Impact of climate change on food security and sustainable development in Diyala Governorate

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Abstract

The research aims to know the impact of climate change on agricultural production in Diyala Governorate, represented by water shortage and desertification. The research reviewed the reality of plant production in the governorate and showed that the areas suitable for agriculture amounted to 3,563,630 dunums, while the unsuitable areas amounted to 2,992,633 dunums, which is a relatively large area, indicating a major problem and at the same time an opportunity to increase the agricultural area of the governorate by reclaiming these lands. The results also indicated that the areas planted with grains have also declined. For example, the wheat crop in 2017 had an area of 579,807 dunums. While in 2022 it became 160,667 dunums. The barley crop also declined significantly, as in 2022 it became 1,090 after its area was 675,700 dunums, while due to the impact of climate change and water scarcity, farmers resorted to expanding the cultivation of vegetable crops. Because it needs fewer supplies, for example, the tomato converter increased its area from 2975 to 5218 in 2022, and the bean crop expanded to 1311.4 dunums. Another result of the research is that desert lands increased from 657476.0 dunums in 2018 to 1544820 dunums, or about 887344 dunums, which causes economic, environmental and social damage to the governorate. In addition, the areas threatened by desertification expanded to 3713860 dunums, which sounds an alarm bell for agricultural production in the governorate, which is an agricultural governorate in which farm income represents a basic component of income. The research concluded that the governorate was greatly affected by climate change and bore economic and environmental costs. Accordingly, the research recommends adopting actual programs to combat desertification and confront these phenomena by adopting risk management strategies and drawing up an agricultural policy that takes into account the development of crop structures that maximize net farm income and maximize net return per unit of water.

Keywords: Desertification, water deficit, crop structure. food security. Economic costs. Environmental sustainabilit.

.1Introduction

Climate change has a major impact on the decline in water resources, and Iraq's location, which is considered a downstream country, is in a critical position because it is negatively affected by the measures of the countries located on the Tigris and Euphrates rivers and the decline in water revenues coming from outside it as a result of building dams and

agricultural development works in the upper basins and population growth and industrial development in it and in the absence of permanent agreements to determine water shares for each participating country, as well as Iraq's geographical location within the dry and semi-dry regions, as well as the economic, political and security conditions it faces [1]. Erosion of agricultural land is one of the natural problems facing agricultural lands in the world because of its impact on soil thickness and its productive capacity, in addition to playing a prominent role in the deterioration of agricultural lands in it, leading to the removal of fertility and reducing the productivity of agricultural crops and the loss of nutrients necessary for production, which prevents their use in agriculture, in addition to the spatial variation that has its positive and negative effects. Some studies have indicated that there are two types of erosion: water erosion, which is active in most environments, while wind erosion is active in arid and semi-arid areas [2]. Droughts can also be considered a temporary decrease in the average availability of water due to the lack of rainfall, which causes water scarcity and insufficient water resources to meet long-term needs [3]. Water scarcity is closely related to the different types of drought (weather, soil, agricultural hydrology), and water scarcity is not only caused by natural causes, but also by human activities [4]. In 1949, Af Heck presented a study entitled "Control of the Rivers of Iraq and How to Benefit from Their Water" by constructing dams and reservoirs and distributing water to benefit from it in various uses in Iraq. In 2001, Al-Najafi published a study on Arab water resources, in which he showed that there is a disparity in the distribution of surface water among Arab countries, as five countries, namely Egypt, Sudan, Iraq, Morocco and Syria, account for more than 80% of the surface water in the Arab world. This water is the most important in providing food supplies in the Arab world, and agriculture accounts for more than 90% of this water, while about 10% is distributed among non-agricultural uses. In 2002, the Arab Organization for Agricultural Development conducted a study on "Enhancing the Use of Water Harvesting Technologies in Arab Countries", which was done through the use of water harvesting technologies in the Arab region. It concluded that water harvesting is an important source in developing water resources and providing water in dry areas where irrigation water is not available, and this has an impact on increasing production and thus achieving profit from establishing agricultural projects. Al-Jubouri (2006) completed her thesis entitled "Arab Water Resources and Their Effects on Arab Food Security with Special Reference to Iraq / Potentials and Determinants[5].As for Diyala Governorate, its climate is hot and dry in the summer, as well as the sources feeding the Diyala River are located in Iran and outside its administrative borders, and the water course has changed and dams have been built outside it by Iran, in addition to the retention of rainwater, especially in recent years, and the drying up of the Diyala River and Lake Hamrin, which made the problem of water conservation and rationalization of its use a priority. Therefore, the government in Diyala Governorate has moved to reduce water quotas for the areas and villages located on it, especially agricultural ones, and to use what is called (Rashan) in order to provide potable water for the residents of the Governorate and urge them to rationalize its use in order to preserve and develop it by carrying out the process of water rationalization by not wasting

ISSN 2072-3857

water, and this appears in all areas of life. Water scarcity has also led to a decrease in the individual share of water to less than 50 liters per person, and has led to the destruction of many orchards, as the total area of orchards in the Governorate is (120,000) dunams, and water scarcity has caused the destruction of (25%) of them, and the area of agricultural land has decreased. The area of the Governorate is (1.5) million dunums, at a rate of (40%), and due to the scarcity and scarcity of water, the phenomenon of removing orchards and converting them into residential units is spreading, and industrial and commercial facilities have been established on agricultural lands [6.[

.1.1Research problem

Although Diyala Governorate is considered one of the Governorate s that play an important and major role in the agricultural sector in producing strategic crops such as wheat, rice, barley and other secondary crops, in addition to citrus orchards and palm summer squash, especially those adjacent to the banks of the Diyala River, it has recently witnessed a significant decline due to water scarcity, lack of rain and control over the sources from which the Diyala River is fed outside the administrative borders of the state, which led to a decrease in the water level in the Diyala River and Lake Hamrin, which led to the removal and bulldozing of orchards and their conversion into residential plots and private industrial facilities with commercial locations.[7 [

.1.2Research objective-:

The importance of the research is highlighted in its ability to study the most important productive changes affecting water scarcity on the agricultural sector in Diyala Governorate through-:

-1Studying the reality of agricultural production in Diyala Governorate

-2Studying the reality of water in Diyala Governorate for the period from 2017-2022

-3Measuring the impact of desertification and water scarcity on agricultural production

.1.3Research hypothesis -:

The research assumes that agricultural production in Diyala Governorate is negatively affected by climate change represented by desertification and water shortage, The water shortage has a greater impact on Diyala Governorate because it is an agricultural governorate.

.2Material and Methods-:

Data on winter and summer crops were obtained from the Ministry of Planning \ Directorate of Agricultural Statistics and from the Directorate of Agriculture in Diyala, as well as obtaining data on water quantities during the period 2017-2022 from the Directorate of Water Resources in Diyala Governorate.

Results and Discussion- :

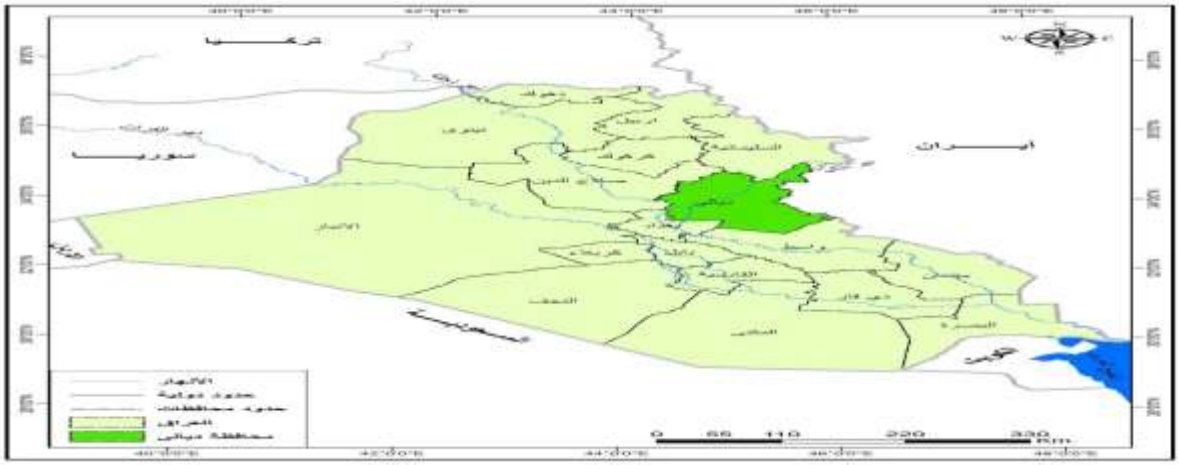
First: - Study of the reality of agricultural production in Diyala Governorate- :

Diyala Governorate location:- Diyala Governorate is located in the northeast of Baghdad Governorate between longitudes 46-44 east and latitudes 35-33 north (Diyala Agriculture Directorate) and is 65 km away from it, and is bordered to the south by Baghdad and Wasit Baghdad and Salah al-Din Governorates, and to the west by the Tigris River separates it from Baghdad and Salah al-Din Governorates, and to the north by Kirkuk and Sulaymaniyah Governorate [8]. The area of the Governorate according to the latest administrative divisions conducted in 2009 is (17685) km2 and constitutes about 40.66% of the area of Iraq, considering that the total area of Iraq is (434920) km2 (Hassan, 2023), and

ISSN 2072-3857

the Diyala River passes through it, which flows into the Tigris River, and it is one of the Governorate s famous for agriculture, especially citrus cultivation. Diyala is locally nicknamed "the city of oranges" which is considered one of its most famous and diverse crops and is also known as "Iraq's food basket". Agriculture is one of the most important sectors of Diyala and contains many different orchards and forests (Diyala Agriculture Directorate). This Governorate is famous for agriculture as most of its residents work in agriculture in both the plant and animal aspects. It is also famous for growing citrus fruits, pomegranates, grapes, apples, apricots, figs, etc. and vegetables of various kinds, as well as producing lentils in addition to wheat and barley, as well as raising poultry in its various activities [9]. [10.[

Figure 1. Location of Diyala Governorate in relation to Iraq



Source: General Authority for Survey, Administrative Map of Iraq, Baghdad, 2007.[3[

Table 1.Agricultural lands in Diyala Governorate classified according to the agricultural divisions affiliated with the Directorate of Agriculture.

No	Agricultural Division	Arable areas/dunum	Relative importance %	Areas not suitable for agriculture/dunum	Relative importance %	Total area dunums	Relative importance %
1	Baqubah Center	74532	2.091463	48265	1.612794	122797	1.872972
2	Bahriz	157669	4.424393	142334	4.756146	300003	4.575823
3	Bani Saad	138181	3.877535	60619	2.025608	198800	3.032215
4	Kanaan	106231	2.980977	114969	3.841734	221200	3.373873
5	Muqdadiyah	137762	3.865777	86544	2.891902	224306	3.421248
6	Al-Wajhiyah	109728	3.079108	51554	1.722697	161282	2.459968
7	Abi Saida	21627	0.606881	5985	0.199991	27612	0.421155

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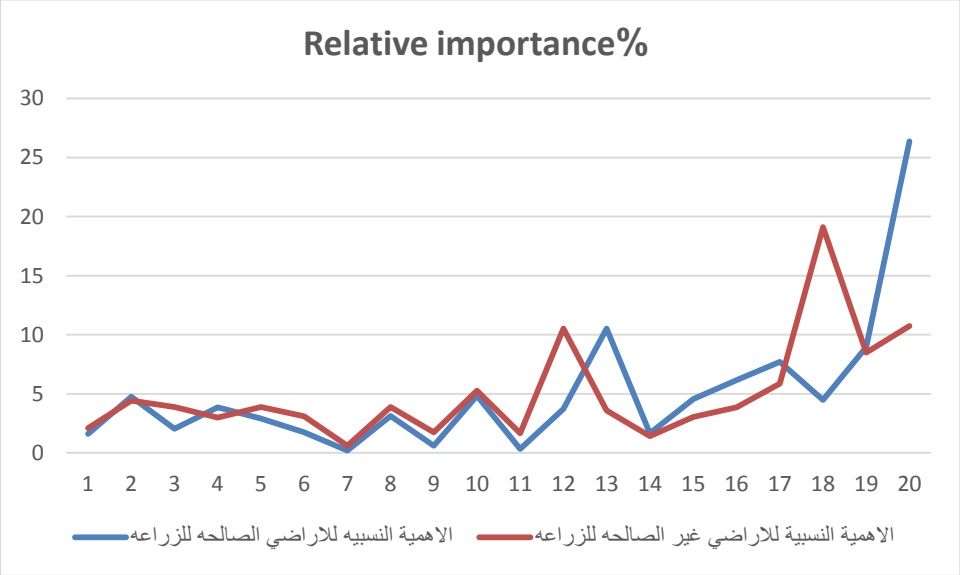
8	Al-Khalis	138234	3.879022	93661	3.129719	231895	3.537
9	Habbab	62061	1.741511	17704	0.591586	79765	1.216623
10	Al-Mansouriyah	187418	5.259188	144560	4.830529	331978	5.063525
11	Dar Al-Salam	59013	1.65598	9657	0.322692	68670	1.047395
12	The Great Dam	374316	10.50378	110976	3.708306	485292	7.401961
13	Khanaqin	127955	3.59058	314942	10.52391	442897	6.755327
14	Jalawla	50180	1.408115	49820	1.664755	100000	1.525259
15	Al-Saadiyah	107767	3.024079	136233	4.552279	244000	3.721632
16	Qara Tepe	137270	3.851971	183982	6.14783	321252	4.899925
17	Jabara	208428	5.848755	230372	7.69797	438800	6.692837
18	Balad Rose	680622	19.09912	133480	4.460286	814102	12.41717
19	Mandali	302000	8.474505	268000	8.955325	570000	8.693977
20	Qazaniyah	382636	10.73725	788976	26.36394	1171612	17.87012
	Total	3563630	100%	2992633	54.35		

Source: Researcher's work based on data from the annual report of the Directorate of Agriculture in Diyala Governorate 2021.

Figure 2. The relative importance of arable and non-arable lands



ISSN 2072-3857

It is noted from Table (1) which shows the areas of arable land and the areas of non-arable land according to the divisions in Diyala Governorate 2021 and their relative importance, it is clear that the smallest area of arable land is within the Abi Saida Agricultural Division, as it amounted to (21627) dunums, and its relative importance amounted to (0.606881186%) of the total arable land, and it is also of less relative importance compared to other divisions, while its percentage of the total arable and non-arable land in it amounted to (78.32%), while the area of arable land belonging to the Baladruz Agricultural Division was the largest area, as it was estimated at (680622) dunums, and it also received the highest percentage in terms of its relative importance, as it amounted to (19.09912084%), and this is due to the vast area of agricultural land in it and most of its residents work in agriculture, and after it came in terms of area and relative importance Each of (Qazaniya, Al-Sadd Al-Azeem, Mandali, Jabara, Al-Mansouriya, Bahraz, Al-Khalis, Bani Saad, Al-Muqdadiya, Qortabah, Khanaqin, Al-Wajhiya, Al-Saadiya, Kanaan, and Baqubah Center) respectively, as their percentages reached (10.73725387%, 10.50378406%, 8.474504929%, 5.848755342%, 5.259187963%, 4.424393105%, 3.879022233%, 3.877534985%, 3.865777311%, 3.851971164%, 3.590580391%, 3.079107539%, 3.02407938%, 2.980977262%, 2.091462918%). While the share of the least relative importance of arable lands belonging to the agricultural people (Habbab, Dar Al-Salam and Jalawla) was (1.741510763%, 1.655979998%, 1.408114759%) respectively.

Table 2. Cultivated areas and production of strategic summer and winter crops in Diyala Governorate.

Crops	Wheat		Barley		Sunflower		Corn	
Years	Area\dunum	Production\tons	Area\dunum	Production\tons	Area\dunum	Production\tons	Area\dunum	Production\tons
2017	579807	206438	675700	3256	-	-	-	-
2018	289980	179133	26286	428	-	-	-	-
2019	373780	309324	25769	12452	6164	2060	41231	19144
2020	637847	256758	58374	2114	-	-	1648	966
2021	472407	274566	32418	-	-	-	-	-
2022	160667	61749	1090	-	-	-		
Total	2514488	1287968	819637	4622093	6164	2060	42879	20110

Source: Researcher's work based on data from the annual report of the Diyala Agriculture Directorate 2021.

ISSN 2072-3857

Table (2), which shows the agricultural and productive areas of the strategic winter and summer crops for the above years, shows that the wheat crop reached its highest production in 2019, as production was estimated at (309,324) tons and an area of (373,780) dunums, while production decreased to (61,749) tons and an area of (160,667) dunums in 2022. The reason is due to the scarcity of water available in the Diyala River and Lake Hamrin, which are considered the lifeline of the Governorate , as they depend on them to provide drinking water in addition to irrigating agricultural areas, in addition to the lack of rainfall in these years and the increase in drought and global warming, which negatively affected the vegetation cover in the Governorate , while the highest production of barley was in 2017, as it was estimated at (675,700) tons and an area of (206,438) dunums, but in the years 2021,2022 There was no production of barley crop and also the low production is due to the same reason above, while for the sunflower and corn crops, production in 2019 amounted to (2060) tons and an area of (6164) dunums for the sunflower crop, while the production quantity for the corn crop in the years (2019,2020) respectively was estimated at (19144, 966) tons and an area of (41231, 1648) dunums respectively, as for the rest of the years we were unable to obtain data from their primary sources[11.[

Table 3. Cultivated areas in dunums for winter crops and vegetables in Diyala Governorate.

Years	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Crops						
Wheat	579807	289980	373780	637847	472407	160667
Barley	675700	26286	25769	58374	32418	1090
Green broad bean	1165	212.5	1165	1220	1125	207
Dried broad bean		20	120	135	35	49
Green onions		145.5	899	-	159	208
Dried onions		25	85	1022.5	679.5	1353.9
Garlic		7	65	69	20	1400
Turnip		68	363	326.5	215	5
Beetroot		3	53	67	19	95
Radish		20	166	150.5	89.5	84

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Lettuce		128	644	484	245	2
Lemon		116.5	558	723	364	2
Cauliflower		146.5	454	685	407	1387
Carrots		2	-	-	-	1947
Spinach		11	40	38	37	131
Chard		8	-	64.5	48.5	
Cress		1	18	19	4	
Celery		1	28	20	10	
Leek		-	1	18	-	
Potatoes		-	40	1083	244	
Basil		1			-	
Tomatoes covered	43	18.5	26	33	39	
Cucumbers covered	142	141.25	116	166.75	100.50	
Cold peppers covered	29	17.5	27	38	34	
Eggplant covered	73	62.75	64	99.5	85.5	
Leaf covered	24	9.5	10	3.75	3	
Okra covered	-	-	4		-	
Strawberries covered	-	5.5	-	2	-	
Watermelon covered	-	14	-		-	

Source: Researcher's work based on data from the annual report of the Diyala Agriculture Directorate 2021.

ISSN 2072-3857

Table (3) shows that the cultivated area of winter crops and vegetables, as the wheat crop reached (637847) dunums, while in 2020 it was the largest area compared to other years, while the cultivated area decreased to (160667) dunums in 2022, in addition to the fact that the barley crop area reached (675700) dunums in 2017, but this area did not remain stable until it began to decrease year after year until it decreased to (1090) dunums in 2022. The same is the case for the fava bean crop, the area decreased in 2022 to (207) dunums, while its largest area was (1125) dunums in 2021. As for vegetables (green onions, turnips, radishes, lettuce, celery, dried broad beans, chard, garden cress, leeks, dried onions, garlic, beets, cauliflower, carrots, spinach, potatoes), there was no area planted for them in 2017, while the largest area planted with vegetables (green onions, turnips, radishes, lettuce, celery) in 2019 reached (899, 363, 166, 644, 28) dunums, respectively, while the largest area planted with vegetables in 2020 was for the following vegetables (dry broad beans, chard, garden cress, leeks, potatoes), reaching (135, 723, 64.5, 19, 18, 1083) dunums, in addition to the fact that in 2022 the largest area for vegetables (dried onions, garlic, beets, cauliflower, carrots, spinach) was (1353.9, 1400, 95, 1387, 1947, 131) respectively. As for the covered vegetables that included (tomatoes, cucumbers, peppers, and eggplant) in 2021 (summer squash, okra, strawberries, and Watermelon), the largest area reached (468, 1667, 140, 1194) dunums in 2021, respectively, while no area was obtained for a year only in 2018 for strawberries and Watermelon, it was (3.3, 112) dunums. As for (summer squash), in the same year, the largest area reached (114) dunums.

Table 4. Total production estimated in tons for winter crops and vegetables in Diyala Governorate.

Years	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Crops						
Wheat	206438	179133	309324	256758	274566	61749.9
Barley	3256	428	12452	2114	-	-
Green broad bean		425	2330	2169	3375	414
Dried broad bean		8	48	54	-	19
Green onions		553	2697		1359	416
Dried onions		75	170	2440	477	241
Garlic		5.6	32	635	10	35
Turnip		150	726	301	430	10
Beetroot		6	106	134	38	245
Radish		44	332	300	179	104

ISSN 2072-3857

Lettuce	512	2576	3067	980	8
Lemon	385	1362	2055	1092	6
Cauliflower	513	1674	34	1221	3409
Carrots	3	332			101
Spinach	15.4	30	0	0	200
Chard	14.4	10	0	0	
Cress	1.5	1	0	4	
Celery	1.5	1	0	0	
Leek	-	1	0		
Potatoes	-	240	7581	1708	
Basil	1.6	-			
Tomatoes covered	172	222	312	396	468
Cucumbers covered	284	1412.5	1160	1667	1005
Cold peppers covered	87	140	54	76	68
Eggplant covered	438	878.5	768	1194	1026
Leaf covered	72	114	40	15	12
Okra covered	-	-	8		
Strawberries covered	-	3.3	-	1	
Watermelon covered	-	112	-		

Source: Researcher's work based on data from the annual report of the Diyala Agriculture Directorate 2021.

Table (4) shows the total production estimated in tons for winter crops and vegetables, as the highest total production of wheat in 2019 reached (309324) tons, and in the same year, the total production of barley reached its highest value (12452) tons, while in 2022, the total production of wheat decreased to (61749.9) tons, while there was no production of barley. The reason for the decrease in the amount of wheat production and the lack of production of barley is the scarcity of water and the lack of rain in particular, and the rain-

ISSN 2072-3857

fed lands depend entirely on rainwater, in addition to the lack of an agricultural plan this year. As for vegetables (green onions, turnips, radishes, carrots), their highest production was in 2019, as it was (2697, 726, 332, 332) tons, respectively. Each of (dried onions, garlic, lettuce, fennel, potatoes) reached (2440, 635, 3067, 2055, 7581) tons, respectively, in 2020, while the production of each of (beets, cauliflower, spinach) in 2022 reached (245, 3409, 200) tons. As for the rest of the vegetables, such as garden cress, celery, basil, and leeks, their production was little or almost non-existent. In addition to the covered vegetables, which included (tomatoes, cucumbers, peppers, Eggplant and summer squash) reached their highest production in the years (2021, 2020, 2018, 2021, 2018) tons, while both strawberries and covered watermelon did not produce anything but 3.3 tons of strawberries and covered watermelon 112 tons in 2018 .

Table 5. Cultivated areas in dunums for summer crops and vegetables in Diyala Governorate.

Years	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Crops						
corn	-	-	41231	1648	-	-
Sunflower	-	-	6164	-	-	-
Rice			20600		-	
Pistachio		1500	2000	1650	-	
Sesame		135	515	302	-	
Mung beans		120	2870	1200	-	
Vetches			50	40	-	
Millet			60		-	
Tomatoes		2957	5818	5845	958	5218
Eggplant		1192	2123	1925	104	1025
Cold pepper		532	838	820	30	450
Hot pepper		30	74	61	12	
Water cucumber		1496	2251	2610	165	4564
Cucumber		77	97	114	89	85
Gourd		306	1484	679	3	864
Tree		3818	12447	12890	1299	3964.0
Watermelon		347	2781	3717	502	514
Okra		1357	1748	1448	253	517

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Green beans	563	851	1367	148	1311.4
Onion	290	40		-	
Green onion	-	250	231	-	
Onion	-	74	125	724	
Charlid	14	-		-	
Celery	13	15		-	
Basil	12	15		-	
Leek	12	15		-	
Tomatoes covered	2148	855		65	2539
Eggplant covered	759	259		15	465
Cold pepper covered	202	168		2	245
Hot pepper covered	-	3		1	12
Water cucumber covered	1070	394		10	547
Tree	221	266		21	359
Watermelon covered	5675	2220		4400	5410.1
Okra covered	2225	890		1250	1684
Spring potatoes	100	20			105
Corn	-	7		38	

Source: Researcher's work based on data from the annual report of the Diyala Agriculture Directorate 2021 .

We note in Table (5) the areas planted with summer crops and vegetables. It is clear that the total area of corn in 2019 and 2020 was (41231, 1648) dunums, while in 2017, 2018, 2021 and 2022 there was no cultivated area, while the sunflower and rice crops had a total area of (6164, 20600) dunums, respectively, in

ISSN 2072-3857

2019. While field pistachios, sesame, mung beans, Vetches and millet had the highest area in 2019 and 2020. In addition, vegetables, including tomatoes, eggplant, cold peppers, hot peppers, water cucumbers, cucumbers, summer squash, watermelons, watermelons and beans were The highest total area for them in the following years 2018, 2019, 2020 and 2022, while the types of onions, chard, celery, basil and leeks decreased, fluctuated and lacked cultivated areas due to the low market value of them, while the highest total area for covered vegetables reached tomatoes, eggplant, cold peppers, hot peppers, water cucumbers, summer squash, watermelons, okra and spring potatoes in the following years 2018, 2019 and 2022.

Table 6. Total production estimated in tons for summer crops and vegetables.

Years / Crops	2017	2018	2019	2020	2021	2022
Corn			19144	966.800	-	
Sunflower			2060		-	
Rice		-	25369500		-	
Pistachio		1500	2000	1650	-	
Sesame		20.25	77.25	45.300	-	
Mung Beans		42	1004.5	420	-	
Vetches		-	25	20	-	
Millet		-	15		-	
Tomatoes		13306.5	26181	26302.500	4311	23575
Eggplant		5960	10615	9625	520	3602
Peppers		798	1257	1476	54	900
Hot pepper		30	74	61	12	-
Cucumber		3291.2	5064	6525	412.5	8891
snak cucumber		192.5	242	285	222.5	167
Summer squash		1224	5194	2376.500	73.5	2288
Watermelon		19090	62235	77340	7794	23558
Watermelon		1214.5	9733	14868	2008	2218
Okra		2442.6	3146	2896	148	964
Green beans		450.4	638	1367	148	459
Onion		435	60			

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Green onions	-	625	577.500		
Onion	-	111	187.500	1086	
Swiss chard	9.8	-		-	
Celery	7.8	9		-	
Basil	7.8	9		-	
Leek	4.8	9		-	
Tomatoes covered	11814	4702		780	9354
Eggplant covered	4554	1554		225	1611
Cold peppers covered	363.6	302		4	600
Hot peppers covered	-	3		1	7
Covered water cucumber	2889	1083		100	1527
Covered summer squash	994.5	1197		73.5	960
Covered leaf	34050	13320		26400	25779
Covered watermelon	8900	3560		5000	7578
Covered okra	200	40			132
Spring potatoes	-	49		266	

Source: Researcher's work based on data from the annual report of the Diyala Agriculture Directorate 2021.

Table (6) shows the total production estimated in tons for summer crops and vegetables, as the total production of corn, sunflower and rice (rice) has no production for the summer season (2017, 2018, 2021, 2022), while in 2019 and 2020, the total production of corn reached (19144, 966.800) tons, respectively, while the total production of sunflower and rice crops in 2019 only amounted to about

(2060, 25369500) tons, respectively. As for each of the field pistachios, it reached (1500, 2000, 1650) tons, sesame reached (20.25, 77.25, 45.300) tons, mung beans reached (42, 1004.5, 420) and Vetches reached (25, 20) tons, their total production for the summer season 2018, 2019, 2020. In the 2017, 2021 and 2022 seasons, there is no production of these crops due to the low demand for them and thus the low price value for them, while the millet crop was not produced in 2019, as it amounted to (15) tons, also for the same previous reason, there was no production quantity in the mentioned seasons. As for vegetables, tomatoes, eggplant, cold peppers, hot peppers, water cucumbers, cucumbers, summer squash, watermelons, okra and beans, the highest production reached (26302.500, 9625, 1476, 8891, 222.5, 5194, 23558, 3146, 1367) respectively for the years 2019, 2020, 2021 and 2022, while onions of all kinds, chard, celery, basil and leeks decreased and fluctuated in production, and for some seasons they were non-existent. The reason is the low market value of it, while the highest production of covered vegetables reached tomatoes, eggplant, cold peppers, hot peppers, water cucumbers, summer squash, watermelons, watermelons, okra and spring potatoes in the following years 2018, 2019, 2021 and 2022.

Second: - Studying the reality of water in Diyala Governorate for the period from 2017-2022.

Water resources, in addition to their impact on the nature and quantity of production, are the main factor determining production and expansion. The process of developing water resources remains one of the main and effective pillars in sustainable agricultural development plans, especially at a time when the problem of providing water is considered one of the most complex problems at the international and local levels. Achieving water security is a guarantee for achieving and continuing food security as a guarantee for sustainable agricultural development, which has become the desired goal of every agricultural policy[12]. The agricultural sector drains about (3300) cubic kilometers of water from the rivers of the globe every year to irrigate crops, i.e. six times the annual discharge of the Mississippi River [13]. The Diyala River is the main source of surface water in Diyala Governorate. The Diyala River Basin has a north-east-southwest extension, as it lies between longitudes (46.18-44.30) east and latitudes (53.50-33.10) north, as it is far from high areas that reach an altitude of 3371 m. Above sea level [14]. and slopes southward to flow into the Tigris River south of Baghdad, where the land height reaches 33 m above sea level [15]. As for rain, it constitutes the second agricultural water resource in Iraq in general and Diyala in particular after surface water, as it is used especially in the northern and northeastern regions where rainfall rates are high, which helps in the spread of rain-fed agriculture. Therefore, Table (7) shows the quantities of water released from Lake Hamrin in Diyala Governorate and its relative importance. The largest quantity of water released from Lake Hamrin in 2019 was estimated at (118184) m3/s, which made its relative importance 44.239%. This in turn led to an increase in the amount of water also coming to each of the Diyala River, the Joint River, the Khalis River, and then the Haruniya River. The quantities of water were estimated at (72959, 26658.8, 18513, 109.2) m3/s respectively, while the amount of water released in 2022 decreased as it was estimated at (9574) m3/s, which led to a decrease in its relative

importance to 3.583%, which in turn led to a decrease in the amounts of water received by each of the Harouniya River, the Diyala River, the Khalis River, and then the Joint River, as it was estimated at (17.0425, 371, 2283, 6633. 107) m3/s respectively. This is due to the scarcity of rain, which led to a significant decrease in the water level of the Diyala River, which greatly affected agricultural production.

Table 7. The amounts of water released from Lake Hamrin to the rivers in Diyala Governorate from 2022-2017

Year	Total amount of water released from Lake Hamrin m3/sec	Khalis River m3/sec	Diyala River m3/sec	Northern Harouniya River m3/sec	Al-Mushtarak River m3/sec	Relative importance %
2017	30950	6907	9830	56.5	14177.6	11.58534
2018	33875	7087	14352	33.95	12421.65	12.68024
2019	118184	18513	72959	109.2	26658.8	44.23915
2020	60300	9359	7770	29.72	14680.68	22.57176
2021	14265	3133	1450	22.45	9063.7	5.339737
2022	9574	2283	371	17.0425	6633.107	3.583781
total	267148	47282	106732	268.8625	83635.54	100

Source: Researcher's work based on data from the Diyala Water Resources Directorate.

Table (8) showed that in 2022, the amount of water coming to Diyala Governorate from Lake Hamrin was 18878.1495 m3/s. While the highest annual total of the amount of water coming in was 2073 m3/s in August, with the highest relative importance, as it constituted 11.332%, while the lowest annual total of the amount of water coming in was 765.4175 m3/s in November, with a relative importance of zero. This is due to the climatic reasons mentioned previously in 2022. Therefore, we notice a clear difference in the amounts of water coming in, which is reflected in the use of agricultural lands. In years in which the amount of water coming in is low, a plan is developed by the agricultural departments and irrigation departments in which the areas are limited due to the scarcity of water. However, in the year in which the water revenue is high, it becomes possible to expand the cultivation of the lands.

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Table 8.The amounts of water released from Lake Hamrin to the rivers in Diyala Governorate in 2022

Month	Total amount of water released from Lake Hamrin m3/sec	Khalis River m3/sec	Diyala River m3/sec	Northern Harouniya River m3/sec	Al-Mushtarak River m3/sec	Total m3/s	Relative importance%
January	795	219	31	1.6	479.4	1526	8.303739
February	700	168	28	1.25	418.75	1316	7.311469
March	855	205	39	2	514	1615	8.930437
April	930	217	40	1.575	558.575	1747.15	9.713808
May	775	178	31	1.15	595.675	1580.825	8.09484
June	770	183	30	1.25	528.775	1513.025	8.042615
July	1034	220	50	1.35	634.6791	1940.029	10.80008
August	1085	217	62	1.6	707.4	2073	11.33278
September	990	198	48	1.575	663.3	1900.875	10.34051
October	930	167	12	1.4	426.6	1537	9.713808
November	0	165	0	1.3175	599.1	765.4175	0
December	710	146	0	0.975	506.853	1363.828	7.415918
Total	9574	2283	371	17.0425	6633.107	18878.15	100

Source: Researcher's work based on data from Diyala Water Resources Directorate.

Third: Measuring the impact of desertification and water scarcity on agricultural production.

Desertification is one of the aspects of land degradation and the decline and decrease of agricultural productivity in one or both of the two elements, namely plant growth and soil, and not in the governing elements (climate and terrain). The decline of plant growth is directly related to the productivity of the land and thus the decline in yield and soil degradation means the loss of some of its fertility or damage to its physical or chemical properties[16]. [17]. It may be easy to measure the degradation of agricultural land if its productivity declines, but the issue has aspects. The problem of pasture degradation and its accompanying effects on livestock is considered degradation from the point of view of the land and its economics, while uprooting forests and

converting them into agricultural lands is environmental degradation because plant growth declines in terms of quantity and biodiversity, but from the point of view of economic benefit, this transformation is considered reclamation and development. While we find that urban encroachment on agricultural lands or the conversion of agricultural lands to other uses is degradation from the point of view of agricultural production, but it is a transformation that raises the financial value of the land and its economic weight[18]. [19]. therefore, Governorate is within the extension of the dry climate, which is characterized by low and fluctuating rainfall and high temperatures for six consecutive months, which is reflected in the manifestations of desertification and its variation in Diyala Governorate. In addition, urban expansion at the expense of agricultural lands is linked to the phenomenon of rapid population growth in the sizes of cities and villages, as the increase in population numbers leads to an increase in demand for agricultural lands[20]. Mining is also one of the common industries that cannot be dispensed with, as the demand for raw materials increases continuously with the increase in development, which is a factor that has a direct impact on agricultural lands in the Governorate due to misuse. The way humans use the land and its natural resources at the local level is one of the most important elements causing desertification [21]. Diyala Governorate e is one of the places that is characterized by the presence of this type of human activities due to the abundance of raw materials in large quantities, especially for construction purposes, such as gravel quarries in the Hamrin Hills and sand and gravel factories on the banks of the Diyala River in Mansouriya al-Jabal [22]. The Environment Department in Diyala Governorate announced an increase in desertification rates in the Governorate by more than 30%, due to drought, declining water resources, and climate change, in addition to unplanned urban expansion and encroachments on the vegetation cover in the cities and towns of the Governorate . In addition to the absence of programs to combat desertification due to the lack of necessary financial allocations and the failure to use modern irrigation techniques, desertification rates in Diyala have increased. The rates have also increased particularly in the north and east of the Governorate , in the districts of Al-Azim, Qazaniya, Mandali, and the outskirts of Muqdadiyah, in addition to the increase in unplanned tree cutting, urban sprawl, and the conversion of orchards into residential lands. Table (9) shows that the area of desert, desertified and desertification-threatened lands for the years 2017-2021 is stable in Diyala Governorate, reaching (657476.0, 1737990.0) dunums, respectively, with a constant relative importance of 13.898% of the total desertified and desertification-threatened lands. The stability of desertified areas for these years is due to the urban expansion witnessed by the Governorate , as well as the stability of sand dunes for the same previous years, reaching (49147.6) dunums, and their relative importance was 17.017%, while the area of desert, desertified and desertification-threatened lands increased in 2022, reaching (1544820.0, 3713860.0) dunums, which led to an increase in the percentage to 30.509% of the total area of desert, desertified and desertification-threatened lands. While the area of sand dunes decreased to (43071.0) dunums, and their relative importance decreased to 14.913%. This is due to the sand dune stabilization operations represented by planting summer

ISSN 2072-3857

squash resistant to salinity, conducting voluntary awareness campaigns, and afforestation. The agricultural lands of farmers affected by the encroachment of sand dunes were treated.[23.[

Table 9. Area of desert, desertified, desertified and sand dune lands in Diyala Governorate for the period 2017-2022

Year	Desert and desertified lands	Lands threatened by desertification	Total desertified and desertified lands	Relative importance %	Sand Dunes	Relative importance % Of sand dunes
2017	657476.0	1737990.0	2395466	13.8980309	49147.6	17.0173367
2018	657476.0	1737990.0	2395466	13.8980309	49147.6	17.0173367
2019	657476.0	1737990.0	2395466	13.8980309	49147.6	17.0173367
2020	657476.0	1737990.0	2395466	13.8980309	49147.6	17.0173367
2021	657476.0	1737990.0	2395466	13.8980309	49147.6	17.0173367
2022	1544820.0	3713860.0	5258680	30.5098454	43071.0	14.9133164
Total	4832200	12403810	17236010	100	288809	100

Source: Researcher's work based on data from the Central Statistical Office for Statistics, Environmental Statistics for Iraq, Agricultural Indicators for the period 2017-2022 [24.[

Conclusions

The world has witnessed major climate changes with serious repercussions. The agricultural sector is the most affected by these changes. These changes, represented by water shortages and desertification, have led to a shrinkage of arable areas, a decline in productivity, and a decrease in the water share allocated to the agricultural sector, especially in Diyala Governorate, where its strategic crops such as wheat, rice, and barley have been affected, in addition to citrus orchards and palm trees. Also, thanks to the above, vegetable crops have disappeared from the summer crop composition in the governorate. Also, the amount of water released from Lake Hamrin has decreased by almost a third, as it was 30,950 m3/s in 2017 and became about 9,574 m3/s in 2022. Also, the desertified areas have increased significantly in the governorate. This calls for taking measures to establish a clear agricultural policy based on developing a crop mix that maximizes net income and maximizes net water returns, as well as developing strategies to address desertification and confront water shortages.

ISSN 2072-3857

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