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ENVIRONMENTAL FEASIBILITY OF INVESTING IN THE WATERS OF THE EASTERN EUPHRATES DRAIN IN DHI QAR GOVERNORATE

VIABILIDADE AMBIENTAL DO INVESTIMENTO NAS ÁGUAS DO CURSO INFERIOR DO EUFRATES ORIENTAL, NA PROVÍNCIA DE DHI QAR

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Abstract
The study of the environmental feasibility of the Euphrates River drainage water came to highlight the agricultural activity in the region and reveal the type of crop in it, and then use the best methods for water desalination, while presenting all the proposed solutions for the purpose of stabilizing the sand dunes with the water of the eastern Euphrates drainage in the study area. The research revealed the types of summer crops represented by (wheat and barley). The research also covered winter crops (rice, yellow corn, white corn, dates, and summer and winter vegetables), and highlighted the importance of the East Euphrates drain in developing fish stocks. Furthermore, the research demonstrated the crucial role of the East Euphrates drain in revitalizing the marshes by employing methods such as reducing salinity in the drain's outlet General) (Reviving the marshes through the formation of treatment plants) (Reviving the marshes and monitoring the salinity of the waters of the general outfall drain through the formation of specialized committees) (The role of the eastern Euphrates drain in preventing flood risks).

Keywords: Environment. Drainage Canal. Dhi Qar.

Resumo
O estudo da viabilidade ambiental das águas da bacia hidrográfica do rio Eufrates teve como objetivo destacar a atividade agrícola na região e identificar os tipos de culturas presentes, para, em seguida, aplicar os melhores métodos de dessalinização da água, ao mesmo tempo em que apresentava todas as soluções propostas com o objetivo de estabilizar as dunas de areia utilizando as águas da bacia hidrográfica do Eufrates Oriental na área de estudo. A pesquisa revelou os tipos de culturas de verão, representadas pelo trigo e pela cevada. A pesquisa também abrangeu as culturas de inverno (arroz, milho amarelo, milho branco, tâmaras e hortaliças de verão e inverno) e destacou a importância da drenagem do Eufrates Oriental no desenvolvimento dos estoques de peixes. Além disso, a pesquisa demonstrou o papel crucial da bacia hidrográfica do Eufrates Oriental na revitalização dos pântanos, empregando métodos como a redução da salinidade na foz da bacia (Revitalização dos pântanos por meio da criação de estações de tratamento) (Revitalização dos pântanos e monitoramento da salinidade das águas da foz geral da bacia por meio da formação de comitês especializados) (O papel da bacia hidrográfica do Eufrates Oriental na prevenção de riscos de enchentes).

Palavras-chave: *Meio Ambiente. Canal de Drenagem. Dhi Qar.*

1 INTRODUCTION

Water represents the primary driver of natural systems for all living organisms and constitutes the fundamental pillar of human and economic stability. Through water availability and quality, the suitability of regions for human utilization is determined, as well as the capacity to exploit and invest in them agriculturally and economically, and to sustain various vital activities. This significance necessitates the study of the qualitative physical and chemical characteristics of irrigation and drainage waters in the study area.

The study area is predominantly agricultural in nature. Farmers rely on irrigation from canals and the main and secondary rivers located west of the agricultural lands. Excessive use of irrigation water has contributed to increased soil salinity. Moreover, water used in agricultural operations, which is withdrawn from the river by pumps, carries dissolved salts, pesticides, and residues of chemical fertilizers. These substances leave negative impacts on plants, weaken their growth, and reduce productivity.

The disposal of irrigation water through drainage systems, or the removal of excess water, has generated additional challenges. Drainage-related problems manifest in soil compaction and increased bulk density, which slow water movement within the soil profile. This, in turn, negatively affects plant growth, leading to leaf yellowing and reduced yields. Accordingly, this research aims to shed light on the most significant qualitative characteristics of irrigation and drainage water in the study area.

1.1 Research problem

The research problem represents a scientific question that can be addressed through systematic investigation and analysis, forming the foundation of scientific inquiry. In this context, the researcher examines the qualitative physical and chemical characteristics of irrigation and drainage waters in the study area.

Thus, the research problem is formulated as follows: **To what extent can drainage water in the study area be utilized or invested?**

1.2 Research hypothesis

The researcher assumes that there is variation in the qualitative characteristics (physical and chemical) of irrigation and drainage waters in Al-Mishkhab District. These characteristics can be evaluated to determine their suitability for use.

Accordingly, the research hypothesis states: **There is a potential for utilizing drainage water in the study area.**

1.3 Research objective

The research aims to determine the potential for utilizing the drainage water of the Euphrates by analyzing water samples and assessing their suitability for environmental and human uses.

2 LOCATION OF THE STUDY AREA

Administratively, the Eastern Euphrates Drainage Project is located within four governorates: Najaf, Al-Qadisiyyah, Al-Muthanna, and Dhi Qar. It lies within the floodplain lands between longitudes (44°24′–46°20′ E) and latitudes (31°17′–32°24′ N), in the central part of the Middle Euphrates region.

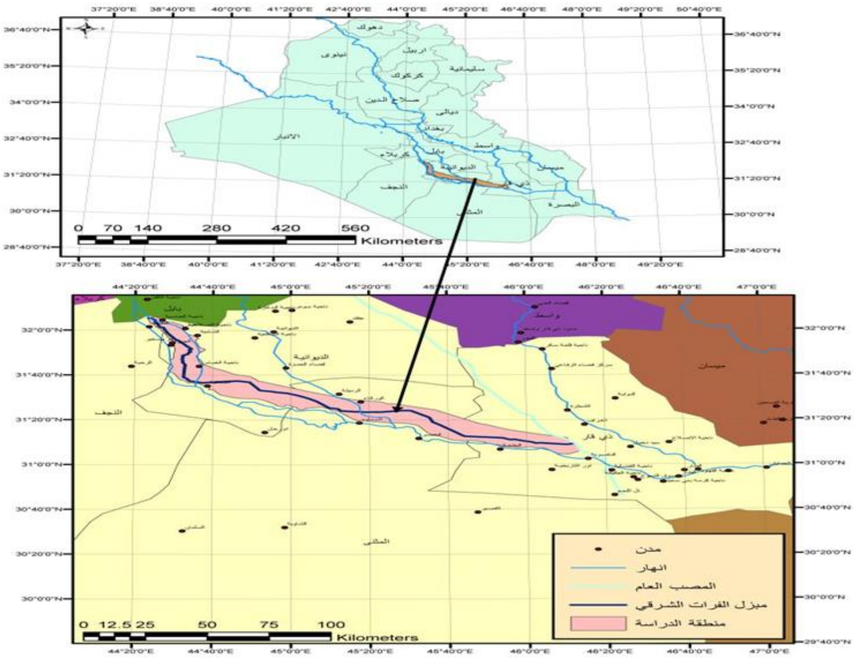
Geographically, the area is bordered to the north by Babylon, to the west and northwest by Najaf, to the south by Al-Muthanna, and to the southeast by Dhi Qar.

The Eastern Euphrates Drainage Canal is located in southern Iraq and represents one of the most important agricultural drainage networks in the Middle Euphrates plain. Its course begins southwest of the city of Najaf and extends southeastward across extensive agricultural lands in the governorates of Al-Qadisiyyah, Dhi Qar, and Al-Muthanna.

The canal aims to discharge excess irrigation water and agricultural drainage water, thereby reducing soil salinity and preventing the rise of groundwater levels (see Map 1).

Map 1

Location of the study area



Source: Based on Landsat Sentinel satellite imagery

2.1 Agricultural activity in the study area

The use of water in agricultural activity represents the most consumptive utilization of water resources within the basin. High evaporation rates, accompanied by variability and scarcity of rainfall, make surface water the principal resource sustaining agricultural operations. The area of arable land within the Euphrates Basin inside Iraq is estimated at approximately one million hectares. The annual water requirement for each cultivated hectare reaches about **14,000 m³/year**, resulting in a total water demand for the irrigated areas of approximately **14 km³/year**.(1)

The availability of surface water in the study area, together with the relatively flat terrain in some parts, has made agriculture the dominant occupation upon which a large proportion of the population depends. However, the location of the area in southern Iraq, at the downstream reaches of both the Euphrates and Al-Gharraf rivers, has negatively affected agricultural productivity because of reduced water shares, particularly during the low-flow (summer) season.(2)

2.2 Agricultural areas and crop types

There is considerable variation among cultivated areas in terms of water requirements. During the winter season, lower temperatures and reduced evaporation prevail, whereas the hot season is characterized by high temperatures, minimal rainfall, longer sunshine duration, and increased wind speed. The flat surface of the study area further accelerates wind movement, reducing humidity levels. Consequently, crop water demand increases, exposing the soils to salinization and raising salt concentrations in the waters of the Eastern Euphrates drainage canal.(3)

Crop type also influences the characteristics of drainage water. Plants differ in water consumption according to crop size, morphology, and the number of irrigation cycles required, which affects both the quantity and quality of drainage return flows.

3 CHANGES IN LAND COVER AND DESERTIFICATION (2021–2025)

Based on the data presented in Table (36) and Map (11), the spatial extent of desertified land in the study area changed noticeably during the period 2021–2025.

Year 2021

- **Summer:** Desertified land covered **12.23745 km² (0.4178%)**; bare soil **2246.33 km² (76.69%)**; natural vegetation **670.4329 km² (22.89%)**;
- **Winter:** Desertified land **13.56 km² (0.46%)**; bare soil **2119 km² (72.34%)**; natural and cultivated vegetation **796.7 km² (27.20%)**.

Year 2022

- **Summer:** Desertified land increased markedly to **2107.0782 km² (71.95%)**; bare soil **643.178 km² (21.95%)**; natural vegetation **178.741 km² (6.10%)**;
- **Winter:** Desertified land **1939.89 km² (66.26%)**; bare soil **583.458 km² (19.83%)**; natural and cultivated vegetation **405.642 km² (13.85%)**.

Year 2023

- **Summer:** Desertified land **1980.393 km² (67.63%)**; bare soil **743.38 km² (25.38%)**; natural vegetation **205.224 km² (7.00%)**;
- **Winter:** Desertified land **1914.39 km² (65.37%)**; bare soil **575.19 km² (19.83%)**; natural and cultivated vegetation **939.14 km² (14.99%)**.

Year 2024

- **Summer:** Desertified land **11.552593 km² (0.39%)**; bare soil **2411.7665 km² (82.34%)**; natural vegetation **505.67695 km² (17.26%)**. The increase in barren land is attributed to land abandonment by farmers due to water scarcity and limited rainfall, as well as irregular cultivation patterns that leave land vulnerable to erosion.(4)
- **Winter:** Desertified land **1891.3 km² (64.57%)**; bare soil **707.16 km² (24.15%)**; natural and cultivated vegetation **330.52 km² (11.18%)**.

Year 2025

- **Summer:** Desertified land **2102.437842 km² (7.18%)**; bare soil **661.575211 km² (2.26%)**; natural vegetation **164.985721 km² (0.56%)**;
- **Winter:** Desertified land **2160.142937 km² (73.75%)**; bare soil **555.087793 km² (18.95%)**; natural and cultivated vegetation **213.767953 km² (7.30%)**.

The expansion of desertified areas is associated with several human and environmental factors, including agricultural neglect caused by water shortages, urban encroachment on farmland, irregular road construction, livestock movement disturbing the upper soil layer, and the removal of trees and shrubs by farmers to expand cultivation areas. These processes have contributed to the reduction of green cover in favor of degraded and barren lands.(5)

Table 1

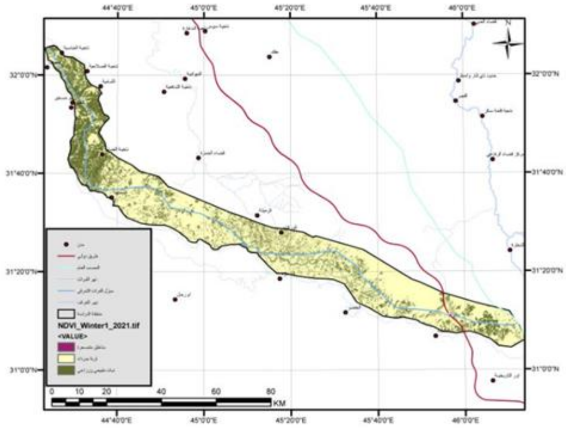
Area (km²) and Percentage (%) of Land Cover Classes in the Study Area (2021–2025)

Class	2021 Summer	%	2021 Winter	%	2022 Summer	%	2022 Winter	%	2023 Summer	%	2023 Winter	%	2024 Summer	%	2024 Winter	%	2025 Summer	%	2025 Winter	%
Desertified Areas	12.23745	0.417803	13.56	0.46	2107.0782	71.95	1939.89	66.264	1980.393	67.63	1914.39	65.37	11.55259	0.39	1891.3	64.57	2102.437842	7.18	2160.142937	73.75
Bare Soil	2246.33	76.69271471	2119	72.34	643.178	21.95	583.458	19.826	743.38	25.38	575.19	19.64	2411.7665	82.34	707.16	24.15	661.575211	2.26	555.087793	18.95
Natural and Agricultural Vegetation	670.4329	22.88948229	796.6	27.20	178.741	6.10	405.642	13.853	205.224	7.00	439.14	14.99	505.67695	17.26	330.52	11.28	164.985721	0.56	213.767953	7.30
Total Area	2929.006	100	2929	100	2928	100	2928	100	2928	100	2928	100	2928.9961	100	2928	100	2928.999	100	2928.999	100

Source: Prepared by the researcher based on Vegetation Cover Index (NDVI) maps for the years (2021–2025).

Map 2

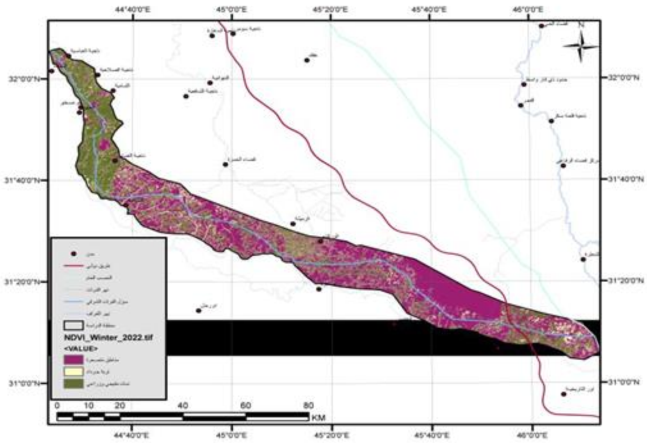
Vegetation Cover Index for Winter 2021



Source: Based on Sentinel satellite data and NDVI vegetation cover equations in ArcGIS Pro 10.8

Map 3

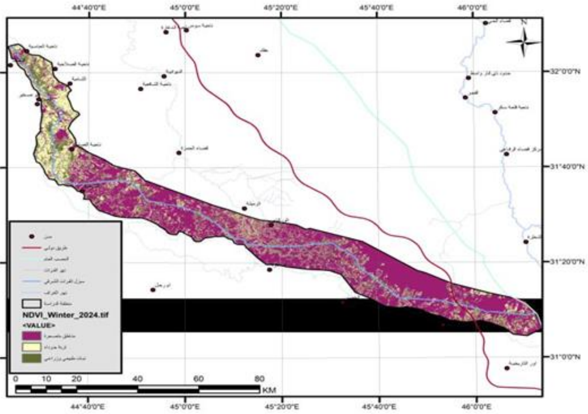
Vegetation Cover Index for Winter 2022



Source: Based on Sentinel satellite data and NDVI vegetation cover equations in ArcGIS Pro 10.8

Map 4

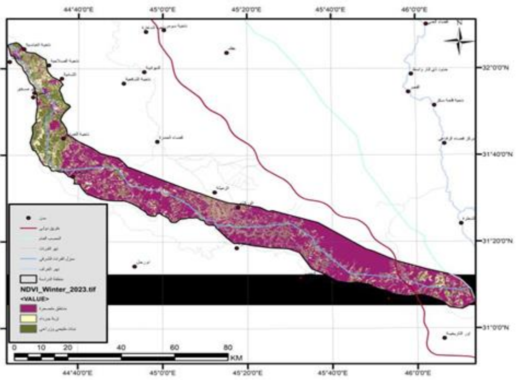
Winter Vegetation Index 2023



Source: Based on Sentinel satellite data and NDVI vegetation cover equations in ArcGIS Pro 10.8

Map 5

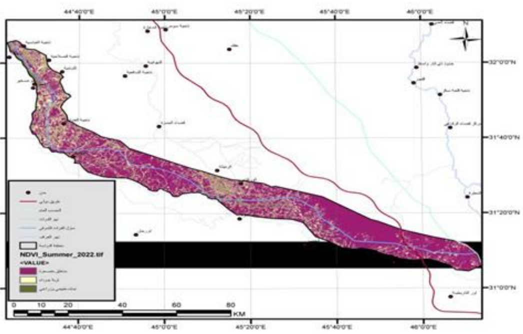
Winter Vegetation Index 2024



Source: Based on Sentinel satellite data and NDVI vegetation cover equations in ArcGIS Pro 10.8

Map 6

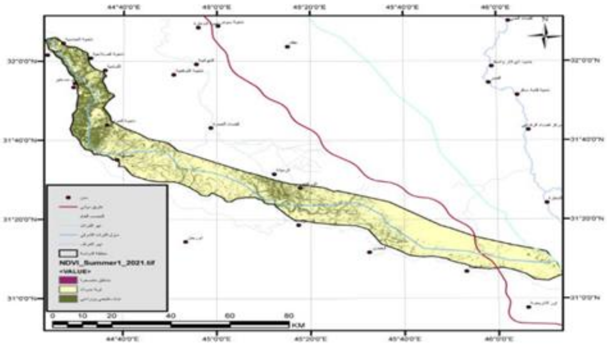
Summer Vegetation Cover Index 2022



Source: Based on Sentinel satellite data and NDVI vegetation cover equations in ArcGIS Pro 10.8

Map 7

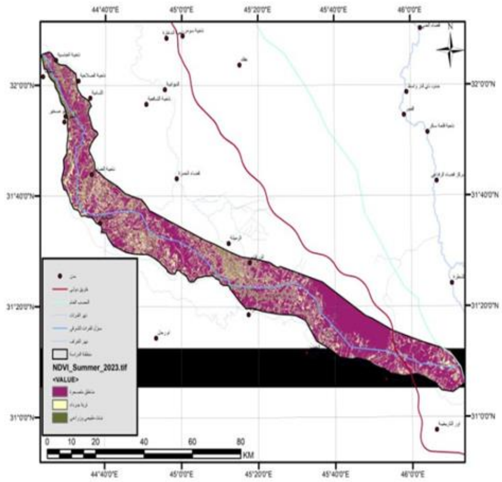
Summer Vegetation Cover Index 2021



Source: Based on Sentinel satellite data and NDVI vegetation cover equations in ArcGIS Pro 10.8

Map 8

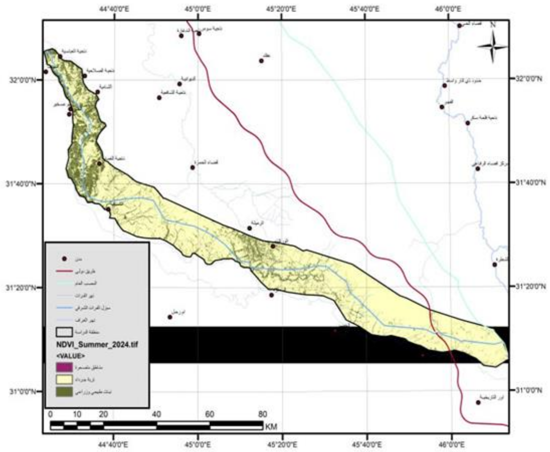
Summer Vegetation Cover Index 2023



Source: Based on Sentinel satellite data and NDVI vegetation cover equations in ArcGIS Pro 10.8

Map 9

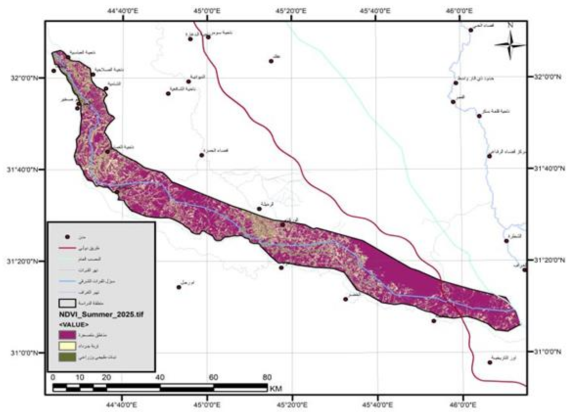
Summer Vegetation Cover Index 2024



Source: Based on Sentinel satellite data and NDVI vegetation cover equations in ArcGIS Pro 10.8

Map 10

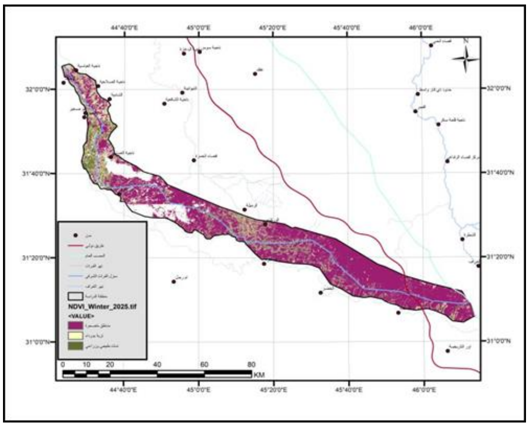
Summer Vegetation Density 2025



Source: Based on Sentinel satellite data and NDVI vegetation cover equations in ArcGIS Pro 10.8

Map 11

Winter Vegetation Density Index 2025



Source: Based on Sentinel satellite data and NDVI vegetation cover equations in ArcGIS Pro 10.8

4 POTENTIAL FOR UTILIZING THE EASTERN EUPHRATES DRAINAGE WATER IN IRRIGATION OF AGRICULTURAL CROPS

Surface (flood) irrigation is one of the most common irrigation methods in the study area due to its relatively low cost compared with other irrigation techniques. This is also related to the topographic setting, as many agricultural lands located within river basins lie at elevations lower than the water levels in canals and rivers. However, this method is characterized by non-uniform water distribution across agricultural fields and requires large quantities of water, resulting in significant water losses and wastage. Tail-end fields (downstream plots) receive less water than those located near irrigation channels and therefore often do not obtain sufficient irrigation.(6)

Pumped irrigation (mechanized irrigation) is used in higher-elevation areas and particularly during the low-flow summer season. The irrigation method plays a major role in increasing soil salinity and influencing the properties of drainage water. In flood irrigation, water is applied directly to the soil surface, causing ponding and infiltration. When excess water combines with high temperatures, salts accumulate due to evaporation, increasing salinity concentrations in drainage canals and raising the volume of return flows. This affects both the qualitative and quantitative characteristics of drainage water.7()

By contrast, pumped irrigation reduces the amount of water discharged into drainage canals because pump operation, discharge rate, and flow velocity can be controlled, thereby regulating water supply to agricultural lands.

Drainage water may be reused for agricultural irrigation after desalination. Desalination is the process of reducing dissolved salts—such as chlorides, sodium, magnesium, sulfates, carbonates, and calcium—from saline water to levels suitable for human and environmental uses, transforming saline water into freshwater through various techniques.(8)

4.1 Methods of desalinating saline water

4.1.1 Reverse Osmosis (RO)

This is one of the most suitable methods for treating brackish water, including wastewater. It is among the most widely used technologies after rapid distillation. The process requires pressure ranging from **25–30 bar**. Water passes through semi-permeable membranes that allow water molecules to pass while retaining dissolved salts. The pressure differential across the membrane constitutes the driving force for separation and dilution of the concentrated solution.(9)

4.1.2 Distillation (thermal processes)

1. **Multi-Stage Flash Distillation (MSF):**

Water is heated to approximately **90–120°C** in a brine heater and then introduced into chambers with low pressure. As temperature decreases gradually from one stage to another, flash evaporation occurs. The vapor condenses in heat-exchange tubes, preheating the incoming feedwater. This method is characterized by long operational continuity (2–5 years), the ability to produce large quantities of desalinated water, and high purity levels (often less than 20 ppm total dissolved salts).(10)

2. **Multiple-Effect Distillation (MED):**

This process takes place in a series of evaporator chambers operating under reduced pressure. The vapor produced in the first evaporator condenses in the second, which in turn acts as a condenser for the first, and so on. Each successive evaporator serves as a condenser for the previous stage, allowing repeated utilization of thermal energy without additional heating after the first chamber.(11)

4.1.3 Blending water sources (mixing with the Euphrates and Al-Gharraf rivers)

This method involves managing saline water during plant growth stages according to crop tolerance. For salt-sensitive crops, non-saline water is used before germination, whereas salt-tolerant crops may be irrigated with saline water after germination, provided that higher-quality water is supplied during critical growth stages. Field experiments conducted in California using Colorado River water mixed with drainage water demonstrated that supplying drainage water at 75% of crop water requirements did not reduce crop yields in crop rotations such as wheat, sugar beet, watermelon, wheat, and cotton.(12)

4.1.4 Solar desalination

This method is simple and relatively low in cost but cannot be applied everywhere because it depends on high ambient temperatures and solar radiation. Water is exposed to solar heat within an enclosed system (solar still), where evaporation occurs and vapor condenses into purified freshwater free of salts. Solar distillation can contribute effectively to water desalination and supply.

4.1.5 Direct and indirect freezing

Known as the Zarchin process (vacuum freezing and evaporation), this method relies on natural physical phenomena. Water cooled in a heat exchanger enters a crystallization tower under very low pressure (approximately 0.005 atm), causing partial flash evaporation. When freezing occurs, the separated ice crystals are salt-free and, after melting, produce water suitable for irrigation. However, this technique is costly, requires large equipment, and needs extensive operational space.(13)

4.1.6 Magnetic water treatment (delta water device)

This magnetic water treatment device alters the physical characteristics of water by facilitating the formation of free ions that can be washed away with drainage water.(14) It increases plant capacity to absorb water by breaking water and salt clusters into smaller particles, thereby improving water use efficiency even in highly saline soils.(15)

4.2 The importance of the eastern euphrates drainage canal in stabilizing sand dunes

Sand dunes are formed as a result of erosion processes that fragment rocks into sand particles of varying sizes and shapes. Continuous wind action transports these particles to different locations. This phenomenon is geomorphological in nature and of aeolian origin, consisting of sand grains derived from natural sources. When the wind encounters obstacles—such as hills, vegetation, or other natural barriers—its velocity decreases, leading to sediment deposition and dune formation. Their heights usually do not exceed several tens of meters; however, under strong winds, larger dunes may develop with heights ranging from approximately **20–50 feet**.

The presence of water in the Eastern Euphrates drainage canal contributes indirectly to dune stabilization by supporting vegetation growth along its banks. Vegetation cover reduces wind speed near the ground surface, binds soil particles, and limits sand movement, thereby mitigating desertification processes and protecting nearby agricultural lands and infrastructure.(16)

4.3 Use of eastern euphrates drainage water in afforestation and plant cultivation

(1) Winter Crops

A. Wheat (Triticum spp.)

Wheat belongs to the Poaceae (grass) family and is a long-day plant that requires extended daylight periods for flowering. It generally needs approximately **10–12 hours of light per day**, which represents the optimal photoperiod for growth and flowering.(17)

If daylight duration decreases, flowering is delayed, and vegetative growth becomes more pronounced.(18)

Wheat occupies an important economic position in Iraqi agriculture, accounting for a substantial proportion of the country's cultivated land. It is typically sown at the beginning of winter and harvested at the end of spring. The optimal climatic conditions for wheat production are cool and relatively moist weather. One of the major limitations of the crop is its weak tolerance to prolonged drought conditions.(19)

According to Table (2), the wheat cultivation area in **2021** reached **328.23 km² (22.48%)** of the total study area, while natural vegetation covered **614.20 km² (21.97%)**.

In **2022**, wheat area declined to **248.99 km² (17.06%)** due to increased crop diseases and climatic variability, particularly higher winter humidity; natural vegetation reached **577.34 km² (20.65%)**.

In **2023**, wheat expanded again to **324.45 km² (22.22%)**, whereas natural vegetation covered **507.31 km² (18.15%)**.

In **2024**, wheat cultivation further increased to **355.10 km² (24.33%)**, while natural vegetation measured **487.67 km² (17.44%)**.

In **2025**, wheat cultivation decreased significantly to **203.11 km² (13.91%)**, whereas natural vegetation increased to **608.87 km² (21.79%)**. This decline is attributed to pest infestations, physiological plant diseases, reduced governmental agricultural support, soil degradation, and rising water salinity, which represents a major constraint to wheat cultivation.

Table 2

Wheat Area and Percentage in the Study Area (Winter Seasons 2021–2025)

Year (Winter)	Wheat Area (km²)	Percentage (%)	Natural Vegetation Area (km²)	Percentage (%)
2021	328.23	22.48	614.20	21.97
2022	248.99	17.06	577.34	20.65
2023	324.45	22.22	507.31	18.15
2024	355.10	24.33	487.67	17.44
2025	203.11	13.91	608.87	21.79
Total	**1459.88**	**100**	**2795.39**	**100**

Source: Prepared by the researcher based on winter-season vegetation cover maps (2021–2025).

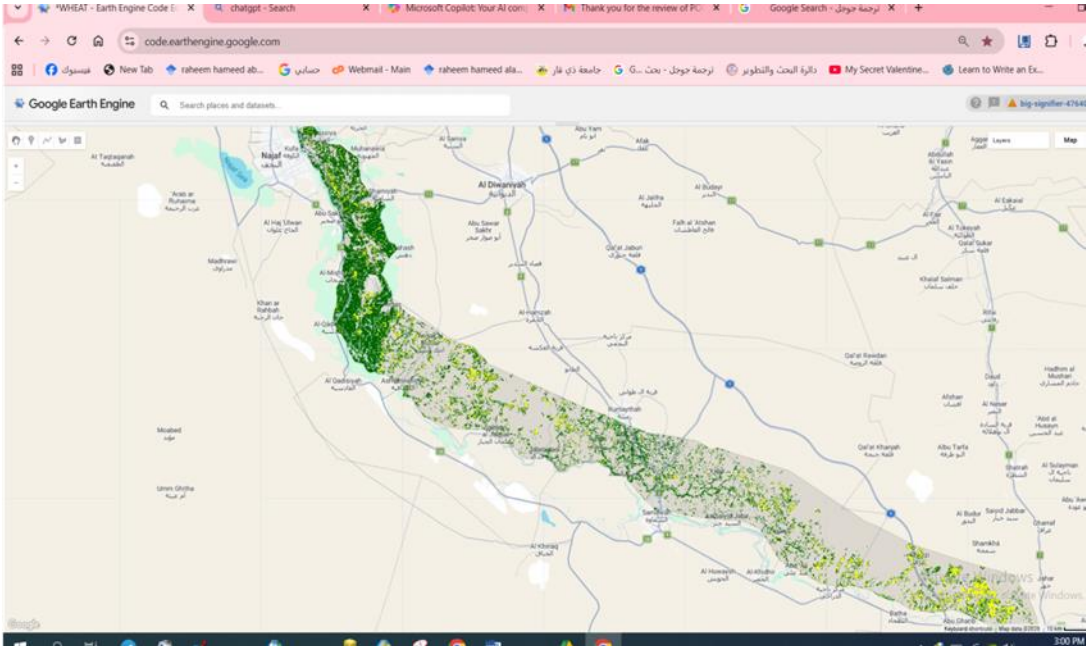
Map 12

Wheat area (km²) and natural vegetation in the study area for the year 2020-2021

Source - / Based on satellite data (Sentinel) and vegetation cover equations (NDVI) in Arc GIS Pro 10 software.

Map 13

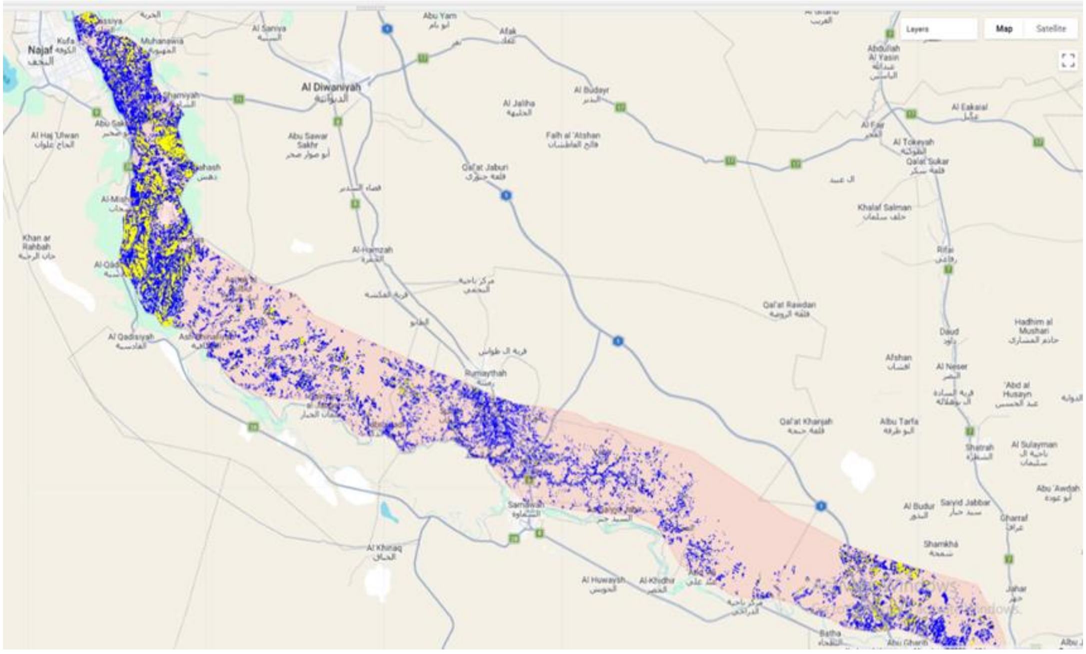
Wheat area km2 and natural vegetation in the study area for the year 2022



Source - / Based on satellite data (Sentinel) and vegetation cover equations (NDVI) in Arc GIS Pro 10 software.

Map 14

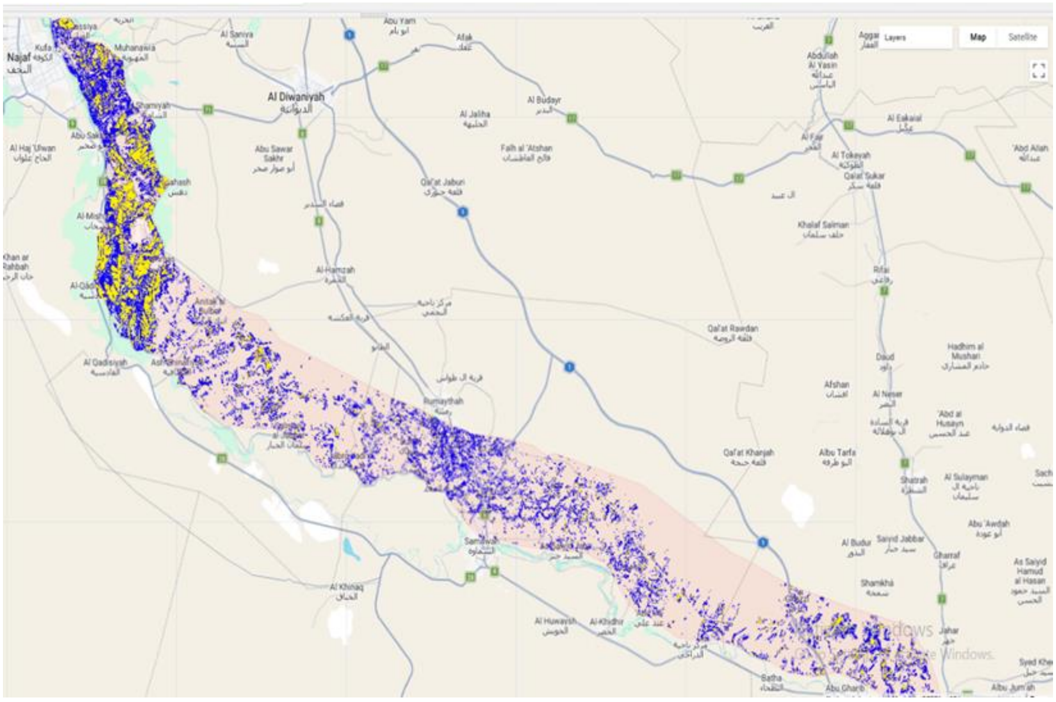
Wheat area (km²) and natural vegetation in the study area for the year 2023



Source - / Based on satellite data (Sentinel) and vegetation cover equations (NDVI) in Arc GIS Pro 10 software.

Map 15

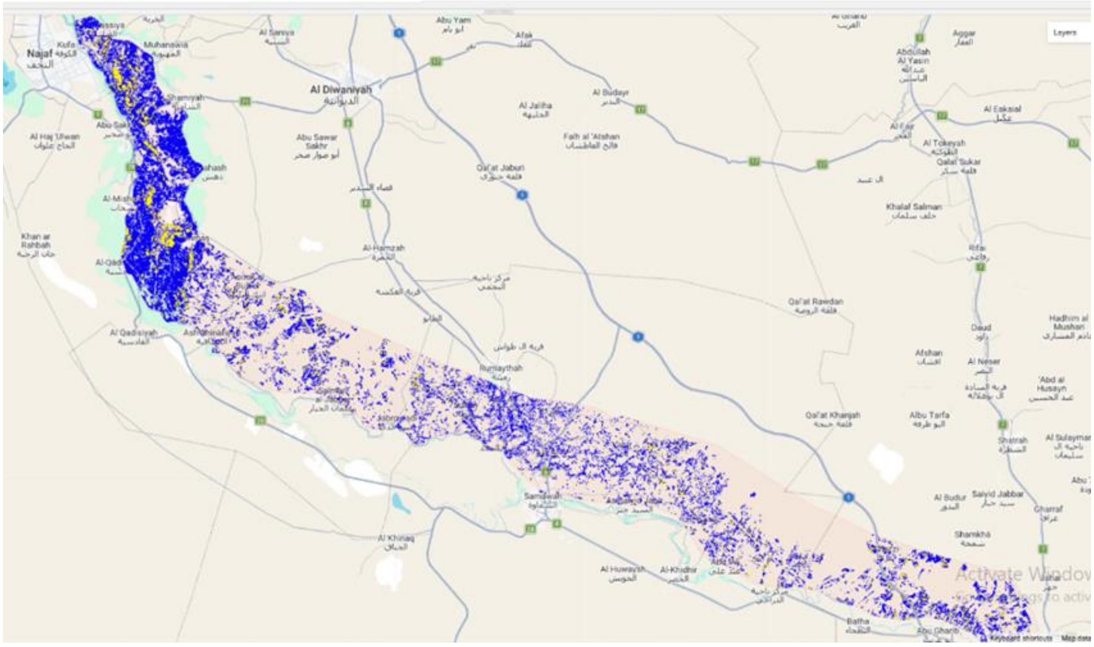
Wheat area (km2) and natural vegetation in the study area for the year 2024



Source - / Based on satellite data (Sentinel) and vegetation cover equations (NDVI) in Arc GIS Pro 10 software.

Map 16

Wheat area km2 and natural vegetation in the study area for the year 2025



Source - / Based on satellite data (Sentinel) and vegetation cover equations (NDVI) in Arc GIS Pro 10 software.

The data presented in Table (3) indicate that the cultivated area of wheat (in dunums) in Al-Batha District, which belongs to the study area, during the period (2001–2024) reached its maximum during the agricultural seasons **2019–2020**, amounting to **22,000 dunums**, followed closely by the **2020–2021** season with **21,995 dunums**.

In contrast, during the seasons **2006–2007**, **2007–2008**, and **2008–2009**, the cultivated area stabilized at **7,000 dunums**. The lowest recorded area was during the **2018–2019** season, when wheat cultivation declined sharply to **5,000 dunums**.

Table 3

Cultivated Area (Dunums) of Wheat in Al-Batha District (2001–2024)

Agricultural Season	Cultivated Area (Dunums)
2000–2001	4700
2001–2002	5100
2002–2003	5100
2003–2004	5250
2004–2005	5500
2005–2006	6500
2006–2007	7000
2007–2008	7000
2008–2009	7000

2010–2011	7500
2011–2012	7750
2012–2013	10000
2013–2014	15000
2014–2015	12000
2015–2016	11040
2016–2017	15000
2017–2018	14400
2018–2019	5000
2019–2020	22000
2020–2021	21995
2021–2022	12000
2022–2023	10423
2023–2024	10200

Source: Republic of Iraq, Ministry of Agriculture, Directorate of Agriculture of Dhi Qar, Al-Batha Agriculture Division, Planning Department, unpublished data, 2024.

Image 1

Agricultural lands planted with wheat irrigated from the eastern Euphrates drain

Source - Field visit dated December 15, 2022

B. Barley (Hordeum vulgare)

Barley is one of the winter crops cultivated in the study area and ranks second in economic importance after wheat. Its cultivation is widespread in central and southern Iraq, particularly in Dhi Qar Governorate, owing to its tolerance to harsh environmental conditions and soil salinity. However, production generally fluctuates from year to year due to low and irregular rainfall during the growing season, reduction in cultivated areas, and declining water levels.(20)

According to the data presented in Table (4), the approved and proposed winter agricultural plan shows spatial variation among administrative districts. The largest planned areas are concentrated in Al-Bathaa District, whereas the smallest are in Al-Gharraf District.

For protected (greenhouse) tomatoes, the total cultivated area amounts to **267 dunums**, with the highest concentration in Al-Dawayah Sub-district (**180 dunums**). The districts of Al-Fajr, Al-Nasr, Al-Shatra, and Al-Bathaa recorded no cultivated area for this crop.

Dry onion cultivation totals **117 dunums**, concentrated mainly in Al-Rifai District (**90 dunums**), while the districts of Al-Fajr, Al-Bathaa, Al-Nasr, and Al-Shatra lack cultivation of this crop. Green onion cultivation reaches **155 dunums**, with Al-Rifai again recording the highest area (**90 dunums**), whereas Al-Nasiriyah and Al-Bathaa show minimal areas (about **1 dunum**).

Broad bean cultivation covers **114 dunums**, mainly in Al-Fajr and Qalat Sukkar Districts (approximately **30 dunums** each). Turnip cultivation totals **72 dunums**, with the largest area in Al-Fajr, while other districts record no cultivated area. Lettuce cultivation also totals **114 dunums**, with the highest areas in Al-Nasr and Qalat Sukkar (about **30 dunums**) and the lowest in Al-Dawayah (**12 dunums**). Garlic cultivation records generally low values across most districts.

Leafy vegetable crops collectively cover **318 dunums**, with the highest share in Al-Fajr (**76 dunums**), followed by Al-Gharraf (**60 dunums**), and the lowest in Al-Nasiriyah (**16 dunums**). Al-Bathaa District records almost no area for these crops.

Vegetable crops overall reach a total cultivated area of **1,155 dunums**, with the highest concentration in Qalat Sukkar District and the lowest in the center of Nasiriyah City (**16 dunums**)

Table 4

Approved Winter Agricultural Plan for the 2022–2023 Season

Source: Republic of Iraq, Ministry of Agriculture, Directorate of Agriculture, Dhi Qar, Plant Production

Agricultural Division	Total Vegetables	Lettuce	Leafy Crops	Garlic	Turnip	Broad Beans	Green Onion	Dry Onion	Protected Tomatoes	Barley	Wheat	Division Total
Al-Fajr	193	18	76	0	30	30	30	9	0	500	14,850	15,543
Qalat Sukkar	149	30	41	0	18	30	15	0	15	800	11,150	12,099
Al-Rifai	248	0	32	0	0	0	90	90	36	700	32,000	32,948
Al-Nasr	124	30	34	0	24	36	0	0	0	900	5,250	6,274
Al-Dawayah	224	12	32	0	0	0	0	0	180	600	27,000	27,824
Al-Shatra	27	0	27	0	0	0	0	0	0	500	12,495	13,477
Al-Gharaf	174	24	60	0	0	18	18	18	36	300	12,450	12,924
Al-Nasiriyah	16	0	16	0	0	0	0	0	0	500	4,250	4,766
Al-Gharaf Basin	1,243	132	346	0	72	114	171	117	291	7,650	169,880	178,773
Al-Bathaa	0	0	0	0	0	0	1	0	0	1,400	28,423	29,823
Euphrates Basin	298	34	0	31	0	0	35	20	178	2,350	40,845	43,491
Total	**1,155**	**114**	**318**	**0**	**72**	**114**	**155**	**117**	**267**	**6,200**	**260,320**	**329,602**

Department, unpublished data, 2024.

It is evident from **Table (5)**, which presents the implemented winter plan for the 2020–2021 agricultural season, that the cultivated area of **wheat** reached its maximum in **Al-Rifai District**, totaling **58,085 dunums**, followed by **Al-Dawayah** with **41,490 dunums**. The smallest areas were recorded in **Al-Nasiriyah** (**4,564 dunums**) and **Al-Gharaf** (**13,692 dunums**), with a total cultivated area for wheat across all districts of **241,214 dunums**.

For **barley**, the total cultivated area amounted to **49,805 dunums**, with the largest share in **Al-Bathaa District** (**12,000 dunums**) and the smallest in **Al-Nasiriyah** (**2,725 dunums**).

The total area planted with **protected (greenhouse) tomatoes** was **408 dunums**, reaching its peak in **Al-Dawayah District** (**140 dunums**) and the lowest in **Al-Nasiriyah** (**8 dunums**).

For **dry onion**, the total cultivated area was **318 dunums**, with **Al-Rifai** recording the largest area (**250 dunums**) and **Al-Nasiriyah** the smallest (**8 dunums**).

Green onion cultivation totaled **540 dunums**, with the largest area in **Al-Rifai** (**350 dunums**) and the smallest in **Al-Nasiriyah** (**10 dunums**).

Broad beans were cultivated over a total area of **370 dunums**, with the maximum in **Al-Fajr District** (**130 dunums**), followed by **Al-Gharaf** (**100 dunums**), and the minimum in **Al-Nasiriyah** (**10 dunums**).

Turnip cultivation covered a total area of **220 dunums**, with the highest areas in **Al-Fajr** (**130 dunums**) and **Al-Nasr** (**60 dunums**), while other districts did not register significant cultivation.

Lettuce was grown over **270 dunums**, with the largest areas in **Al-Dawayah** (**80 dunums**) and the smallest in **Al-Nasiriyah** (**10 dunums**).

Garlic was not cultivated in any of the districts of the study area during this season.

The total area of **fodder crops** was **2,434 dunums**, with the largest share in **Al-Shatra** (**600 dunums**), followed by **Qalat Sukkar** (**500 dunums**), and the smallest in **Al-Nasiriyah** (**40 dunums**).

Finally, **leafy vegetable crops** were cultivated over a total of **600 dunums**, with the maximum area in **Al-Gharaf District** (**200 dunums**), followed by **Qalat Sukkar** (**160 dunums**), and the minimum in **Al-Nasiriyah** (**20 dunums**).

Table 5

Implemented Winter Agricultural Plan for the 2020–2021 Season

Division	Total	Leafy Crops	Fodder Crops	Garlic	Lettuce	Turnip	Broad Beans	Green Onion	Dry Onion	Protected Tomatoes	Barley	Wheat
Al-Fajr	27,607	100	200	0	30	130	130	100	30	0	6,557	20,330
Qalat Sukkar	26,740	160	500	0	30	30	50	50	0	50	4,480	21,390
Al-Rifai	66,481	0	400	0	0	0	0	350	250	110	7,286	58,085
Al-Nasr	23,406	30	300	0	80	60	80	0	0	0	5,100	17,756
Al-Dawayah	46,740	0	294	0	80	0	0	0	0	140	4,736	41,490
Al-Shatra	19,637	90	600	0	0	0	0	0	0	0	4,007	14,940
Al-Gharaf	17,206	200	100	0	40	0	100	30	30	100	2,914	13,692
Al-Nasiriyah	7,395	20	40	0	10	0	10	10	8	8	2,725	4,564
Al-Gharaf Basin	373,994	610	2,464	10	330	220	380	570	318	518	55,997	312,577
Al-Bathaa	33,995	0	0	0	0	0	0	0	0	0	12,000	21,995
Euphrates Basin	47,970	50	50	15	0	0	0	35	30	160	14,018	33,612
Total	421,964	600	2,434	0	270	220	370	540	318	408	49,805	241,214

Source: Republic of Iraq, Ministry of Agriculture, Directorate of Agriculture, Dhi Qar, Plant Production Department, unpublished data, 2024.

5 SUMMER CROPS

A. Rice:

Rice belongs to the Poaceae (grass) family and is the most productive cereal after maize. It constitutes an important source of carbohydrates and is rich in sugars, dietary fiber, proteins, fats, calcium, iron, and other minerals. Rice cultivation occupies extensive areas in central and southern Iraq, while its cultivation is limited in the northern regions. It requires a temperature range of 20–30°C and a germination period of 5–14 days.(21)

Data from **Table (6)** show that the total area cultivated with rice in 2023 was 5,443 ha. There is significant variation in rice cultivation across districts. Al-Warka district ranked first in cultivated area, with 3,023 ha (55.539%), followed by Al-Shanafiyah district with 1,300 ha (23.883%), and Al-Shamiya district with 1,120 ha (20.576%). Al-Hamza, Al-Khidr, Al-Rifai, Al-Fajr, Al-Nasr, and Al-Bathaa districts did not have any significant rice cultivation in 2023.

Table 6

Areas Cultivated with Rice by Administrative Unit in 2023

Administrative Unit	Area Cultivated (ha)	% of Total
Al-Nasr	0	0
Al-Fajr	0	0
Al-Rifai	0	0
Al-Bathaa	0	0
Al-Khidr	0	0
Al-Warka	3,023	55.539
Al-Hamza	0	0
Al-Shanafiyah	1,300	23.883
Al-Shamiya	1,120	20.576
Total	5,443	100

Sources:
1. Republic of Iraq, Ministry of Agriculture, Directorate of Agriculture, Dhi Qar, Plant Production Department, unpublished data, 2024.
2. Republic of Iraq, Ministry of Agriculture, Directorate of Agriculture, Al-Muthanna, Plant Production Department, unpublished data, 2024.
3. Republic of Iraq, Ministry of Agriculture, Directorate of Agriculture, Al-Qadisiyah, Plant Production Department, unpublished data, 2024.

B. Maize (Corn):

Maize is an important cereal crop due to its high nutritional value for humans and livestock and its use in vegetable oil production. Its cultivation in the study area relies on irrigation rather than rainfall because the region experiences variable precipitation. Maize is a thermophilic crop, favoring warm temperatures, and its cultivation contributes significantly to increasing the productivity per hectare of agricultural land in the study area. Additionally, maize stalks can be used as organic matter to fertilize the soil.(22)

C. White Maize

White maize is considered one of the world’s important economic crops, ranking fifth after wheat, barley, rice, and yellow maize. It is primarily used as animal fodder, while its grains serve as a food source for low-income populations and impoverished communities.(23) It is a cereal forage crop that also serves as a raw material in industries such as alcohol production, starch extraction, and cellulose manufacturing.

The importance of white maize in the study area and southern Iraq lies in its ability to tolerate drought and salinity, conditions prevalent in the region. Its cultivation is optimal under an average annual rainfall of 350 mm. The timing of planting, selection of appropriate sowing dates, optimal temperatures for germination and growth, and intensity and duration of light exposure are crucial agronomic factors affecting crop performance.

The most suitable soils for white maize cultivation are silty loam and clayey loam soils with low salinity levels.

6 DATE PALM

Date palm is a crop that thrives in arid and semi-arid regions, including the study area, which lies near the 35° latitude line—the northern limit of date palm cultivation. This crop dominates the study area and is widely cultivated in central and southern Iraq. Date palms require substantial amounts of water, approximately 1,400 m^3 per dunum, with peak water demand occurring during the pollination period. After the harvest season, irrigation is required once every 6–12 days.(24)

Data from **Table (7)** and **Figure (2)** indicate significant variation in the number of date palms across administrative units. The total number of date palms in 2023 was 120,162, increasing to 216,159 in 2024. Al-Warka district ranked first in both years, with 120,000 palms in 2023 and 278,000 in 2024. Al-Khidr district ranked second, with 88,000 palms in 2023 and 96,000 in 2024. The increase in date palm numbers in these districts is attributed to the crop’s high nutritional and economic value, as well as government support for farmers, which has positively impacted cultivation.

Al-Hamza district ranked third in both years, with 63,500 palms; Al-Shamiya ranked fourth, with 45,575 palms in 2023 and 45,580 in 2024; Al-Rifai ranked fifth with 45,260 palms; Al-Bathaa and Al-Fajr occupied sixth and seventh positions in 2023, respectively, while in 2024, Al-Fajr moved to sixth and Al-Bathaa to seventh with 31,930 palms. Al-Nasr ranked eighth with 24,714 palms in both years, and Al-Shanafiyah ranked ninth with 10,750 palms in 2023 and 10,940 in 2024.

In 2025, the total number of date palms reached 240,077. Al-Warka maintained first place with 296,000 palms, followed by Al-Khidr with 120,000 palms, Al-Hamza with 63,500 palms, Al-Shamiya with 45,580 palms, Al-Rifai with 45,360 palms, Al-Bathaa with 31,930 palms, Al-Fajr with 36,280 palms, Al-Nasr with 24,947 palms, and Al-Shanafiyah with 10,860 palms.

Table 7

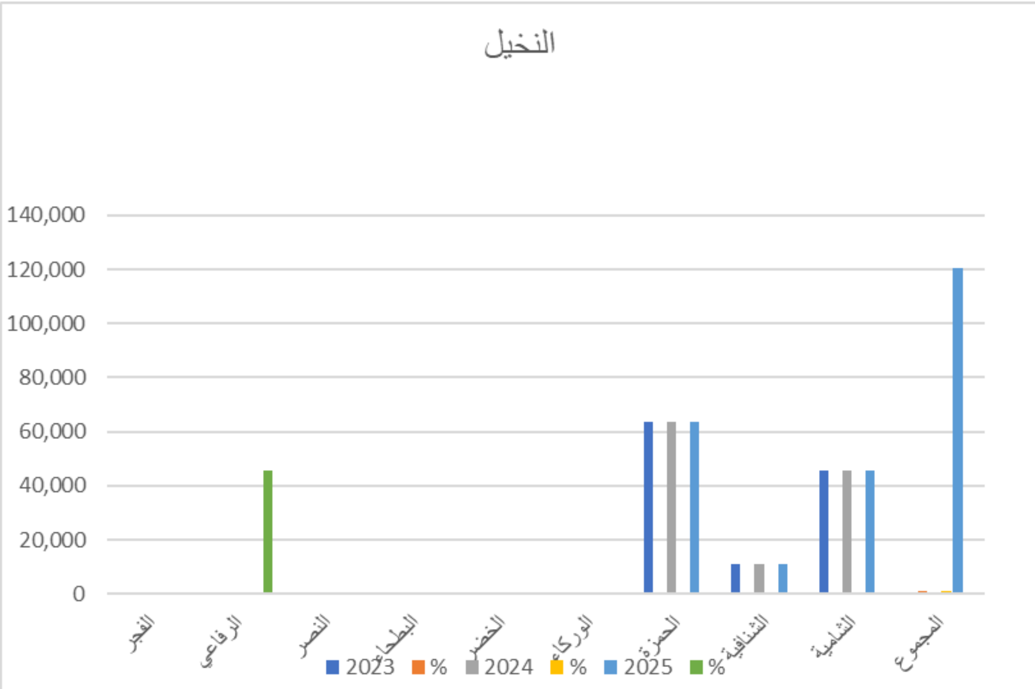
Number of Date Palms in Administrative Units for the Period 2023–2025

Administrative Unit	2023 Count	2023 %	2024 Count	2024 %	2025 Count	2025 %
Al-Fajr	27,900	23.21	37,320	1.7	36,280	1.5
Al-Rifai	45,260	37.00	45,260	2.0	45,360	18.0
Al-Nasr	24,714	2.00	24,714	11.4	24,947	10.0
Al-Bathaa	31,930	2.60	31,930	14.0	30,930	12.0
Al-Khidr	88,000	7.30	96,000	4.4	120,000	49.0
Al-Warka	120,000	9.90	278,000	12.0	296,000	2.0
Al-Hamza	63,500	5.20	63,500	29.0	63,500	2.0
Al-Shanafiyah	10,750	8.94	10,940	5.0	10,860	4.0
Al-Shamiya	45,575	3.70	45,580	21.0	45,580	1.8
Total	120,162	100.0	216,159	100.0	240,077	100.0

Source:
1. Republic of Iraq, Ministry of Agriculture, Thi-Qar Directorate of Agriculture, Statistics Division, unpublished data, 2024.
2. Republic of Iraq, Ministry of Agriculture, Al-Muthanna Directorate of Agriculture, Statistics Section, unpublished data, 2024.
3. Republic of Iraq, Ministry of Agriculture, Al-Qadisiyah Directorate of Agriculture, Statistics Section, unpublished data, 2024.

Figure 2

Number of palm trees in administrative units for the period (2023-2024-2025)



7 SUMMER AND WINTER VEGETABLES

Vegetables constitute a group of plants with high nutritional and commercial value. They are among the most important crops in the study area, ranking second only to cereal crops. Their significance lies in their richness in carbohydrates, which are present in the plants as sugars or starch. When cultivating vegetables, proximity to consumption areas is taken into account, as they are highly perishable crops. Transportation costs increase with distance despite advances in transport systems and food preservation methods. Vegetable cultivation requirements vary depending on the type of crop.(25)

7.1 Importance of the eastern euphrates spillway in fisheries development

Fishery resources represent a renewable and valuable source of nutrition and one of the best food commodities. They form a comprehensive and sustainable growth base, providing investment opportunities, employment, and poverty alleviation. Fisheries are therefore highly significant for their primary and effective role in supporting the national economy. Due to their nutritional value and richness in essential elements, including proteins (approximately 18.5%) and vitamins, fisheries are relied upon by most countries. The average annual per capita consumption is about 16.7 kg. However, population growth, overgrazing, and increasing river pollution have limited production.(26)

The waters of the Eastern Euphrates Spillway can be utilized for fisheries development by raising water levels, coordinating international agreements with upstream countries such as Iran, Turkey, and Syria to supplement the Tigris and Euphrates rivers, and directing water to the marshlands. This approach promotes fisheries and enhances education and awareness in the study area across economic, social, and health sectors, creating a generation that engages with water resources sustainably. Additionally, this water can help flush soils in the Eastern Euphrates Spillway region and create artificial floods in dried marshlands, washing away accumulated salts, chemicals, and harmful substances, positively impacting marshland revival and fisheries development.(27)

7.2 Importance of the Eastern Euphrates Spillway in marshland revitalization

The marshlands are ponds or low-lying lands that are filled with water for most or part of the year, or shallow waterlogged areas in southern Iraq's alluvial plains. They are located between latitudes 33.00°–35.30° N and longitudes 44°–48° E, occupying the southern, central, and upper parts of the alluvial plain (south of Baghdad). Their area ranges from approximately 3,000 km² in drought years to 13,000 km² in wet years, constituting about 3% of Iraq's total area (435,520 km²).(28)

The marshlands can be revitalized via the Eastern Euphrates Spillway through the following approaches:

1. **Reducing salinity in the main spillway discharge:** Despite the implementation of the spillway, salinity levels in the main outlet water remain high, especially since the 1990s, much higher than in the 1970s, due to reduced water inflows and insufficient spillway discharge into rivers and marshes. High salinity in the Euphrates Spillway and main outlet water results from both the quantity and quality of water in southern Iraq, contributing to soil salinity originating from the Tigris, Euphrates, and Shatt al-Arab rivers. Salinity reduction can be achieved through appropriate desalination methods for the study area, including reverse osmosis, which improves water quality for various uses. Additionally, treating industrial wastewater and reducing salt content can produce high-purity water, thereby revitalizing the marshlands.(29)
2. **Reducing soil salinity in the study area:** The soils of central and southern Iraq, including the study area, are characterized by weak structure, poor physical, chemical, and biological properties, and low organic content (about 1%), exacerbated by high temperatures, low rainfall, limited vegetation cover, improper land use, and poor irrigation management. These conditions negatively affect crop productivity and increase salinity in the Eastern Euphrates Spillway water.(30)
3. **Marshland revitalization through treatment plants:** Treatment plants aim to remove pollutants from the Euphrates Spillway water, including pesticides, which are among the main contaminants. Consideration must

be given to the costs and expertise required for these plants, with the Ministry of Water Resources and related agencies responsible for their implementation.(31)

4. **Monitoring spillway water salinity through specialized committees:** A national high-level committee, chaired by the Minister of Water Resources and including relevant ministries and the General Secretariat of the Council of Ministers, periodically monitors marshland conditions, identifies challenges and needs, and evaluates potential projects. Since the inclusion of the marshlands in UNESCO's World Heritage list in 2016, tourism has increased, highlighting the marshes' value. These committees oversee water salinity and discharge management to support sustainable marshland revitalization.(32)

8 THE ROLE OF THE EASTERN EUPHRATES SPILLWAY IN FLOOD PREVENTION

The study area has experienced multiple floods in the years 1963, 1966, 1968, 1977, 1981, 1983, 1988, 1989, 1995, 1999, and 2002, with varying severity. The most severe event occurred in 1981, (33)which caused significant impact in the study area. Given that the study area is characterized by arid and semi-arid conditions, the primary role of the spillway is to remove excess water from beneath the soil surface, lower the groundwater table, prevent the rise of salts to the soil surface, and remove excess surface water. This is achieved by collecting and transferring groundwater into the spillway network and away from agricultural lands, thus preventing water accumulation at the soil surface.

The Eastern Euphrates Spillway can be utilized to mitigate flood risks through natural or artificial removal of excess water, whether on the surface or underground. It channels water exceeding the needs of agricultural lands, reducing the risk of flooding when Euphrates River levels rise. The spillway directs this water through its secondary branches to the main spillway discharge channel, thereby protecting agricultural lands and residential areas from flood damage.

8.1 Proposed solutions for stabilizing sand dunes using Spillway water

1. Permanent Biological Treatment:

This method represents a long-term solution for sand dune stabilization. It involves planting tree species capable of withstanding harsh conditions such as drought, high salinity in the spillway water, elevated nitrates, dissolved substances, and high water temperatures. This approach ensures the long-term stabilization of dunes, enhances vegetation cover, and promotes the growth of new plant species. Complete protection from overgrazing and the entry of animals is necessary to preserve the soil layer covering the dunes. Additionally, water from the Eastern Euphrates Spillway and the main discharge should be treated to reduce salinity before irrigation of resilient shrubs.

2. Windbreaks and Green Belts:

Despite the high salinity of the main discharge (exceeding 3,000 mg/L), this method involves planting trees and shrubs resistant to climatic stress. (34)Windbreaks and green belts are established in sandy areas to reduce wind speed, which contributes to soil erosion. Beyond wind reduction, these barriers also minimize evaporation, increase soil particle cohesion, and help retain soil moisture—critical in arid regions like the study area where soils are saline and dry.(35)

3. Construction of Earthen Dams:

Earthen dams protect the Eastern Euphrates Spillway, agricultural lands, and irrigation projects. They are typically constructed in three defensive lines, spaced 2–4 meters apart, with lengths of 500–1,000 meters, positioned perpendicular to the prevailing wind direction. These structures act as physical barriers to reduce sand movement.(36)

4. Green Manure Cultivation:

Green manure improves soil fertility, reduces erosion, and stabilizes soils. It discourages indiscriminate land plowing, which can exacerbate sand dune expansion. Modern agricultural techniques, including contour farming, are encouraged to improve soil productivity. Marginal cultivation should be minimized, and specialized committees established to oversee dune management.(37)

5. Trench Excavation:

The primary objective of trenching is to dismantle accumulated sand dunes by digging longitudinal or transverse trenches. Bulldozers are then used to disrupt dune formation. Trenches should be excavated to significant depths to ensure long-term effectiveness, although periodic sand accumulation may require re-excavation over time.(38)

8.2 Results

1. The study indicated that the total area of arable land within the Euphrates Basin in Iraq amounts to one million hectares. The annual water requirement per hectare is estimated at 14,000 m^3, resulting in a total water demand for these agricultural areas of approximately 14 km^3 per year;
2. The research revealed that the area of desertified land in the study area during the summer of 2022 increased to 2,107.0782 km^2, representing 71.95% of the total area. Bare soil covered 643.178 km^2 (21.95%), while natural vegetation occupied 178.741 km^2, accounting for 6.10%;
3. The wheat area in 2021 reached 328.23 km^2 (22.48% of the total study area), while natural vegetation covered 614.20 km^2 (21.97%). In 2022, the wheat area decreased to 248.99 km^2 (17.06%);
4. Natural vegetation in 2022 accounted for 577.34 km^2 (20.65%). In 2023, the wheat area increased again to 324.45 km^2 (22.22%);
5. The cultivated area for wheat per dunam in Al-Bat'ha District during 2001–2024 reached its maximum in 2019–2020 at 22,000 dunams, followed closely by 2020–2021 with 21,995 dunams;
6. For the 2022–2023 winter season, the total wheat area in the study region is estimated at 465.79 km^2, with the highest concentration in Al-Shatra District. The total area for wheat cultivation across the study area is 260.32 km^2, with the lowest area in Nasiriyah at 4,250 dunams. The total area cultivated with barley is 6,200 dunams;
7. The total area planted with rice in 2023 reached 5,443 dunams. Al-Warkaa District ranked first with 3,023 dunams (55.539%), followed by Al-Shanafia District with 1,300 dunams (23.883%).

8.3 Recommendations

1. Establish treatment plants for the Eastern Euphrates Spillway to reduce salinity and monitor water pollution levels;
2. Improve the quality of spillway water by reducing salts and impurities using reverse osmosis techniques and enhance soil quality through the addition of organic matter;
3. Educate farmers on the optimal use of fertilizers and pesticides according to crop requirements and raise awareness of the importance of the Eastern Euphrates Spillway as a critical water resource;
4. Promote the cultivation of salt- and drought-tolerant crops in the study area, including date palms, wheat, and barley, which contributes to stabilizing sand dunes and improving soil quality.

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Authors' Contribution

All authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study's findings are fully available within the article.

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