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Study the Implications of the Potential Expansion of Organic Agriculture on Self-sufficiency and Production Inputs (Chemical Fertilizers and Pesticides)

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ABSTRACT

Background: Despite the high average per capita income and the Human Development Index for the Kingdom of Saudi Arabia, the average area of organic farms does not exceed 23.5 thousand hectares during the period 2018-2022. Therefore, this study aimed to measure the impact of potential expansion in organic agriculture on self-sufficiency and production inputs (chemical fertilizers and pesticides).

Methods: This study relied on secondary data from the FAOSTAT website and the statistical book issued by the Ministry of Environment, Water and Agriculture, in addition to studies and research related to organic agriculture. In achieving its objectives, this study also relied on economic and statistical analysis.

Result: This study showed that the productivity of organic farms is lower than that estimated for conventional farms, with rates ranging from a minimum of 19.2% for green fodder crops to a maximum of 74.8% for palm trees. With the doubling of the area of organic farms, a small relative decline in both total production and self-sufficiency of food products is expected. This is due to the modest average area of organic farms and their low productivity compared to conventional farms and most of the area of organic farms is planted with palm trees and fruits. It was also found that with the increase in organic farms by 100%, the amount of savings in chemical fertilizers and pesticides is estimated at 17041.8, 464.0 tons for each, respectively. Finally, the agricultural policy put the producer in front of two options: Namely organic agriculture and good agricultural practices. Therefore, this study recommends the need to compare organic agriculture with good agricultural practices from the point of view of the producer, the country and environmental sustainability.

Key words: Chemical fertilizers and pesticides, Local production, Organic agriculture, Self-sufficiency ratio, Traditional agriculture.

INTRODUCTION

The Kingdom of Saudi Arabia signed an agreement with the German Foundation for Technical Cooperation in the field of organic agriculture, where the agreement includes controls, legislation, standards and training of Saudi cadres to carry out supervision and follow-up. Some agricultural companies began converting part of their production to organic products in 2000, then many companies and farms turned to organic agriculture, as the number of organic farms increased from 48 farms in 2007 to 400 farms by the end of 2021 (Ministry of Environment, Water and Agriculture, 2022). The Ministry of Environment, Water and Agriculture prepared the Saudi National Agriculture Strategy 2030, which included the development of organic agriculture.

Organic agriculture in the kingdom of Saudi Arabia faces several problems, the most important of which are: (1) the high prices of organic agriculture inputs and integrated biological control in local markets, (2) the lack of sufficient demand for organic products due to the lack of awareness of consumers of organic products and their high prices in the markets, as the market size of organic products in the Kingdom reached 0.25% of the global market size for the same products of 124.8 billion euros in 2021 (Willer *et al*., 2023), (3) the unavailability of waste shredding and flipping machines for the production of organic fertilizers, except in some agricultural projects and companies that have obtained the organic agriculture certificate, (4) the unavailability of integrated biological

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control, means Predators used to eliminate pests as an alternative to pesticides, except in the National Agricultural Company in Al-Jouf region, in addition to the Ministry of Environment, Water and agriculture establishing the central laboratory located in the Nakheel Center in Unaizah in Qassim region for the production of parasites.

A study (MacRae *et al*., 2007) showed that most organic farms in North America are successful under organic management due to lower input costs, greater diversity of production and marketing channels, resilience to changing market conditions, higher insurance premiums and better adaptability to natural phenomena. In Canada, agricultural systems are underperforming, requiring more employment, increased demand for local goods and services and increased commitment to civic engagement. A study (Meemken and Qaim, 2018) showed that organic agriculture currently accounts for only 1% of the world's total agricultural land area and is less productive than its traditional counterpart. In the case of expansion of organic agriculture, this leads to a decrease in total domestic production, leading to a shortage of supply and thus an increase in the prices of products in the markets. Organic farming is not a model for sustainable agriculture and food security, but it contributes with conventional agriculture to increasing sustainable productivity.

A study (Das *et al*., 2022) examined the extent to which organic agriculture contributes to South Asia's water and food security. This study showed that organic agriculture has potential to promote quality food production, proper use of renewable resources, long-term soil fertility conservation, biological pest control and efficient use of water resources. A study (Goktuna and Hamzaoglu, 2023) focused on the characteristics of consumers of organic products and the extent to which they are aware of environmental awareness and identify the problems hindering organic agriculture in Turkey. This study showed that consumers of organic products are interested in health issues. Some consumers consider organic food a necessity, while some consumers see organic food as a diversity in food choice.

Organic agriculture and integrated biological control is good alternative to the conservation of land, water and human resources and the production of healthy food free of chemical fertilizer residues and pesticides and subject to environmental conditions and quality standards imposed by the European Union and the United States of America. Despite the positive effects gained from the application of organic agriculture and integrated biological control, it coincides with a decrease in productivity and therefore, the country forced to expand imports to meet the growing consumer needs and thus the amount of the deficit in the trade balance and the balance of payments increases.

Research objectives

This study mainly aimed to measure the impact of the potential expansion of organic agriculture on self-sufficiency and production inputs (chemical fertilizers and pesticides) by studying the following objectives:

1- The current situation of organic agriculture at the global level and the Kingdom of Saudi Arabia.
2- Comparative economic analysis between the productivity of organic farms and their conventional counterparts.
3- Measuring the impact of the potential expansion of the area of organic farms on:
- Total production and self-sufficiency ratio of food products.
- The use of chemical fertilizers and pesticides in Saudi agriculture.

MATERIALS AND METHODS

This study relied on secondary data from the FAOSTAT website and the statistical book issued by the Ministry of Environment, Water and Agriculture, in addition to studies and research related to organic agriculture. In achieving its objectives, this study also relied on the economic and statistical analysis represented by the (t) test to identify the significance of the difference between the average productivity of organic farms and its estimated counterpart for traditional farms between 2018-2022. The value of (t) was calculated by the following equation (William, 2003):

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sigma \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

$$\sigma^2 = \frac{(n_1 - 1)\sigma_1^2 + (n_2 - 1)\sigma_2^2}{n_1 + n_2 - 2}$$

Due to water scarcity in Saudi Arabia, the expansion of organic farms is through transformation or at the expense of the area of traditional farms. The total production of the various crops was estimated through the following economic equations:

$$Pro_{of} = APH_{of} \times AEC_{of} \quad ....(1)$$

$$Pro_{tf} = APH_{tf} \times AEC_{tf} \quad ....(2)$$

$$Total\ Pro = Pro_{of} + Pro_{tf} \quad ....(3)$$

Pro_{of} = Organic production in thousand tons.
APH_{of} = Average productivity per hectare in organic farms.
AEC_{of} = Area of the organic plantations expected to be planted.
Pro_{tf} = Traditional production in thousand tons.
APH_{of} = Average yield per hectare in conventional farms.
AEC_{of} = Area of traditional farms expected to be cultivated.
Total Pro = Total production in thousand tons.

According to the requirements of organic farming, it is forbidden to add chemical fertilizers and pesticides. Considering the increase in the area of organic farms, it was possible to calculate the amount of savings in the use of chemical fertilizers and pesticides through the following equation:

$$QS_{fp} = ASLU_{fP} \times AEC_{of} \quad ....(4)$$

Where:

QS_{fp} = Amount of savings in chemical fertilizers and pesticides in tons.

$ASLU_{fP}$ = Average area unit share of chemical fertilizers and pesticides.

AEC_{of} = Area of the organic farms expected to be planted.

RESULTS AND DISCUSSION

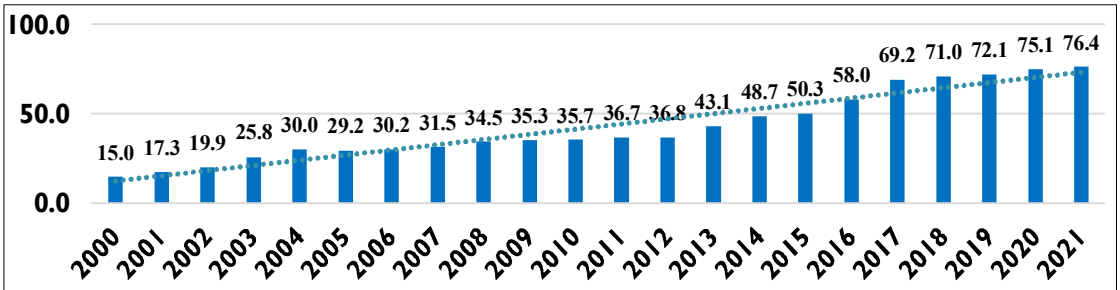
First: The current situation of organic agriculture at the global level and the kingdom of Saudi Arabia

Studying the current situation of organic agriculture at the global level, it is clear from the data provided in Fig (1) that the area of organic farms increased from 15.0 million hectares in 2000 to 76.4 million hectares in 2021, means the area of organic farms increased at an annual growth rate of 7.1%* during the period 2000-2021. Organic products are grown in 191 countries. The Oceania countries occupy the first place in organic agriculture, where the area planted with organic products amounted about 36.0 million hectares, represented 47.1% of the total area of organic farms and about 9.7% of the total area of agricultural land in 2021. The European countries ranked second in organic agriculture with an area of 17.84 million hectares, amounting to 23.4% of the total area of organic farms and about 3.6% of the total area of agricultural land of the European countries (Table 1).

Through the study of the geographical distribution of organic agriculture, it is clear from the data provided in Table (2) that organic agriculture is concentrated in Australia, amounting to 46.71% of the total area of organic farms which is 76.4 million hectares, followed by Argentina, France, China, Uruguay, India, Spain, the United States of America and Italy. The ratio of the area of organic farms to the total area of agricultural land ranged from a minimum of 0.5% for the country of China to a maximum of 19.6% for the country of Uruguay.

The global market for organic products (retail sales value) reached 124.8 billion euros, equivalent to 130.6 billion dollars in 2021. At the country level, the USA ranks first in the market volume of organic products, with a value of 48.62 billion euros, equivalent to 50.2 billion dollars, followed by Germany, France, China, Canada, Italy, Switzerland, the United Kingdom, Sweden and Spain, respectively (Fig 2).

In view of the total population, Switzerland ranked first, with an average per capita of organic products of 445 euros, equivalent to 490.8 dollars/ person in 2021, followed by Sweden, Germany, France, the USA and Canada (Fig 3).



Source: Willer *et al.* (2023). The World of organic agriculture statistics and emerging trends 2023, Research institute of organic agriculture FiBL IFOAM - Organics international.

Fig 1: Evolution of the area of organic farms worldwide in million hectares during the period 2000-2021.

Table 1: The relative importance of the area of organic farms worldwide in 2021.

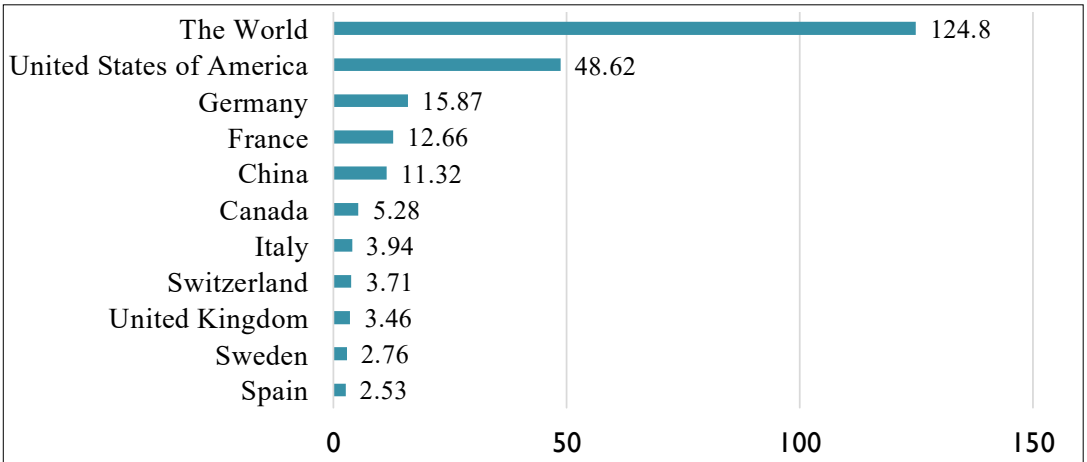
Continent	Area million hectares	%	Ratio of organic farms area to total agricultural land area %
Africa	2.66	3.5	0.2
Asia	6.50	8.5	0.4
Europe	17.84	23.4	3.6
Latin America	9.87	12.9	1.4
North America	3.54	4.6	0.8
Oceania	35.99	47.1	9.7
The world (191 countries)	76.40	100	1.6

Source: Helga willer, Bernhard schlatter and Jan Trávníček (2023). The world of organic agriculture statistics and emerging trends 2023, Research institute of organic agriculture FiBL IFOAM- Organics international.

*$Ln\ Y_1 = 2.832 + 0.071T$

(62.46)** (20.68)**

$R^2 = 0.96$ F = 427.71



Source: Willer *et al.* (2023). The world of organic agriculture statistics and emerging trends 2023, Research institute of organic agriculture FiBL IFOAM- Organics international.

Fig 2: Global market size for organic products (value of sales at retail price in billion euros in 2021).

Table 2: Geographical distribution of the area of organic farms and its percentage to the total area of agricultural land in 2021.

Country	Area million hectares	%	Ratio of organic farms area to total agricultural land area %
Australia	35.69	46.71	9.9
Argentina	4.07	5.33	2.7
France	2.78	3.64	9.6
China	2.75	3.60	0.5
Uruguay	2.74	3.59	19.6
India	2.66	3.48	1.5
Spain	2.64	3.46	10.8
United States	2.33	3.05	0.6
Italy	2.19	2.87	16.7
Germany	1.80	2.36	10.8
Brazil	1.48	1.94	0.6
Canada	1.22	1.60	2.1
Other countries	14.05	18.39	-
The world	76.40	100.00	1.6

Source: Willer *et al.* (2023). The world of organic agriculture statistics and emerging trends 2023, Research institute of organic agriculture FiBL IFOAM- Organics international.

Table 3: Quantity of world exports of organic products in 2021.

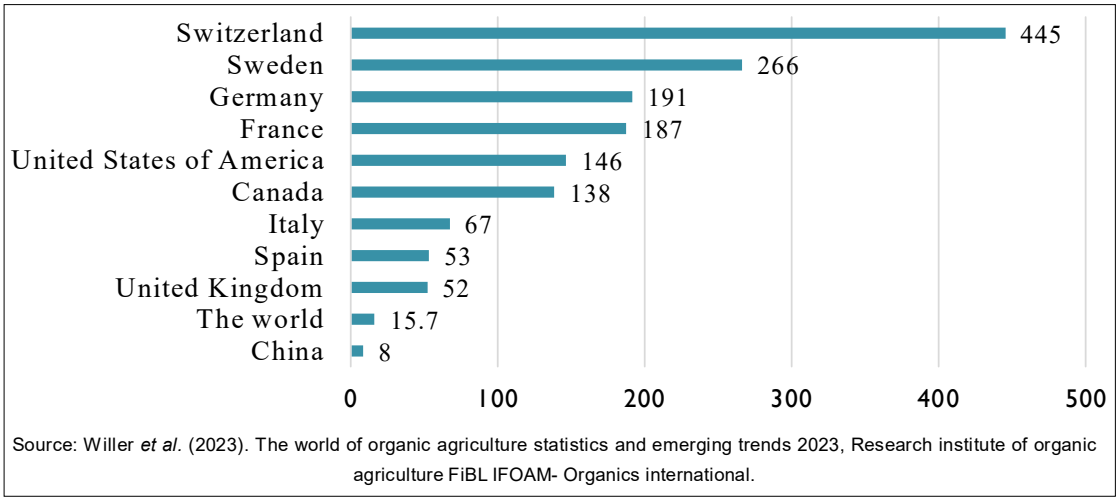
Continent	Quantity in thousand tons	%
Africa	458.70	9.78
Asia	674.71	14.39
Europe	679.01	14.48
Latin America	2662.28	56.77
North America	180.30	3.85
Oceania	34.17	0.73
The world	4689.17	100.00

Source: Willer *et al.* (2023). The world of organic agriculture statistics and emerging trends 2023, Research institute of organic agriculture FiBL IFOAM- Organics international.

The global exports of organic products amounted to 4.69 million tons in 2021. Latin America ranked first in exports of organic products, with a percentage of 56.77% of the total amount of world exports, followed by European countries, Asia, Africa and North America, with percentages of 14.48%, 14.39%, 9.78%, 3.85% respectively (Table 3). The EU countries imported organic products amounting to 2.87 million tons, which is 61.2%, followed by the United States of America with 38.8% of the total amount of imports of organic products amounting to 4.69 million tons in 2021 (Fig 4).

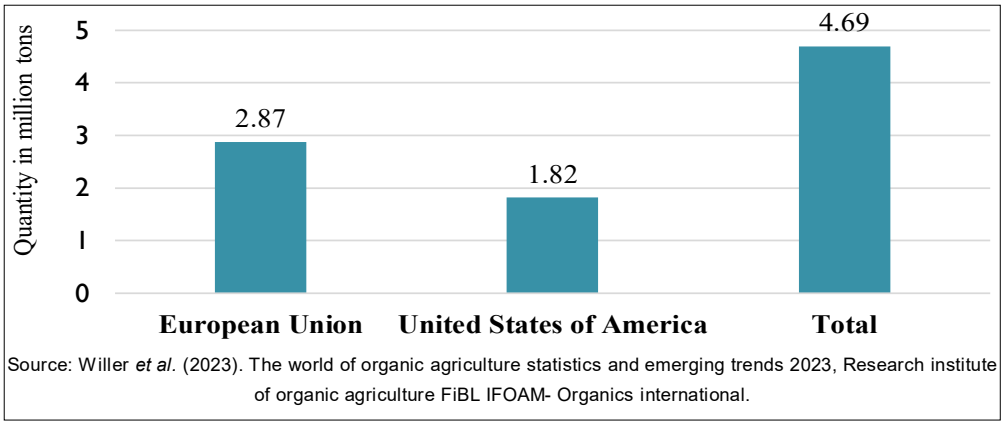
As for the current situation of organic agriculture in the kingdom of Saudi Arabia, it is clear from the data provided

in Fig 5 that the area of organic farms decreased from 22.21 thousand hectares in 2007 to 13.08 thousand hectares in 2016, then increased to 27.11 thousand hectares in 2021, then declined to 23.32 thousand hectares in 2022, due to the exit of green feed from the structure of the crop composition beginning in 2022, in order to



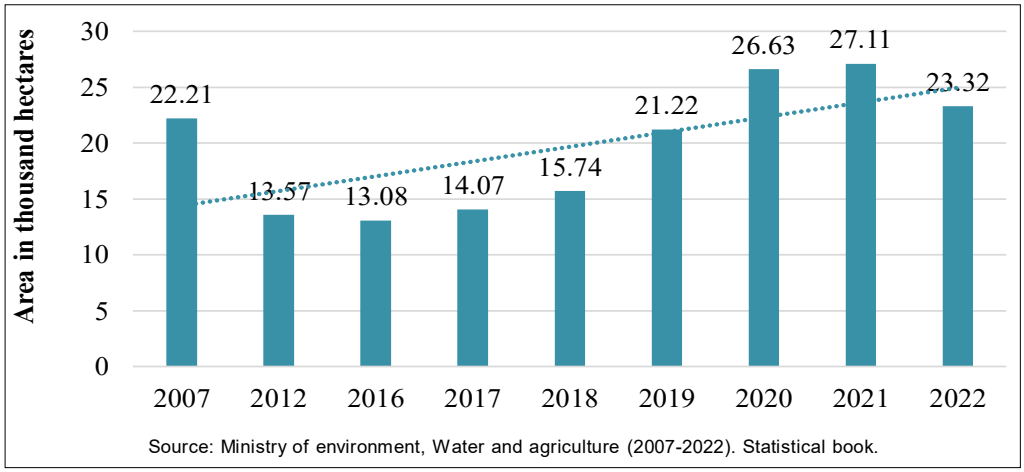
Source: Willer *et al.* (2023). The world of organic agriculture statistics and emerging trends 2023, Research institute of organic agriculture FiBL IFOAM- Organics international.

Fig 3: Average per capita ? in euro 2021.



Source: Willer *et al.* (2023). The world of organic agriculture statistics and emerging trends 2023, Research institute of organic agriculture FiBL IFOAM- Organics international.

Fig 4: Geographical distribution of imports of organic products in million tons in 2021.



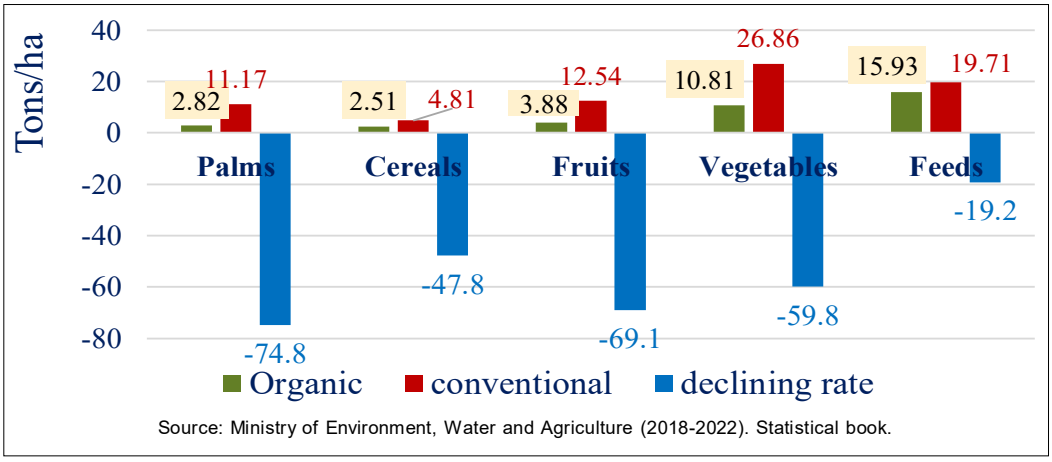
Source: Ministry of environment, Water and agriculture (2007-2022). Statistical book.

Fig 5: Evolution of the area of organic farms in thousand hectares during the period 2007-2022.

rationalize water consumption in the agricultural sector. Fruits are considered one of the most important organic crops, with an average area of 12.89 thousand hectares, representing 8.1% of the total fruit area during the period 2018-2022, followed by palms with an area of 5.26 thousand hectares, representing 3.64% of the total palm area during the study period (Table 4).

Second: Comparative economic analysis between the productivity of organic farms and their traditional counterparts in Saudi agriculture

By conducting a comparative economic analysis between the productivity of organic farms and their traditional counterparts in Saudi agriculture, it is clear from the data contained in Fig (6) that the productivity of organic farms is lower than that estimated for traditional farms at rates ranging from a minimum of 19.2% for green fodder crops to a maximum of 74.8% for palm during the period 2018-2022. By studying the significance of the difference between the average productivity of organic farms and their traditional counterparts during the period 2018-2022, it is clear from the data in Table (5) that the calculated value of (t) is higher than its tabular counterpart of 2.896 at the probability level of 1% and degrees of freedom of 8 for each of the productivity of palms, cereals, fruits and vegetables, which means that there are significant differences between the productivity of organic farms and their traditional counterparts for those crops. This is due to the different nitrogen content in both organic and chemical fertilizers. Farmers produce organic fertilizers or compost, whose analysis requires the addition of other substances to increase the percentage of nitrogen, as the percentage of nitrogen in the compost produced does not exceed 1.2%. Therefore, the compost circulating in the markets is a soil improver only and not an alternative to chemical fertilizers. To become an alternative to chemical fertilizers, nitrogen needs to be increased, adding the horns of slaughtered animals and fish by grinding them and adding them to compost (Youssef, 2011).



Source: Ministry of Environment, Water and Agriculture (2018-2022). Statistical book.

Fig 6: Amount and percentage of variation in productivity between organic agriculture and its conventional counterpart during the period 2018-2022.

Table 4: The relative importance of the area and production of organic farms during the period 2018-2022.

Crops	Organic farming		At the kingdom level		Relative importance %	
	Area thousand hectares	Production thousand tons	Area thousand hectares	Production thousand tons	Area	Production
Palms	5.26	14.85	144.51	1505.30	3.64	0.99
Cereals	0.62	1.55	234.23	1167.30	0.26	0.13
Fruits	12.89	49.98	159.18	1840.77	8.10	2.72
Feeds	0.55	7.37	301.35	6083.83	0.18	0.12
Vegetables	0.53	5.77	94.44	2659.84	0.57	0.12
Medicinal and aromatic plants	0.12	0.41	-	-	-	-
Total	23.46	-	752.98	-	3.12	-

Source: Ministry of environment, Water and agriculture (2018-2022). Statistical book.

Third: Measuring the impact of the expansion of the area of organic farms on the total local production and the percentage of self-sufficiency of food products

By studying the impact of the potential expansion of the area of organic farms on the total domestic production and the percentage of self-sufficiency of food products, it is clear from the data in Table (6), that in light of the doubling of the area of organic farms (increase in its area by 100%), a small relative decrease is expected in both the total domestic production and the percentage of self-sufficiency of food products, as the rate of decrease in each ranged from a minimum of 0.13% for cereals to a maximum of 7.46% for fruits. This is due to the modest average area of organic farms of 23.5 thousand hectares and their low productivity compared to traditional farms during the period 2018-2022 and most of the area of organic farms in Saudi Arabia is planted with palm and fruit.

Table 5: Test (t) of the significance of the difference between the average productivity of organic farms and their traditional counterparts during the period 2018-2022.

Crops	Average farm productivity Tons/ha		σ^2		t test
	Organic	Traditional	Organic	Traditional	
palms	2.82	11.17	0.22	1.46	11.16**
Cereals	2.51	4.81	0.44	0.24	4.83**
Fruits	3.88	12.54	2.57	7.27	4.22**
vegetables	10.81	26.86	6.91	24.12	5.00**
Green fodder	15.93	19.71	33.3	15.31	1.11 ns

**Significant at the probability level of 1%, ns non-significant.

Source: Ministry of environment, Water and agriculture (2018-2022). Statistical book.

Table 6: Measuring the impact of the expansion of the area of organic farms on production and the percentage of self-sufficiency of food products.

Statement	Period 2018 - 2022			Considering the expansion of organic agriculture			
	Production thousand tons	Consumption thousand tons	Self -sufficiency ratio	Production thousand tons	Self -sufficiency ratio	Production	Declining rate Self-sufficiency ratio
Expansion of the area of organic farms by 25%							
Dates	1508.58	1291.59	116.8	1498.18	116.0	0.69	0.68
Rest of fruit	1516.28	2693.21	56.3	1488.37	55.3	1.84	1.78
Cereals	1127.91	7469.60	15.1	1127.56	15.09	0.03	0.07
Vegetables	2407.47	3209.96	75.0	2405.34	74.9	0.09	0.13
Expansion of the area of organic farms by 50%							
Dates	1508.58	1291.59	116.8	1487.20	115.1	1.42	1.46
Rest of fruit	1516.28	2693.21	56.3	1460.45	54.2	3.68	3.73
Cereals	1127.91	7469.60	15.1	1127.21	15.09	0.06	0.07
Vegetables	2407.47	3209.96	75.0	2403.20	74.8	0.18	0.27
Expansion of the area of organic farms by 75%							
Dates	1508.58	1291.59	116.8	1476.22	114.3	2.15	2.14
Rest of fruit	1516.28	2693.21	56.3	1432.53	53.2	5.52	5.51
Cereals	1127.91	7469.60	15.1	1126.85	15.08	0.09	0.13
Vegetables	2407.47	3209.96	75.0	2401.06	74.8	0.27	0.27
Expansion of the area of organic farms by 100%							
Dates	1508.58	1291.59	116.8	1465.23	113.4	2.87	2.91
Rest of fruit	1516.28	2693.21	56.3	1404.61	52.1	7.36	7.46
Cereals	1127.91	7469.60	15.1	1126.50	15.08	0.13	0.13
Vegetables	2407.47	3209.96	75.0	2398.91	74.7	0.36	0.40

Source: (1) Ministry of environment, Water and agriculture (2018-2022). Statistical book, (2) Food and agriculture organization, website (FAOSTAT).

Table 7: Amount of savings in chemical fertilizers and pesticides during the period 2018-2022.

Statement	Average consumption thousand tons	Average cropping area thousand hectares	Average share of land unit Kg/ha	Average area organic farms thousand hectares	The average amount of savings in chemical fertilizers and pesticides in tons
Chemical fertilizers					
Nitrogen	176.90	833.86	212.15	23.50	4985.5
Phosphate	83.25	833.86	99.84	23.50	2346.2
Potassium	42.20	833.86	50.61	23.50	1189.3
Total	302.35	833.86	362.59	23.50	8520.9
Pesticides					
Insecticides	5.43	833.86	6.51	23.50	153.0
Herbicides	1.26	833.86	1.51	23.50	35.5
Fungicides	1.54	833.86	1.85	23.50	43.5
Total	8.23	833.86	9.87	23.50	232.0

Source: (1) Ministry of Environment, Water and agriculture (2018-2022). Statistical book, (2) Food and Agriculture Organization, website (FAOSTAT).

Table 8: Measuring the impact of expanding the area of organic farms on the amount of savings in chemical fertilizers and pesticides.

Statement	25%	50%	75%	100%
Chemical fertilizers in tons				
Nitrogen	6231.9	7478.3	8724.6	9971.0
Phosphate	2932.8	3519.3	4105.9	4692.4
Potassium	1486.6	1784.0	2081.3	2378.6
Total	10651.1	12781.4	14911.6	17041.8
Pesticides				
Insecticides	191.3	229.5	267.8	306.0
Herbicides	44.4	53.3	62.1	71.0
Fungicides	54.4	65.3	76.1	87.0
Total	290.0	348.0	406.0	464.0

Source: (1) Ministry of environment, Water and agriculture (2018-2022). Statistical book, (2) Food and agriculture organization, website (FAOSTAT).

Fourth: Measuring the impact of expanding the area of organic farms on the consumption of chemical fertilizers and pesticides in Saudi agriculture

Organic agriculture depends on the use of organic fertilizers (natural and manufactured) instead of chemical fertilizers, as well as the use of safe alternatives pesticides, because of this has a good impact on the quality of agricultural products, through which clean and safe crops are produced free from pollution and the accumulation of harmful elements to human health, especially the accumulation of nitrogen fertilizers and pesticides. It is clear from the data provided in Table (7) that considering the average crop area and the consumption of chemical fertilizers and pesticides in Saudi agriculture, the average share of the land unit of chemical fertilizers and pesticides is estimated at about 362.6 and 9.87 kg/ ha respectively, during the period 2018-2022. Given the average area of organic farms of 23.5 thousand hectares, the amount of annual savings in chemical fertilizers and pesticides is estimated at 8520.5 and 232.0 tons each, respectively.

With the potential expansion of organic farms, the savings in chemical fertilizers and pesticides increase. It is clear from the data in Table (8) that in light of the increase in the area of organic farms by 25%, the amount of savings in chemical fertilizers and pesticides is estimated at 10651.1 and 290.0 tons each, respectively. With the doubling of the area of organic farms (100% increase), the savings in chemical fertilizers and pesticides are estimated at 17041.8 and 464.0 tons each, respectively.

CONCLUSION

Despite the high average per capita income and the Human Development Index of the kingdom of Saudi Arabia, the market size for organic products is no more than 0.25% of the global market size for the same products of 124.8 billion euros in 2021. Also, the average area of organic farms is no more than 23.5 thousand hectares during 2018-2022. The steady volume of organic agriculture in the kingdom is because it suffers from a shortage of water, and to ensure its sustainability and provision for future generations, the crop structure was restructured, and the crop area was reduced from 1.38 million hectares in 1990 to 534.5 thousand hectares in 2022.

The Ministry of Environment, Water and Agriculture has adopted the Good Agricultural Practices Project (Saudi G.A.P) since 2017 to ensure food safety and security, consumer protection and environmental preservation. The project also contributed to rationalizing the consumption of water, chemical fertilizers, and pesticides, in addition to increasing the use of organic fertilizers and encouraging farmers to grow high-value-added crops such as fruits and vegetables.

Although organic farming results in the production of healthy food free of chemical fertilizer and pesticide residues, it leads to a reduction in total production and self-sufficiency. Considering international wars and crises, governments are forced to use productive methods that result in increased production and the extent to which it contributes to self-sufficiency and food security. In the light of the determinants of supply and demand for food commodities and the potential of supply, the agricultural policy has put the producer in front of two options, namely organic agriculture, and good farming practices, so this study recommends the need to compare organic agriculture with good agricultural practices from the point of view of the producer, the state and environmental sustainability.

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Conflict of interest

On behalf of all authors of the manuscript, I declare that there are no conflicts of interest related to this study.

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