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Analysis of Agricultural Water Uses in Almansouriya District in Iraq

Challenges and Solutions

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List of Abbreviations

AWC	Available Water Capacity
CV	Coefficient of Variation
ETI	Effective Evapotranspiration
FC	Field Capacity
FY	Actual Farm Yield
GBWP	Gross Biomass Water Production
GW	Groundwater
PY	Potential Farm yield
RCE	Annual Rainwater Collection Efficiency
RWH	Rain Water Harvesting
TBP	Total Biomass Production
WP	Wilting Points

1. Introduction

Globally, the agricultural sector consumes an average of 70% of the freshwater taken from surface and ground sources, with a significant portion dedicated to irrigation. In certain developing countries, this percentage rises to 90%. Climate change is exacerbating water scarcity, endangering over 30 countries that primarily depend on agriculture with severe water shortages (GIZ, n.d).

What gives importance to such a study are the agricultural land uses in Almansouria district. It is considered one of the agricultural areas that depend primarily on agricultural production, as the majority of its population is rural. Studying it at the level of agricultural districts is an important basic requirement for the success of development plans and programs to benefit from the region's resources for what it provides in terms of data and information about agricultural land uses in its agricultural aspects. It also reveals the most prominent obstacles that these uses suffer by studying the challenges that face the District and suggesting solutions depending on baseline studies and scientific methods to reach the best use of agricultural land (Zghir, 2013).

For this study, the main and sub-objectives are summarized in Table 1.

Table 1 The main and sub-objectives of the study

Objectives	Sub Objectives
Investigation of the agricultural water uses in Almansouria District	Establishment of Baseline Assessment
	Addressing the water-related challenges
Suggestion of potential solutions to address the identified challenges	-

2. Methodology

The methodologies used in the current study are illustrated in Table 2.

Table 2 Methodology overview with data sources and tools

Methodologies			
Product		Data Source	Tool
Study Area Delineation		Depending on literature reviews and agricultural data.	QGIS
Hydro-Climatic Conditions	Precipitation	The geodata (CHIRPS) are processed and transformed into presentable maps.	RStudio
	Temperatures	CRU-TS 4.06 (Harris et al., 2020) downscaled with WorldClim 2.1 (Fick & Hijmans, 2017).	RStudio
Topography		The geodata (DIVAGIS) are processed and transformed into presentable maps.	QGIS
Soil Types		Soil data was obtained from FAO digital soil map (FAO, 2006).	QGIS

Soil Water Balance	Precipitation and evapotranspiration data for the calculation of soil water balance are obtained from CHIRPS and GLEAMv3.6 (Funk et al., 2014; Miralles et al., 2011), respectively.	QGIS
Crop Water Requirements	CLIMWAT 2.0 by choosing the country (Iraq) and the station Khanaqin as it is the nearest station to the study area	CROPWAT 8.0
Crop Water Productivity	WaPOR uses the ETLook model which is linked with remote sensing data (Bastiaanssen et al., 2012). However, the data was processed on a decadal basis from 2010-2020.	QGIS
Irrigation Performance Indicators	WaPOR DATA	QGIS
Irrigation Water Scheduling	Field capacity and wilting points are calculated using SOIL GRIDS where FC is the water volume content at -33 kPa, and WP is the water volume content at -1500 kPa. In addition to using soil water balance data.	Excel
Rain Water Harvesting	The rainfall data was obtained from CHIRPS as a satellite rainfall product	Excel
Challenges Identification	Depending on literature reviews	-
Solutions Suggestions	Depending on literature reviews	-

3. Related Challenges

Figure 1 summarizes the related challenges in the study area. However, these challenges are also considered to be general (country scale) but it is still threatening the agricultural sector in the country. In Almansouriya district, we will focus on several challenges to suggest well-designed solutions. The following points are the selected challenges in the district:

- Low water quantities especially after dams' constructions on the rivers upstream in Turkey and Iran.
- High levels of salinity in the groundwater which is considered the main irrigation source.
- High evaporation levels from water sources (water streams and irrigation lakes) due to high temperatures.

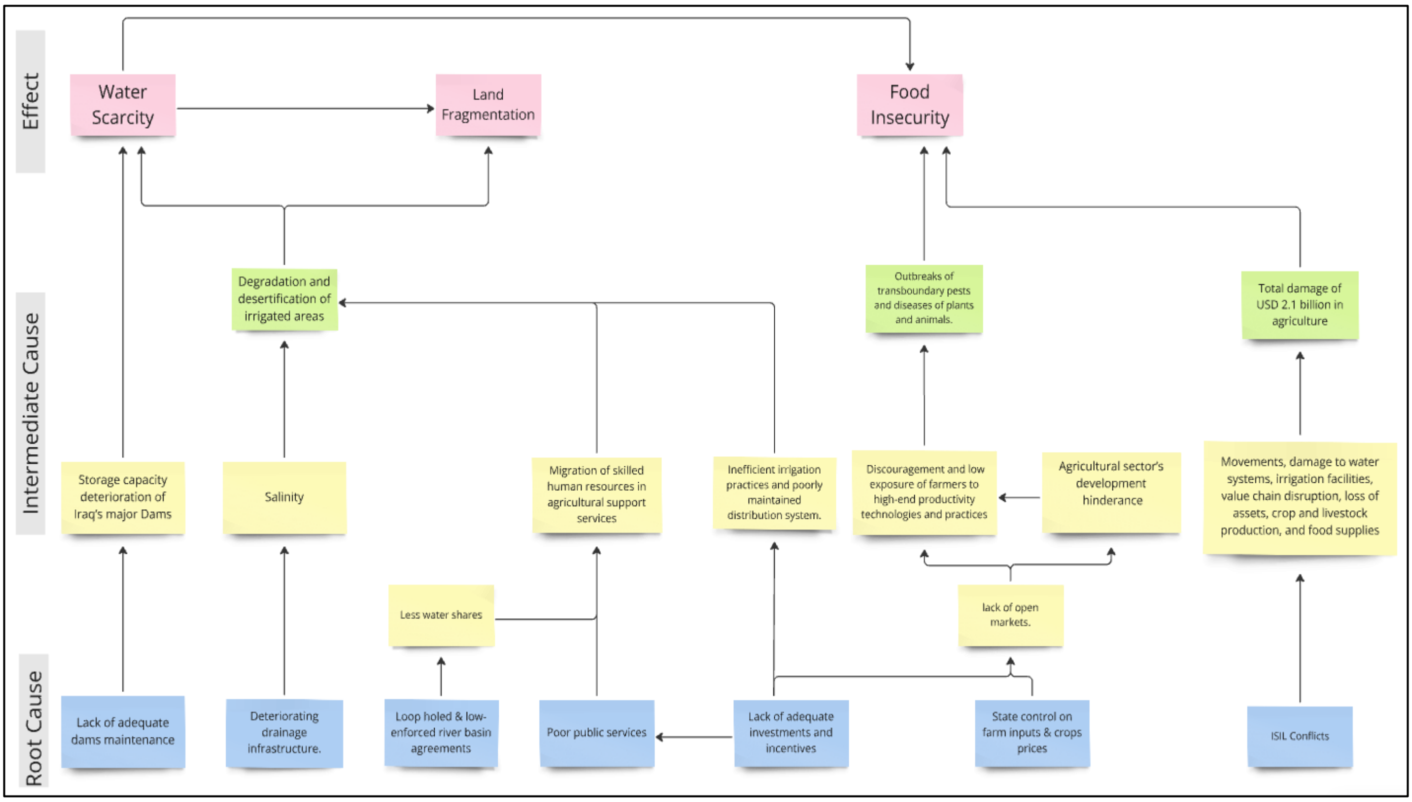

Figure 1 The main challenges

Source:(Cordesman, 2018; IFAD, 2017; World Bank, 2018; World Bank & FAO, 2012)

The boundaries of the study area are represented by Almansouriya District and its entire administrative borders, as shown in Figure 2, which include the northeastern section of Al-Khalis District within Diyala Governorate. Almansouriya is one of the four districts of Al-Khalis District, which includes (Habhab - Almansouria - Al-Sadd Al-Gradem - Al-Salam) and is located in the latitude of (33°-34°) northern and in the longitude of (44°-45°) eastern (Yassin, 2022).

As for Almansouriya administrative borders, it is bordered to the north by Qurtaba District and Al-Saadiya District, to the east by the Diyala River and the Muqdadiya District, to the south by Al-Salam District, and the west by the Great Dam District. The study area occupies an area of 331 km^2 and consists of 17 agricultural districts (Zghir, 2013).

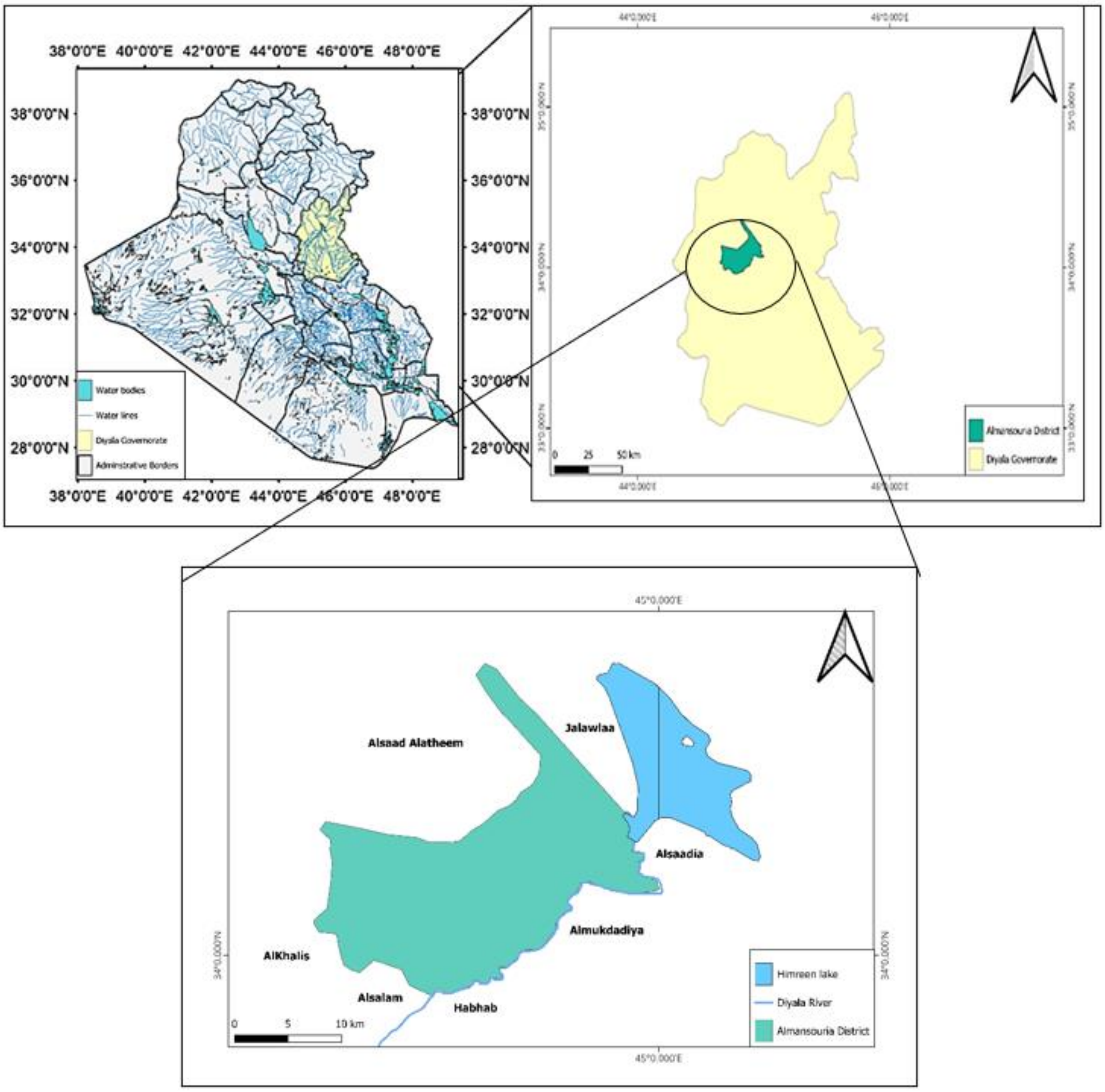

Figure 2 Almansouriya District location

Source: (Iraq map, Rivers, and Lakes from DIVAGIS (Hijmans et al., 2004), All data processed and visualized by QGIS)

5. Baseline Assessment

5.1.Topography

The topographic map (**Figure 3**) of the study area shows that Almansouriya District is located within the wavy (the highest elevation of 150 m) and the plain region (the lowest value of 48 m) which is represented by the Hamrin Mountain range and the floodplains within Diyala Governorate. The Wavy region is represented by small height hills which are located north and northeast of Almansouriya while the plain region is the dominant and located between Hamrin mountains and the meeting point of the Diyala River, south of Baghdad (Zghir, 2013).

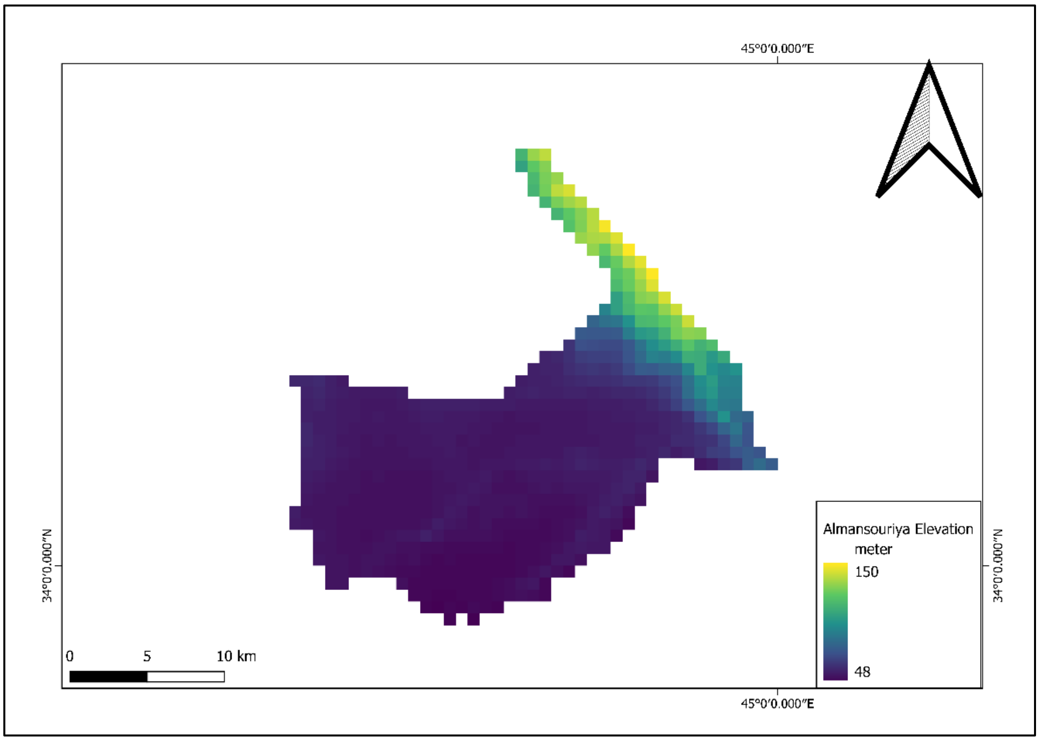

Figure 3 Topographic map of Almansouriya District
Source: Data obtained from DIVAGIS (Hijmans et al., 2004). All data processed by QGIS

5.2. Land Cover

As shown from the land cover map in 2010 (Figure 4) and 2020 (Figure 5), the dominant land cover is agricultural land where the irrigated pattern is widely spread in Almansouriya. Scattered areas are built-up areas where the villages of the farmers are located. Interestingly, the fallow area in 2010 was reclaimed into rainfed and irrigated agricultural lands. according to the literature in 2013, the fallow area was planted with wheat and barley, summer/winter vegetables, presence of approximately 36 greenhouses, in addition to the existence of some cows and poultry breeding activities. Additionally, the north region of the district has no agricultural activity with no built-up area due to the topography of that region (Zghir, 2013). All the aforementioned agriculture and livestock breeding in 2013 indicated the changing of fallow land into agricultural.

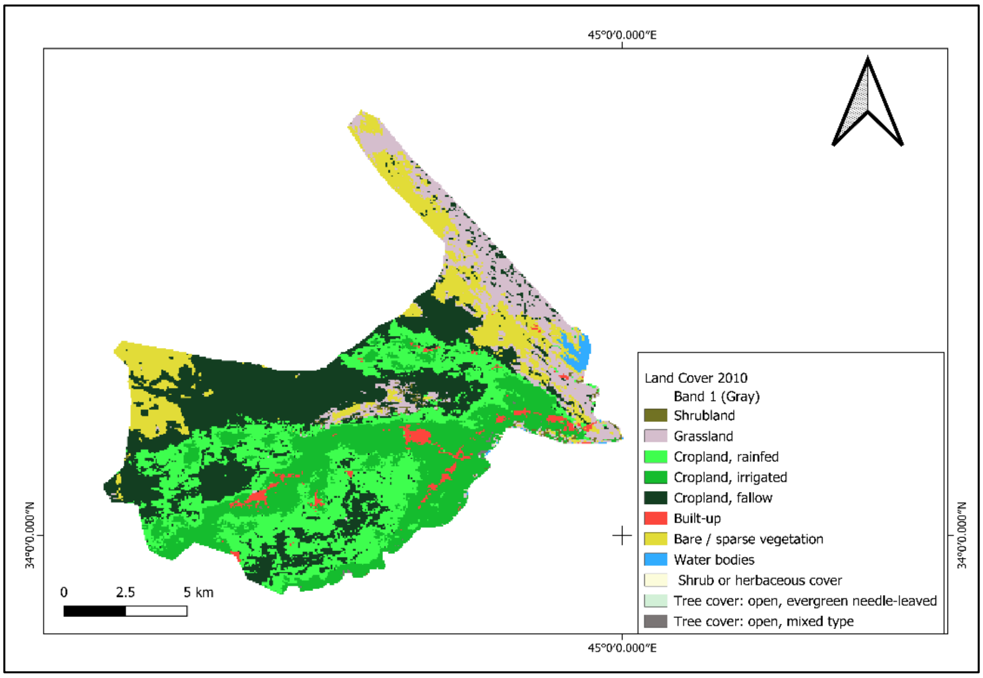

Figure 4 Land Cover map for Almansouriya District in 2010
Source: Data from WaPor (FAO, 2020). All data processed by QGIS

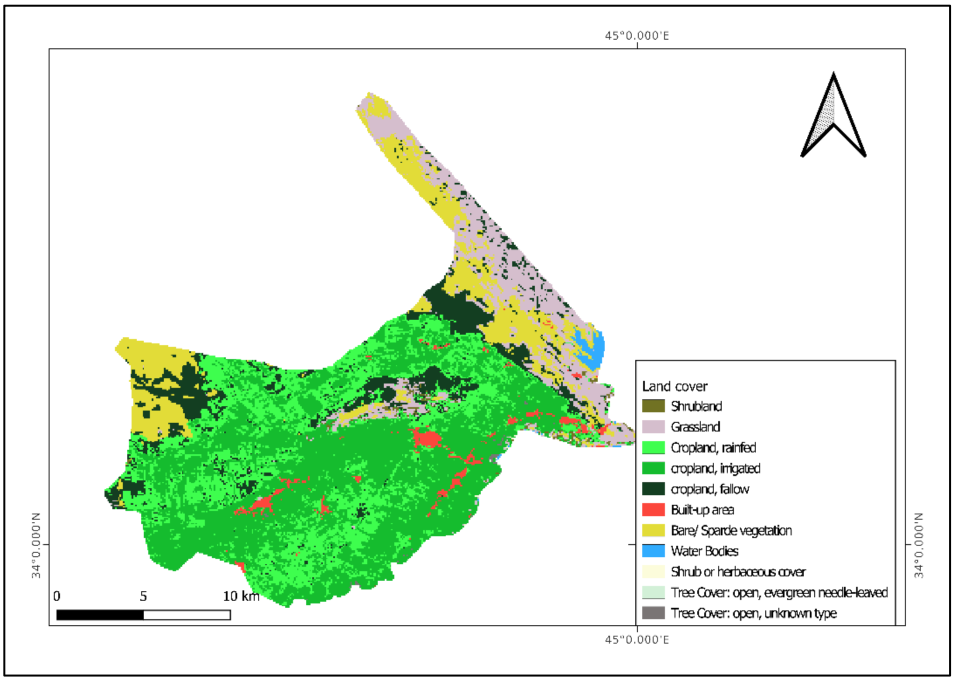

Figure 5 Land Cover map for Almansouriya District in 2020
Source: Data from WaPor (FAO, 2020). All data processed by QGIS

5.3. Hydro-Climatic Conditions

5.3.1. Precipitation

Rainfall in the study area is characterized by its seasonality and fluctuation in most years, and it falls in certain seasons of the year, represented by the fall, winter, and spring seasons. Rainfall falls in the study area from the end of November and continues to increase until it reaches its peak in January (Almusawi & Alkinany, 2006), and by observing **Figure 6**, we find that the study area has a fluctuated precipitation for all years but it has a similar pattern where the maximum precipitation occurs in the southwest region and decrease on the northeast region. However, the maximum average reached 40 mm in 2018 but ranged from 15- 25 mm for most of the year.

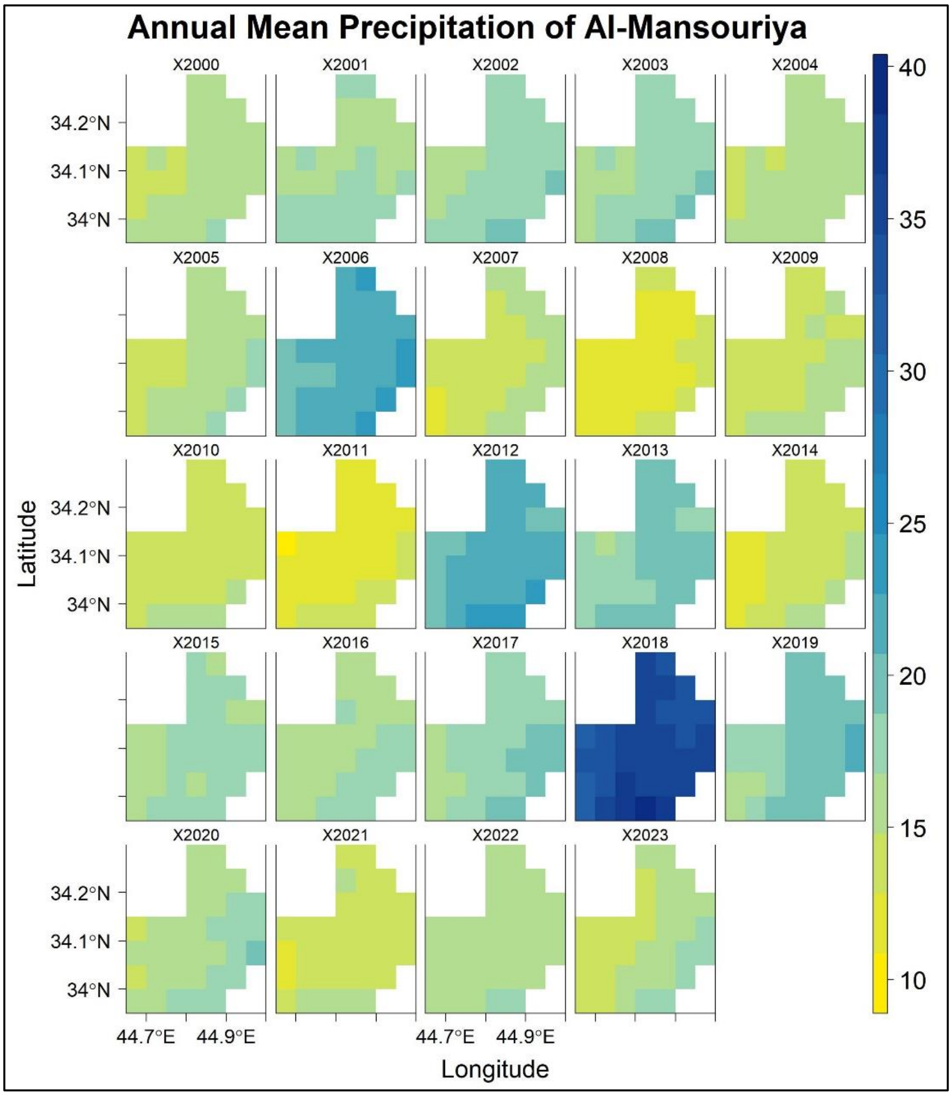

Figure 6 Annual mean precipitation (2000-2023)
Source: Precipitation data are obtained from CHIRPS (Funk et al., 2014). All data processed and visualized by RStudio

5.3.2. Temperature

According to (Al-Ansari, 2020), Iraqi weather is divided into a hot season extending from April to October while the cold season is from November until March. After processing the data, during the hot season, the minimum temperatures ranged between 15-22 °C (shown in figure 7-A), while the maximum temperature reached 48 °C (shown in figure 7-B). For the cold season (shown in Figures 7-C and 7-D), the minimum and maximum temperatures ranged between (8-15) °C and (21-29) °C, respectively.

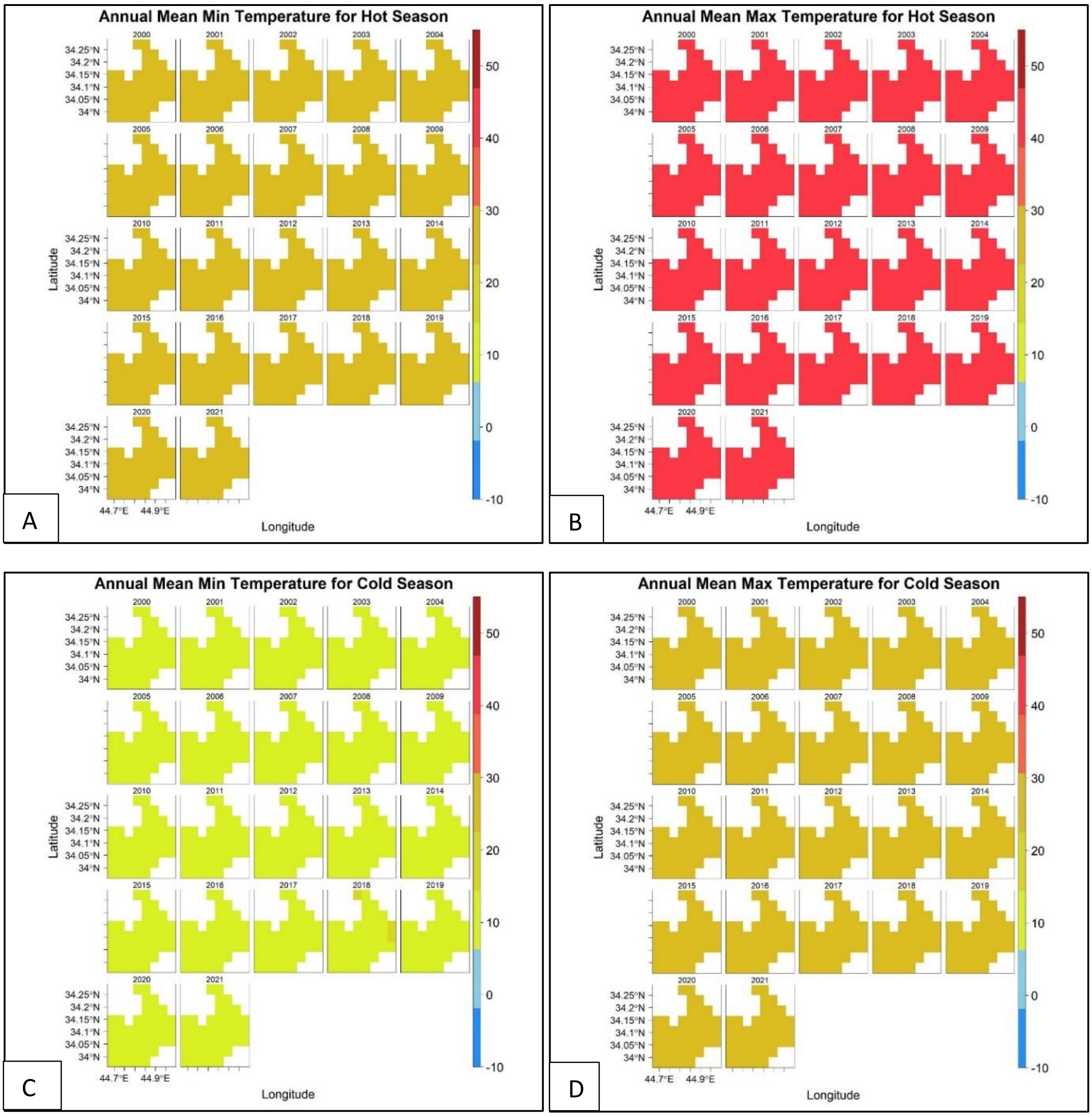

Figure 7 Temperature distribution in Almansouriya District in the hot season (April- October) and cold season (November- March) from 2000-2021. (A) Annual Mean minimum temperature for the hot season; (B) Annual mean maximum temperature for the hot season; (C) Annual mean minimum temperature for the cold season; and (D) Annual mean maximum temperature for the cold season.

Source: Temperature data are obtained from CRU-TS 4.06 (Harris et al., 2020) downscaled with WorldClim 2.1 (Fick & Hijmans, 2017). All data processed and visualized by RStudio

5.3.3. Evaporation

Evaporation in the study area is characterized by an increase in the summer, with rates reaching 227 mm month of July at Khanaqin stations, as shown in Table 3. The increase in evaporation is due to many reasons, including high temperatures, fluctuations in rainfall, and increased wind speed, which causes increased water consumption. The amount of evaporation in January reached 38 mm. The decrease in evaporation is due to many reasons, including low temperatures, rainfall, and high relative humidity uses of agricultural land in the study area and the necessity of providing water to plants, especially when evaporation levels are high (Abdulsattar & Aziz, 2017).

Table 3 Monthly averages of evaporation values at two Khanaqin stations in 1980-2017

Month	Evaporation (mm)
January	38
February	51
March	87
April	130
May	180
June	214
July	227
August	209
September	162
October	125
November	65
December	40

Source: (Abdulsattar & Aziz, 2017)

5.4. Soil Types

The prevailing soils in the study area are soils transported by the Diyala and Tigris rivers and the temporary rivers that come from the eastern highlands bordering Iran. They consist of fragments of limestone, sand, and clay rocks that prevail in the Diyala River basin (Aljubouri et al., 2015). The sedimentary plains were formed in ancient geological times dating back to the Cretaceous era and Miocene and alluvial deposits. River for the modern era (Zghir, 2013).

Each type of agricultural soil has a specific agricultural crop that is well cultivated in it and not in others, depending on its general characteristics. As shown in Figure 8, and despite the small area of the study area, the geographical distribution of the soil varies from one place to another, which distinguishes the agricultural style practiced by the population.

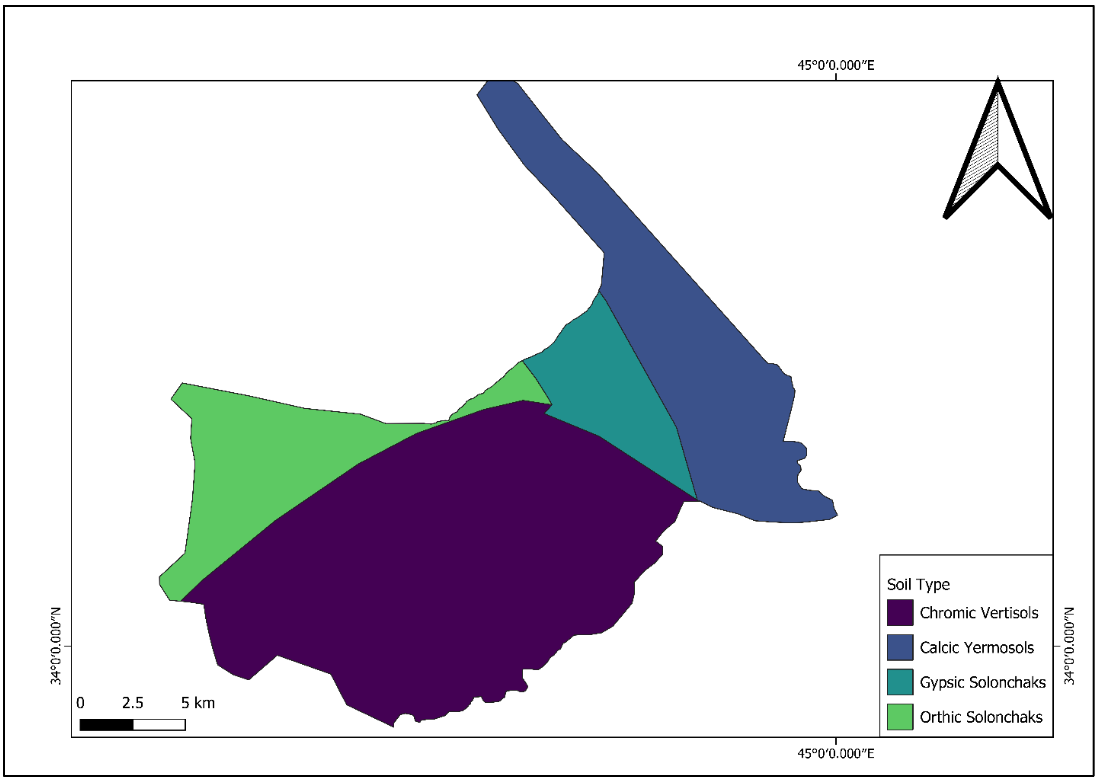

Figure 8 Soil Map of Almansouriya District
Source: Soil data obtained from FAO digital soil map (FAO, 2006). The data was processed and visualized by QGIS

5.5. Dominant Crops

As shown in Figure 9, 56% of Almansouriya land use is arable area and 14% of that area is completely reclaimed, However, different crops are planted within the totally reclaimed area such as 5% of Bastana which includes (palm trees, grapes, pomegranate, Citrus trees and almond trees, fig and olive trees, etc.) and 19% of Grains (wheat, barley, yellow corn, and mung beans) and 0.55% of Industrial (sunflowers and sesame), 0.42% of protected agriculture (Pepper, eggplant, tree, cucumber, tomato, etc.), and 1% of vegetables (winter and summer vegetables) (Zghir, 2013)

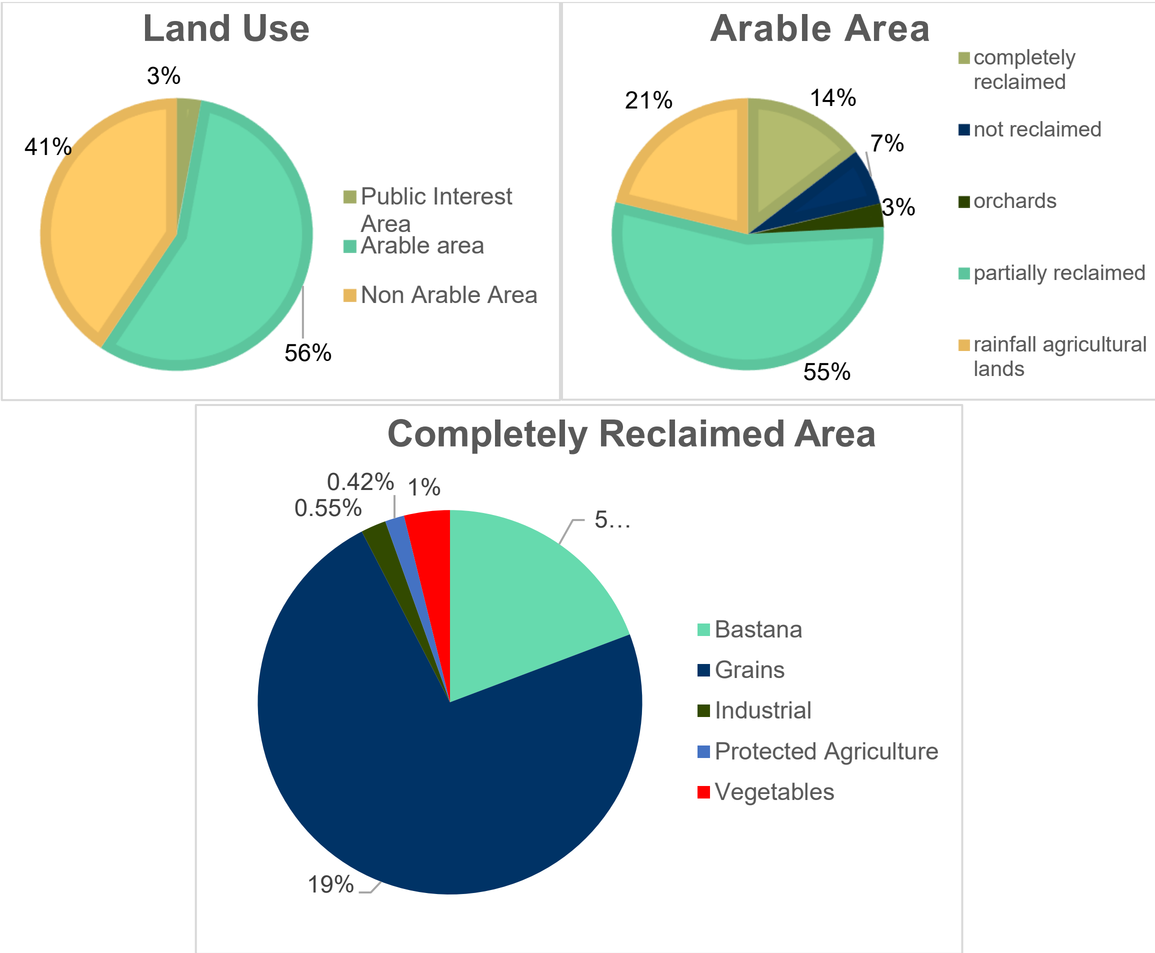

Figure 9 Land use and its relation with crops distribution in Almansouriya District
Source: (Cordesman, 2018; EEA, 2021; IFAD, 2017; World Bank, 2018; World Bank & FAO, 2012)

5.6. Field Water Balance

As shown in Table 4, the difference between precipitation and evapotranspiration results in water balance which indicates whether the area suffers from lack of water or there is any surplus. The results showed that the area suffers from the lack of water due to the minus values, or at least the area depends on other sources of water which could be either groundwater or surface water.

Table 4 Field Water Balance in Almansouria District

Date	Precipitation (mm)	Evapotranspiration (mm)	Water Balance (mm)
Jan	0.751400614	1.557169278	-0.805768664
Feb	1.434449495	2.242117172	-0.807667677
Mar	1.028476498	3.583600154	-2.555123656
April	0.733243651	5.197105238	-4.463861587
May	0.159538556	6.849003994	-6.689465438

Jun	0.00185127	7.938089206	-7.936237937
Jul	0	8.145872197	-8.145872197
Aug	0	7.508995853	-7.508995853
Sep	9.92×10^{-5}	5.941427143	-5.941327937
Oct	0.18281275	3.938161598	-3.755348848
Nov	0.986545079	2.18627746	-1.199732381
Dec	1.581806298	1.517795699	0.064010599

Source: ClimateEngine (Huntington et al., 2017). All data processed by Excel

5.7.Crop Water Requirements

The chosen crop type was barley as it is an important crop in the study area. As shown in Figure 10, the column decade represents the planting period where the decade is 10 days, hence 1 month has 3 decades (ex. 1 decade is from 1-10, 2 decade is from 11-20, and 3 decade is from 21-31).

Stage column is driven from crop data which refers to the stage of growing plant. However, ETc represents the ETo (reference evapotranspiration) multiplied by Kc (crop coefficient). In the last column, irrigation requirement for barley is highly needed during the summer season where an equal amount is required from June to mid-July with a value of effective rainfall of zero. Hence, we need to depend on another irrigation method (most probably not from rainfall).

Crop Water Requirements

ETo station: KANAQIN — Crop: Barley

Rain station: KANAQIN — Planting date: 30/04

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Apr	3	Init	0.30	1.61	1.6	1.0	1.6
May	1	Init	0.30	1.78	17.8	8.3	9.6
May	2	Deve	0.37	2.44	24.4	6.1	18.3
May	3	Deve	0.72	5.07	55.8	4.1	51.7
Jun	1	Mid	1.08	8.21	82.1	0.1	81.9
Jun	2	Mid	1.18	9.59	95.9	0.0	95.9
Jun	3	Mid	1.18	9.60	96.0	0.0	96.0
Jul	1	Mid	1.18	9.58	95.8	0.0	95.8
Jul	2	Mid	1.18	9.63	96.3	0.0	96.3
Jul	3	Late	1.16	9.35	102.9	0.0	102.9
Aug	1	Late	0.91	7.32	73.2	0.0	73.2
Aug	2	Late	0.60	4.79	47.9	0.0	47.9
Aug	3	Late	0.34	2.50	17.5	0.0	17.5
					807.2	**19.6**	**788.5**

Figure 10 Crop Irrigation Scheduling

Source: CLIMWAT 2.0 (FAO, 1993). All data was processed and visualized by CLIMWAT

5.8. Irrigation Scheduling

The main objective of calculating the irrigation scheduling for barley crops in Almansouriya District is to conserve water, avoid both over- and under-irrigation, protect the environment, and maintain soil health. Moreover, it led to increased energy efficiency and adapted irrigation practices to a certain climate condition, ensuring sustainable and effective water management for agriculture and landscapes.

After importing the data from the CropWat and depending on SoilGrids which calculates the FC and WP which are field capacity and wilting points where FC is the water volume content at -33 kPa, and WP is the water volume content at -1500 kPa, which are 0.287 and 0.232 mm, respectively, the obtained results showed how often can we irrigate barley per day.

As shown in Table 5, Barley requires high irrigation during the planting and before harvesting phase which can be seen during the mid-growth period (5 days) whereas more irrigation is required in May and August which are the starting month of planting and before harvesting. Also, barley requires a minimum of 100 mm of water, and typically around 125 mm, from germination to the reproductive growth stage to yield grain. The water requirements during the vegetative growth phase depend on the environmental temperatures. For instance, plants need more moisture for transpiration in a warm, dry spring compared to a cool one (Government of Alberta, 2011).

Table 5 Irrigation scheduling for barley

Date	Water Balance (mm)	ETc (mm/day)	Gross irrigation requirement (mm/day)	Precipi-tation of the system (mm/hr)	irrigation per day (hr/day)	AWC (mm)	Frequency (days)	Irrigat-ion (hr/event)
May	-6.689465	3.161290323	2.56	2	1.28	49.5	15.65816327	24
Jun	-7.936237	9.133333333	9.12	2	4.56	49.5	5.419708029	
Jul	-8.145872	9.516129032	9.51	2	4.755	49.5	5.201694915	
Aug	-7.508995	4.470967742	4.47	2	2.235	49.5	11.07142857	

Source: Water balance data adopted from (Huntington et al., 2017), ETc and Gross irrigation required from CropWat exercise, and AWC data from SoilGrids (Poggio et al., 2021). All data processed and organized using Excel

5.9. Crop Water Productivity

According to FAO, (2016), GBWP is the quantity of biomass production in relation to the total volume of water consumed in a given period. When the biomass production is related to total evapotranspiration, this will result in an indicator of the vegetation development impact on consumptive water use and thus on water balance

GBWP is calculated as the following equation:

$$GBWP = Yield / ETIactual$$

(Where Yield is expressed in kg/ha and actual ETI is expressed in m³/ha.)

As shown in Figure 11, significant spatial variation of GBWP was observed. There is an increase of GBWP in 2020, especially in the areas where the irrigation croplands are introduced.

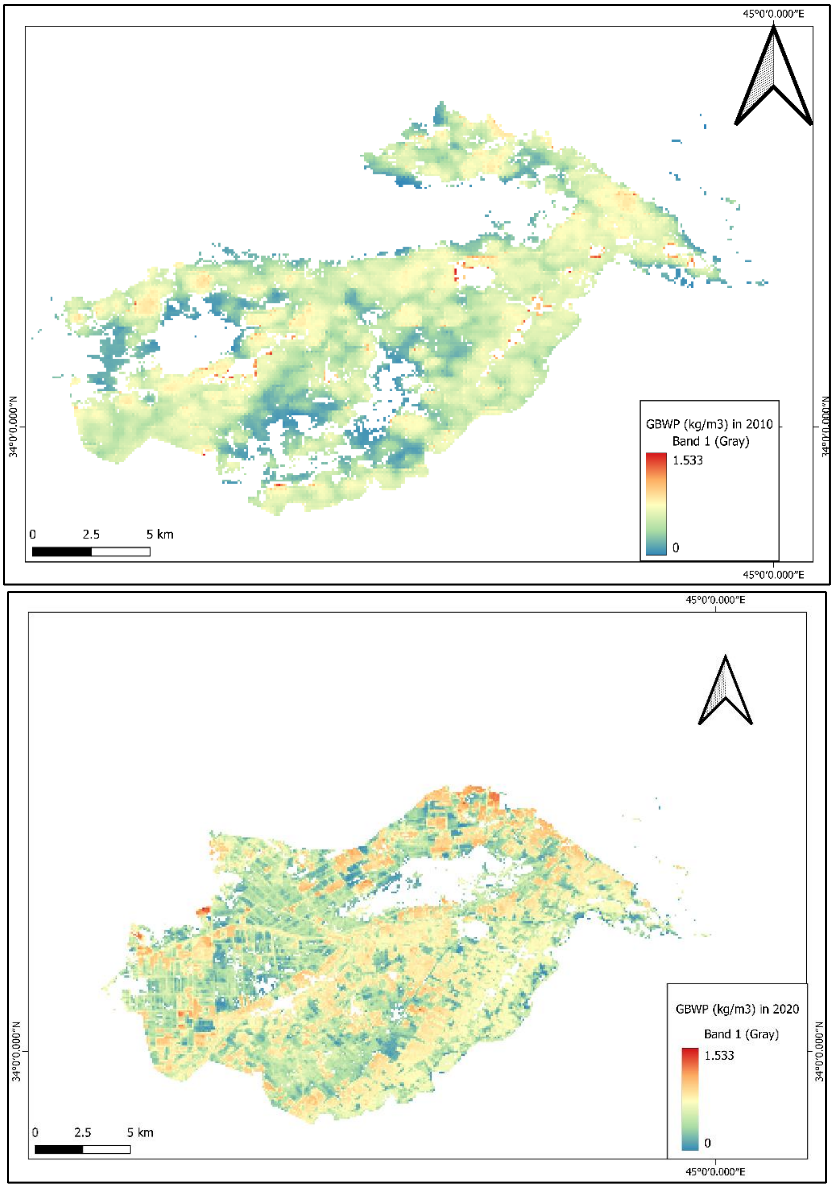

Figure 11 Gross Cropo Biomass Water Productivity in 2010 and 2020
Source: Data from WaPOR (Bastiaanssen et al., 2012). All data processed and visualized using QGIS.

5.10. Irrigation Performance Indicator

Using performance indicators or benchmarks could help define critical challenges and measure the level of enhancement that different approaches may have in crop growing. Additionally, comparing agricultural practices such as using fertilizers, environmental factors, and others, all help in analyzing and understanding the crop response to achieve efficient practices and sustainable products (van Grinsven et al., 2019)

In this study, two indicators were proposed to study the irrigation performance in Almansouriya district which are adequacy and equity.

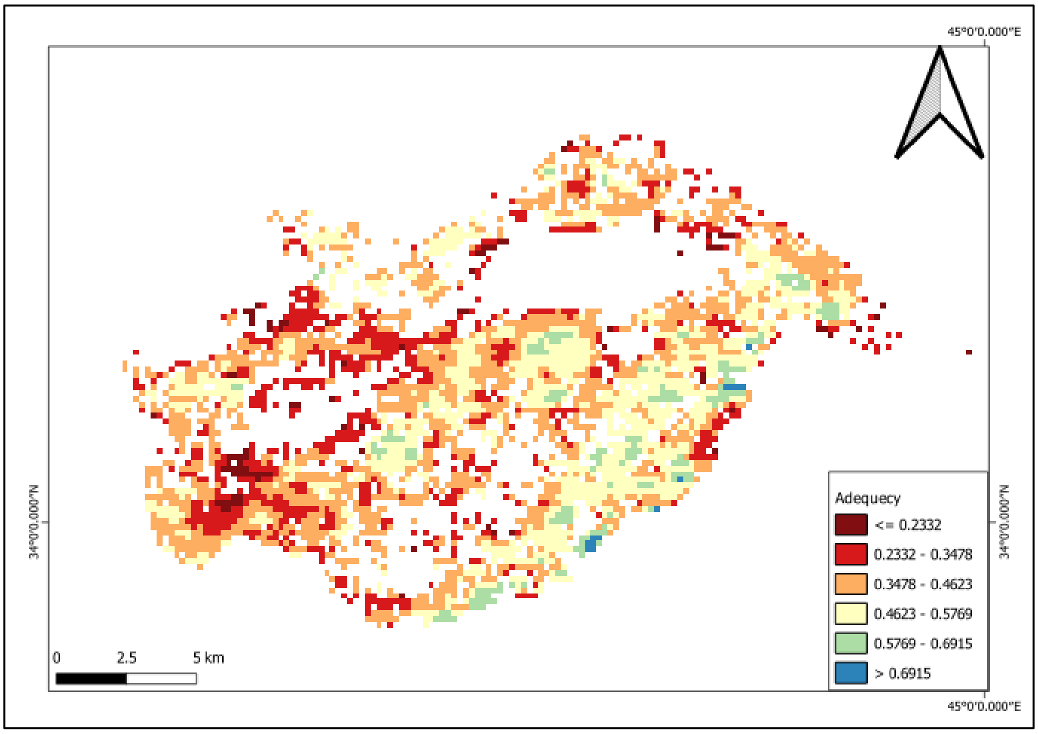

Figure 12 Adequacy values of the irrigated crop land in Almansouria district in 2020
Source: Data from WaPor (FAO, 2020). All data processed by QGIS

Table 6 the adequacy value categorization

Value	Indicator
0.8 - 1	Good adequacy
0.68 - 0.8	Acceptable
≤ 0.68	Poor

Source: (Bandara, 2006)

As shown in Figure 12 and depending on Table 6, the northern part of the study area has an adequacy value ranging between 0.23- 0.69 which indicates the poor water supply and the agricultural lands receiving inadequate water due to water stress in the region. This result could be a result of the climatic conditions and poor water supply due to drought and shortage in water supply for irrigation purposes.

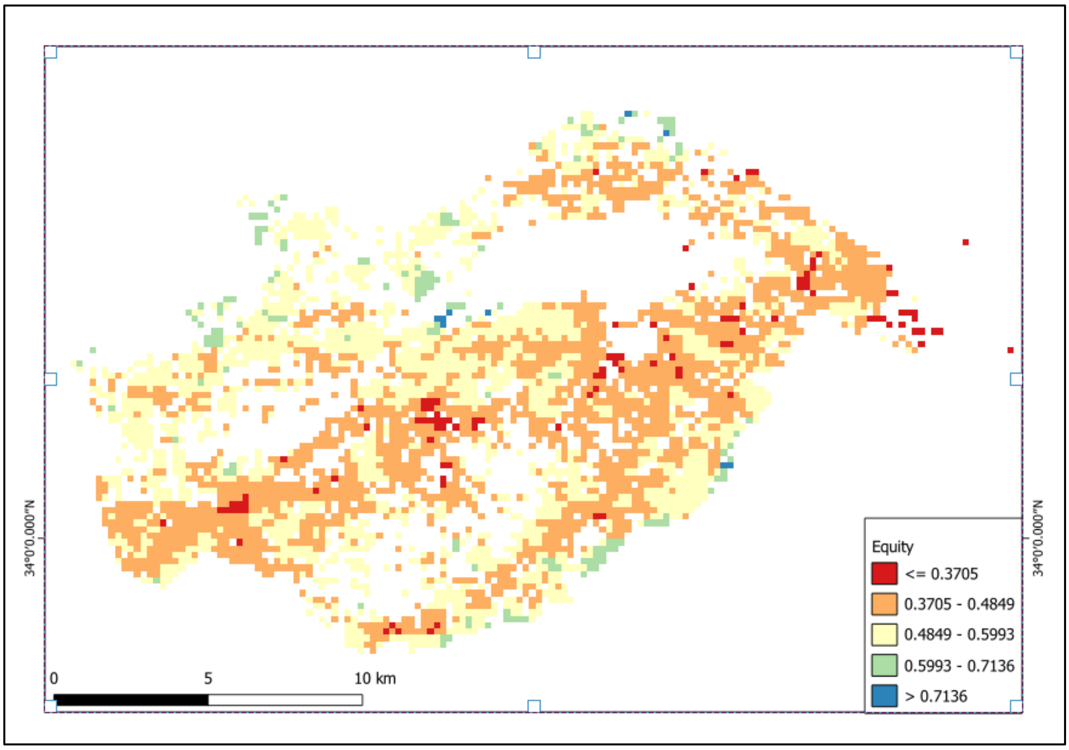

Figure 13 Equity values of the irrigated crop land in Almansouria district in 2020
Source: Data from WaPor (FAO, 2020). All data processed by QGIS

Table 7 Equity values categories

Value	Indicator
0 - 0.1	Good
0.1 - 0.25	Fair
≤ 0.25	Poor

As shown in Figure 13, and depending on Table 7, the Coefficient of Variation (CV) of equity indicator ranges between 0.3 and 0.7 which indicates to a poor in the study area that indicates that during the growing seasons, there was inadequate water and not able to meet the crop water requirements, which is obviously true due to high required irrigation water during the growing seasons.

5.11. Crop Yield Gap

The yield gap can be defined as the disparity measure between the actual farm yield (FY) and the potential yield (PY), expressed as a percentage of FY. The difference sheds light on how much growth in a year can be obtained if the farm conditions are optimal. It is recommended to have the yield gap expressed relatively to FY, which reflects plausibility, as the Farm yield is the actual obtained yield not the projected one (PY).

The average crop yield (this layer is also called the actual yield) was calculated from the crop yield layers (TBP) for two seasons (2010 and 2020). As shown in Figure 14, there is a positive expanding pattern of increased yield starting from the central areas to the borders of the reclaimed areas. This expansion reflects a positive influence of the reclaiming activity on the farmers. Nonetheless, the expansion follows a pivotal shape, rather than a uniform circular area, which indicates some potential hidden problems in the lands that should be addressed with some stakeholder engagement frameworks. However, the result should be compared with potential yield but due to no data being available for the country level generally and for the crop level (barely) particularly, it has been considered calculating the previous raster and getting the average yield in kg per ha.

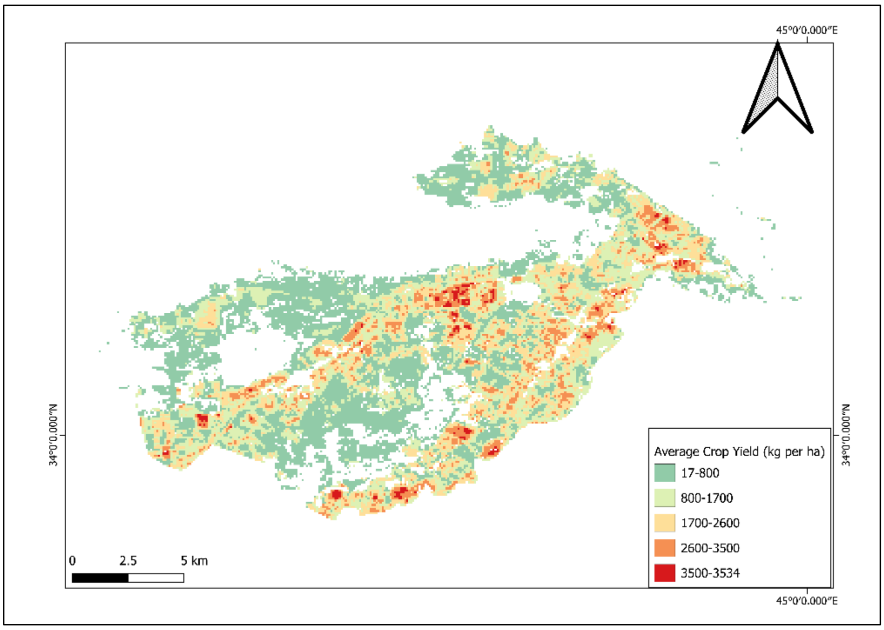

Figure 14 Average Crop Yield In Almansouriya District
Source: Data from WaPOR (Bastiaanssen et al. 2012). All data processed and visualized using QGIS

5.12. Water Resources

The dominant water resources in Almansouriya District which are used for irrigation purposes are surface water and groundwater.

5.12.1. Surface Water

- **Diyala River:** Originates from the Zagros mountains inside Iran with 3 main tributaries: Sirwan, Tanjeru, and Wand River. The river flows passing through Sulimaniyah and Diyala governorates and joining the Tigris River approximately 5 Km southern border of Baghdad (Abbas et al., 2016).
- **Alkhalis Stream:** The length of the stream is 19 km within the study area. It is dusty in nature, unlined, and divides the Mansouriya district into two parts. From it branches the Al-Shawhani, Sherwin, and Al-Marfu streams, and irrigates all the agricultural districts within

the study area. Thus, it serves two important purposes when operating, which are regulating the processed drainage as well as measuring its quantity to secure the needed water according to the agricultural density, the area of the irrigated unit, and the type of irrigated land (Zghir, 2013).

- **Diyala Dam** Located inside the study area (Almansouriya) contributes to supplying the Diyala River with quantities of water for agricultural purposes in the summer season (Zghir, 2013).

5.12.2. Groundwater

Groundwater in the study area is obtained by drilling wells, withdrawing water from them, and investing it in a simple way, especially in the provinces far from streams and water canals, but the problem of salinity contributes to this groundwater, which harms agricultural production. The number of wells for private benefit reached 142 wells which are distributed among the regions of the district as shown in Table 8.

Table 8 Almansouria sub-regions with the characteristics of their wells (2008-2012)

Region	Area of Agricultural land (ha)	Number of wells	Depth (m)	Salt concentration (ppm)
Shroin	155.7	64	40-36	3000-2240
Kurd Ali	35.2	21	40-36	3000-2240
Mansuriya Aljabal	26.8	22	40-36	3000-2240
Shohani	32.5	15	90-36	6000-4190
Almashrooa	11.0	8	74-42	7150-2380
Almarfooa	28.0	6	90-48	5100-2380
Singer Sulaimani	10.9	6	40-36	-

Source: (Zghir, 2013)

5.13. Irrigation System

5.13.1. Surface Irrigation

It is the dominant irrigation method in Almansouriya District where the flow begins on one side of the field and gradually spreads until the entire field is irrigated. This can be achieved by either flooding the entire field simultaneously (basin irrigation), directing water into small channels (furrows), or flooding strips of land (borders) until the whole field is covered.

5.13.2. Irrigation by Means

Water is delivered to agricultural lands using this method, by using either diesel or electric pumps, or a combination of both. This irrigation method is more prevalent than surface irrigation in the study area, although it varies between districts depending on the region's characteristics. It is especially noticeable in higher agricultural areas along riverbanks and irrigation channels where surface irrigation is not feasible.

5.13.3. Drip Irrigation

This method stands out for its versatility in irrigating a wide range of crops and soil types with varying topographies (different elevations) without requiring any modifications or leveling. It is also suitable for irrigating sandy soils. In the study area, modern irrigation systems were introduced in 2012. These systems were used for crop irrigation in several agricultural districts, with 216 drip irrigation devices distributed across various districts within Almansouriya region (Zghir, 2013).

5.13.4. Sprinkler irrigation

Sprinkler or spray irrigation involves applying water in a controlled way, mimicking natural rainfall. The water is distributed through a system that may include pumps, valves, pipes, and sprinklers. This method can be used for residential, industrial, and agricultural purposes (Water Science School, 2018). The number of central pivot irrigation systems is 10, spread across three agricultural districts. However, most of these systems were not used due to the high prices of fuels. (World Bank, 2018).

6. The Suggested Interventions

According to the aforementioned challenges in section 3, four interventions were suggested to tackle the groundwater challenges (salinity) and surface water challenges (low water quantities and evaporation), as shown in Table 9.

Table 9 A summary of the suggested intervention for the three challenges

Challenge Scale	Groundwater	Surface Water	
Challenges / Interventions	Salinity	Low Water Quantity	Evaporation
Wet/dry detention Ponds			
Rainwater harvesting			
Windbreaks			
Modular floating covers			

6.1. Wet Detention Ponds

A wet pond, also referred to as a detention or retention pond, as shown in Figure 15, is a stormwater management facility designed to temporarily store water and release it gradually without maintaining a permanent pool. The discharge is regulated by the outlet control at the minor outlet design, positioned at the basin's lowest point. Table 10 illustrates the contribution of this intervention to the water quantity challenge.

Table 10 Description of how the wet detention ponds tackle the challenges

Challenge	Description	Reference
Water Quantity	This contributes to tackling the water quantity challenges by storing the excess rainwater or the water from streams temporarily and releasing it during the dry period to irrigate the crops.	(UNaLab, 2022)

Figure 15 Wet Retention Ponds in Agricultural Lands
Source: (BTL LINERS, n.d.)

6.2. Rainwater harvesting

Rainwater harvesting for agriculture, as shown in Figure 16, is an important step that involves the collection, conveyance, storage, delivery, and use of rainwater runoff, primarily for crop systems, directly at the point of collection on the farm. For instance, in the Caribbean, this practice is predominantly used by small farmers. Its successful implementation relies on both empirical formulas derived from complex statistical calculations and a thorough understanding of the defining characteristics of rainwater harvesting (FAO, 2014).

Planning for storing rainwater runoff in rain-fed systems necessitates understanding annual cumulative storage, storage patterns, and water demand patterns (FAO, 2014). Dimensioning of the RWH system helps to calculate the annual cumulative storage of rainwater runoff from a specific annual rainfall at 70% frequency, considering the known catchment surface area (200 m^2) and RCE (0.30). It also offers guidance on managing cumulative storage through production planning and ensuring storage is properly sized to prevent water loss due to spillage. The required calculations are shown in Table 11. However, Table 12 illustrates the contribution of this intervention to the water quantity and salinity challenge.

Table 11 Cumulative rainfall calculation for the design year 2000

Months (date)	1st Precipitation (mm)	2nd Precipitation (m)	3rd Collected water (m^3)	4th water Runoff Collected (m^3)	5th Cumulative Runoff (m^3)
Jan	33.8051	0.0338051	6.76102	2.028306	2.028306
Feb	15.18	0.01518	3.036	0.9108	2.939106
Mar	28.3648	0.0283648	5.67296	1.701888	4.640994
Apr	30.026	0.030026	6.0052	1.80156	6.442554
May	2.2128	0.0022128	0.44256	0.132768	6.575322
Jun	0	0	0	0	6.575322
Jul	0	0	0	0	6.575322
Aug	0	0	0	0	6.575322
Sep	0.0592	0.0000592	0.01184	0.003552	6.578874
Oct	3.5299	0.0035299	0.70598	0.211794	6.790668
Nov	17.0952	0.0170952	3.41904	1.025712	7.81638
Dec	53.5667	0.0535667	10.71334	3.214002	11.030382

Table 12 Description of how the rainwater harvesting system tackles the challenges

Challenge	Description	Reference
Water Quantity	It helps conserve soil and water resources while enhancing crop yields. Rainwater harvesting can also safeguard crops from drought and is considered an alternative source in Almansouriya District besides groundwater and surface water.	(Smart Water, 2024)
Salinity	This method can assist farmers in decreasing their dependence on irrigation and alternative water sources, by decreasing the dependence on groundwater, the salinity will decrease and the GW quality enhanced. Additionally, recharging aquifers with low-salinity rainwater creates a freshwater layer above the denser saline groundwater.	(India Water Portal, 2018)

Figure 16 Rainwater Harvesting System in Agricultural Land
Source: (Yamuna, 2022)

6.3. Windbreaks

Windbreaks are natural barriers created using trees, shrubs, or other plants to protect areas from wind. In agriculture, they are used to shield crops, minimize soil erosion, and conserve water by reducing evaporation and temperature (Helfer et al., 2009), as shown in Figure 17. Table 13 illustrates the contribution of this intervention to the evaporation and water quantity challenges.

Table 13 Description of how the windbreaks tackle the challenges

Challenge	Description	Reference
Evaporation	reduce evaporation by slowing down the movement of hot air over water surfaces, which helps form a moisture layer that minimizes the humidity gradient and evaporation. Trees in windbreaks also release moisture through transpiration.	(Hashemi Monfared et al., 2019; Helfer et al., 2009)
Water Quantity	As long as the windbreaks reduce the water evaporation from lakes, it would result in maintaining the water quantities in the ponds.	-

Figure 17 Windbreaks in Agricultural Land
Source: (Sottosanti, 2023)

6.4. Modular Floating Covers

They are individual units that float on the water's surface, providing partial coverage. These covers reflect solar radiation and serve as barriers to water vapor. They are made from various materials, and designed to be adaptable and flexible for different water bodies, ensuring efficient water loss reduction through evaporation without compromising water quality (Hao et al., 2023). Table 14 illustrates the contribution of this intervention to the evaporation and water quantity challenges.

Table 14 Description of how the modular floating covers tackle the challenges

Challenge	Description	Reference
Evaporation	It can reflect solar radiation and act as a barriers to water vapor. The suspended covers, supported by wooden or steel structures, can reduce evaporation by 75 to 90% without compromising water quality	(Gallego-Elvira et al., 2011; Shalaby et al., 2024)
Water Quantity	As long as the modular floating covers reduce the water evaporation from lakes, it would result in maintaining the water quantities in the ponds	-

Figure 18 Modular floating cover over a pond

7. Conclusion

The study of agricultural water usage in Almansouriya District reveals significant challenges related to water scarcity, high salinity in groundwater, and considerable evaporation rates. These problems are triggered by climatic conditions and inefficient water management practices. The study proposes several interventions to address these challenges, including rainwater harvesting (RWH), wet detention ponds, windbreaks, and modular floating covers.

Although rainwater harvesting is limited by low rainfall during the hot season, it can be effective when used in conjunction with other solutions like modular floating covers. These covers help reduce evaporation and maintain water levels in both wet retention ponds and RWH basins. Additionally, windbreaks are recommended to decrease evaporation and water consumption by creating a microclimate that conserves moisture. This study emphasizes the importance of implementing multiple strategies to achieve sustainable water use and enhance agricultural resilience in the face of climatic and environmental challenges.

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