Journal homepage
www.ajas.uoanbar.edu.iq
Anbar Journal of Agricultural Sciences
(University of Anbar – College of Agriculture)

SUITABILITY OF WADI HALWAT WATERSHEDS FOR GROWING WHEAT AND OLIVE TREES WITHIN THE DRY ENVIRONMENT OF THE ANBAR GOVERNORATE

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Article info

Received: 2025-01-20
Accepted: 2025-03-23
Published: 2025-06-30

DOI-Crossref:
10.32649/ajas.2025.187605

Cite as:
Yaqub, M. T., Hassan, M. A., and Mekelf, A. A. (2025). Suitability of wadi halwat watersheds for growing wheat and olive trees within the dry environment of the anbar governorate. Anbar Journal of Agricultural Sciences, 23(1): 711-727.

Abstract

In view of the increasing population and scarcity of land and water resources due to the drought situation in Iraq, effective management of these resources has become an extremely urgent need to achieve sustainable agricultural development. In this sense, an assessment of the Earth's suitability for use is one of the most important tools to help manage these resources appropriately and to use GIS geographic information systems. Four soil profiles were drilled to represent all the different geomorphological units of the land on 15/2/2024, samples were collected from different soil horizons and prepared for laboratory analysis to demonstrate the relationship between the topography and soil data, a soil map was compiled using Arc-GIS 10.3. The results showed that the study area includes four topography features: the Euphrates River floodplain sediments, the valley stream floodplain, the upper valley floodplain and the Jabia upland foothill unit. The results of the evaluation showed through the use of the standard method sys et al 1993 that 15.04% of the land is very suitable S1 for the cultivation of the spelt crop and concentrated in both the Euphrates River Flood Plain Deposit Unit and the Halwat Valley Flood Plain and 24.46% of the land is moderate Suitable S2 concentrated in the Valley's Flood Plain Unit and 60.50% of the land is not suitable within the northern highlands of the

forest. The results showed three classes of relevance, as follows: (S2) by (9.89%), (S3) by 22.93% and (N) by 66.77% and the most specific factors for crop cultivation are the gypsum content and organic content.

Keywords: Wadi Halwat, Land evaluation, Land suitability, Cultivation of wheat.

دراسة ملائمة مستجمعات مياه وادي حليوات لزراعة محصول الحنطة واشجار الزيتون ضمن البيئة الجافة لمحافظة الانبار

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الخلاصة

نظرا للزيادة السكانية وندرة الموارد الارضية والمائية بسبب حالة الجفاف في العراق اصبحت الادارة الفعالة لهذه الموارد ضرورة ملحة للغاية لتحقيق التنمية الزراعية المستدامة ومن هذا المنطلق يعد تقييم ملائمة الارض للاستخدام من اهم الادوات التي تساعد في ادارة هذه الموارد وبشكل مناسب واستخدام نظم المعلومات الجغرافية GIS. تم حفر اربعة مقاطع للتربة لتمثل جميع الوحدات الجيومورفولوجية المختلفة من الأرض، تم حفر اربعة مقاطع للتربة لتمثل جميع الوحدات الجيومورفولوجية المختلفة من الأرض في 2024/2/15، وتم جمع عينات من أفاق التربة المختلفة وإعدادها للتحليل المختبري وبيان العلاقة بين التضاريس وبيانات التربة، تم تجميع خريطة التربة باستخدام Arc–GIS 10.3. وأظهرت النتائج أن منطقة الدراسة والتي تشمل اربعة تضاريس وهي: رواسب السهل الفيضي لنهر الفرات، السهل الفيضي لمجرى الوادي، اعالي السهل الفيضي للوادي ووحدة سفوح المرتفعات للجابية، اظهرت نتائج التقييم من خلال استخدام الطريقة القياسية sys et al 1993 ان 15.04% من الاراضي ملائمة جدا S1 لزراعة محصول الحنطة وتركزت في كل من وحدة رواسب السهل الفيضي لنهر الفرات والسهل الفيضي لوادي حليوات و24.46% من الاراضي ذات ملائمة جيدة S2 تركزت في أراضي وحدة السهل الفيضي للوادي والمسيلات المائية و60.50% من الأراضي غير ملائمة ضمن وحدة سفوح المرتفعات الشمالية للجابية، اما اصناف ملائمة اشجار الزيتون اظهرت النتائج وجود ثلاث فئات للملائمة وكما يلي: (S2) بنسبة (9.89%)، و(S3) بنسبة 22.93% و(N) وغير الملائم بنسبة 66.77%، وان العوامل الأكثر تحديدا لزراعة المحاصيل هي المحتوى الجبسي ومحتوى المادة العضوية.

كلمات مفتاحية: وادي حليوات، تقييم الأراضي، ملاءمة الأرض، زراعة القمح.

Introduction

As a key component of a country's overall development the agricultural sector requires serious planning in the area of land, water, economic and social resources, as well as environmental and climatic conditions. Land assessment relates to land performance or efficiency when used for any specific purpose (6). It is defined as an assessment or development of a land's potential for agriculture, forestry, pastures, services, and others (11). It also involves assessing its suitability and potential for improvement for use based on land use type (LUT) (5).

Land suitability for winter wheat cultivation based on multi-standard decision support using GIS and MCDS-GIS approaches in the Yarmouk Basin (southern Syria) indicated that western Syria is a suitable for wheat cultivation rather than the eastern region to which climate change and water shortage are subjected (12). (24) noted the impact of the variation of the agricultural system on some sedimentary soil characteristics in the Abu Ghraib-Iraq area during which four agricultural systems were identified: clover, palm, grain and lobia crops as well as untapped land Following identification of the inspection sites, pedons representing each type of agricultural system were drilled and their prospects determined. The results showed differences in the morphological, chemical, and physical characteristics of the soil between the locations horizontally and vertically owing to the different management methods used in each agricultural system in terms of tillage and fertilization (2).

The land in western Iraq was assessed according to the standard method in a study to determine the impact of cement plant emissions on the viability of the adjacent lands for growing wheat and olive trees. The main determinant for this purpose was the physical factor of the soil. It showed a high content of gypsum in all locations while the land around the Al-Qaim cement factory showed high carbonate content as a major factor limiting the cultivation of wheat. Land for olive trees cultivation was not suitable (N2s) owing to the high first grade gypsum content and the second-degree soil organic content at the Kubasa factory, as all land showed a marginal (S3s) suitability for olive trees agriculture. An evaluation of the wastelands west of Anbar showed that the main determinant for growing the pistachio crop was the amount of gypsum and the degree of soil reaction, and that climate was not a determining factor in the study area (14).

The study concluded that the types of suitability ranged from N1 to N2 (13) and factors determining the cultivation were soil depth, gypsum, and soil texture, while the climate was suitable from the (S1) class at a degree of 87.15 of the climate index. The pedons (P1, P2, P3, P6, P8) were distributed under the S3s suitability class and the suitability degree reached 31-49 and the determining factor was depth and gypsum levels. The P4 and P5 pedons were distributed under the N1s class, which is actually unsuitable and will likely change to the S3s class in the event of improvement or removal of the limit. In evaluating the suitability of the lands of Majnoon, west of Anbar according to the modified Storey index, (3) explained that when the two classes (S1) and (S2) were reached, the medium suitability class (S2) prevailed over the high suitability one (S1) (16).

In a study using the analytical hierarchy process under different land uses in Nigeria and the savannah region of northern Guinea, it was found that 89.73% of the area was

highly suitable for tomato cultivation, while 10.27% was moderately suitable. The limiting factors for these soils were low fertility and poor drainage. The study showed that management techniques including incorporation of organic matter and inorganic fertilizers and improvement of drainage conditions are necessary to achieve sustainable productivity.

The aim of this research is to study the suitability of the soil of the Halwat Valley watersheds for the cultivation of wheat (Triticum aestivum) and olive trees (Olea europacae) using the land evaluation system (19 and 21). The two are strategic crops with high economic value, and are located within the main physiographic unit of the island in Iraq's Anbar governorate. For this purpose, a digital elevation model (DEM) and a Landsat 8 image were created to extract the geomorphological units of the study area.

Materials and Methods

Study area: The study area is located in Ramadi district of Anbar governorate within Al-Budiab district between longitudes 43°8'1" to 43°10'18" east, and latitudes 33°35'16" to 33°30'47" north. It is bordered by the Tharthar depression at the north, the Euphrates River to the south, the Al-Bu Asaf and Al-Tarabsha districts to the west, and an extension of the Al-Jaraishi district to the east. The area covers 124.3 km2 (310.825 dunums) and is characterized by sedimentary soils within the flood plain of the Euphrates River and gypsum desert soils in the northern part. Figure 1 shows the distribution of contour lines in the area.

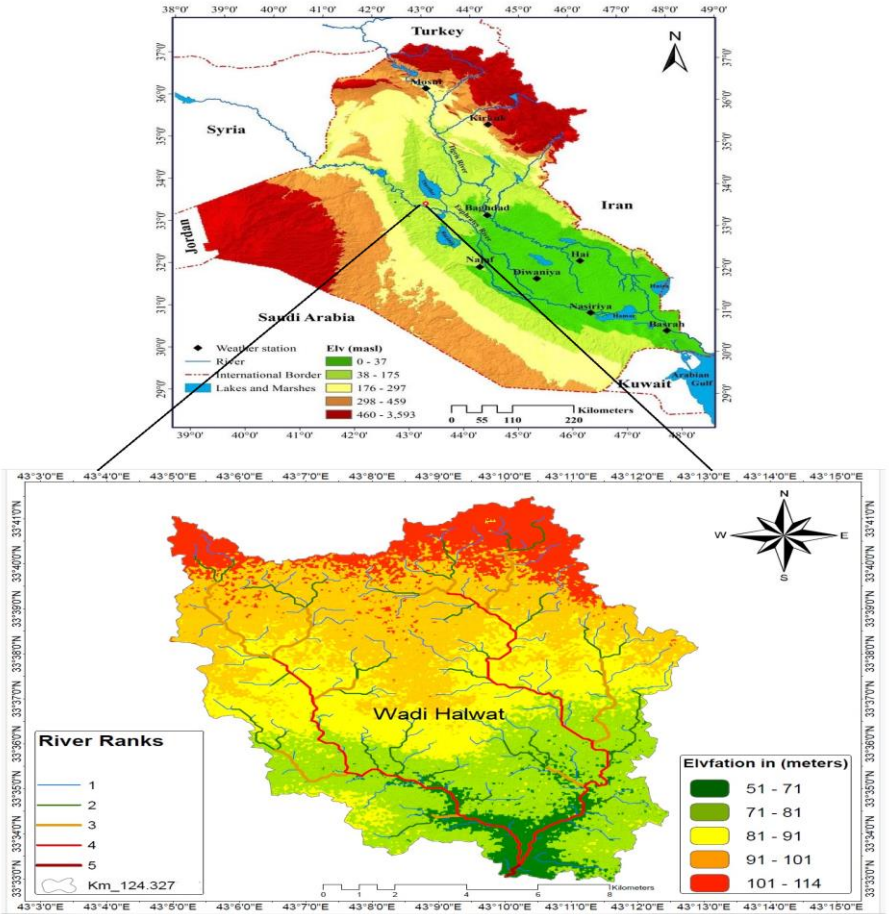

Fig. 1: Location of the study area.

Fieldwork: Due to the lack of a semi-detailed soil map of the study area, the soil survey work was conducted using the free survey method. The area was surveyed as a preliminary step by field investigation and observing local changes by identifying the type and density of vegetation cover and its topography, the nature of agricultural use in the valley basin, and soil-management techniques used. The soil texture was examined by touch. A total of 12 holes were drilled to a depth of 100 cm covering the entire area of the basin. Four field test sites (pedons) were selected and identified. They were examined morphologically based on (17 and 23) in terms of soil texture, soil color, natural vegetation, presence of gypsum and lime, as well as texture, porosity, root distribution, and effective soil depth.

Observations were also recorded on natural vegetation and agricultural use for each site. Then, representative soil material samples were obtained for each pedon horizon for measuring soil salinity and concentrations of dissolved sodium, calcium, and magnesium ions, and calculating the sodium sorbate (SAR) and exchangeable sodium percentage (ESP). The soil characteristics were classified according to the results of the field study and laboratory analyses. Figure 2 shows the distributions of representative soil pedons and examination sites within the valley basin.

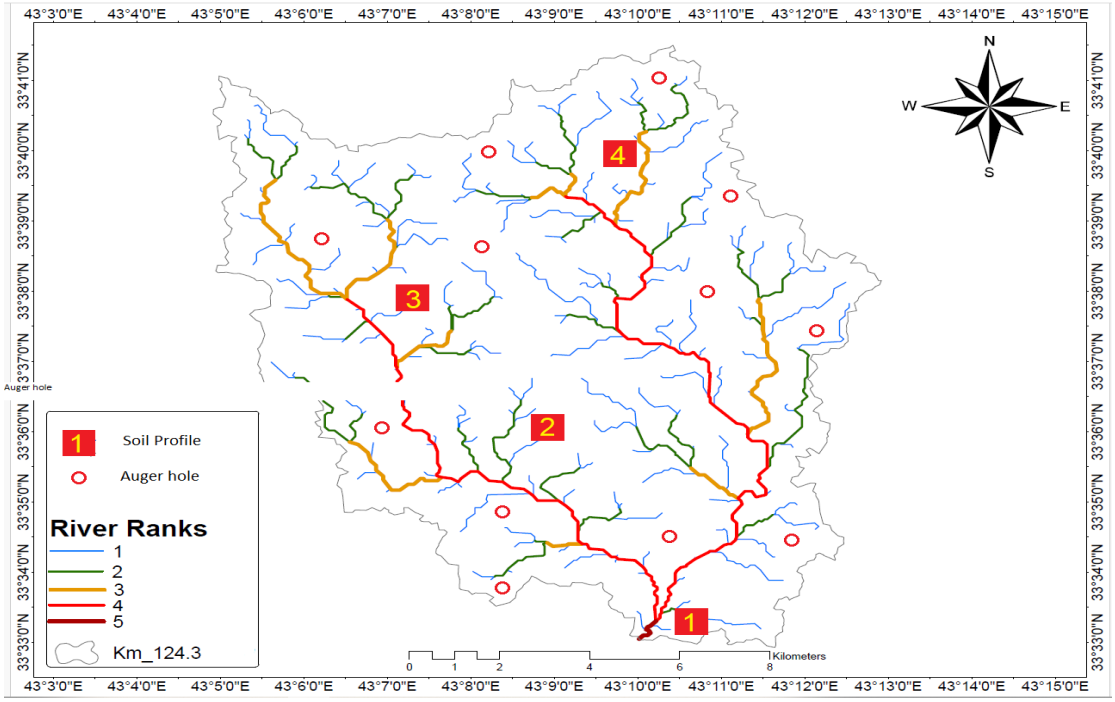

Fig. 2: Distributions of representative soil pedestals and test sites within the valley water shed.

Laboratory Analysis: The soil samples were subjected to laboratory analysis to estimate the following chemical properties in the saturated soil paste:

1. Electrical conductivity according to method (15).
2. Soil reaction degree (pH) according to method (15).
3. Dissolved sodium: estimated using an Optima flame photometer, model SP3000.
4. Dissolved calcium and magnesium (estimated in meq L^{-1}) according to method (10).
5. Percentage of gypsum according to method (22).

6. Percentage of calcium carbonate: determined by titration with 0.5 N sodium hydroxide according to the method in Handbook No. 60
7. The exchange capacity of cations according to the method by (7).
8. The percentage of organic matter was determined according to the Walkley-Black method described in (9).
9. The exchangeable cations were determined according to the method in Handbook No. 60. Then, the percentage of saturation with bases was calculated using the formula:

   Percentage of saturation with bases = Exchangeable (Ca+Mg+Na+K)/CEC×100
10. The distribution of soil particle sizes was estimated using a pipette according to the method by (8).

Using GIS software: A satellite image taken from Landsat (8) 2021 with the ETM(+) sensor was used with specifications marked C08_L1TP_169037_20210520_20210520_01_RT_B1.TIF by enhanced transverse scanner of the Landsat Thematic Mapper from the official website of the US Geological Survey (USGS2024 Global Visualization Viewer) (UTM38) for track 169 and row 37, and using the GIS-ver 10.8 program.

Land evaluation: The land evaluation process for the Al-Muhammadi valley water catchment area was based on the suitability of the land for growing wheat and olive trees according to (19 and 21) and the climatic, soil, and topographic requirements as follows:

Determining and evaluating the agro-ecological characteristics and those that directly affect the suitability of the land such as soil and environmental-climatic characteristics, hydrological conditions, and topography. The evaluation process involved following a link between the parametric and limitation methods proposed by (21), classifying land according suitability for a specific crop based on the standard method associated with the determinants for the purpose of defining the land index. It was calculated by multiplying the individual estimates of the characteristics according to the standard method and then defining the ranks and classes of the system according to the values of the land index proposed by (21). The following were the steps involved in evaluating and classifying the land:

1. Determining the use of the land i.e., for cultivation of wheat under irrigated conditions, and cultivation of olive trees under irrigated conditions.
2. Preparing the data for describing the land units, which include climate, topography, physical conditions of the soil, soil fertility, salinity, and alkalinity. The climate characteristics of the study area for wheat and olive trees were prepared according to their growth periods based on (20), as it includes the climate and topographic characteristics.
3. Evaluating the characteristics of the land to diagnose the level of specificity for each characteristic and the degree of its suitability for the type of land use. The evaluation method relied on the joint method of determinants and arithmetical estimation of the limitation parametric method proposed by (21).

Wheat crop:

Climatic characteristics: The climatic characteristics of the study area were matched with those listed in the climatic requirements table. Each characteristic of the region's climate was given a corresponding estimate representing the level of specificity it represents in the requirements table. Then the estimates were multiplied by each other to extract an index of the suitability of the study area's climate for the wheat crop.

$$\text{Climate index}= \frac{A1\times A2\times A3\times \ldots\ldots\times An}{10^{2n-2}}$$

$$=A1\times\frac{A2}{100}\times\frac{A3}{100}\quad\times\frac{An}{100}$$

where A1, A2 = estimates of climatic characteristics n,

The climate-suitable varieties for wheat plant growth can be found according to this guide and the final overall climate estimates based on the table proposed by (18) and the linear equations shown to extract the final climate estimates (Table 1).

Table 1: Classification of climate suitability according to the values of climate coefficients and the final climate estimates.

Climatic classification	Limitation level for climatic classification (overall evaluation)	Climatic index(ci)	Climatic rating (R)	Linear equation for calculating R
S1(suitable)	No	100-76	100-98	**R=92+0.08ci**
S2 (mod. suitable)	Slight	75-51	98-85	**R=59+0.5ci**
S3 (marginally suitable	Moderate	50-26	85-65	**R=45+0.8ci**
N1 (non-suitable)	Severe	25-12	65-45	**R=26.5+1.54ci**
N2 (non-suitable)	Very Severe	12>	<45	**R=3.75ci**

Soil and topographic characteristics: The pedological and topographical characteristics of the soil in the land units were matched with those in the wheat crop requirements table, and included the following characteristics.

1. Topography (t): represented by slope (as a percentage).
2. Waterlogging (w): Wetness

- Drainage: determined by the depth of spotting, the depth of groundwater and its degree of salinity.

3. Direct soil characteristics:

- *Soil physical conditions (S) and including:*

1. Soil texture/soil structure
2. Soil depth (cm)
3. CaCO3 (%)
4. Gypsum (%)
5. Soil characteristics affecting soil fertility: including:

1. CEC for the clay fraction cmol (+) Kg^{-1}
2. Base saturation (%)
3. Cation group (bases) cmol (+) Kg^{-1}
4. pH
5. Percentage of organic matter (OM)

6. Salinity and alkalinity properties (n): They include:

1. ESP (%)
2. ECe dsm^{-1}

Olive Tree Crop: To evaluate the suitability of the land for growing irrigated olive trees, the same steps were followed as for wheat using the climatic requirements table, the soil and topographic conditions, and the olive tree requirements table. The soil and topographic characteristics of the land units were evaluated once for growing olive trees. The suitability index was extracted for each unit representing its suitability for growing irrigated olive trees. The equation is as follows:

$$\text{Land index} = \frac{A1 \times A2 \times A3 \times \ldots\ldots \times An}{10^{2n-2}}$$

where A1, A2, A3,. An is the evaluation of the estimates given for the various characteristics of the land, including the overall climate estimate.

5. Classification of land suitability for irrigated agriculture

The final evaluation involved classifying the lands according to their suitability for wheat and olive trees under irrigated conditions. The results of the land suitability index were used to define the suitability ranks and categories within the FAO system, as follows:

Order S: (suitable) land index > 25
Class S1: suitable (land index > 75)
Class S2: moderately suitable (land index) (50-75)
Class S3: moderately suitable (land index) (25-50)
Order N: not suitable < 25
Class N1: unsuitable, with severe limitation which can be corrected
Class N2: unsuitable, with severe/or very strict limitations that cannot be corrected

Characteristics of the study area:

Climate: The climate of Iraq is characterized as semi-continental and falls within the climate of dry and semi-arid lands, where it is hot and dry in the summer and cold and rainy in the winter, with rainfall amounts varying from year to year. There is also a difference between night and daytime temperatures. The climate of the study area is classified as dry based on the Thornthwaite equation, with a dryness coefficient value of 5.57, and that for the De Martonne equation reached 3.19, while the dryness index based on the Koppen equation reached 1.49. All the indexes indicate that the climate of the region falls within the dry areas based on the climatic characteristics of the study area.

Figure 3 presents the climate conditions for Ramadi for 1991-2020. Average annual temperatures were 22.43 °C, peaking during the months of June, July, and August at 32.1, 35.2, 36.2 °C, respectively. May, June, and July had the most sunshine representing 36.09% of the total 6075 sunshine hours for the period. Meanwhile, monthly average rainfall was 8.63 mm with a total of 103.6 mm recorded annually. Rainfall was limited to the months of October-May, and there was no rain during June-August.

This indicates that the region falls within the 100 to 150 mm rain lines, while the relative monthly humidity values ranged between 30.5-75.5% and an annual average of 51.28%. The region experiences high evaporation rates in summer due to the high temperature, low rainfall, and poor vegetation cover, with the maximum in July and August at 493 mm and 459 mm, respectively, or 30.52% of the annual total of 3118.8 mm. Figure 3 shows the relationship between temperature, rainfall, and evaporation in Ramadi for the period from 1991-2020.

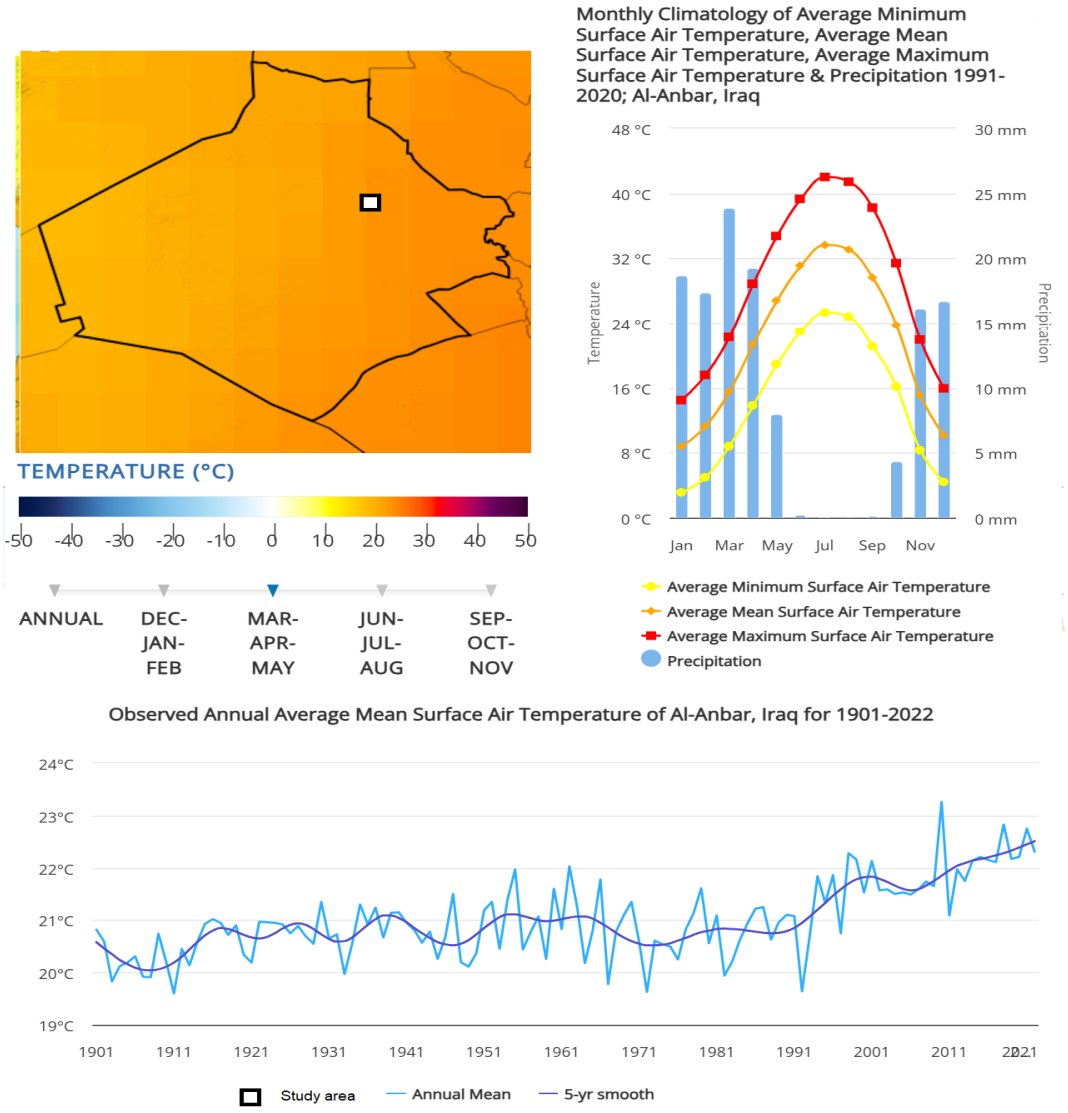

Fig. 3: Average surface air temperatures at Anbar, 1991-2020.

Source: Ramadi Meteorological Station.

Geomorphology: The landforms in dry areas, including the study area, reflect natural conditions, and vary according to differences in geological structure, surface features, climate type, soil type, water resources, and natural vegetation. All dry areas around the world are affected by such factors, and it is necessary to point out the landforms in these areas, which are largely the result of running water. A dry area may be exposed to heavy rain only every few years, and when that occurs, water appears in river valleys to perform the same functions of erosion, transport, and sedimentation that perennial rivers do in humid areas. The study area was affected during the Holocene epoch by the sediments of the Euphrates River and the aeolian sediments

transported from neighboring areas. The succession of rainy and dry periods in the Pleistocene era created relatively deep and wide valleys in the area due to water erosion. Figure 4 shows the geological features of the study area.

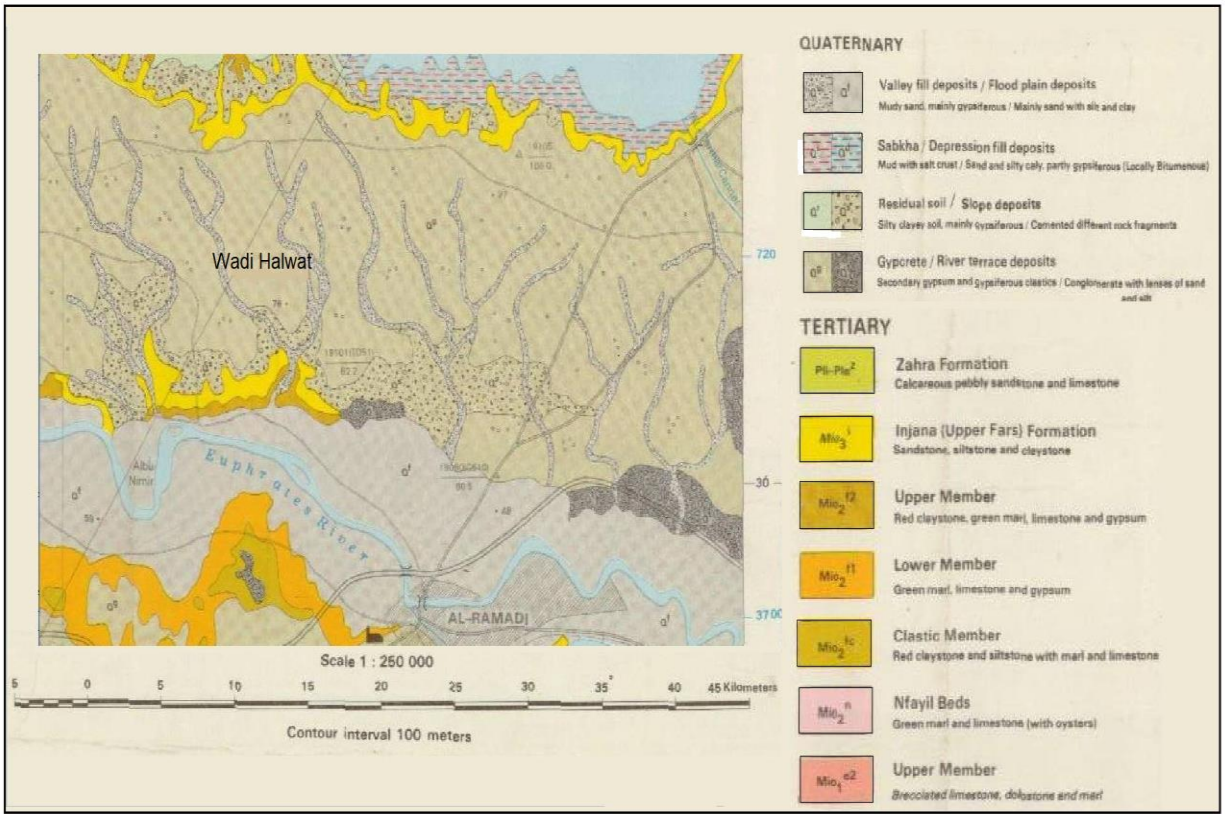

Fig. 4: Geological features of the study area.

Land use and natural vegetation: TA field survey of the study area showed earlier cultivation of wheat and barley crops depending on rainfall and supplementary irrigation with well water during the winter season. As for the summer season, it is characterized by the cultivation of summer crops and vegetables such as watermelon, field pistachios, and onions, especially in the southern parts near the Euphrates River. The salinity of the well water used in agriculture especially in summer, inappropriate irrigation management methods, and the use of flood irrigation led to the deterioration of the land and reduced productivity. Farmers abandoned their lands due to salinization and salt accumulation, their poor economic situations, lack of sound agricultural plans, and the uncertain security situation. The lack of rain and high temperatures and evaporation rates led to the spread of weak vegetation cover especially in winter and in areas where rainwater ran and collected. As for summer, natural vegetation is limited to some drought-resistant plants, such as *Centaurea sinaica*, *Salicornicum haloxylon*, *Gundelia tourneforti*, *Malv*a spp, and *Alhagi maurorum*.

Results and Discussion

Land suitability classification: Land suitability in the study area for growing wheat and olive trees included evaluating its soil characteristics and topography as well as climate characteristics. The evaluation results were used for determining land suitability categories included according to the (18) system. The system represents the

climate suitability classification according to the values of climate coefficients and final climate estimates, and the climatic, topographic, and soil requirements for the two crops.

Suitability for irrigated wheat cultivation:

Evaluation of the climate:

Determination of the climatic requirements for wheat: The wheat varieties grown in the country in winter fall within the spring wheat group, and based on the information proposed by (20). It includes the climatic requirements for the crop but excludes rain as the wheat is grown in irrigated areas.

Determining the different growth periods and climate suitability: Based on (4), the best time for planting wheat crops in the central and southern regions is in the second half of November, where germination must occur before winter when the seedlings are not exposed to low temperatures. Also, the long cold stretches lead to extended growth periods. Different growth periods for the crop were determined during the growing season to evaluate the climate hardeners (Appendix 4), and taking into consideration the study by (1) which included planting wheat for the central regions which are almost similar climate-wise to the study area (Table 2).

Table 2: Stages of the life of the wheat crop.

N	Life stages	Period	Days
1	Growing cycle	5/1 – 11/5	168
2	Vegetative stage	3/8 – 12/12	86
3	Flowering stage	3/24 – 3/8	16
4	Yield formation	5/1 – 3/24	38
5	Ripening stage	5/16 – 5/1	15

After determining the crop growth periods for the year, the values of the climate elements for these periods were calculated. According to the climate information for the city of Ramadi in Figure 5, the climate was evaluated based on the estimates included in the requirements table by applying the following equation:

$$R = 92 + 0.08 (ci)$$

where R: estimate; (ci): climate index

The estimate reached 99.9, indicating that the climate of the area is of the 1S type and is suitable for growing wheat.

Evaluation of soil conditions and topography: The table of requirements for soil characteristics, hydrological conditions, and topography for wheat crop cultivation (21) included the values of these characteristics with their value ranges for different limitation levels. The characteristics are: topography (t) (represented by slope (%)), soil hydrological conditions (W) which include flooding and drainage, soil physical conditions (texture/structure, presence of rocks and stones on the surface, soil depth, CaCO3 content (%), gypsum content (%), CEC and pH, organic matter content (%), total exchangeable bases (Na, K, Ca), base saturation ratio, salinity and alkalinity status (n) expressed as ECe and ESP.

Evaluation of results for wheat cultivation: The evaluation of the land characteristics shown in Table 5, and summarized cartographically in Table 6, show that the main limiting factors for wheat cultivation are physical conditions and the presence of gypsum. The suitability of the land in the area for wheat cultivation are classified as follows:

1. S1: Fully suitable in the 1P pedon, and covers 15.04% of the total area. No physical environment and salinity limitations.
2. S2: Moderately suitable: the land unit includes moderate limitations that do not prevent its exploitation, more than one of the severe limitations, or more than one of the very severe limitations for wheat cultivation. It includes the 2P site and constitutes 24.46% of the total area.
3. Not suitable (N1sf): Determined by the physical conditions of the soil, such as its high gypsum content, as well as organic matter content that affect the growth of the crop. It included the 3P and 4P pedons covering 75.2 km^2 or 60.5% of the total. Figure 6 maps out the suitability of the current lands for wheat cultivation.

Table 3: Cartographic distribution of the land suitability map for wheat cultivation.

Pedon	Area km^2	% of Total Area	Land Suitability	Total Area (Donm)
P1	18.7	15.04	S1	**46.76**
P2	30.4	24.46	S2s	**76.02**
P3, P4	75.2	60.50	N1sf	**188.05**

Suitability for olive tree cultivation:

Evaluation of climate conditions: The suitability of the study area's climate for olive production was evaluated (21) based on (20) on the climatic requirements of olive trees and climatic information of Ramadi. The results of the evaluation is the climatic index (Ci). The rain factor was omitted due to the scarcity of rainfall in the region and the dependence on irrigation. The steps mentioned for wheat requirements were followed for olive tree cultivation. As shown in Table 5, the suitability of the study climate is S2 based on the value of the climatic index (Ci) and using the following equation:

$$R = 45+0.8\ Ci$$

Soil and topography suitability: Soil and topography characteristics were evaluated based on the requirements of the soil characteristics and its hydrological and topographical conditions for olive tree cultivation. The same steps for land suitability for wheat cultivation were carried out, namely topography, texture, soil depth, gypsum and lime status, soil fertility, salinity and alkalinity.

Land suitability evaluation: Table 5 presents the results of the suitability evaluation using the standard method based on the value multiplication method. The study sites varied in their suitability levels depending on the issues affecting the root zones from the high gypsum content, as well as climate conditions. The varieties suitable for olive tree cultivation were distributed as follows:

1. S2c: Moderately suitable. The limiting factor is climate suitability, and this class included the 1P pedon covering 12.3 km^2 or 9.89% of the study area.

2. S3cf. Marginally suitable. The limiting factor is climate suitability and organic matter content. Includes the 2P pedon covering 28.5 km^2 or 22.93% of the study area.
3. N1scf: Not suitable. The limiting factors are the physical conditions of the soil, such as its high gypsum content, and climate conditions affecting crop growth and organic matter content. This class included 3P and 4P covering 83.0 km^2 or 66.77% of the total study area.

Figure 7 and Table 4 show the current land suitability map and the cartographic distribution of the land for olive tree cultivation. Table 5 shows the current land suitability categories for olive tree cultivation.

Table 4: Cartographic distribution of the land suitability map for olive cultivation.

Pedon	Area km^2	% of Total Area	Land Suitability	Total Area (Donm)
P1	11.7	9.89	S2c	**30.78**
P2	21.5	22.93	S3cf	**72.27**
P3, P4	66.8	66.77	N1scf	**207.55**

Table 5: Suitability of the study area lands for irrigated wheat and olive tree cultivation according to the characteristics of the land.

Pedon No.	Climate (c)	Top.(t) Slope %	Wetness (w) Drainage	Physical Soil condition(s)				Fertility condition (f)						Salinity/ dSm^{-1}/ ESP %)(	Land index	Land class
				Texture	Depth (cm)	$CaCO_3$ (%)	Gypsum (%)	CEC $Cmol^{(+)}$ Kg^{-1}clay	Base saturation (%)	Sum of bases $Cmol^{(+)}$ kg^{-1}soil	PH	O.M (%)	Mean			
Wheat yield (*Triticum aestivum*)																
P1	99.9	<1	well	L	110	18.5	2.5	19	>80	<8	7.6	2.4		2.7/7.0		
	2	0	0	0	0	0	0	0	0	0	0	0		1		
	100	100	100	100	100	100	100	100	100	100	98	100	98	85	84	**S1**
P2	99.9	<1	well	SL	110	25.6	13	14	>80	<8	7.8	1.4		3.1/7.0		
	2	0	0	2	0	1	3 2	2	0	0		0		1		
	100	100	100	70	100	85	40 70	70	100	100		95	67	95	38	**S2s**
P3	99.9	1-2	well	SC	75	26.6	44.2	12	>80	<8	7.6	0.9		4.1/7.3		
	2	1	0	1	1	1	3	2	0	0	0	2		1		
	100	90	100	90	91.2	85	39	70	100	100	98	70	48	95	12	**N1sf**
P4	99.9	2-3	well	CL	72.5	23.5	45.1	25	>80	<8	7.7	0.38		4.3/7.4		
	2	1	0	0	2	1	3	0	0	0	1	3		1		
	100	85	100	100	72.5	85	38	100	100	100	90	50	45	95	9	**N1sf**
Olive tree yield (*Olea europaca*)																
P1	78.6	<1	well	L	110	18.5	2.5	19	>80	<8	7.6	2.4		2.7/7.0		
	2	0	0	0	0	0	0	1	0	0	0	0		1		
	78.6	100	100	100	100	100	100	90	100	100	98	100	89	85	59	**S2c**
P2	78.6	<1	well	SL	110	25.6	13	14	>80	<8	7.6	1.4		3.1/7.0		
	2	0	0	0	0	0	3 1	1	0	0	0	2		1		
	78.6	100	100	95	100	100	90	93	100	100	100	65	61	95	39	**S3cf**
P3	78.6	1-2	well	SC	80	26.6	44.2	22	>80	<8	7.7	0.9		4.1/7.3		
	2	1	0	1	1	0	3	2	0	0	1	2		1		
	78.6	95	100	90	90	100	56	65	100	100	90	65	59	95	19	**N1scf**
P4	78.6	2-3	well	CL	72.5	23.5	45.1	25	>80	<8	7.7	0.38		4.3/7.4		
	2	1	0	1	2	0	3	0	0	0	1	3		1		
	78.6	85	100	85	72.5	100	57	100	100	100	90	50	45	95	10	**N1scf**

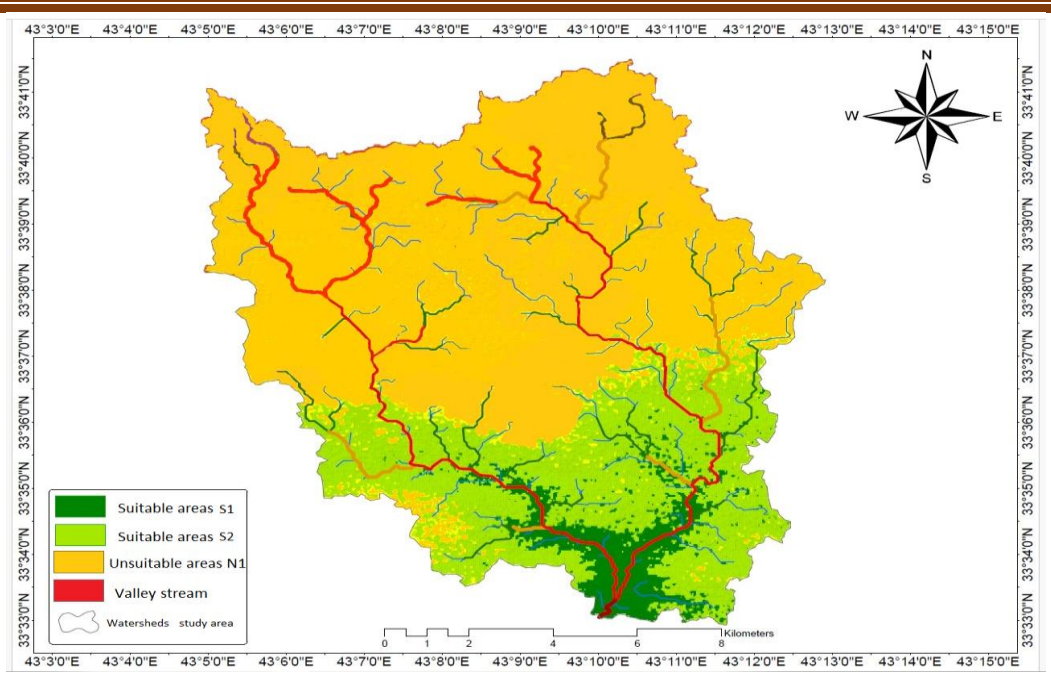

Fig. 6: Suitability of land for wheat cultivation.

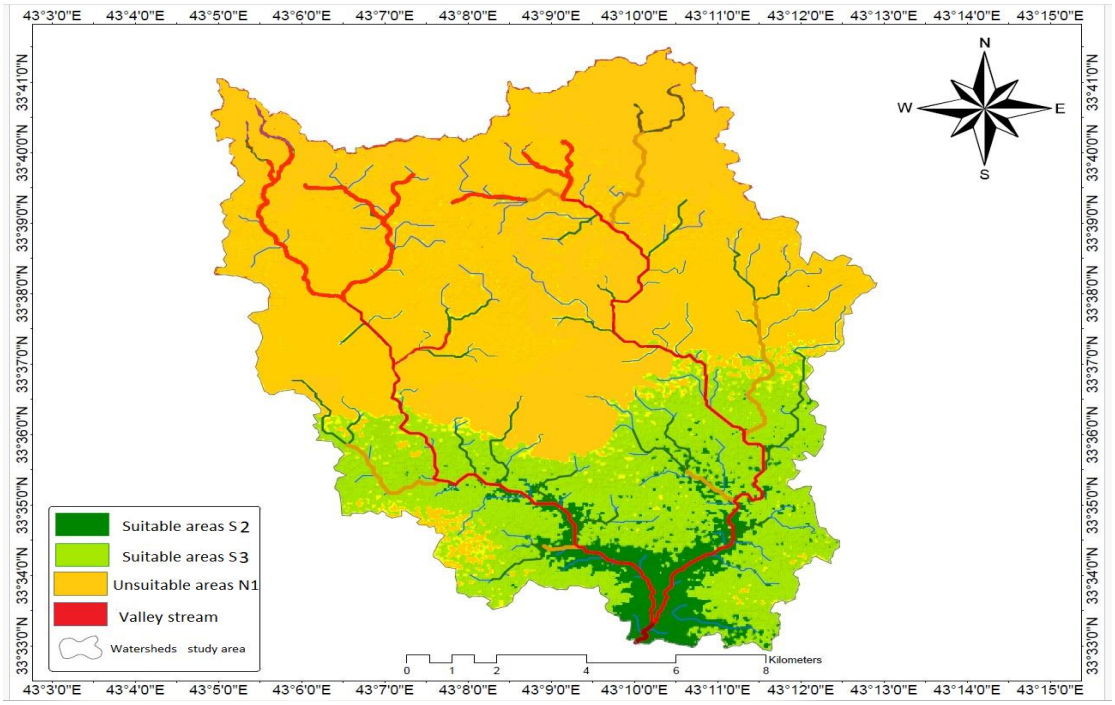

Fig. 7: Suitability of land for olive tree cultivation.

Conclusions

This analysis of the suitability of the land for wheat and olive cultivation provides important information for future development planning for the two crops in Anbar governorate. This research processed and analyzed geographic information systems in conjunction with using the evaluation criteria for land suitability (8 and 10). This is the first study that relied on the use of climatic, topographic and soil factors in modeling the suitability of land for cultivation of the two crops in the area. The spatial suitability of the land was obtained after analyzing selected criteria such as soil properties, and

topographic and climatic factors, based on the characteristics of the land and the crops' requirements. Areas deemed very suitable for wheat crops comprised 9.9%, while suitable and unsuitable levels formed 23% and 67%, respectively. For olive trees, the suitable areas were 2S (9.9%) and 3S (23%) while the unsuitable areas comprised 67% in Jabia Wadi Halwat region. The actual current land suitability assessment in this study provides a useful approach to assist farmers and decision-makers in implementing suitability assessments for the two crops.

Supplementary Materials:

No Supplementary Materials.

Author Contributions:

Author 1: methodology, writing—original draft preparation; M.T. Yaqub, Hassan M.A. and Abdulkarem Ahmed Mekelf r writing—review and editing. All authors have read and agreed to the published version of the manuscript.

Funding:

This research received no external funding.

Institutional Review Board Statement:

The study was conducted following the protocol authorized by the Head of the Ethics Committee, University of Anbar, Iraq Republic.

Informed Consent Statement:

No Informed Consent Statement.

Data Availability Statement:

No Data Availability Statement.

Conflicts of Interest:

The authors declare no conflict of interest.

Acknowledgments:

The authors are grateful for the assistance of the College Dean, and the Head of the Soil and Water Dept., College of Agriculture, University of Anbar, Iraq.

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