Journal of Experimental Biology and Agricultural Sciences

<http://www.jebas.org>

ISSN No. 2320 – 8694

MAIZE PRODUCTION STRATEGY IN SAUDI ARABIA

Othman S. Al nashwan, Khalid N. Al rwis, Adel M. Ghanem,
Sharaf El-din B. Ahamed*, Nageeb M. Aldawdahi

Department of Agricultural Economics, College of Food and Agricultural Sciences, King Saud University, P.O. Box 2460, Riyadh 11451.

Received – August 20, 2019; Revision – October 28, 2019; Accepted – November 29, 2019

Available Online – December 25, 2019

DOI: [http://dx.doi.org/10.18006/2019.7\(6\).543.553](http://dx.doi.org/10.18006/2019.7(6).543.553)

KEYWORDS

Maize
Productivity
Strategy
Economic guidance
Linear programming

ABSTRACT

This study develops a strategy for the production of maize in Saudi Arabia by examining the current situation, determining priority regions, and providing economic guidance for land resources used in maize production. This study uses the methodology of point estimation and linear programming. The results of study suggested that current maize production is concentrated only in the Arabian Shield areas (Makkah, Madinah, Jazan, Asir, Najran, and Al Baha), which are low productivity areas. The share of cultivated area and maize production in these areas is 86.51% and 79.13%, respectively. Further, result of study revealed that Hail ranked first among priority regions for maize production, this was followed by Qassim, Al-Jawf, Riyadh, and Sharqia. Result of study also suggested that economic guidance for land resources of 17,840 hectares derived using linear programming leads to a decrease in water use by 37.7%, an increase in maize production by 79.95%, a decrease in the quantity of imports by 1.9%, and an increase in the self-sufficiency ratio from 2.32% to 4.16%. Result of study recommends that Ministry of Environment, Water and Agriculture review the policy of maize production by shifting maize cultivation to areas with high and medium productivity in priority regions and considering economic guidance for land resources used in maize production.

* Corresponding author

E-mail: salaagib@ksu.edu.sa (Sharaf El-din B. Ahamed)

Peer review under responsibility of Journal of Experimental Biology and Agricultural Sciences.

Production and Hosting by Horizon Publisher India [HPI]
(<http://www.horizonpublisherindia.in/>).
All rights reserved.

All the articles published by [Journal of Experimental Biology and Agricultural Sciences](#) are licensed under a [Creative Commons Attribution-NonCommercial 4.0 International License](#) Based on a work at www.jebas.org.

1 Introduction

Maize, a summer cereal, has high economic importance, and is used as food and feed in Saudi Arabia, with a production of 93.9 thousand tons, available consumption of 1.58 million tons, and a self-sufficiency rate of 5.9% in 2016. Given the inability of domestic production to fully meet the consumption needs of maize, the country has been forced to rely on imports. The Kingdom of Saudi Arabia imported 1.49 million tons valued at \$319.23 million representing 1.66% of the value of agricultural imports amounting to \$19.28 billion in 2016 (Arab Organization for Agricultural Development, 2017). Maize cultivation is currently concentrated in low productivity areas (Makkah, Madinah, Jazan, Najran, and Al baha). The total area planted with maize crops in these regions was 15,440 hectares, representing 86.51% of the agricultural cultivation. While relative importance of maize area in high productivity area is only 13.5% of the total area planted (17.84 thousand hectares) with maize crop in 2015 (General Authority for Statistics, 2015). Low productivity does not allow for comparative advantage in production due to high losses in agricultural resources used, which leads to increase maize production costs in low productivity areas. Thus, a strategy is required to reorient the land resources used in maize production in the Kingdom of Saudi Arabia.

Various previously conducted studies have examined the economics of maize production. Fufa & Hassan (2003) estimated a stochastic maize production technology and carried out a production risk analysis for maize farmers in Ethiopia. Results of this study suggested that improved maize technology exhibits constant returns to scale, whereas non-adopters use a technology with decreasing returns to scale. The study showed that timely planting is critical for stable maize yield among both adopters and non-adopters. Nevertheless, the results showed that factors which are under the control of farmers do not sufficiently explain maize yield variability compared to natural factors such as rainfall, frost, pests, and diseases. According to the report of Arab Organization for Agricultural Development (2006), the average yield of maize for irrigated land in the Arab world was 4.63 ton/ha, while it was reported 8.15 ton/ha for developed countries. The low productivity of maize in the Arab world is attributed to the traditional pattern of agriculture, small size of agricultural tenure and dispersion, low use of production inputs, lack of agricultural techniques, weak extension capacity, absence of marketing services and natural constraints.

Abbas & Al-Akili (2015) studied the costs of maize production in the Babil province of Iraq. The variable production costs of both domestic and hybrid seed varieties accounted for 91.64% and 95.47% of the total cost, respectively. There are also significant differences between the local and hybrid seed varieties in terms of productivity, costs, and total income. The average farm area for

both local and hybrid seed was estimated to be 8.96 and 4.95 ha, respectively. Uya et al. (2015) assessed the impact of factors on adaptation to drought for maize production in the Dakrong district, Vietnam. They found that increasing household's capitals, experience, maize production scale, gender and non-farm income significantly increased the probability of applying at least one adaptation measure in maize production. Similarly, Zhang et al. (2017) reported that combination of drip irrigation, plastic film mulching, and increased planting density improved final maize yield in Xinjiang. Maximum economic return and the irrigation level were linearly related to the price of water.

This study was conducted to develop a strategy for maize production by determining priority regions and economic guidance for land resources by using the point estimation and linear programming methodology.

Study undertaken issues related to the current status of maize production in Saudi Arabia in 2015, disparities in productivity among the regions, the prioritization of regions in maize production, economic guidance for land resources used in maize production, and an analysis of the sensitivity to changes in productivity and specific resource constraints for maize production in Saudi Arabia.

2 Materials and Methods

This study is based on dividing the maize production areas into three productivity categories based on the range (the difference between the largest and the smallest values) and the number of categories using the rule given by Thomas & Pawel (2006) $2.5 \times \sqrt[n]{n}$. The length of the category was calculated by dividing the range by the number of categories. Priority regions in the production of maize based on the scoring technique according to several criteria (Blank & Tarquin, 1989) such as (1) water needs of maize, (2) average productivity per hectare, (3) water use efficiency (WUE) in maize production, (4) the relative importance of the maize cultivation area in the different regions, and (5) relative importance of the total crop area. The first four criteria reflect the production and environmental characteristics and the importance of the crop from the farmers' perspective, and the fifth criterion reflects the efficiency of volume or capacity of the production areas. An area gradient of zero to 100 was used, the grades were obtained and prioritized by maize that were collected and prioritized. This study, in planning the maize production strategy for the different production areas, was based on the economic orientation of the cultivated area in the light of the priority of the production areas, which were determined by the method of scoring technique according to the mentioned criteria. Cultivated areas were distributed in light of the relative importance of the points obtained by each area. The method of point estimation was used in the study of the proposed crop composition

of Saudi Arabia in 2017 (Ministry of Environment, Water and Agriculture, 2017).

This study is based on the economic guidance for land resources used in maize production based on priorities identified in the point estimation method (i.e., the points obtained by each region as follows):

Average share per point of maize area = total area planted by maize crop ÷ total number of points for maize production areas

Area planted with maize crop in each region = average share per point of maize area × number of points for production area

Economic guidance for land resources in the linear programming model was also adopted in present study, this model can be expressed as follows (Bector & Chandra, 2005):

Max $Z = C X$,

s.t.

$A X \leq b$,

$X \geq 0$,

Where Z is the value of the maximizing function, which is to maximize the local maize production given the resource constraints, the most important of which are land and water resources. C represents an $n \times 1$ vector for the productivity of the earth unit (hectare). X represents an $n \times 1$ vector of the 11

production regions. A represents a matrix of technical transactions of the rank $(m \times n)$. A sensitivity analysis, called the post-optimization analysis, was carried out to determine the degree of response of the optimal solution, or the elasticity of the proposed production areas to the expected changes in the productivity of the ground unit (hectare) and the resource determinants. Finally, detailed results of the agricultural census conducted by the General Authority for Statistics (2015) was used, in addition to specialized studies in assessing the water needs of crops in the different production areas.

Linear programming is one of the most important methods used in determining the optimal plan for the distribution of cultivated areas. It was used in studying the future plan for Saudi agriculture in 2004. It was also used in the study of the expected crop composition in the light of water and food security considerations of Saudi Arabia (Ghanem et al., 2010). Finally, this study relied on the detailed results of the agricultural census conducted by the General Authority for Statistics in 2015, in addition to the specialized studies in estimating the water needs of different crops, the most important of which is the Hussain et al. (2010).

3 Results and discussion

3.1 The current situation of maize production in Saudi Arabia

Table 1 represents the current status of maize production in the various regions of the Kingdom of Saudi Arabia in 2015. It shows that the area planted with maize have 17843 hectares, while total maize production was 63350 tons with a value of 77.34 million

Table 1 Relative importance of the area and production of maize in different regions in 2015

Region	Area (hectares)	%	Production (thousand tons)	%
Riyadh	589	3.30	2.69	4.25
Eastern region	4	0.02	0.02	0.03
Qassim	489	2.74	2.26	3.57
Al-Jawf	221	1.24	1.02	1.61
Hail	1105	6.19	7.22	11.41
Makkah	5436	30.47	18.37	29.00
Madina El Monawara	12	0.07	0.04	0.06
Jazan	2306	12.92	6.64	10.47
Asir	5365	30.07	17.76	28.03
Najran	17	0.10	0.06	0.09
Al Baha	2299	12.88	7.26	11.47
Kingdom	17843	100	63.35	100

Source: General Authority for Statistics, detailed results of the agricultural census for 2015.

riyals. Maize production is concentrated in five productive areas i.e. Makkah Al Mukarramah (29%), Asir (28.03%), Al Baha (11.47%), Hail (11.41%), and Jazan (10.47%). The relative importance of the production of the above-mentioned areas is 90.38%, while the contribution of the rest of the productive areas does not exceed 9.62%.

3.2 Disparities in maize productivity in the different regions

Productivity is a measure of the efficiency of converting agricultural resources into a final output (i.e., the ability to convert inputs to outputs according to specific conditions at a certain cost over a specified period of time). Productivity can also defined as amount produced by one unit of production and it is calculated by dividing maize production by the cultivated area (Suleiman, 2014). The productivity index can be expressed as follows:

Productivity index = (comparative productivity area ÷ base area productivity) × 100.

It is clear from Table 2 that maize productivity ranged from a minimum of 2.88ton/ha in Jazan region to a maximum of 6.53 ton/ha in the Hail region with an average of 3.55 ton/ha in 2015. This index was used to determine the extent of variation in maize productivity among regions.

In current study, index of maize productivity was calculated by taking the productivity of the Jazan region as 100 percent since it is the lowest in terms of maize productivity. From table 2 it is clear

that all regions have higher productivity compared to the Jazan region ranging from a minimum of 9.7% for the Al Baha region to a maximum of 126.7% for the Hail region. To compare the productivity of the regions with the average productivity at the Kingdom level, the calculation of the index shows that the productivity of Riyadh, Eastern region, Qassim, Al-Jawf, and Hail exceeds the average productivity in the Kingdom by 28.7%, 40.8%, 30.1%, 30.1%, 83.9%, respectively. The productivity of the some regions was lower than the average productivity of Kingdom and it ranging from a minimum of 0.6% for Najran to a maximum of 18.9% for Jazan in 2015. The disparity in maize productivity among the regions is due to the variation in agricultural fertility, water quality, irrigation, temperature, humidity, rainfall, as well as the experience of the maize farmers.

By dividing maize production areas into different productive categories (Table 3), results of study revealed that areas of the Arabian Shield (Makkah, Madinah, Jazan, Asir, Najran, and Al Baha) are in the low productivity category (less than 3.68 ton/ha), while the share of cultivated area and maize production in low productivity category reached 86.51% and 79.13%, respectively. Riyadh, Eastern region, Qassim, and Al-Jawf are in the medium productivity category (3.68 ton/ha and more but less than 6.09 ton/ha) while the share of cultivated area and maize production in the average productivity area was 7.3% and 9.46%, respectively. In the highest productivity category, only Hail region (6.09 ton/ha and more) was considered, where the area of cultivated area and maize production was 6.19% and 11.41%, respectively.

Table 2 The extent of inequality in maize productivity for different regions in 2015

Region	Yield (tons / ha)	Productivity index (Jazan region = 100)	Rate of change in productivity%	Productivity index (Kingdom = 100)	Rate of change in productivity%
Riyadh	4.57	158.7	58.7	128.7	28.7
Eastern region	5.00	173.6	73.6	140.8	40.8
Qassim	4.62	160.4	60.4	130.1	30.1
Al-Jawf	4.62	160.4	60.4	130.1	30.1
Hail	6.53	226.7	126.7	183.9	83.9
Makkah	3.38	117.4	17.4	95.2	-4.8
Madina El Monawara	3.33	115.6	15.6	93.8	-6.2
Jazan	2.88	100	-	81.1	-18.9
Asir	3.31	114.9	14.9	93.2	-6.8
Najran	3.53	122.6	22.6	99.4	-0.6
Al Baha	3.16	109.7	9.7	89.0	-11.0
Kingdom	3.55	123.3	23.3	100	-

Source: Compiled and calculated from data in Table 1.

Table 3 Distribution of maize production areas to different productivity categories

Productivity Category	Regions	Area (ha)	%	Local production per thousand tons	%
Low					
Less than 3.68 ton/ha	Makkah, Madinah, Jazan, Asir, Najran, and Al-Baha	15,435	86.51	50.13	79.13
Medium					
3.68 ton/ha and more but less than 6.09 ton/ha	Riyadh, Eastern region, Qassim, and Al-Jawf	1,303	7.30	5.99	9.46
High					
6.09 ton/ha and more	Hail	1,105	6.19	7.22	11.41
Total		17,843	100	63.35	100

Source: Table 2.

Table 4 Criteria for determining priority areas for maize production in Saudi Arabia, 2015

Region	Productivity ton/ha	Water needs Thousand m ³ /ha	Water use efficiency ton/thousand m ³	Relative importance of maize area)(%)	Relative importance of cropland)(%)
Riyadh	4.57	11.28	0.41	3.30	27.4
Eastern region	5.00	7.35	0.68	0.02	7.2
Qassim	4.62	7.03	0.66	2.74	13.8
Al-Jawf	4.62	7.35	0.63	1.24	19.9
Hail	6.53	6.91	0.95	6.19	11.1
Makkah	3.38	16.13	0.21	30.47	5.34
Madina El Monawara	3.33	11.28	0.30	0.07	2.31
Jazan	2.88	11.47	0.25	12.92	5.55
Asir	3.31	8.44	0.39	30.07	2.20
Najran	3.53	11.00	0.32	0.10	0.51
Al Baha	3.16	10.08	0.31	12.88	0.48

Source: General Authority for Statistics, detailed results of the agricultural census for 2015

3.3 Determining maize production priority regions

Priority regions for maize production have been identified through the criteria in Table 4. Result of study revealed that (i) per hectare productivity ranging from a minimum of 2.88 ton/ha in the Jazan region to a maximum of 6.53 ton/ha in the Hail region, (ii) water requirement of maize ranging from a minimum of 6.91 thousand m³/ha in the Hail region to a maximum of 16,130 m³/ha in the Makkah region, (iii) water use efficiency expressed as the average productivity of the water unit ranging from a minimum of 0.21 ton/thousand m³ in the Makkah region to a maximum of 0.95 ton/thousand m³ in the Hail region, (iv) the relative importance of the area planted

with maize, which ranged from a minimum of 0.02% for the eastern region to a maximum of 30.47% for the Makkah region and (v) the relative importance of the cropland area ranging from a minimum of 0.48% for the Al Baha region to a maximum of 27.4% for the Riyadh region.

A composite standard was used to combine the results of the criteria using the scoring technique. It is clear from Table 5 that the prioritization of the regions in maize production based on the results of the combined criteria places the Hail region in first place, followed by Qassim, Al-Jawf, Riyadh and Eastern region (tied for fourth place), Makkah, Jazan, and Najran and Al Baha (tied for seventh place), and Medina, ranked last.

Table 5 Results applying the criteria for determining priority areas in maize production in Saudi Arabia

Region	Productivity Of the ground unit	Water needs	Water use efficiency	Relative importance of maize area	Relative importance of crop area	Total points	Arrangement areas
Riyadh	60	20	60	50	100	290	4
Eastern region	80	60	90	0	60	290	4
Qassim	70	70	80	40	80	340	2
Al-Jawf	70	60	70	30	90	320	3
Hail	90	80	100	60	70	400	1
Makkah	40	0	0	100	40	180	6
Madina El Monawara	30	20	20	10	30	110	8
Jazan	0	10	10	80	50	150	7
Asir	20	50	50	90	20	230	5
Najran	50	30	40	20	10	150	7
Al Baha	10	40	30	70	0	150	7

Source: Table 4.

Table 6 Economic guidance for land resources based on prioritization of areas in the point estimation method

Region	Proposed area in hectare	%	Quantity of water used in million m ³		Production of maize in thousand tons	
			Current situation	Proposed	Current situation	Proposed
Riyadh	1,982.6	11.11	6.64	22.36	2.69	9.06
Eastern region	1,982.6	11.11	0.03	14.57	0.02	9.91
Qassim	2,324.4	13.03	3.44	16.34	2.26	10.74
Al-Jawf	2,187.6	12.26	1.62	16.08	1.02	10.11
Hail	2,734.6	15.33	7.64	18.90	7.22	17.86
Makkah	1,230.6	6.90	87.68	19.85	18.37	4.16
Madina El Monawara	752.0	4.21	0.14	8.48	0.04	2.50
Jazan	1,025.5	5.75	26.45	11.76	6.64	2.95
Asir	1,572.4	8.81	45.28	13.27	17.76	5.20
Najran	1,025.5	5.75	0.19	11.28	0.06	3.62
Al Baha	1,025.5	5.75	23.17	10.34	7.26	3.24
Total	17,843	100	202.28	163.23	63.35	79.36

Source: Tables 1 and 5.

3.4 Economic guidance for land resources used in maize production

The economic guidance for the land resources used in the production of maize was based on the prioritization of areas in the point estimation method presented earlier. Table 6 shows

that the area proposed for maize crop cultivation is 17,840 hectares. It is concentrated in several areas, of which the most important are Hail (15.33%), Qassim (13.03%), Al-Jawf (12.26%), Riyadh (11.11%), Asir (8.81%), and Makkah (6.90%). The relative importance of the proposed area of maize in Jazan, Najran, and Al Baha area was 5.75% in the three

regions, followed by Al Madinah Al Munawwarah (4.21%). The economic guidance for land resources in the point estimation method reduces the amount of water used in maize production from 202.28 million m³ to 163.23 million m³, decreasing by 19.3%, while domestic production of maize increases from 63,350 tons to 79,360 tons at a rate of 25.3%. Under the proposed economic guidance, average maize productivity is estimated at 4.45 ton/ha, which is 0.9 ton/ha over 3.55 ton/ha, the average productivity under the current situation.

The economic guidance for land resources was also carried out using a linear programming model, which consists of the objective function that is optimized for maize production under resource constraints, the most important of which are land and water resources. The first is the existing area with maize plantations at the level of the Kingdom, while the second to sixth relate to the possibility of expanding the cultivated land in areas with medium to high productivity (Riyadh, Eastern region, Qassim, Juff, and Hail). The seventh restriction relates to the possibility of reducing the cultivation of maize in areas with low productivity (Makkah, Madinah, Jazan, Asir, Najran, and Al Baha). Restrictions on water resources can be expressed in the eighth restriction as the possibility of reducing the amount of water used in maize production. A linear programming model using the following equations was

formulated:

Max: $4.57X_1 + 5.0X_2 + 4.62X_3 + 4.62X_4 + 6.53X_5 + 3.38X_6 + 3.33X_7 + 2.88X_8 + 3.31X_9 + 3.53X_{10} + 3.16X_{11}$	
s. t	
$X_1 + X_2 + X_3 + \dots + X_{11}$	$= 17,843$
X_1	≥ 589
X_2	≥ 4
X_3	≥ 489
X_4	≥ 221
X_5	$\geq 1,105$
$X_6 + X_7 + X_8 + X_9 + X_{10} + X_{11}$	$\leq 15,435$
$11.28X_1 + 7.35X_2 + 7.03X_3 + 7.35X_4 + 6.91X_5 + 16.13X_6 + 11.28X_7 + 11.47X_8 + 8.44X_9 + 11.0X_{10} + 10.08X_{11}$	$\leq 202,280$
$X_1, X_2, X_3, \dots, X_{11}$	≥ 0

It is clear from the results of the linear programming in Tables 7 and 8 that the area proposed for maize crop cultivation is 17840 hectares, of which 16540 hectares are allocated to Hail, and about 589, 489, 221 and 4 hectares are allocated for the Riyadh, Qassim, Al-Jawf, and Eastern region respectively. The proposed economic directive requires the use of 126.03 million m³ of water, representing 62.3% of the available water (202.28 million m³),

Table7 Cultivated area, production, and sensitivity analysis of productivity change in the proposed guidance

Region	Productivity per ton	Area cultivated hectare		Local production per thousand tons		The range of productivity change of the ground unit	
		Current situation	Proposed	Current situation	Proposed	minimum	maximum
Riyadh	4.57	589	589	2.69	2.69	-	6.53
Eastern region	5.00	4	4	0.02	0.02	-	6.53
Qassim	4.62	489	489	2.26	2.26	-	6.53
Al-Jawf	4.62	221	221	1.02	1.02	-	6.53
Hail	6.53	1,105	16,540	7.22	108.01	5.0	-
Makkah	3.38	5,436	-	18.37	-	-	6.53
Madina El Monawara	3.33	12	-	0.04	-	-	6.53
Jazan	2.88	2,306	-	6.64	-	-	6.53
Asir	3.31	5,365	-	17.76	-	-	6.53
Najran	3.53	17	-	0.06	-	-	6.53
Al Baha	3.16	2,299	-	7.26	-	-	6.53
Total	-	17,843	17,843	63.35	114.00	-	-

Table8 Available, used and surplus economic determinants and resources and sensitivity analysis of the change in the resource constraints used in the proposed guidance

Determinants of resource	Available	The used	Surplus and deficit	Used to Available %	The range of resource change minimum maximum	
Total area of maize in hectare	17,843	17,843	-	100	2,408	28,878.2
Areas of high productivity per hectare:						
Hail	1,105	16,540	-15,435		0	16,540
Areas of medium productivity per hectare:						
Riyadh	589	589	-	100	-	16,024
Eastern region	4	4	-	100	-	15,439
Qassim	489	489	-	100	-	15,924
Al-Jawf	221	221	-	100	-	15,656
Areas of low productivity per hectare:						
Makkah	5,436	-	5,436	-	-	-
Madina El Monawara	12	-	12	-	-	-
Jazan	2,306	-	2,306	-	-	-
Asir	5,365	-	5,365	-	-	-
Najran	17	-	17	-	-	-
Al Baha	2,299	-	2,299	-	-	-
Water resources million m ³	202.28	126.03	76.25		126.03	-

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

leaving a surplus water resource of 76.25 million m³. The total production of maize according to the proposed economic guidance is 114,000 tons. Thus, under the proposed economic guidance total production will increase by 50,650 tons (79.95%). Further, under such guidance, the average productivity per hectare is estimated to be 6.39 ton/hectare, while it is 3.55 ton/ha in current situation. Thus, the average productivity per hectare of maize in the proposed economic guidance is higher than the current situation of 2.84 ton/ha.

A sensitivity analysis of the linear programming model was carried out to determine the robustness of the solution to changes in both productivity and resource determinants that are required by production conditions, and to determine the extent to which these changes can be adapted to without changing the proposed routing pattern or optimal solution of the linear programming model. As for the changes in the productivity of the land unit (hectare), it is clear from table 7 that productivity in Hail can be reduced minimally, while maize production in other regions can be increased only in maximum limits without changing the pattern under the proposed guidance. As for the changes that may occur in

the resource determinants, it is clear from table 8 that the total area under maize production can be reduced minimally. The other determinants related to maize cultivation in Hail, Riyadh, and Eastern region, increase in maximum limits only. Finally, with regard to the water resource determinant, it was found that the quantity used can only be reduced minimally without changing the proposed pattern of guidance.

Conclusion

Results of current study revealed that there is a flaw in the production policy of maize. Production is concentrated in the Arabian Shield areas (Makkah, Madinah, Jazan, Asir, Najran, and Al Baha). The low productivity of the Arab Shield area makes it impossible to achieve comparative advantage, in addition to wasting agricultural resources used in maize production. By determining priority regions and economic guidance for land resources using linear programming, it was found that the total production area planted with maize can increase by 79.95% and the quantity of water used can decrease by 37.7%. The application of the proposed economic directive by using linear programming

demonstrates an increase in production to replace the amount of imports (i.e., reducing the amount of Saudi imports from 2.67 million tons to 2.62 million tons or by 1.9%). Given the local consumption of 2.74 million tons of maize, implementation of the proposed economic guidance leads to increasing the self-sufficiency of maize from 2.32% to 4.16%. The results of this study suggest that the Ministry of Environment, Water, and Agriculture review the policy of maize production by shifting maize cultivation into areas with high and medium productivity in priority regions and considering economic guidance for land resources used in maize production.

Acknowledgement

The authors would like to acknowledge the Deanship of Scientific Research at King Saud University through the College of Food and Agricultural Sciences - Research Center for funding this work. The authors are also grateful to the Deanship of Scientific Research at King Saud University for their technical support.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

- Abbas NK, Osamah KA (2015) An Estimation of Cost Function of Maize in Iraq- Babil Province (As Case Study) Season 2013. *Iraqi Journal of Agricultural Sciences* 46: 559-568.
- Arab Organization for Agricultural Development (2006) National Analytical Study for the Development of Maize Production in the Arab World. Khartoum, Sudan.
- Arab Organization for Agricultural Development (2017) Annual Report of Arab Agricultural Statistics Volume 37. Khartoum, Sudan.
- Bector CR, Chandra S (2005) *Fuzzy Mathematical Programming and Fuzzy Matrix Games*. Springer-Verlag Berlin Heidelberg, New York, .
- Blank LT, Tarquin AJ (1989) *Engineering Economy*, Third Edition. McGraw- Hill Book Company, New York.
- Fufa B, Hassan RM (2003) Stochastic maize production technology and production risk analysis in Dadar district, East Ethiopia. *Agrekon* 42: 116-128.
- General Authority for Statistics (2015) Detailed results of the agricultural census for the year 2015. Saudi Arabia.
- Ghanem, Adel Khalifa and Sahar Abdel Moneim Kamra (2010) Projected crop composition in the light of water and food security considerations of Saudi Arabia, Conference of the strategy of agricultural development and challenges of Egyptian food security, Faculty of Agriculture, Alexandria University, held on 28-29 July, 2010 at Alexandria University, Egypt.
- Hussain G, Alquwaizany A, Al-Zarah A (2010) Guidelines for Irrigation Water Quality and Water Management in The Kingdom of Saudi Arabia: An Overview. *Journal of Applied Sciences* 10: 79-96. DOI: 10.3923/jas.2010.79.96.
- Ministry of Environment, Water and Agriculture (2017) Study of Crop Structure in Saudi Arabia.
- Suleiman AA (2014) *Agricultural Production Economics*. Amman, Jordan: Dar Zahran Publishing and Distribution.
- Thomas H, Pawel L (2006) *Statistics: Methods and Applications Comprehensive Reference for Science, Industry, and Data Mining*. Tulsa, OK: StatSoft. Inc.
- Uya TC, Limnirankul B, Chaovanapoonphol Y (2015) Factors Impact on Farmers' Adaptation to Drought in Maize Production in Highland Area of Central Vietnam. In: 1st International Conference on Asian Highland Natural Resources Management. Agriculture and Agricultural Science Procedia, 5: 75 – 82.
- Zhang G, Liu C, Xiao C, Xie R, Ming B, Hou P, Liu G, Xu W, Shen D, Wang K, Li S (2017) Optimizing water use efficiency and economic return of super high yield spring maize under drip irrigation and plastic mulching in arid areas of China. *Field Crops Research* 211: 137-146.