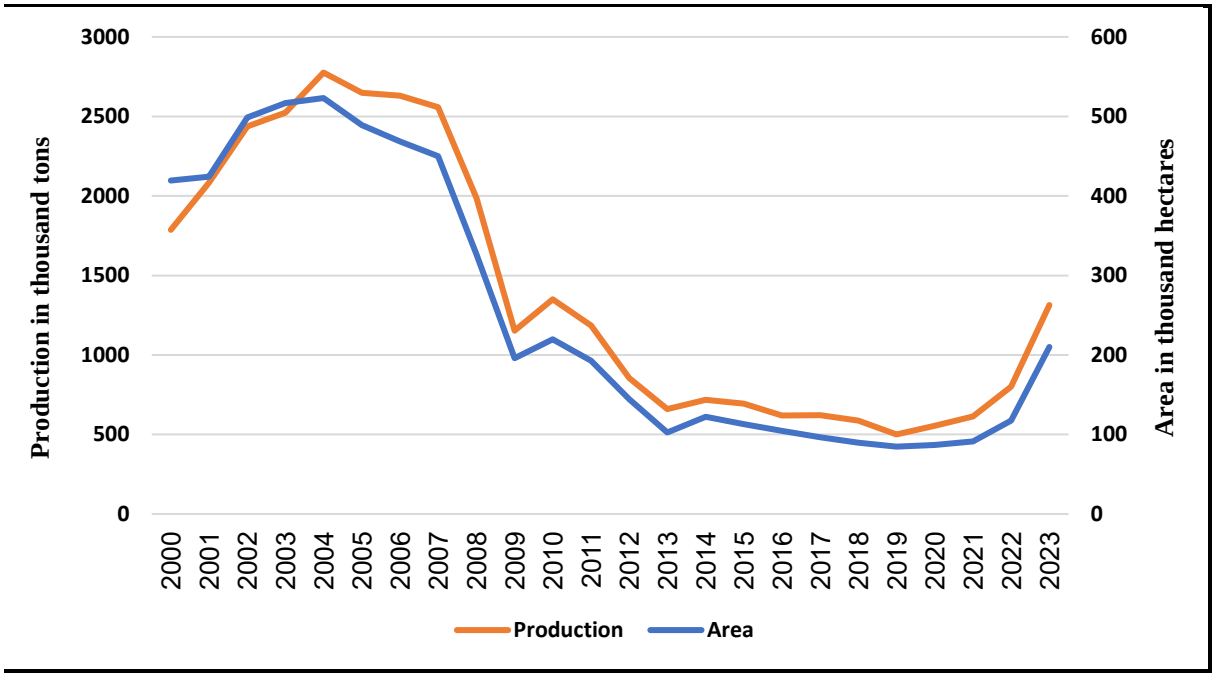

Figure (1): Area and production of wheat in the Kingdom of Saudi Arabia during the period 2000-2023.

The study of (Alrwis, 2009) dealt with the impact of Resolution (335) on production, import and strategic stock of wheat. It is expected that the total social loss will decrease from 1467.4 million riyals in 2008 to 868.3 million riyals in 2015, while the amount of change in government spending will increase from 303.85 million riyals in 2008 to 3215.89 million riyals in 2015. This study recommended the following: (1) Reviewing the government resolution issued regarding wheat and not abandoning its cultivation in light of the increasing global trend towards biofuel production, (2) Focusing wheat cultivation on farms with large capacities due to their ability to achieve high production efficiency. (Al-Nashwan, 2010) study interested in conducting an economic evaluation of the impact of Resolution (335) issued regarding wheat, by studying the positive and negative effects according to the method of analyzing the benefits gained and the social loss of wheat, where the ratio of benefits to social loss reached 0.41 during the period 2009-2016. This study recommended the necessity of reconsidering the government resolution issued regarding wheat and not abandoning wheat cultivation, especially in areas with a comparative advantage in its production.

Some studies have addressed the agricultural crop production strategy, as the study (Ghanem et al., 2019) aimed to develop an economic plan to increase potato production and reduce the amount of water used in water-stressed

areas. This study showed that the proposed plan includes increasing potato production by 30.64%, to reduce the amount of water used in water-stressed sedimentary shelf areas by 70.48%, and thus reduce the use of non-renewable groundwater. The proposed economic plan also leads to reducing imports and increasing the self-sufficiency rate for potatoes from 89.45% to 116.85%. This study recommended the need to reconsider the potato production policy by focusing potato cultivation in areas with high and medium productivity according to the priorities of the regions and the proposed economic direction of the land and water resources used in potato production.

The study (Al Nashwan et al., 2019) aimed to develop a strategy for corn production in the Kingdom of Saudi Arabia. This study showed that the economic orientation of land resources amounting to 17.84 thousand hectares leads to a decrease in the amount of water used by 37.7%, an increase in corn production by 79.95%, in addition to a decrease in the amount of imports by 1.9%, and an increase in the self-sufficiency rate from 2.32% to 4.16%. Finally, this study recommended the need to reconsider the corn production policy by focusing on corn cultivation in areas with high and medium productivity according to the priorities of the regions and the economic orientation of land resources used in corn production.

The study (Ghanem et al., 2022) addressed the impact of food sovereignty of cereal crops on water consumption in the agricultural sector during the period 1990-2020. This study showed that the total amount of water used in cereal production amounted to 136.32 billion m3, representing 27.0% of the total amount of water used in the agricultural sector during the period 1990-2020. A 10% increase in each of the ratio of cereal area to crop area and the ratio of summer cereal area to its winter counterpart leads to an increase in the amount of water used in cereal production by 10.7% and 3.66% for each, respectively. Also, a 10% increase in the estimated amount of water used in cereal production leads to an increase in the amount of water used in the agricultural sector by 2.8%. In light of the scarcity of water resources, the goal of rationalizing water consumption requires expanding the cultivation of the most important winter cereal crops (wheat) and reducing the area of summer cereal crops with high water requirements, the most important of which is sorghum.

The non-renewable groundwater used for agricultural purposes in the alluvial shelf areas (Riyadh, Eastern Province, Qassim, Al-Jawf, Hail, Tabuk, Northern Borders) amounted to 9.36 billion m3, representing 79.5% of the total water used in the agricultural sector, amounting 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, Najran) amounted to 2.41 billion m3, representing 20.5% of the total used in the agricultural sector in 2023 (Ministry of Environment, Water and Agriculture, 2023).

Wheat cultivation is concentrated in the alluvial shelf areas, where the average area planted with wheat in these areas reached 115.96 thousand hectares, representing 77.8% of the average total area planted with wheat, which amounted to 148.98 thousand hectares, while the average area planted with wheat in the Arabian Shield areas reached 33.02 thousand hectares, representing 22.2% of the average total area planted with wheat during the period 2018-2023 (Ministry of Environment, Water and Agriculture, 2023). It was also noted that wheat productivity increased in certain areas such as Tabuk (7.89 tons/ha), Hail (7.52 tons/ha), Al-Jawf (7.17 tons/ha), while wheat productivity decreased in several areas, most notably Madinah (4.54 tons/ha), Jazan (4.09 tons/ha). It is known that low productivity does not achieve a comparative advantage in production, due to the increased loss of agricultural resources used and thus increased production costs of wheat in areas with low productivity. In this field, the study raises the following question: Is it possible to increase wheat production on the one hand and reduce the amount of water used, especially in sedimentary shelf areas on the other hand?

2- Research objectives

This research aimed to develop an economic plan to increase wheat production and reduce the amount of water used in water-stressed alluvial shelf areas, by studying the following objectives:

1. The current status of wheat cultivation in the Kingdom during the period 2018-2023.
2. The disparity in wheat productivity between agricultural regions.
3. Determining the priority of productive regions in wheat cultivation.
4. The proposed economic plan for wheat production using linear programming.
5. Sensitivity analysis of the change in productivity and the specific resource constraints of the wheat production map in the Kingdom of Saudi Arabia.

3- Study Methodology

This study relied on secondary data issued by the General Authority for Statistics, the Ministry of Environment, Water and Agriculture, in order to achieve its objectives, in addition to a survey study and determining the crop composition of the governorates of the Kingdom of Saudi Arabia according to the environmental systems of each governorate (Ministry of Environment, Water and Agriculture, 2020). This study also relied on quantitative economic analysis represented by each of:

a. Dividing the wheat production areas into three categories, by calculating the range (the difference between the largest and smallest value) and the number of categories using the following law (Thomas and Pawel,

2006): $2.5\times\sqrt[4]{n}$, where n represents the production areas, which are 13 regions, and the category length was calculated by dividing the range by the number of categories.

b. Determining the priority of regions in wheat production, using the Scoring Technique according to several criteria, the most important of which are (Blank, Tarquin, 1989): (1) Water requirements for wheat, (2) Average productivity per hectare, (3) Water use efficiency in wheat production, (4) The relative importance of wheat area in different production regions, this criterion reflects the production and environmental characteristics and the importance of the crop from the farmers' point of view, (5) The relative importance of the area of agricultural holdings for each region, this criterion reflects the efficiency of the size or capacity of the production regions. A gradation of regions was used ranging from zero to one hundred, then the scores obtained by each region were collected and their priorities in wheat production were arranged.

c. (T) The economic orientation of the agricultural resources available for wheat cultivation, using the linear programming model, and it can be expressed as follows (Bector and Chandra, 2005):

$$Max\ Z = C\ X$$
$$s.t:$$
$$A\ X \leq b$$
$$X \geq 0$$

Where: Z represents the value of the objective function to be maximized, which is to maximize local wheat production in light of resource constraints, the most important of which are land and water resources. Also, C expresses a vector of order (nx1) for the productivity of the land unit (hectare), while X expresses a vector of order (nx1) for the 13 productive regions. As for A, it expresses the matrix of technical coefficients of order (m x n). A sensitivity analysis, called post-optimality analysis, was conducted to determine the degree of response of the optimal solution or the flexibility of the proposed productive regions to meet the expected changes in the productivity of the land unit (hectare) and resource constraints.

4- Research results

4-1 The current status of wheat cultivation and production in the Kingdom of Saudi Arabia

By studying the current status of wheat cultivation and production in various production regions during the period 2018-2023, it is clear from the data in Table (1) that the average area planted with wheat crops amounted to 148.98 thousand hectares, and the average wheat production amounted to 953.89 thousand tons during the study period. Wheat cultivation and production are concentrated in the alluvial shelf areas: Al-Jawf (24.99%), Riyadh (18.41%), Qassim (16.34%), Hail (14.69%), Tabuk (7.91%), Eastern Province (2.33%), Northern Borders (0.02%). From the above, it is clear that the total relative importance of the production of the sedimentary shelf areas reached 84.69%, while the contribution of the Arabian Shield areas (Makkah, Madinah, Asir, Jazan, Najran, Al-Baha) does not exceed 15.31%. It is known that the sedimentary shelf areas are characterized by low and variable rainfall rates, and they depend on non-renewable groundwater. Therefore, the continuation of this situation affects the strategic water reserve in those areas. In light of the water needs and the area planted with wheat, the average amount of water used reached 1014.57 million m3, representing 7.9% of the average total water used in the agricultural sector, which amounted to 12.67 billion m3 during the period 2018-2023 (Figure 2).

Table (1): Average area and wheat production in different regions during the period 2018-2023.

Region	Area in thousand hectares	Production in thousand tons	Average productivity tons/hectare	Relative importance %	
				Area	Production
Riyadh	25.93	175.62	6.77	17.41	18.41
Makkah	3.68	18.5	5.03	2.47	1.94
Madinah	0.75	3.42	4.54	0.50	0.36
Qassim	24.84	155.82	6.27	16.67	16.34
Eastern	3.7	22.24	6	2.48	2.33
Asir	7.36	36.31	4.94	4.94	3.81
Tabuk	9.57	75.5	7.89	6.42	7.91
Hail	18.64	140.17	7.52	12.51	14.69
Northern Borders	0.03	0.17	5.87	0.02	0.02
Jazan	20.23	82.7	4.09	13.58	8.67
Najran	0.28	1.32	4.79	0.19	0.14
Al-Baha	0.72	3.77	5.26	0.48	0.40
Al-Jawf	33.25	238.35	7.17	22.32	24.99
Total	148.98	953.89	6.4	100.00	100.00

Source: Calculated from: (1) General Authority for Statistics, Agricultural Statistics, period 2018-2023, (2) Ministry of Environment, Water and Agriculture, Statistical Book, period 2018.

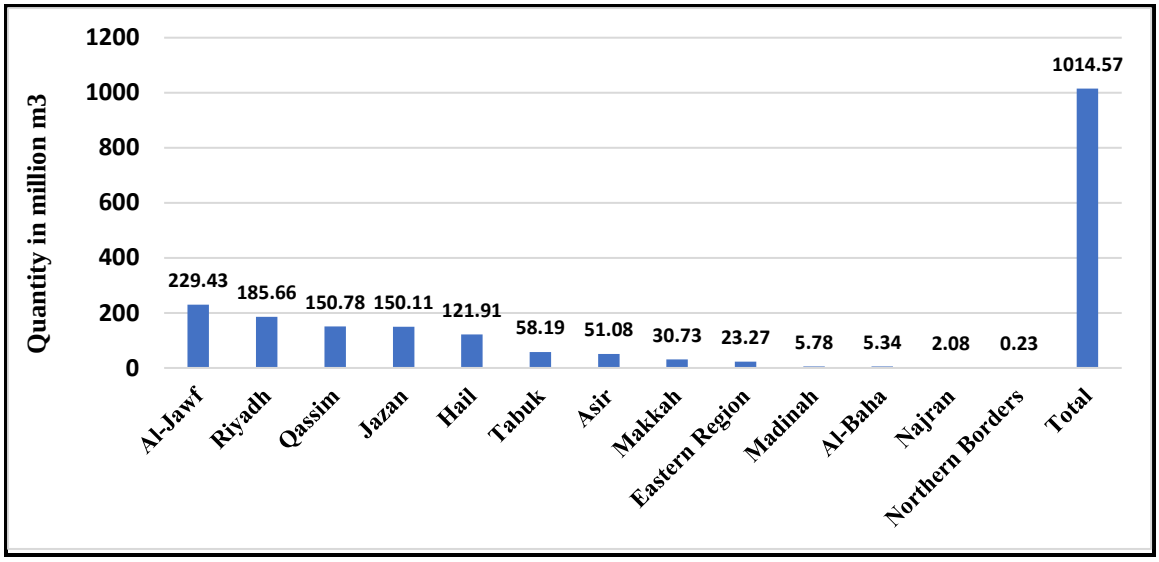

Figure (2): Average amount of water used in wheat production during the period 2018-2023.

4-2 Variation in wheat productivity between agricultural regions

Productivity is a measure of the efficiency of converting agricultural resources into final output, i.e. the amount produced by one unit of production elements, and is calculated by dividing wheat production by the cultivated area. The data in Table (2) shows that wheat productivity ranged between a minimum of 4.09 tons/ha in Jazan region and a maximum of 7.89 tons/ha in Tabuk region, with an average estimated at about 6.40 tons/ha during the study period. The index was used to determine the amount of variation in wheat productivity between regions. The productivity index could be expressed by the following equation:

Productivity index = (productivity of comparison area ÷ productivity of base area) × 100. The wheat productivity index was calculated, considering that the productivity of the Jazan region is equal to 100, since it is the region with the lowest wheat productivity.

It is also clear from the data in Table (2) that the productivity of all regions is higher than its estimated counterpart for Jazan region, at a rate ranging between a minimum of 11.0% for Madinah region and a maximum of 92.9% for Tabuk region. In the case of comparing the productivity of the regions with the average productivity at the Kingdom level, it is clear from calculating the index that the productivity of Tabuk, Hail, Al-Jouf, and Riyadh regions is higher than its estimated counterpart at the Kingdom level at rates of 23.3%, 17.5%, 12.0%, and 5.8%, respectively. As for the productivity of the rest of the regions, it decreased from its estimated counterpart at the Kingdom level at rates ranging between a minimum of 2.0% for Qassim region and a maximum of 36.1% for Jazan region. The disparity in wheat productivity between regions is attributed to the disparity in the degree of fertility of agricultural lands and the quality of water used in irrigation, in addition to the disparity in temperature, humidity, rainfall rates, and the experience of wheat farmers.

Table (2): The amount of variation in average wheat productivity for different regions during the period 2018-2023.

Region	The record number considering that the productivity of Jazan region = 100	Rate of change in % productivity	The standard number considering that the average productivity of the Kingdom = 100	Rate of change in productivity %
Riyadh	165.5	65.5	105.8	5.8
Makkah	123.0	23.0	78.6	-21.4
Madinah	111.0	11.0	70.9	-29.1
Qassim	153.3	53.3	98.0	-2.0
Eastern Region	146.7	46.7	93.8	-6.3
Asir	120.8	20.8	77.2	-22.8
Tabuk	192.9	92.9	123.3	23.3
Hail	183.9	83.9	117.5	17.5
Northern Borders	143.5	43.5	91.7	-8.3
Jazan	100.0	-	63.9	-36.1
Najran	117.1	17.1	74.8	-25.2
Al-Baha	128.6	28.6	82.2	-17.8
Al-Jawf	175.3	75.3	112.0	12.0
Total	156.5	56.5	100.0	-

Source: Data in Table (1).

By distributing wheat production areas across different production categories, it is clear from the data in Table (3) that the regions of Madinah and Jazan fall into the low production category (less than 4.6 tons/hectare), where the percentage of cultivated area and production for low production category areas reached 14.08% and 9.03% for each, respectively. Riyadh, Makkah, Qassim, Eastern Province, Asir, Northern Borders, Najran and Al-Baha regions fall into the medium production category (4.6 to less than 7.0 tons/hectare), where the percentage of cultivated area and production for medium production category areas reached 44.66% and 43.38% for each, respectively. As for the high production category (7.0 tons/hectare and more), it includes Tabuk, Hail and Al-Jawf regions, where the percentage of cultivated area and production for high production category areas reached 41.25% and 47.60% for each, respectively.

Table (3): Relative distribution of wheat production areas among the different production categories.

Production category	Region	Area in thousand hectares	%	Production in thousand tons	%
Less than 4.6 tons	Madinah, Jazan	20.98	14.08	86.12	9.03
4.6 to less than 7.0 tons	Riyadh, Makkah, Qassim, Eastern Province, Asir, Northern Borders, Najran, Al Bahah	66.54	44.66	413.75	43.38
7.0 tons and above	Tabuk, Hail, Al Jawf	61.46	41.25	454.02	47.60
Total		148.98	100	953.89	100

Source: Data in Table (1).

4-3 Determining the priority of productive areas in wheat cultivation

The priority of areas in wheat cultivation was determined through the criteria mentioned in Tables (4, 5), which show the following: (1) Hectare productivity, which ranged between a minimum of 4.09 tons/hectare in Jazan region and a maximum of 7.89 tons/hectare in Tabuk region, (2) Water requirements, which ranged between a minimum of 6.08 thousand m3/hectare in Tabuk region and a maximum of 8.35 thousand m3/hectare in Makkah region, (3) Water use efficiency expressed by the average water unit productivity, which ranged between a minimum of 0.55 tons/thousand m3 in Jazan region and a maximum of 1.30 tons/thousand m3 in Tabuk region, (4) The percentage of the area planted with wheat crop, which ranged between a minimum of 0.02% in the Northern Borders region and a maximum of 22.32% in Al-Jawf region, (5) The percentage of the area Agricultural holdings, ranging from a minimum of 0.27% in the Northern Borders region to a maximum of 24.61% in the Riyadh region.

It is clear from the data in Table (6) that the priority of productive regions in wheat cultivation places Al-Jouf region in first place, followed by Al-Qassim and Tabuk regions, then Hail region in third place. As for Riyadh region, it came in fourth place, followed by the Eastern Region, Asir, Al-Baha, Jazan, Makkah Al-Mukarramah, Northern Borders, then Madinah and Najran regions, respectively.

Table (4): Average productivity, water requirements, water use efficiency, and relative importance of wheat area and agricultural holdings during the period 2018-2023.

Region	Productivity tons/hectare	Water requirements thousand m3/hectare	Water use efficiency tons/thousand m3	Wheat area %	Agricultural % holdings area
Riyadh	6.77	7.16	0.95	17.41	24.61
Makkah	5.03	8.35	0.60	2.47	5.20
Madinah	4.54	7.70	0.59	0.50	3.11
Qassim	6.27	6.07	1.03	16.67	17.61
Eastern	6	6.29	0.95	2.48	18.94
Asir	4.94	6.94	0.71	4.94	0.89
Tabuk	7.89	6.08	1.30	6.42	3.65
Hail	7.52	6.54	1.15	12.51	9.99
Northern Borders	5.87	7.81	0.75	0.02	0.27
Jazan	4.09	7.42	0.55	13.58	3.12
Najran	4.79	7.44	0.64	0.19	0.35
Al-Baha	5.26	7.42	0.71	0.48	0.55
Al-Jawf	7.17	6.90	1.04	22.32	11.71

Source: Compiled and calculated from: (1) General Authority for Statistics, Agricultural Statistics, period 2018-2023, (2) Ministry of Environment, Water and Agriculture, Statistical Book, period 2018-2023, (3) Ministry of Environment, Water and Agriculture, Survey Study and Determination of Crop Structure of the Governorates of the Kingdom of Saudi Arabia According to the Environmental Systems of Each Governorate, 2020.

Table (5): Ranking of production areas according to the criteria used during the period 2018-2023.

Region	Ranking				
	Productivity	Water requirements	Water use efficiency	Wheat area	Agricultural holdings area
Riyadh	4	7	5	2	1
Makkah	9	13	9	9	6
Madinah	12	11	10	10	9
Qassim	5	1	4	3	3
Eastern	6	3	5	8	2
Asir	10	6	7	7	10
Tabuk	1	2	1	6	7
Hail	2	4	2	5	5
Northern Borders	7	12	6	13	13
Jazan	13	9	11	4	8
Najran	11	10	8	12	12
Al-Baha	8	8	7	11	11
Al-Jawf	3	5	3	1	4

Source: Data in Table (4).

Table (6): Results of the criteria for determining the priority of productive areas in wheat cultivation.

Region	Productivity per unit of land	Water requirements	Water use efficiency	Wheat area ratio	Percentage of holding area	Total Points	ranking regions
Riyadh	70	50	60	90	100	370	4
Makkah	30	0	20	30	50	130	9
Madinah	10	20	10	20	30	90	11
Qassim	60	100	70	80	80	390	2
Eastern	50	90	60	30	90	320	5
Asir	30	60	40	40	20	190	6
Tabuk	100	100	100	50	40	390	2
Hail	90	80	90	60	60	380	3
Northern Borders	50	10	50	0	0	110	10
Jazan	0	40	0	70	30	140	8
Najran	20	30	30	10	0	90	11
Al-Baha	40	40	40	20	10	150	7
Al-Jawf	80	70	80	100	70	400	1

Source: Collected and calculated from the data in Table (5).

4-4 The proposed economic plan for wheat cultivation and production in the Kingdom of Saudi Arabia

The economic guidance of land and water resources was carried out using a linear programming model consisting of an objective function that maximizes wheat production under the following resource constraints:

1- Land resources can be expressed in six restrictions, the first of which relates to the stability of the area planted with wheat at the level of the Kingdom, while the restrictions from the second to the fourth relate to the possibility of increasing the area planted with wheat in areas with high productivity (Tabuk, Hail, Al-Jawf), while the fifth restriction relates to the possibility of increasing the area planted with wheat in areas with priority in wheat cultivation according to the point estimation method (Al-Jawf, Tabuk, Qassim, Hail, Riyadh, Eastern Province), while the sixth restriction relates to the possibility of limiting wheat cultivation in areas with low productivity (Madinah, Jazan).

2- Water resources can be expressed with only two constraints. The first is related to the possibility of reducing the amount of water used to produce wheat in the alluvial shelf areas (Riyadh, Qassim, Eastern Province, Tabuk, Hail, Northern Borders, Al-Jawf), while the second is related to the possibility of increasing the amount of water used to produce wheat in the Arabian Shield areas (Makkah, Madinah, Asir, Jazan, Najran, Al-Baha).

The linear programming model used in the following equations was formulated:

$\boldsymbol{Max}$: $6.77X_1 + 5.03X_2 + 4.54X_3 + 6.27X_4 + 6.0X_5 + 4.94X_6 + 7.89X_7 + 7.52X_8 + 5.87X_9 + 4.09X_{10} + 4.79X_{11} + 5.26X_{12} + 7.17X_{13}$		
S. t.:		
$X_1 + X_2 + X_3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + X_{13}$	=	148.98
X_7	≥	9.57
X_8	≥	18.64
X_{13}	≥	33.25
$X_1 + X_4 + X_5 + X_7 + X_8 + X_{13}$	≥	115.93
$X_3 + X_{10}$	≤	20.98
$7.16X_1 + 6.07X_4 + 6.29X_5 + 6.08X_7 + 6.54X_8 + 7.81X_9 + 6.90X_{13}$	≤	769.46
$8.35X_2 + 7.70X_3 + 6.94X_6 + 7.42X_{10} + 7.44X_{11} + 7.42X_{12}$	≥	245.11
$X_1, X_2, X_3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots X_{13}$	≥	0

The linear programming results in Tables (7, 8) show that the proposed area for wheat cultivation is 148.98 thousand hectares, of which 67.74 thousand hectares are allocated to Tabuk region, 33.25 thousand hectares to Al-Jouf region. An area of 29.35 and 18.64 thousand hectares is allocated to Makkah and Hail regions respectively. The proposed economic guidance requires the use of a quantity of water in the sedimentary shelf areas amounting to 763.19 million m3, representing 99.2% of the available water amounting to 769.46 million m3, and thus a surplus of water resources remains in the sedimentary shelf areas amounting to 6.27 million m3, representing 0.81% of the available water amount in the sedimentary shelf areas. In the Arabian Shield areas, the amount of water used is 245.07 million m3, which is almost equal to the amount of water available in the Arabian Shield areas. The total wheat production according to the proposed economic guidance is 1060.66 thousand tons, and thus the total production under the proposed economic guidance is 106.77 thousand tons higher than its counterpart in the current situation, i.e. an increase of 11.2%. In light of the proposed economic guidance, the average productivity per hectare is estimated at about 7.12 tons, while it reached 6.40 tons/hectare under the current situation, and thus the average productivity per hectare of wheat crop in the proposed economic guidance is 0.72 tons/hectare higher than its counterpart in the current situation. In light of the average local wheat consumption of 3772 thousand tons, implementing the proposed plan will lead to an increase in the self-sufficiency rate for wheat from 25.29% to 28.12%, due to the increase in production in the proposed plan by 106.77 thousand tons.

Table (7): Cultivated area, production, and sensitivity analysis of productivity change in the proposed guidance.

Region	Productivity in tons	Cultivated area in thousand hectares		Local production in thousand tons		Range of productivity change per unit of land	
		Current	Suggested	Current	Suggested	Minimum	Maximum
Riyadh	6.77	25.93	-	175.62	-	-	7.89
Makkah	5.03	3.68	29.35	18.5	147.63	4.93	7.89
Madinah	4.54	0.75	-	3.42	-	-	5.25
Qassim	6.27	24.84	-	155.82	-	-	7.89
Eastern	6	3.7	-	22.24	-	-	7.89
Asir	4.94	7.36	-	36.31	-	-	5.51
Tabuk	7.89	9.57	67.74	75.5	534.47	7.52	-
Hail	7.52	18.64	18.64	140.17	140.17	-	7.89
Northern Borders	5.87	0.03	-	0.17	-	-	7.89
Jazan	4.09	20.23	-	82.7	-	-	5.35
Najran	4.79	0.28	-	1.32	-	-	5.34
Al-Baha	5.26	0.72	-	3.77	-	-	5.35
Al-Jawf	7.17	33.25	33.25	238.35	238.40	-	7.89
Total	-	148.98	148.98	953.89	1060.66	-	-

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 guidance pattern or the optimal solution of the linear programming model. With regard to the changes that may occur in the productivity of the land unit (hectare),

it is clear from the data in Table (7) that the productivity of the land unit (hectare) can be reduced in the regions of Tabuk and Makkah Al-Mukarramah, while the productivity of the rest of the regions can be increased to maximum limits without changing the proposed guidance pattern.

As for the changes that may occur in the resource determinants, it is clear from the data in Table (8) that the total area planted with wheat can be changed within minimum and maximum limits, while the rest of the determinants related to the wheat area in each of the Tabuk, Hail, and Al-Jawf regions can be increased within maximum limits only. Finally, with regard to the water resources determinant in the sedimentary shelf areas, it was found that the quantities used can be reduced within minimum limits only, while in the Arabian Shield areas, it was found that the quantities used of water can be changed within minimum and maximum limits without the need to change the proposed guidance pattern.

Table (8): The amount available and used and the sensitivity analysis to changes in resource determinants in the proposed directive.

Resource determinants	Available	user	Surplus and deficit	Range of resource change	
				Minimum	Maximum
Total area in thousand hectares	148.98	148.98	0	145.28	150.02
Area planted with wheat in high productivity areas:					
Tabuk	9.57	67.74	58.17-	-	67.74
Hail	18.64	18.64	0	0	32.33
Al-Jawf	33.25	33.25	0	0	40.93
Priority areas for wheat cultivation	115.93	119.63	3.7-	-	119.63
Area of low productivity areas	20.98	0	20.98	0	-
Water resources of the sedimentary shelf in million m3	769.46	763.19	6.27	763.16	-
Water resources of the Arabian Shield in million m3	245.11	245.07	0	236.46	275.97

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

5- Conclusion:

Wheat is concentrated in the water-stressed alluvial shelf areas (Riyadh, Eastern Province, Qassim, Al-Jawf, Hail and Tabuk), and there is a disparity in productivity between agricultural regions, ranging from a minimum of 4.09 tons/ha for Jazan region to a maximum of 7.89 tons/ha for Tabuk region during the period 2018-2023. The regions with low productivity (Madinah, Jazan) are unable to achieve a comparative advantage, in addition to the waste of agricultural resources used in wheat production. By determining the priority of regions using the point estimation method and the proposed economic plan using linear programming, it was found that in light of the stability of the total area planted with wheat crops at 148.98 thousand hectares, production can be increased by 11.2% and the amount of water used in the water-stressed alluvial shelf areas can be reduced by 6.27 million m3. The proposed economic guidance also entails replacing the increase in production with imports. In light of the average local consumption of wheat of 3,772 thousand tons, implementing the proposed economic guidance will lead to an increase in the self-sufficiency rate from 25.3% to 28.1%. In light of the results of this study, it is recommended that the Ministry of Environment, Water and Agriculture reconsider its wheat production policy, so that its cultivation is focused on areas with high productivity (Tabuk, Al-Jouf, Hail) and not in areas with low productivity (Madinah, Jazan).

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6- References:

- Alrwis, Khalid Nahar (2009). Measuring the impact of government decision on production, import and strategic stock of wheat in the Kingdom of Saudi Arabia. Journal of the Faculty of Commerce for Scientific Research, Faculty of Commerce, Alexandria University, Issue 2, Volume 46, pp: 97-122.
- Ghanem, Adel Mohamed Khalifa; Alduwais, Abdel Aziz Mohamed; Alamri, Yosef Abdel Rahman; Alnafissa, Mohamed Abdel Latif (2019). Potato Production Strategy in the Kingdom of Saudi Arabia, Egyptian Journal of Agricultural Economics, Volume 29, Issue 4, December, pp: 1447-1456.
- Alnashwan, Othman Saad (2010). Economic evaluation of the impact of Government Resolution No. 335 on wheat. Agricultural Development Strategy and Challenges of Egyptian Food Security Conference, Faculty of Agriculture, Alexandria University, (28-29) July, pp: 219-231.
- General Authority for Statistics. Agricultural Statistics, period 2018-2023.

- Ministry of Environment, Water and Agriculture (2020). Survey study and determination of the crop composition of the Kingdom's governorates Ministry of Environment, Water and Agriculture. Statistical Book, period 2018-2023.
- Alnashwan, O. S., Khalid bin Nahar Al Ruwis, Adel Mohammed Khalifa Ghanem, Sharaf al-Din Bakri Ahamed and Najib Aldudhi (2019). Maize production strategy in Saudi Arabia, Journal of Experimental Biology and Agricultural Science, December, Volume 7, Issue 6, p:545-553.
- Bector, C.R. and Chandra, S. (2005). Fuzzy Mathematical Programming and Fuzzy Matrix Games, Springer Berlin Heidelberg New York.
- Blank, L. T. and Tarquin A.J., (1989). Engineering Economy, Third Edition, Mc Grow- Hill Book Company, New York.
- Ghanem, Adel M.; Alruwis, Khalid N.; Alnashwan, Othman S.; Almojil, Suleiman A.; Al-Madra'a, Sattam F.; Alaagib, Sharafeldin B. and Aldawdahi, Najeeb M. (2022). The impact of food sovereignty of cereal crops on water consumption in the agricultural sector in Kingdom of Saudi Arabia, Journal of the Austrian Society of Agricultural Economics (JASAE), Volume 18, Issue 9, October, p: 1269- 1279.
- Thomas H. and Pawel L., (2006). Statistics: Methods and Applications Comprehensive Reference for Science, Industry, and Data Mining, Stat soft. Inc., United States of America.