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Journal of American Science

MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

An analytical study for the impact of climate changes on the most important medicinal and aromatic plants

Prof. Dr. Sayeda Hamed Amer Abdeljawwad[1], Dr. Shahira M. Reda[2], Dr. Nagwa M. Ahmed[3], Dr. Taher M. Saied Kadah[4]

[1]Head of Research at Land Research Department - Agricultural Economics Research Institute.
[2]Senior Researcher at Agricultural Policy Research Department - Agricultural Economics Research Institute.
[3]Senior Researcher at Central laboratory for Agricultural Climate (CLAC)
[4]Senior Researcher at the Central Laboratory for Analysis of Pesticide Residues and Heavy Metals in Food
[1,2,3,4,]Agricultural Research Center, Egypt.
Email: Shahira_mrd14@yahoo.com

Abstract: The research aimed at analyzing whether or not there is an impact of climate change? On the net yield of the most important medicinal and aromatic plants during the period (2000 -2021) through the study of the effect of maximum and minimum temperatures, average humidity, precipitation rate and time on the net yield of the most important medicinal and aromatic plants (anise, cumin, caraway, chamomile). Using descriptive and quantitative statistical methods and general temporal direction of area, production, productivity and net yield, Ricardo's method was also used to assess the economic impact of climate. The research concluded that the most important medicinal and aromatic plants (cumin, anise, caraway, and chamomile) are sensitive to climate changes.
[Sayeda Hamed Amer Abdeljawwad, Shahira M. Reda, Nagwa M. Ahmed, Taher M. Saied Kadah. **An analytical study for the impact of climate changes on the most important medicinal and aromatic plants.** *J Am Sci* 2023;19(4):50-69]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). http://www.jofamericanscience.org 05.doi:10.7537/marsjas190423.05.

Key Words: Climate changes, medicinal and aromatic plants, Ricardo Approach.

Introduction:

The phenomenon of climate changes is one the most important universal phenomenon, and these changes occur due to the dynamic processes such as volcanoes or as a result of external forces such as the change in the intensity of solar radiation or large meteorites, and recently because of the human activities and paying attention to the development of industry in the past 150 years and burning billions of tons of fossil fuels to generate energy, which released the greenhouse gases such as carbon dioxide, which is one of the most important causes of climate change, as these gases led to raising the temperature with approximately 1,2 Celsius Degrees compared to the time before the industrial revolution. The climate change is defined according to the United Nations Framework Convention on Climate Changes as the change resulting directly or indirectly from the human activities that lead to a change in the formalization of the global atmosphere, which is observed at similar time intervals. Among the features of the climatic changes that occur at the present time are the severe drought that invades some regions, the devastating floods and torrential rains, the melting of ice in the north and south poles in addition to the increase in the water level in the seas and oceans, the matter which leads to the possibility of drowning parts of the world, especially the lowlands (1).

The agricultural production activities are the most sensitive and affected by the climate change among all sectors (2), and the spatial differences did not emerge as an influence on the severity of the effects of climate change, as there is evidence that the tropical regions are the most vulnerable to the negative impact, while it is likely that the productivity increases due to the global warming phenomenon in the mild climates (3), and many efforts were exerted to measure the economic impact of climate change on agriculture, which mainly focuses on the United States and other developed countries (4), while some studies were conducted to evaluate the impact of climate change on the agriculture in the developing countries(5), as the agricultural production systems in the developing countries such as Africa are deemed more vulnerable to the climate change because they have the lowest capital intensity and technological flexibility to adapt, as most of them are in the areas of hot climates, and it is likely that the temperatures will be higher beside the frequent drought waves and irregular rainfall (6).

The medicinal and aromatic plants are of great economic value and importance, as the demand for them is increasing globally and locally (7). Egypt has a huge economic wealth of medicinal and aromatic plants, as it occupies the fifth place among the Egyptian crops for exploration; as the importance of these plants is due to the fact that they are the future of alternative medicine on the global level, where the world currently tends to use the herbs to treat some diseases. The medicinal and aromatic plants are also used in the manufacture of medications, perfumes, cosmetics, food and pesticides, which support the Egyptian economy; especially with the increase in the modern universal trend to shift to everything that is natural. Egypt's exports of medicinal and aromatic plants are about 90%, which reflects their economic importance; where they are being cultivated in five main governorates within Egypt, namely Fayoum, Beni Suef, Minya, Assiut and Gharbia; as they represent 80% of the land area cultivated with the medicinal and aromatic plants within the Arab Republic of Egypt. The areas of medicinal and aromatic plants reach 120 thousand feddan; and the value of medicinal plant exports with their cultivation is about 8 to 10 billion pounds per year [8].

Problem:

The agricultural production activity is one of the most sensitive and affected activities by the climate change, and it is expected that the agricultural sector in general will be affected and the agricultural crops in particular because they are closely related to the climatic conditions. This research pays attention to the medicinal and aromatic plants as crops of value and economic importance within the Arab Republic of Egypt. Consequently, the research problem is represented in whether the climate change phenomenon affected the net yield of the most important medicinal and aromatic plants (Cumin, Anise, Caraway, Chamomile) during (2000-2021) or not? what are the percentages of these effects? Are they negative effects? or are some of them having positive effects on the net yield of medicinal and aromatic plants?

Objective:

The research aims to analyze whether there is an impact of climate change or not? on the net yield of the most important medicinal and aromatic plants during (2000-2021), through studying the effect of maximum and minimum temperatures, average humidity percentage, rainfall rate and time on the net yield of the most important medicinal and aromatic plants (Anise, Cumin, Caraway, Chamomile).

Method and Data sources:

This research uses the statistical analysis methods such as percentages and averages, in addition to some of the statistical analysis models such as Multiple Regression in the linear form and the exponential form. Ricardo Approach was also used to evaluate the economic impact of climate change, as Ricardo Model takes either equation (1) or equation (2) according to whether the data is available for the annual net yields or the net capital returns (land value V_L).

$$\Delta W = W(E_B) - W(E_A) = \sum_{i=1}^{n} (P_{LB} L_{Bi} - P_{LA} L_{Ai}) \quad (1)$$

Where: each of P_{LA}, L_A at E_A, and each of P_{LB}, L_B at E_B

The present value of welfare change is as follows:

$$\int_0^{Q_B} \Delta W e^{-rt} dt = \sum_{i=1}^{n} (V_{LB} LB_{Bi} - V_{LA} L_{Ai}) \quad (2)$$

The research used the Ricardo Approach, where the net yield per feddan was used for the crops of Cumin, Anise, Caraway, and Chamomile in the most important governorates as a dependent variable, which is regression on the independent variables. The non-linear model of second degree was chosen because it is easy to be interpreted [9]. The data were obtained from the secondary sources represented in the Central Administration of Agricultural Economics in the Economic Affairs Sector and the Central Laboratory of Climate at the Agricultural Research Center during (2001-2021). In addition to depending on some scientific references, research and studies closely related to the subject of the research.

The following scenarios were conducted to predict the extent of the climate changes impact on the study crops:

- The first scenario: the estimated average of net yield at maximum temperature increase with 0.5°C.
- The second scenario: the estimated average of net yield at maximum temperature decrease with 0.5°C.
- The third scenario: the estimated average of net yield at minimum temperature increase with 0.5°C.
- The fourth scenario: the estimated average of net yield at the minimum temperature decrease with 0.5°C.
- The fifth scenario: the estimated average of net yield at relative humidity increase with 0.5 %.
- The sixth scenario: the estimated average of net yield at relative humidity decrease with 0.5 %.

The results of the most important previous studies of climate changes in the agricultural sector:

The most important social and economic effects of climate changes are represented in: the effects related to land resources, where the Island States are expected to disappear, the effects related to water, where it is expected that the areas suffering from drought and water scarcity will increase and effects related to food production, where the production is expected to decrease with about 30% in the developing countries [(10)].

The negative impact of climate change in 2030 in some Arab countries on the productivity of wheat, corn, barley, rice and sorghum, compared to a year (without climate change), while there is only a positive effect on the cotton crop. There are other effects caused by the climatic changes, including the pests and diseases, as it is expected that the leaf rust disease of wheat will increase in the future compared to the yellow rust disease because it needs high temperatures (18-22°C) and humidity (70-80%), in addition to the increase in rates of evaporation, which will double the pressure on the productivity and negatively affect the water resources [(11)].

Egypt is one of the areas vulnerable to risks, including the drowning of parts of the Delta due to the rise of sea levels resulting from the melting of ice in the polar areas and the rise of water levels in the seas and oceans. The changes negatively affect the productivity of many agricultural crops, in addition to their impact on the crop patterns, increasing the desertification rates, increasing the need for water as a result of high temperatures, increasing the evaporation rates and the high temperatures that lead to an increase in soil erosion rates by 2050. Some of the regionalization strategies to overcome the negative effects of climate changes are represented in developing new varieties that tolerate heat, salinity, drought and have a short growing season to reduce the necessary water needs for them, changing the dates of cultivation to suit the new climatic conditions, and reducing the area of crops that are extravagant in consumption and cultivating alternative crops whose growing season and water consumption is lower, in addition to reducing the emissions through increasing the means of absorbing carbon dioxide via the afforestation and forestry, while utilizing of the treated wastewater [(11)].

It was found that there is a possibility of losing about 12%, 15% of the high-quality agricultural area in the Delta region as a result of salinization or drowning with the rise of sea level. It is expected that the climate changes will affect negatively on the self-sufficiency rate and the field crops productivity. Among these changes in 2030 is the expectation of two scenarios, the first is the optimistic scenario, that no parts of the Delta will be submerged, but the second scenario is the possibility of submerging about 15% of the Delta lands, as the cultivated area will be decreased with about 9,0 million feddan, thus the cropped area will decrease with about 406,1 million feddan, equivalent to about 25,6% of the cropped area if parts of the Delta are not submerged [(12)].

The future climatic changes will negatively affect the agriculture and food system in general and the most agricultural crops in particular, and this will increase the average net yield per feddan of the wheat crop with a significant growth rate estimated at about 65,20 EGP/feddan during (2000-2017). There are also negative implications for the rising of maximum and minimum temperatures and the relative humidity (with the exception of the high average humidity with about 5%, as the effect is positive on the net feddan yield of the wheat crop). While the effects were positive and increasing due to the decrease in the minimum and maximum temperatures and the relative humidity [(13)].

It is expected that the rise in temperature will lead to future changes in the prevailing cropped patterns within Egypt. Although it is expected that there will be a decrease in the yield of some crops, an increase in the yield of others is expected. By 2050, it is expected that the output of wheat and corn will decrease with percentage of 18% and 19% respectively, compared to the current situation. On the other hand, the climate changes are expected to lead to an increase in the yield of the cotton crop[(14)].

When measuring the economic impact of climate change on the summer maize crop, show research the sensitivity of the net feddan yield of the summer maize crop due to the change of the maximum temperatures whether with decrease or increase, while it is sensitive to the decrease in the minimum temperature and the relative humidity [(15)].

A study concluded that there is a long-term significant relationship between average temperatures and productivity of maize and wheat crops, as the temperature greatly affects the productivity of the two crops in the long term more than in the short term and that the average rainfall did not have a significant effect, either in the long or in the short term [(16)].

The "medicinal plants" in Sinai were not spared from the effects of climatic changes, as they are threatened with extinction. These plants have contributed to the treatment of many chronic diseases, which the Bedouin of Sinai consider as their means of healing from all diseases. Dr./ Mohamed Saleh, the chief sheikh of St. Catherine and an expert of the medicinal plants and medicine in Sinai, says that Sinai contains 472 medicinal plants, including 19 varieties and species, among which there is no place in the world except St. Catherine, and 42 species that are threatened with extinction due to the effects of climate change. He also explained that Sinai, especially its southern region is characterized by clear changes in the nature of the climate. In that one region, there is more than one nature of weather that ranges from below zero to high temperatures at the same time of the year, indicating that 17 species of them are endangered with extinction, as they are rare and most of which are found in Sinai, and the continuation of climate change threatens their existence and continuity [(17)].

Results and discussion

The relative importance of the area of medicinal and aromatic plants from the cropped area:

Table (1) shows The average area of medicinal and aromatic plants during (2016-2017) was about 98,2 thousand feddan, which representing about 61,0% of the cropped area to be estimated at about 16.1 million feddan, and this clarifies the low economic importance of medicinal and aromatic plants from the percentage of the area they represent in the cropped patterns.

Table (2) shows the order of the most important medicinal and aromatic plants in terms of area and the net yield for 2021. It was found that chamomile occupies the first place in terms of area, as it was about 13,2 thousand feddan with percentage of about 23,5% of total area of medicinal and aromatic plants, while Caraway occupies the second place with percentage of about 19,29%, then Anise, Rose Geranium and Cumin with percentage of about 15,24%, 10,04% and 6,36%, while the Caraway occupies the first place in terms of the net yield which was about 22,5 thousand EGP per feddan with percentage of about 23,7%, followed by Cumin with about 16,5 thousand EGP with percentage of about 17,3%, then Anise with percentage of about 15,9%.

Table (1): The relative importance of the area of medicinal and aromatic plants from the cropped area during (2016-2021)

Year	Crop area	medicinal and aromatic plants area	% Medicinal and aromatic plants area of crop area
2016	15.8	80.7	0.51
2017	16.0	98.2	0.61
2018	16.1	104.2	0.65
2019	16.2	108.7	0.67
2020	16.3	99.1	0.61
2021	16.4	43.3	0.26
Average	**16.1**	**98.2**	**0.61**

Source: The Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Central Administration of Agricultural Economy, Bulletin of Agricultural Statistics during (2010-2021).

Table (2): The relative importance of the most important medicinal and aromatic plants in terms of the area and the net yield in 2021

Item	Area	%	Order	Net revenue	%	Order
Chamomile	13186	23.52	1	1435	1.5	8
Caraway	10813	19.29	2	22544	23.7	1
Anise	8544	15.24	3	15092	15.9	3
Green thyme	5627	10.04	4	10129	10.7	5
Cimun	3563	6.36	5	16495	17.3	2
dry coriander	3259	5.81	6	11741	12.3	4
Marjoram	2973	5.30	7	8389	8.8	6
Green mint	2961	5.28	8	8389	8.8	7
Fennel	2883	5.14	9	873	0.9	9
Other	6600	17.9		-	-	

Source: The Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Central Administration of Agricultural Economy, Bulletin of Agricultural Statistics, (2021).

The directional relationship of the variables of the most important medicinal and aromatic plants during (2000-2021):

Through studying the directional relationship of the medicinal and aromatic plants variables, it is obvious from Table (1) that:

The development of the Cumin crop productivity variables:

- **Area:** It is evident from the data of Table (1) in the annex that the area of Cumin within Egypt ranged between 1611 feddan in 2015 as a minimum and about 7817 feddan in 2002 as a maximum, and through estimating the equation of the General Temporal Trend of the Cumin area during the study period, it was found that the linear image is the best mathematical form suitable for the nature of the data, as the results indicated an increase in the area of the Cumin crop with statistically significant annual rate estimated at about 6332,519 feddan per year and represent about 156,7% of annual average of the Cumin crop which was about 4042,5 feddan, and the significance of the model as a whole was also proven, and the results showed that about 17,6% of the changes occurring in the Cumin crop area during the study period is due to the time.

- **Productivity:** It is evident from the data of Table (1) in the annex that the average productivity of the Cumin crop was about 0,593 tons/feddan during the study period and ranged between 0,459 tons/feddan in 2001 as a minimum and about 0,839 tons/feddan in 2019 as a maximum, and via estimating the General Time Trend equation for the Cumin productivity during the study period, it was found that the exponential image is the best mathematical form suitable for the nature of the data, as the results indicated an increase in the productivity of the Cumin crop with a rate of about 3% annually, and the significance of the model as a whole was proven, and the results manifested that about 64% of the changes occurring in the productivity of the Cumin crop during the study period is due to the time.
- **Production:** It became clear from the data of Table (1) in the annex that the average production of the Cumin crop was about 2317,8 tons during the study period, and it ranged between 986 tons as a minimum in 2015 and about 3787 tons in 2002 as a maximum. By estimating the General Temporal Trend equation for the Cumin crop production, it was found that the linear image is the best mathematical form suitable for the nature of the data, as it the results calrified that the Cumin crop production increased at a statistically significant annual rate estimated at about 3021,922 feddan per year and represents about 130,4% of the annual average of the Cumin crop production, which is about 2317,8 feddan and the significance of the model as a whole was proven, and the results indicated that about 19% of the changes occurring in the Cumin crop production during the study period is due to the time.
- **Net yield:** It became evident from the data of Table (1) in the annex that the average net yield of the Cumin crop was about 6931,5 EGP/feddan during the study period and ranged between 2549 EGP/feddan in 2001 as a minimum and about 18233 EGP/feddan in 2019 as a maximum, and through estimating the General Time Trend equation for the net yield of the Cumin crop during the study period, the results showed that the exponential image is the best mathematical form suitable for the nature of the data, as the results indicated an annual increase in the net yield of the Cumin crop with a rate of 8% per year, and the significance of the model as a whole was also proven and the results indicated that about 75% of the changes occurring in the net yield of the Cumin crop during the study period is due to the time.

The development of the Anise crop productivity variables:

- **Area:** It is clear from the data of Table (1) in the annex that the area of Anise within Egypt ranged between 996 feddan in 2001 as a minimum and about 8544 feddan in 2021 as a maximum, and through estimating the General Temporal Trend equation for the area of Anise during the study period, it was found that the linear image is the best mathematical form suitable for the nature of the data, where the results indicated an increase in the Anise crop area with statistically significant annual rate of 225,65 feddan annually and represent about 7,7% of the average annual area of Anise crop area which is about 2923 feddan, and the significance of the model as a whole was also proven and the results clarified that about 39% of the changes occurring in the Anise crop area during the study period is due to the time.
- **Productivity:** It is obvious from the data of Table (1) in the annex that the average productivity of the Anise crop productivity was about 0,725% tons/feddan during the study period and ranged between 0,489 tons/feddan in 2000 as a minimum and about 1,146 tons/feddan in 2019 as a maximum, and throug estimating the General Temporal Trend equation for the Anise productivity during the study period, it was found that the exponential image is the best mathematical form suitable for the nature of the data, as the results indicated an increase in the Anise crop productivity with statistically significant annual rate of 3,7% annually and the significance of the model as a whole was also proven and the results clarified that about 87% of the changes occurring in the Anise crop productivity during the study period is due to the time.
- **Production:** It became clear from the data of Table (1) in the annex that the average production of the Anise crop was about 2503 tons during the study period, and ranged between 541 thousand tons as a minimum in 2001, and about 9738 tons in 2019 as a maximum, and by estimating the General Time Trend equation for the Anise production during the study period, it was found that the exponential image is the best mathematical form suitable for the nature of the data, as the results indicated an increase in the Anise crop production with a rate about 9,5% annually, and the significance of the model was proven as a whole, where the results manifested that about 53% of the changes occurring in the

production of the Anise crop during the study period is due to the time.

- **Net yield:** It is evident from the data of Table (1) in the annex that the average net yield of the Anise crop was about 6552 EGP/feddan during the study period and ranged between 1664 EGP/feddan in 2000 as a minimum and about 15354 EGP/feddan in 2019 as a maximum, and through estimating the General Time Trend equation for the net yield of the Anise crop during the study period, it was found that the exponential image is the best mathematical form suitable for the nature of the data, as the results indicated an increase in the net yield of the Anise crop with a rate of about 10,5% per year, and the significance of the model as a whole was also proven and the results indicated that about 92% of the changes occurring in the net yield of the Anise crop during the study period is due to the time.

The development of the Caraway crop productivity variables:

- **Area:** It is clear from the data of Table (1) in the annex that the area of Caraway within Egypt ranged between 1496 feddan in 2000 as a minimum and about 19254 feddan in 2019 as a maximum, and through estimating the General Temporal Trend equation for the area of Caraway crop during the study period, it was found that the exponential image is the best mathematical form suitable for the nature of the data, where the results indicated an increase in the Caraway crop area with a rate of 8,3% annually and the significance of the model as a whole was also proven and the results manifested that about 83% of the changes occurring in the Caraway crop area during the study period is due to the time.
- **Productivity:** It is obvious from the data of Table (1) in the annex that the average productivity of the Caraway crop was about 0,894 tons/feddan during the study period and ranged between 0,731 in 2008 as a minimum and about 1,092 tons/feddan in 2021 as maximum and throug estimating the General Temporal Trend equation for the Caraway productivity during the study period, it was found that the linear image is the best mathematical form suitable for the nature of the data, as the results indicated an increase in the Caraway crop productivity with statistically significant annual rate of 0,809 tons/feddan annually and represented about 90,5% of the annual average of the Caraway crop productivity which is about 0,894 ton/feddan and the significance of the model as a whole was also proven and the results clarified that about 25% of the changes occurring in the Caraway crop productivity during the study period is due to the time.
- **Production**: according to the data of the attached schedule (1) that the average of Caraway Yield reached around 6173 ton during the survey period, and ranged from 1355 ton as a minimum in 2000 to 17333 ton as a maximum in 2019 by the evaluation of the general time trend equation for the Caraway Yield during the survey period, was shown that the exponential function is the best functions suitable for the nature of the plants. The results indicated the annual increase in the Caraway Yield at a rate of 9.0% as well as the whole significance test and the results were shown that a percent of approximately 70% of the changes in the Caraway Yield during the survey period are due to the process of time.
- **Net return:** pursuant to the data of the attached table (1), was shown that the net return average of the Caraway Yield reached approximately 6006 pound/ feddan during the survey period and ranged from 58.5 pound/ feddan as a minimum in 2016 to approximately 22391 pound/ feddan in 2020 as a maximum. By the evaluation of the general time trend equation for the Caraway net return during the survey period was shown that the linear function is the best functions suitable for the nature of the plants. The results indicated the annual decrease in the Caraway net return at a rate of 3565.2 pound/ feddan represented a percentage of 59.5% of the Caraway net return annual average that represents approximately 6006 pound/ feddan as well as the whole significance test and the results were shown that a percent of approximately 45% of the changes in the Caraway net return during the survey period are due to the process of time.

The development of the Productive variables for Chamomile Yield:

- **Area**: according to the data of the attached schedule (1) that the space area designated for the Chamomile Yield in Egypt ranged from 7198 feddan as a minimum in 2000 and approximately 16567 feddan as a maximum in 2019. By the evaluation of the general time trend equation for the space area designated for the Chamomile Yield during the survey period was shown that the exponential function is the best functions suitable for the nature of the plants. The results indicated the annual increase in the space area designated for the Chamomile Yield at a rate of 3.3% as well as the whole significance test and the results were shown that a percent of approximately 71% of the changes in the space area designated for the Chamomile Yield during the survey period are due to the process of time. (table 3)
- **Productivity**: pursuant to the data of the attached schedule (1) that the average of Chamomile yield reached around 0.891 ton/ feddan during the survey

period, ranged from 0.760 ton/ feddan as a minimum in 2001 to 1.390 ton/ feddan as a maximum in 2019. By the evaluation of the general time trend equation for the Chamomile Yield during the survey period was shown that the exponential function is the best functions suitable for the nature of the plants. The results indicated the annual increase in the Chamomile Yield at a rate of 1.3% as well as the whole significance test and the results were shown that a percent of approximately 42% of the changes in the Chamomile Yield during the survey period is due to the process of time. (table 3)

- **Production**: according to the data of the attached schedule (1) that the average of Chamomile Yield reached approximately 9633.4 ton during the survey period, ranged from 5562 ton as a minimum in 2001 to 23035 ton as a maximum in 2019. By the evaluation of the general time trend equation for the Chamomile Yield during the survey period was shown that the exponential function is the best functions suitable for the nature of the plants. The results indicated the annual increase in the Chamomile Yield at a rate of 4.6% as well as the whole significance test and the results were shown that a percent of approximately 69% of the changes in the Chamomile Yield during the survey period are due to the process of time. (table 3)
- **Net return**: according to the data of the attached table (1) was shown that the net return average of the Chamomile Yield reached approximately 1164.5 pound/ feddan during the survey period and ranged from 1321.8 pound/ feddan as a minimum in 2016 to approximately 4110 thousand pounds/ feddan in 2019 as a maximum. By the evaluation of the general time trend equation for the net return average of the Chamomile Yield during the survey period was shown that the statistical significance isn't proven regarding the different significance levels; this means that it is relatively stable around the annual average for the period indicated.

Table (3): The general time trend for the productive variables of the medical and aromatic plants During the period of (2000-2021)

Statement			Index	General temporal trend equation	R2	F	Change rate (%)
Cumin	**Area**	Feddan	**Linear**	$\hat{Y_i} = -199.4 + 6335.519Xi$ (-4.18)** (10.14)**	0.47	17.6	156.7
	Productivity	Ton/feddan	**exponential**	$ln\hat{Y_i} = 0.477 + 0.03Xi$ (5.99)** (25.29)**	0.64	35.85	3.0
	Production	Ton	**Linear**	$\hat{Y_i} = -61.230 + 3021.922Xi$ (-2.18)** (8.17)**	0.19	4.73	130.4
	Net return	Thousand pounds	**exponential**	$ln\hat{Y_i} = 2315.64 + 0.08Xi$ (7.42)** (7.77)**	0.75	60.31	8.0
Anise	**Area**	Feddan	**Linear**	$\hat{Y_i} = 328.403 + 225.65Xi$ **(3.58) (0.397)	0.39	12.82	7.7
	Productivity	Ton/feddan	**exponential**	$ln\hat{Y_i} = 0.46 + 0.037Xi$ (23.57)** (11.37)**	0.87	129.4	3.7
	Production	ton	**exponential**	$ln\hat{Y_i} = 567.69 + 0.095Xi$ (3.80)** (4.77)**	0.53	22.73	9.5
	Net return	Thousand pounds	**exponential**	$ln\hat{Y_i} = 1553.3 + 0.105Xi$ (11.0)** (15.23)**	0.92	231.93	10. **5**
Caraway	**Area**	Feddan	**exponential**	$ln\hat{Y_i} = 2110.3 + 0.083Xi$ (6.03)** (6.58)**	0.83	43.296	8.3
	Productivity	Ton/feddan	**exponential**	$\hat{Y_i} = 0.007 + 0.809Xi$ (2.61)** (21.83)**	0.25	6.79	90. 5
	Production	ton	**exponential**	$ln\hat{Y_i} = 1731.1 + 0.09Xi$ (5.91) ** (6.95)**	0.70	48.28	9.0
	Net return	Thousand pounds	**exponential**	$\hat{Y_i} = 832.51 - 3565.2Xi^2$ (4.45)** (-1.45)	0.45	19.83	59.5-
Chamomile	**Area**	Feddan	**exponential**	$ln\hat{Y_i} = 6992.01 + 0.033Xi$ (16.06) ** (6.93)**	0.71	48.04	3.3
	Productivity	Ton/feddan	**exponential**	$ln\hat{Y_i} = 0.764 + 0.013xi$ (22.96)** (3.82)**	0.42	14.598	1.3
	Production	ton	**exponential**	$ln\hat{Y_i} = 5338.1 + 0.046Xi$ (11.02) ** (6.59)**	0.69	43.46	4.6
	Net return	Thousand pounds	Characterized by relative stability at annual average				

Whereas: ln Y,Y= estimated value of the study variables, Xi = time variable whereas 21,…….2,1= i

Resource: calculated and collected by the data of Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Central Administration of Agricultural Economics and the bulletin of the agricultural statistics during the period of (2000-2021).

The impact of the climate changes on the most important medical and aromatic plants during the period of (2000- 2020):

Table (4) has shown the average of Cumin net return reached approximately 8597 pounds, as it reached its maximum in 2020 estimated approximately by 26.3 thousand pounds at the level of the Republic, while it reached its maximum for Minya Governorate estimated approximately by 10.3 thousand pounds, by the statistical significance growth rate reached annually approximately 9.2% during the period of (2000-2020). The average of maximum and minimum temperature, relative humidity and the rainfall amount reached approximately respectively 28º C, 17 º C, 58% and 0.9 mm and by the statistical non-significance growth rate.

While, the average of Anise net return reached approximately 7101 pounds, as it reached its maximum in 2012 estimated approximately by 13.4 thousand pounds at the level of the Republic, while it reached its maximum for Al Sharqia Governorate estimated approximately by 8.7 thousand pounds, by the statistical significance growth rate reached annually approximately 5.7% during the same period. The average of maximum and minimum temperature, relative humidity and the rainfall amount reached approximately respectively 29º C, 16 º C, 52% and 0.6 mm and by the statistical non-significance growth rate. While, the average of Caraway net return reached approximately 6151 pounds, as it reached its maximum in 2018 estimated approximately by 24.7 thousand pounds at the level of the Republic, while it reached its maximum for Beni Suef Governorate estimated approximately by 12 thousand pounds, by the statistical significance growth rate reached annually approximately 13.2% during the same period. The average of maximum and minimum temperature, relative humidity and the rainfall amount reached approximately respectively 29º C, 16 º C (by the statistical significance growth rate), 55% (the statistical significance growth rate) and 0.8 mm and by the statistical non-significance growth rate.

While, the average of Chamomile net return reached approximately 1522 pounds, as it reached its maximum in 2019 estimated approximately by 4547 thousand pounds at the level of the Republic, while it reached its maximum for Minya Governorate estimated approximately by 5432 pounds, by the statistical significance growth rate reached annually approximately 2.54% during the same period. The average of maximum and minimum temperature, relative humidity and the rainfall amount reached approximately respectively 29º C, 16.7 º C (by the statistical significance growth rate), 51.3% (the statistical significance growth rate) and 0.7 mm and by the statistical non-significance growth rate.

The table (5) has shown that the Ricardo model mentions to the impact of the climate changes on the net return of the survey yields during the period of (2000-2020), and was shown that the cumin yield variables, subject of the survey, explain about 62% of changes in the dependent variable, and the significance of the impact of all variables, subject of the survey, was shown except the impact of relative humidity average, rainfall amount, relative humidity square, the average of maximum temperature x average of relative humidity, the average of minimum temperature in average of relative humidity, rainfall amount in average of relative humidity .

While, it has been shown that the Anise Yield variables, subject of the survey, explain about 76% of changes in the dependent variable, and has been shown the significance of the impact of all variables, subject of the survey, except the impact of the process of time.

While, it has been shown that the Caraway Yield variables, subject of the survey, explain about 61% of changes in the dependent variable, and has been shown the significance of the impact of all variables, subject of the survey, except the impact of each of the average of minimum temperature and rainfall amount square.

While, it has been shown that the Chamomile Yield variables, subject of the survey, explain about 37% of changes in the dependent variable, and has been shown the significance of the impact of all variables, subject of the survey, except the impact of the average of minimum temperature, the average square of minimum temperature, the average of minimum temperature in and relative humidity.

The simulations of the climate change impacts on the most important medical and aromatic plants:

The simulation of the climate change impact, the estimated functions of the model contained in table (6) in order to calculate the impacts of change in the temperature, relative humidity and rainfall amount on the survey yields net return, whereas the increase and decrease in each of maximum temperature and minimum temperature were calculated by approximately 0.5 º C and the average of relative humidity was calculated by approximately 0.5 % and the impact of the rainfall amount wasn't calculated **as the rainfall is natural and the farmer can overcome their effects by reducing or increasing irrigation**.

It was shown by table (6) and figure (1) of the Climate change scenario, the negative effect of the high maximum and minimum temperature 0.5 º C and high and low relative humidity on the cumin yield net return at a rate reached approximately 298.8 %, 357,7%, 32.7% of the current revenue net return, and approximately 396%, 483.1%, 0.01% of model calculated revenue net return, the impact of the low maximum and minimum temperature (approximately 0.5 ^{o} C) on the Cumin Yield net return at a rate reached approximately 234.5 %, 290,1% of the current revenue net return, and approximately 397.3%, 479.9% of model calculated revenue net return average.

It was shown the negative effect of the high maximum temperature and low minimum temperature of 0.5 ^{o} C and high relative humidity 0.5% on the Anise Yield net return at a rate reached approximately 1717.1 %, 326.1%, 1.27% of the current revenue net return average, and approximately 1703.1%, 324.2%, 17917% of model calculated net return average, the impact of the low maximum and minimum temperature (approximately 0.5 ^{o} C) and the relative humidity on the anise yield net return at a rate reached approximately 1718.8 %, 327.9%, 2.9% of the current revenue net return, and approximately 1703.1%, 324.2%, 2% of model calculated revenue net return average.

It was shown the negative effect of the high maximum temperature of 0.5 ^{o} C on the Caraway Yield net return at a rate reached approximately 10.89 % of the current revenue net return average, and approximately 15.6% of model calculated net return average, the impact of the low maximum temperature and high minimum temperature (approximately 0.5 ^{o} C) and the high and low relative humidity 0.5% on the Caraway Yield net return at a rate reached approximately 18.64%, 19.64%, 6.11%, 5.67% of the current revenue net return average, and approximately 14.94%, 11.78%, 0.40% of model calculated revenue net return average.

It was shown the negative effect of the high and low maximum temperature, high minimum temperature of 0.5 ^{o} C and the high and low relative humidity 0.5% on the Chamomile Yield net return at a rate reached approximately 10.38 %, 0.69%, 18.25%, 10.82%, 10,82% of the current revenue net return average, and approximately 34% (positive effect), 11.16 (positive effect), 7.61%, 0.12%, 0.14% of model calculated net return average, the impact of the low minimum temperature (approximately 0.5 ^{o} C) on the Chamomile Yield net return at a rate reached approximately 5.03% of the current revenue net return average, and approximately 19.23% of model calculated revenue net return average.

Therefore, it was shown from the above- mentioned:

Cumin Crop:

- The effect was negative in case of the high maximum and minimum temperature, low and high relative humidity.
- The effect was positive in case of the high maximum and minimum temperature.

Anise Crop:

- The effect was negative in case of the high maximum temperature and low minimum temperature and high relative humidity.
- The effect was positive in case of the low maximum temperature and high minimum temperature and low relative humidity.

Caraway Crop:

- The effect was negative in case of the high maximum temperature.
- The effect was positive in case of the low maximum and minimum temperature and high minimum temperature, high and low relative humidity.

Chamomile Crop:

- The effect was negative in case of the high and low maximum temperature, high minimum temperature, high and low relative humidity.
- The effect was positive in case of the low minimum temperature.

  Consequently, the feddan net return of the survey yields is sensitive to the climate change.

Conclusions:

The research aimed at analyzing whether or not there is an impact of climate change? On the net yield of the most important medicinal and aromatic plants during the period (2000 -2021) through the study of the effect of maximum and minimum temperatures, average humidity, precipitation rate and time on the net yield of the most important medicinal and aromatic plants (anise, cumin, caraway, chamomile). Using descriptive and quantitative statistical methods and general temporal direction of area, production, productivity and net yield, Ricardo's method was also used to assess the economic impact of climate change.

Table (4): Climatic variables and net yield of the most important medicinal and aromatic plant crops during the period (2000 – 2020)

Years	cumin					Anise					Caraway					Chamomile				
	Net return	Maximum temperature	Minimum temperature	Mean relative humidity	Amount of rainfall	Net return	Maximum temperature	Minimum temperature	Mean relative humidity	Amount of rainfall	Net return	Maximum temperature	Minimum temperature	Mean relative humidity	Amount of rainfall	Net return	Maximum temperature	Minimum temperature	Mean relative humidity	Amount of rainfall
	Pound	degrees Celsius	degrees Celsius	%		Pound	degrees Celsius	degrees Celsius	%		Pound	degrees Celsius	degrees Celsius	%		Pound	degrees Celsius	degrees Celsius	%	
2000	6531	27	16	59	1.1	3386	28	15	55	0.6	2366	28	15	58	0.9	-	-	-	-	-
2001	3302	28	17	57	0.5	3420	29	16	53	0.2	2323	29	16	56	0.4	-	-	-	-	-
2002	3771	29	16	56	0.6	3541	29	16	53	0.2	1710	29	16	55	0.5	-	-	-	-	-
2003	3520	28	16	55	0.8	4243	29	15	51	0.4	2062	29	15	54	0.6	-	-	-	-	-
2004	3656	28	16	57	1.1	3984	29	16	53	0.8	2650	29	16	56	0.9	1425	29.0	15.6	53.1	0.8
2005	3349	28	16	57	1.0	4172	29	16	54	0.8	2585	29	16	56	0.9	2184	28.7	15.7	54.0	0.8
2006	2533	28	16	58	1.1	3927	29	16	54	0.8	2564	29	16	57	0.9	1044	28.8	15.9	54.2	0.8
2007	7897	28	17	57	0.8	6467	29	16	53	0.8	2204	29	16	56	0.7	591	29.2	16.2	53.3	0.8
2008	7196	29	17	56	0.9	6720	30	17	53	0.8	1621	30	17	56	0.8	3971	29.6	16.6	53.3	0.8

Growth rate	Average	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
9.2**	8597	26338	17906	15102	19596	6535	8772	6418	10465	10033	9032	6226	5546
-0.1	28	29	29	30	27	28	27	28	23	28	28	30	29
0.4	17	17	18	18	16	18	17	17	14	17	16	18	17
1.1	58	126	52	51	51	54	58	58	45	55	56	55	55
0.7	0.9	0.9	0.7	0.9	0.5	1.4	1.5	1.2	1.1	0.8	0.7	0.7	0.7
5.7**	7101	12571	7309	12589	9116	7179	10692	7458	5344	13429	7941	7982	7651
0.1	29	29	29	30	29	29	29	29	29	29	28	31	30
0.1	16	17	17	18	17	17	17	17	17	17	16	18	17
0.1	52	51	48	50	51	50	50	51	49	49	52	51	51
1.1	0.6	0.7	0.6	0.7	0.5	0.8	0.8	0.9	0.6	0.5	0.5	0.5	0.4
13.2**	6151	19649	19649	20267	24653	-562	1705	2869	3489	3862	3406	1784	1820
-0.04	29	29	29	30	28	29	28	28	25	29	29	31	30
0.5**	16	17	17	18	16	17	17	17	14	17	16	18	17
-0.5**	55	51	51	50	50	53	57	57	46	54	55	54	54
0.5	0.8	0.6	0.6	0.8	0.4	1.2	1.3	1.2	1.0	0.7	0.5	0.6	0.6
2.54**	1522	4106	4547	477	2956	-1856	-197	1126	-64	969	735	3351	507
0.03	29.2	28.8	29.2	29.7	29.0	29.4	28.9	28.7	29.2	29.0	28.5	30.9	29.6
0.62**	16.7	17.2	17.3	18.0	17.2	17.3	16.7	17.2	16.7	16.5	16.0	17.8	16.9
-0.52**	51.3	50.9	48.0	50.4	51.4	50.3	50.1	50.6	49.5	49.4	51.9	50.9	50.8
-0.72	0.7	0.7	0.6	0.7	0.5	0.8	0.8	0.9	0.6	0.5	0.5	0.5	0.4

*Note: There are no data on chamomile during the period (2000-2003)

Table continued (4): Climate variables and net yield of the most important medicinal and aromatic plant crops at the level of the most important governorates during the average period (2000-2020)

cumin

Governorates	Net return (Pound)	Maximum temperature (degrees Celsius)	Minimum temperature (degrees Celsius)	Mean relative humidity (%)	Amount of rainfall
Al-Behira	4581	29	16	71	0.6
Al-Sharkeya	8685	28	18	53	1.2
El-Fayoum	8756	28	17	53	1.0
Elmenia	10332	30	15	50	0.1
Bani Suief					
Kafr El-Skeikh	7976	24	17	64	1.6
Average	**8066**	**28**	**17**	**58**	**0.9**

Anise

Governorates	Net return (Pound)	Maximum temperature (degrees Celsius)	Minimum temperature (degrees Celsius)	Mean relative humidity (%)	Amount of rainfall
Al-Behira					
Al-Sharkeya	8660	28	18	53	1.2
El-Fayoum	7206	28	17	53	1.0
Elmenia	7044	30	15	50	0.1
Bani Suief	8346	30	16	50	0.1
Kafr El-Skeikh					
Average	**7814**	**29**	**16**	**52**	**0.6**

Caraway

Governorates	Net return (Pound)	Maximum temperature (degrees Celsius)	Minimum temperature (degrees Celsius)	Mean relative humidity (%)	Amount of rainfall
Al-Behira	5413	29	16	71	0.6
Al-Sharkeya	5226	28	18	53	1.2
El-Fayoum	7834	28	17	53	1.0
Elmenia	5397	30	15	50	0.1
Bani Suief	12098	30	16	50	0.1
Kafr El-Skeikh	6497	24	17	64	1.6
Average	**7077**	**28**	**16**	**57**	**0.8**

Chamomile

Governorates	Net return (Pound)	Maximum temperature (degrees Celsius)	Minimum temperature (degrees Celsius)	Mean relative humidity (%)	Amount of rainfall
Al-Behira					
Al-Sharkeya	-103	27	17	51	1.1
El-Fayoum	1072	28	17	53	1.0
Elmenia	5342	30	15	50	0.1
Bani Suief	2030	30	16	50	0.1
Kafr El-Skeikh					
Average	**2085**	**29**	**16**	**51**	**0.6**

*, * * significant at the level of 0.05, 0.01 respectively.

Source: Calculated from the data of:

1- Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, **Bulletin of Agricultural Statistics**, various issues.

2- Ministry of Agriculture and Land Reclamation, Agricultural Research Centre, Central Lab. for Agricultural Climate**, unpublished data.**

Table (5): Parameters of the Ricardo model's estimates of the impact of climate changes on the net yield of the most important medicinal and aromatic plants during the period (2000 – 2020)

Variable	Ricardo's model estimates for cumin crop				Ricardo's model estimates for anise crop				Ricardo's model estimates for caraway crop				Ricardo's model estimates for Chamomile crop			
	Coefficient	Std. Error	t-Statis.	Prob.	Coefficient	Std. Error	t-Statis.	Prob.	Coefficient	Std. Error	t-Statis.	Prob.	Coefficient	Std. Error	t-Statis.	Prob.
C	1150362	495123	2.32	0.02	4113657.0	430476.8	9.56	0.00	-942420.5	128302.7	-7.35	0.00	2900748	360884	8.04	0.00
X1	-45944	25773	-1.78	0.08	-243985.4	13695.3	-17.82	0.00	29469.2	3065.0	9.61	0.00	-91711	15658	-5.86	0.00
X2	-55501	13857	-4.01	0.00	46439.6	9427.7	4.93	0.00	-70.9	4983.4	-0.01	0.99	-18790	10881	-1.73	0.08
X3	118	4952	0.02	0.98	-28964.6	9209.6	-3.15	0.00	21909.0	2915.7	7.51	0.00	-55042	6279	-8.77	0.00
X4	-174443	248471	-0.70	0.48	-2566825	301157.2	-8.52	0.00	1235329.0	129227.3	9.56	0.00	-2026028	321870	-6.29	0.00
X5	676	346	1.96	0.05	2371.2	139.4	17.01	0.00	-374.0	29.7	-12.60	0.00	314	138	2.27	0.02
X6	1590	330	4.82	0.00	375.3	181.4	2.07	0.04	1693.9	156.8	10.80	0.00	248	131	1.89	0.06
X7	-47	29	-1.60	0.11	-106.6	38.0	-2.80	0.01	2.0	0.4	5.44	0.00	99	39	2.55	0.01
X8	-8458	3199	-2.64	0.01	18363.6	1919.4	9.57	0.00	661.9	1223.2	0.54	0.59	4099	1913	2.14	0.03
X9	93	120	0.78	0.44	1855.4	200.6	9.25	0.00	-229.4	64.1	-3.58	0.00	1406	233	6.04	0.00
X10	-36740	5394	-6.81	0.00	143844.1	17216.7	8.35	0.00	-37696.3	3690.0	-10.22	0.00	50665	16190	3.13	0.00
X11	76	118	0.64	0.52	-1028.1	106.4	-9.66	0.00	-999.6	85.9	-11.63	0.00	250	191	1.31	0.19
X12	60951	12934	4.71	0.00	-100915.7	14586.1	-6.92	0.00	-18421.0	4280.5	-4.30	0.00	32181	13390	2.40	0.02
X13	4506	4391	1.03	0.31	45038.3	6008.9	7.50	0.00	-22928.3	2296.6	-9.98	0.00	38797	6295	6.16	0.00
X14	661	77	8.57	0.00	-2561.8	335.7	-7.63	0.00	727.9	62.2	11.69	0.00	-934	318	-2.94	0.00
X15	-1160	232	-4.99	0.00	1808.3	277.0	6.53	0.00	285.0	72.7	3.92	0.00	-689	268	-2.57	0.01
X16	1454	141	10.30	0.00	-1631.8	233.1	-7.00	0.00	463.5	113.1	4.10	0.00	265	129	2.05	0.04
X17	1211	119	10.21	0.00	57.4	30.8	1.86	0.06	1131.4	43.7	25.91	0.00	131	40	3.28	0.00

R-squared	0.623	R-squared	0.76	R-squared	0.612	R-squared	0.37
Adjusted R-squared	0.615	Adjusted R-squared	0.752	0.751901	0.608	Adjusted R-squared	0.36
S.E. of regression	4580.328	S.E. of regression	2308.4	2308.390	6138.6	S.E. of regression	1949.66
Sum squared resid	1.64E+10	Sum squared resid	4.46E+09	4.46E+09	6.66E+10	Sum squared resid	3.18E+09
Log likelihood	-7849.97	Log likelihood	-7825.5	Log likelihood	-18103.3	Log likelihood	-7681.1
F-statistic	75.76	F-statistic	153.3	F-statistic	163.95	F-statistic	29.3
Prob(F-statistic)	0.00	Prob(F-statistic)	0.00	Prob(F-statistic)	0.00	Prob(F-statistic)	0.00
Mean dependent var	8548.16	Mean dependent var	7361.1	Mean dependent var	7033.8	Mean dependent var	1386.2
S.D. dependent var	7378.04	S.D. dependent var	4634.4	S.D. dependent var	9806.2	S.D. dependent var	2437.9
Akaike info criterion	19.72	Akaike info criterion	18.4	Akaike info criterion	20.3	Akaike info criterion	18.01
Schwarz criterion	19.82	Schwarz criterion	18.45	Schwarz criterion	20.3	Schwarz criterion	18.11
Hannan-Quinn criter.	19.76	Hannan-Quinn criter.	18.39	Hannan-Quinn criter.	20.3	Hannan-Quinn criter.	18.048
Durbin-Watson stat	2.70	Durbin-Watson stat	2.62	Durbin-Watson stat	1.17	Durbin-Watson stat	2.0893

Whereas:

C	: Constant	**X^6**	: Square of Minimum Temperature	**X12**	: Minimum Temperature × Precipitation Rate
X^1	: Maximum Temperature	**X^7**	: square of the average relative humidity	**X13**	: Relative humidity × precipitation rate
X^2	:Minimum Temperature	**X^8**	: Square precipitation rate	**X14**	: Maximum Temperature x Relative Humidity rate x precipitation rate
X3	: Average relative humidity	**X^9**	: Maximum Temperature x Relative Humidity rate	**X15**	: Maximum Temperature x Relative Humidity rate x precipitation rate
X^4	: precipitation rate	**X10**	: Maximum Temperature x precipitation rate	**X16**	: Formal variable reflecting place or province
X^5	:Square of Maximum Temperature	**X11**	: Minimum temperature x relative humidity rate	**X17**	: Formal variable reflecting time

Source: Calculated from the data of:
1. Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, **Bulletin of Agricultural Statistics**, various issues.
2- Ministry of Agriculture and Land Reclamation, Agricultural Research Centre, Central Lab. for Agricultural Climate**, unpublished data.**

Table (6): Analysis of sensitivity to the effects of change in the climatic factors of the most important medicinal and aromatic plants during the period (2000 – 2020)

	Governorates	Current net return	Calculated net return	First scenario	second scenario	third scenario	forth scenario	fifth scenario	Sixth scenario
Cumin	2000	6531	5619	-16013	28590	-23715	33369	5619	5618
	2001	3302	4629	-18342	27601	-18899	32380	4630	4629
	2002	3771	1547	-21424	24519	-18421	29298	1548	1547
	2003	3520	2689	-20283	25661	-17432	30439	2690	2689
	2004	3656	2084	-20888	25056	-19886	29834	2084	2083
	2005	3349	4495	-18477	27466	-19670	32245	4495	4494
	2006	2533	3260	-19712	26232	-22132	31010	3261	3259
	2007	7897	7201	-15770	30173	-23121	34952	7202	7201
	2008	7196	6225	-16746	29197	-26203	33976	6226	6225
	2009	5546	6320	-16651	29292	-25061	34071	6321	6320
	2010	6226	6664	-16308	29636	-25666	34414	6664	6663
	2011	9032	13145	-9827	36117	-23256	40895	13146	13144
	2012	10033	11290	-11681	34262	-24490	39041	11291	11290
	2013	10465	11298	-11674	34269	-20549	39048	11298	11297
	2014	6418	9022	-13949	31994	-21525	36773	9023	9022
	2015	8772	14612	-8360	37584	-21430	42362	14613	14611
	2016	6535	15363	-7609	38335	-21086	43113	15363	15362
	2017	19596	17639	-5333	40611	-14605	45389	17639	17638
	2018	15102	13579	-9393	36551	-16460	41330	13580	13579
	2019	17906	16244	-6728	39215	-16453	43994	16244	16243

	2020	26338	18528	-1609	44334	-18728	49113	21363	21362
	Average*	8597	5782	-17087	28754	-22150	33533	5783	5782
	Calculated change rate of		-32.7	-298.8	234.5	-357.7	290.1	-32.7	-32.7
	Calculated change rate of calculated %			-396	397.3	-483.1	479.9	0.01	-0.01
Anise	2000	3386	3771	-118222	125763	26990	-19449	3626	3915
	2001	3420	2332	-119661	124324	25551	-20888	2187	2476
	2002	3541	3844	-118149	125836	27063	-19376	3699	3989
	2003	4243	4390	-117603	126383	27610	-18830	4245	4535
	2004	3984	3157	-118836	125149	26376	-20063	3012	3301
	2005	4172	5375	-116618	127368	28595	-17845	5230	5520
	2006	3927	5111	-116881	127104	28331	-18109	4966	5256
	2007	6467	5061	-116931	127054	28281	-18158	4917	5206
	2008	6720	6601	-115392	128593	29820	-16619	6456	6745
	2009	7651	6315	-115677	128308	29535	-16904	6171	6460
	2010	7982	8898	-113095	130891	32118	-14322	8753	9043
	2011	7941	9078	-112915	131071	32298	-14142	8933	9223
	2012	13429	10452	-111541	132445	33672	-12768	10307	10597
	2013	5344	6394	-115599	128387	29614	-16826	6249	6539
	2014	7458	6969	-115024	128962	30189	-16251	6824	7114
	2015	10692	11145	-110848	133137	34364	-12075	11000	11289
	2016	7179	11176	-110816	133169	34396	-12043	11031	11321
	2017	9116	9764	-112229	131756	32983	-13456	9619	9908
	2018	12589	10068	-111925	132061	33288	-13152	9923	10213
	2019	7309	8673	-113320	130665	31893	-14547	8528	8818
	2020	12571	11853	-110140	133845	35072	-11367	11708	11997
	Average*	7101	7163	-114830	129156	30383	-16057	7018	7308
	Calculated change rate of		0.9	-1717.1	1718.8	327.9	-326.1	-1.2	2.9
	Calculated change rate of calculated %			-1703.1	1703.1	324.2	-324.2	-2.0	2.0

Source: Calculated from table 1

Table continued (6): Analysis of sensitivity to the effects of change in the climatic factors of the most important medicinal and aromatic plants during the period (2000 – 2020)

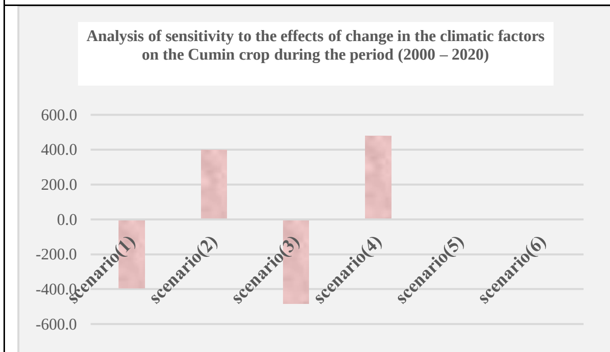
Caraway	Governorates	Current net return	Calculated net return	First scenario	second scenario	third scenario	forth scenario	fifth scenario	Sixth scenario
	2000	2366	2322	1283	3174	227	5264	2330	2315
	2001	2323	2003	-177	3996	3516	1336	2000	2006
	2002	1710	-2021	-4149	-81	-1822	-1374	-2020	-2023

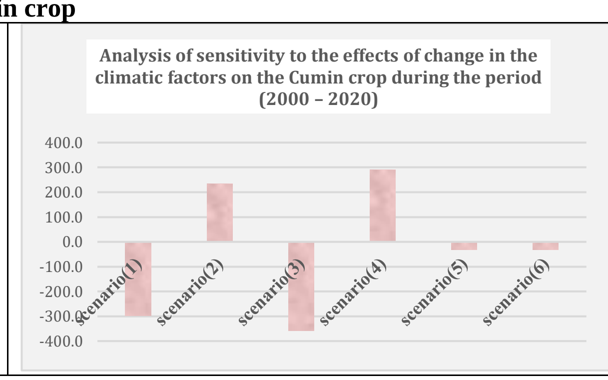
	2003	2062	-1573	-3533	200	-1550	-749	-1568	-1578
	2004	2650	-482	-1988	838	-1264	1147	-473	-490
	2005	2585	2677	1053	4113	1527	4674	2684	2669
	2006	2564	2938	1411	4278	2143	4580	2945	2931
	2007	2204	2552	631	4287	2795	3157	2557	2548
	2008	1621	1216	-976	3221	1780	1499	1220	1213
	2009	1820	4864	4803	4738	5633	4942	4863	4865
	2010	1784	2401	796	3819	4867	781	2396	2405
	2011	3406	9884	7880	11700	10221	10393	9886	9881
	2012	3862	9802	7631	11785	11752	8698	9802	9801
	2013	3489	5556	6624	4302	6280	5680	5557	5555
	2014	2869	5560	7152	3780	5303	6664	5561	5558
	2015	1705	4995	9763	40	4188	6648	4996	4994
	2016	-562	8744	9306	7995	10374	7961	8748	8739
	2017	24653	17825	16712	18751	19143	17355	17828	17822
	2018	20267	16494	14196	18605	20924	12911	16495	16493
	2019	19649	16911	15451	18183	20367	14301	16909	16913
	2020	19649	16911	15451	18183	20367	14301	16909	16913
	Average*	5842	6170	5206	6948	6989	6199	6173	6168
	Calculated change rate of		5.63	-10.89	18.94	19.64	6.11	5.67	5.59
	Calculated change rate of calculated %			-15.63	14.94	11.78	0.40	0.04	-0.04
Chamomile	2004	1425	554	1075	190	-324	1556	550	550
	2005	2184	1354	2134	731	299	2534	1350	1350
	2006	1044	2353	3085	1777	1113	3717	2348	2348
	2007	591	1237	1750	882	364	2235	1233	1233
	2008	3971	1286	2263	466	553	2144	1281	1281
	2009	507	1383	1207	1716	1975	915	1380	1380
	2010	3351	2259	2745	1930	2867	1776	2250	2250
	2011	735	1152	1216	1245	1263	1166	1153	1153
	2012	969	1485	440	2688	1897	1198	1486	1486
	2013	-64	824	370	1435	1160	612	823	823
	2014	1126	1031	1342	876	1061	1125	1031	1031
	2015	-197	551	80	1178	420	806	550	550
	2016	-1856	616	419	970	639	718	615	615
	2017	2956	2283	2024	2699	2527	2163	2283	2283
	2018	477	301	91	667	452	273	300	300
	2019	4547	1651	126	3334	1939	1488	1654	1654
	2020	4106	2786	2818	2911	2948	2748	2787	2787
	Average*	25873	23108	23187	25695	21152	27175	23075	23075
	Calculated change rate of		-10.69	-10.38	-0.69	-18.25	5.03	-10.82	-10.82
	Calculated change rate of calculated %			0.34	11.16	-7.61	19.23	-0.12	-0.14

Note: There are no data on chamomile crop during the period (2000-2003)
Source: Calculated from table 4

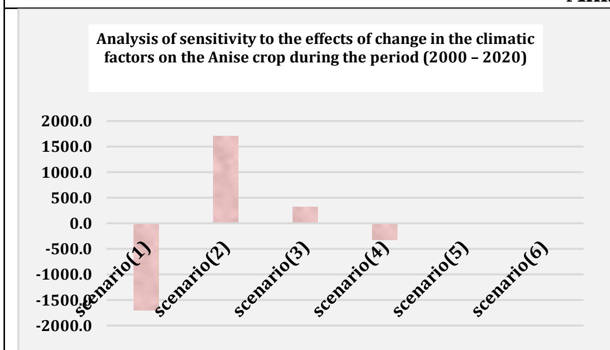
Figure (1) Analysis of sensitivity to the effects of change in the climatic factors of the most important medicinal and aromatic plants during the period (2000 – 2020)

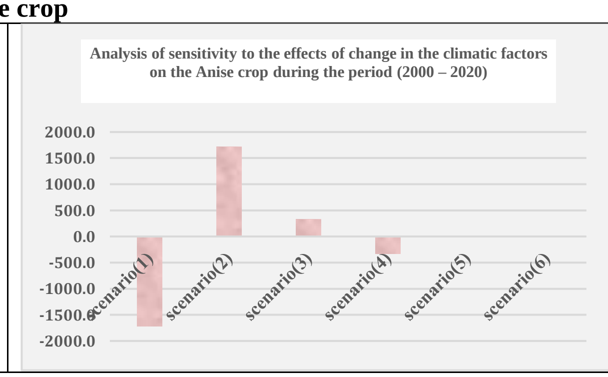
Cumin crop



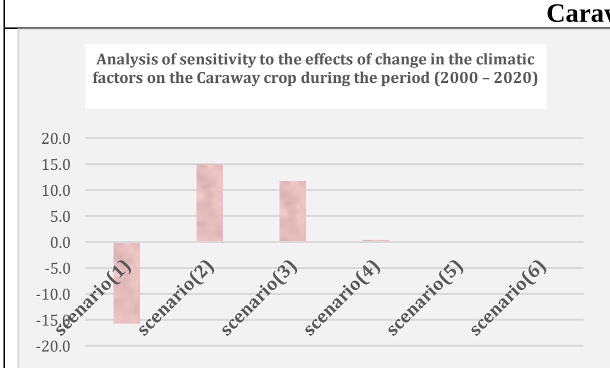


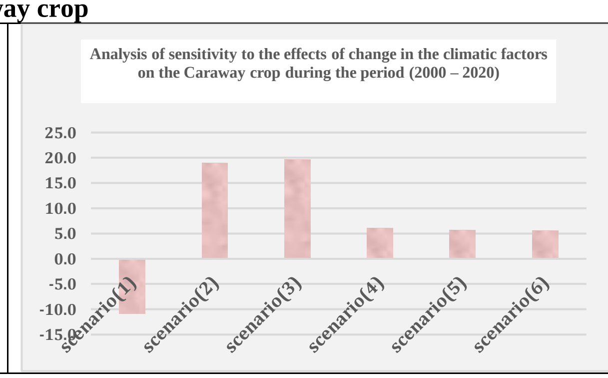
Anise crop



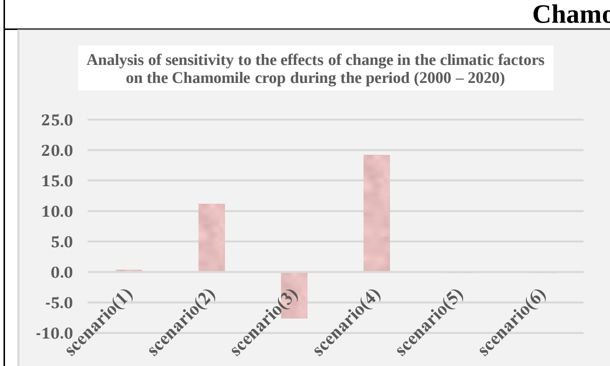


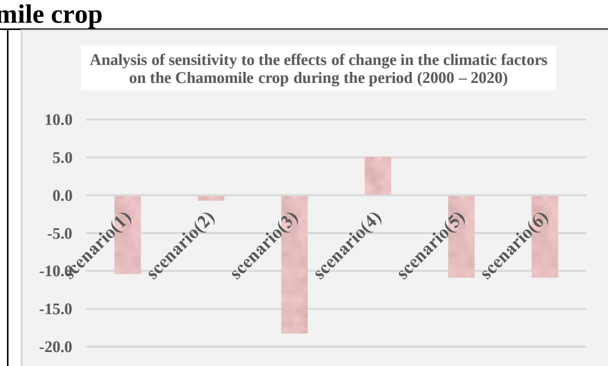
Caraway crop





Chamomile crop





Source: Table (6) The rate of change of the calculated net return from the calculated

Source: Table (6) The rate of change of the calculated net return from the current

The most important results of the study:

- The average area of medicinal and aromatic plants during the period (2016-2021) was about 98.2 thousand Feddan, representing about 0.61% of the crop area, estimated at about 16.1 million Feddan, which shows the low economic importance of medicinal and aromatic plants from the percentage of the area they represent in the crop structure.
- Chamomile occupies the first place in terms of area, reaching about 13.2 thousand Feddan, with about 23.5% of the total area of medicinal and aromatic plants, while caraway occupies the second place with about 19.29%, followed by anise, green tar, cumin, with about 15.24%, 10.04%, 6.36%, while caraway occupies the first place in terms of net yield, with a net yield of about 22.5 thousand pounds per feddan, with about 23.7%, followed by cumin with about 16.5 thousand pounds, with about 17.3%, and then anise with about 15.9%.
- The net yield of the cumin and anise crop increased at a rate of about 8%, 10.5% annually, while the yield of the caraway crop decreased at a statistically significant annual rate, representing about 59.5% of the annual average, while the net yield of chamomile was relatively stable around the annual average.
- For cumin, the effect was negative on the net feddanage yield for the increase in the maximum and minimum temperature rise (0.5 °C) and relative humidity (0.5%), while it was positive for maximum and minimum temperature drop (0.5 °C).
- Anise had a negative effect on the net feddanage yield at the increase of maximum temperature (0.5 °C) and relative humidity (0.5%), while it was positive at the decrease maximum temperature (0.5 °C) and negative at the decrease minimum temperature (0.5 °C).
- Caraway had a negative effect on the net feddanage yield at the increase of the maximum temperature (0.5 °C), while it was positive at the increase of the minimum temperature (0.5 °C) and increase and decrease of relative humidity (0.5%).
- Chamomile diathesis had a negative effect on the net feddanage yield at the increase of maximum and minimum temperatures (0.5 °C) and increase and decrease of relative humidity (0.5%), while it was positive at the decrease of minimum temperatures (0.5 °C).
- The sensitivity of the net cumin yield is affected by the change of the maximum and minimum temperature either by the decrease or the increase, while it is not affected by the increase or decrease of the relative humidity.
- The sensitivity of anise net yield is affected by the change of the maximum and minimum temperature either by the decrease or the increase.
- The sensitivity of the net yield of the caraway is affected by the change of the maximum and minimum temperature either by decrease or increase.
- The sensitivity of the net chamomile yield is affected by the change of the maximum and minimum temperature either by the decrease or the increase, while it is not affected by the increase or decrease of the relative humidity.

Recommendations:

- Studying regionalization to find out the means through which it is possible to overcome or alleviate the shortage in crop productivity that has been negatively affected by climate change.
- Establishing a database to complete the lack of available data on the adverse effects of climate change.
- Encourage scientific and technological research on all issues related to climate change, develop specific plans and clear funding, and follow policies and programs that support climate-smart agriculture.

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Appendix (1): The development of the productive variables of the most important medicinal and aromatic plants during the period (2000 – 2021)

Years	Cumin				Anise				Caraway				Chamomile			
	Area	Productivity	Production	Net return	Area	Productivity	Production	Net return	Area	Productivity	Production	Net return	Area	Productivity	Production	Net return
	Feddan	Ton/feddan	Ton	pound	Feddan	Ton/feddan	Ton	pound	Feddan	Ton/feddan	Ton	pound	Feddan	Ton/feddan	Ton	pound
2000	6867	0.491	3375	2660	1554	0.489	760	1664	1496	0.906	1355	1941	7198	0.798	5745	-
2001	7039	0.459	3230	2549	996	0.543	541	2111	2455	0.905	2221	2056	7323	0.760	5562	-
2002	7817	0.484	3787	2994	1277	0.511	653	1852	3348	0.921	3085	2351	7541	0.789	5952	-
2003	7326	0.496	3637	3493	1613	0.539	869	2511	3732	0.910	3396	2481	7621	0.833	6345	-
2004	4906	0.527	2585	2944	2159	0.588	1269	2690	4546	0.874	3975	2338	9813	0.954	9359	2095
2005	5142	0.529	2722	3006	2216	0.593	1313	2634	3564	0.866	3086	2315	9483	0.837	7935	2137
2006	3772	0.569	2147	3203	1056	0.567	1864	2247	2917	0.755	2202	1791	7284	0.827	6022	1799
2007	4177	0.624	2608	5368	2786	0.598	1666	3177	5545	0.788	4367	2052	8776	0.832	7304	871
2008	2128	0.582	1238	6123	1619	0.663	1073	4326	4468	0.713	3186	1659	9304	0.816	7588	756

2009	3153	0.568	1792	6026	1941	0.671	1303	5751	7371	0.830	6121	2257	11502	0.843	9700	1313
2010	5425	0.593	3219	6353	6151	0.687	4226	6710	5138	0.768	3944	1684	10184	0.867	8828	1566
2011	3487	0.608	2121	7003	3566	0.690	2459	6694	4063	0.858	3488	2206	10038	0.858	8612	1067
2012	1941	0.596	1157	6782	1011	0.644	651	7571	6384	1.007	6426	2937	11549	0.866	10004	874
2013	1836	0.617	1132	7021	1091	0.580	633	5268	3705	0.852	3156	2087	8763	0.853	7475	633
2014	2846	0.529	1505	5149	1583	0.730	1155	7200	3514	0.908	3189	2108	11099	0.869	9642	652
2015	1611	0.612	986	6276	1570	0.896	1406	9300	6379	0.881	5621	1526	8986	0.841	7555	507
2016	1727	0.626	1081	4736	2408	0.865	2082	6614	7824	0.893	6990	-58	12661	0.929	11763	-1322
2017	2587	0.655	1694	14479	2816	0.892	2511	11783	14653	0.951	13939	19941	15071	0.944	14220	1660
2018	3909	0.745	2913	16383	3244	0.970	3147	12873	19254	0.900	17333	16542	15920	0.883	14056	140
2019	4094	0.839	3434	18233	8494	1.146	9738	15354	19254	1.052	17333	19582	16567	1.390	23035	4110
2020	3582	0.724	2592	14071	6619	1.118	7402	15005	9275	1.034	9588	22391	11812	0.924	10910	1322
2021	3563	0.571	2036	7642	8544	0.976	8337	10813	10813	1.092	11804	19945	13186	1.086	14323	778
Aver	**4042.5**	**0.593**	**2317.8**	**6931.5**	**2923**	**0.725**	**2503**	**6552**	**6804**	**0.894**	**6173**	**6006**	**10531**	**0.891**	**9633.4**	**1164.5**
MIN	**1611**	**0.459**	**986**	**2549.1**	**996**	**0.489**	**541**	**1664**	**1496**	**0.713**	**1355**	**-58.5**	**7198**	**0.760**	**5562**	**-1322**
MAX	**7817**	**0.839**	**3787**	**18233**	**8544**	**1.146**	**9738**	**15354**	**19254**	**1.092**	**17333**	**22391**	**16567**	**1.390**	**23035**	**4110.0**

Source: Ministry of Agriculture and Agrarian Reclamation, Economic Affairs Sector, Central Department of Agricultural Economy, Bulletin of Agricultural Statistics, during the period (2000-2021).

3/25/2023