Climatic Requirements of Land Suitability for Wheat Cultivation in the Soils of Al-Midhatiya District / Babylon Governorate

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Abstract

This study was conducted in Al-Midhatiya District, located within Babylon Governorate in central Iraq, between the longitudes 32°23'0.462" – 32°27'57.300" E and the latitudes 44°31'42.573" – 44°46'12.004" N. The study area covers 2,410.61 hectares and represents part of the Euphrates alluvial plain (Middle Euphrates). After determining the mean air temperatures, rainfall amounts, and their temporal distribution, the results were compared with the reference values of wheat climatic requirements based on the tables of [13]. Accordingly, the lands of the study area were classified into different climatic suitability classes (S1, S2, S3, N), depending on the degree of correspondence between the actual climatic values and the optimal thresholds for wheat production.

Keywords:- climatic requirements, land suitability, wheat crop, Al-Midhatiya District

Introduction

Climatic factors are among the most influential environmental determinants of agricultural production, as they simultaneously affect both soil and plants. When these factors are not within their optimal ranges for a given crop, productivity is negatively impacted. Consequently, specific crops tend to be concentrated in climatically similar regions. Climatic elements such as rainfall, temperature, and wind differ in their effects on agricultural crops; for example, rainfall may represent the decisive factor in the cultivation and production of a particular crop. Hence, rainfall is considered a basic requirement when assessing land suitability for crop cultivation, with quantitative values assigned based on the crop’s life cycle from germination to harvest. Agricultural practices and techniques are largely governed by climatic conditions, as each crop has a specific climatic environment in which it can thrive. Climate determines the type of crops that can be cultivated, their planting dates, growth stages, and maturation periods, thereby acting as a key factor in the success or failure of agriculture [1].Climate is considered one of the most fundamental determinants in evaluating land suitability for wheat cultivation, as it forms the environmental framework that defines the crop’s response to various growth factors. According to the classical methodology proposed b [13] within the Land Suitability Classification system, climate is treated as a limiting factor that can raise or lower suitability ratings even when soil properties and water resources are adequate. This system highlights key elements such as temperature, rainfall amount and distribution, and the length of the growing period as direct determinants of wheat productivity.Wheat requires moderate temperatures during vegetative growth, while the grain-filling stage benefits from relatively lower temperatures to reduce heat stress and ensure optimal accumulation of starch and protein. Recent studies have shown that exceeding the optimum temperature threshold during flowering significantly reduces fertilization rates and the number of grains per spike [2]. Furthermore, rising temperatures associated with climate change accelerate wheat maturation, shortening the photosynthetic period and reducing total biomass accumulation [14] Rainfall, on the other hand, plays a pivotal role in determining agricultural suitability, not only in terms of annual totals but also regarding its temporal distribution throughout the growing season. In arid and semi-arid environments, rainfall is often insufficient or irregular, necessitating irrigation to stabilize yields [8]. Climatic assessment following the Sys approach indicates that rainfall deficits during critical growth stages, such as tillering and grain filling, represent major limiting factors. Among secondary climatic elements, relative humidity and wind can exert indirect effects: low humidity increases transpiration and water loss, while strong winds exacerbate plant water stress. Recent climate models project that parts of the Mesopotamian Basin will experience greater rainfall variability and more frequent droughts by the mid-21st century, negatively affecting the agricultural suitability index for wheat [3] Conversely, adopting precision agriculture techniques and introducing genetically improved cultivars tolerant to heat and drought can help mitigate climatic constraints on land suitability. Experimental evidence suggests that integrating climatic analysis with geospatial assessment using GIS and remote sensing significantly enhances the accuracy of identifying areas most suitable for wheat cultivation under climate change conditions [7].

Given the importance of climate, this study aims to examine the climatic requirements for wheat cultivation following the methodology of [13].

Materials and Methods

The study area is located in Al-Midhatiya District within Babylon Governorate in central Iraq. It is bordered to the north by Al-Mahawil District, to the south by Jurf Al-Nasr Sub-district, to the east by the city of Hilla, and to the west by Al-Iskandariya Sub-district. Geographically, it lies between the longitudes 32°23'0.462" – 32°27'57.300" E and the latitudes 44°31'42.573" – 44°46'12.004" N. The total area of the study region is 2,410.61 hectares, representing part of the Euphrates alluvial plain (Middle Euphrates).

Climatic Requirements

The methodology of [13] was adopted to evaluate the climatic suitability for wheat cultivation in Al-Midhatiya District, Babylon Governorate. The evaluation relied on the climatic data presented in Table (5), with particular focus on two main parameters: temperature and rainfall, as they are the primary determinants of wheat production in arid and semi-arid environments.

- Temperature

According to the results in Table (1), the wheat growth cycle in the study area begins on November 20 and ends on April 26, covering an average of 157 days. To estimate the mean temperature over the growth cycle, the monthly averages of maximum and minimum temperatures were calculated for the months within this period, taking into account the actual number of days in each month. The following formula was applied:

$$T_{mean} = \frac{(T.mean11 \times 11 \ day) + (T.mean12 \times 31 \ day) + (T.mean1 \times 31 \ day) + (T.mean2 \times 28 \ day) + (T.mean3 \times 31 \ day) + (T.mean4 \times 26 \ day)}{157 \ day}$$

Where:

T.mean- = monthly mean temperature (°C)

- 11 day- = number of days from November 20 to 30 included in the growth cycle
- 157 day- = total number of days of the growth cycle

Based on this the average temperatures for each of the four main growth stages of wheat were determined and compared with the

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optimal thermal requirements of the crop as defined by [13].

- Rainfall and Moisture Requirements

The evaluation was based on the monthly rainfall records from the Al-Midhatiya meteorological station (Table 1) distributed across the entire growing season. The total rainfall received during the growth cycle (November 20 – April 26) was calculated and compared with the estimated water requirements of wheat.

Particular attention was given to rainfall regularity and timing since precipitation during the tillering and grain-filling stages has the most significant impact on crop yield. To determine the adequacy of available moisture the monthly ratio of precipitation to potential evapotranspiration (P/ETp) was used to estimate possible water deficits that might limit climatic suitability. In cases of insufficient rainfall the land was considered to require supplementary irrigation which is treated as a climatic constraint in the suitability classification.

- Climatic Classification

Climate is considered one of the prominent factors in soil formation due to its significant influence on the rate and depth of soil-forming processes, as well as its impact on the physical, chemical, and biological properties of soils [3]. Climatic factors greatly affect both the environment and human activities. High temperatures, low rainfall, and elevated evaporation rates are among the main challenges facing the study area.

After determining mean temperatures rainfall amounts and their temporal distribution the results were compared with the reference values of wheat climatic requirements according to the tables of [13]. Accordingly the lands of the study area were classified into climatic suitability classes (S1 S2 S3 N) depending on the degree of correspondence between the actual climatic values and the optimal thresholds for wheat. Climate suitability was first assessed according to Table (2) then matched with the climatic requirements of wheat shown in Table (3) to derive the final climatic suitability class for wheat cultivation in the study area.

Table 1. Wheat growth stages

Days	To Months	From Months	Stage
157	20- April	20- November	Growing Cycle
108	8- March	20- November	Vegetation Stage
16	24- March	8- March	Flowering Stage
33	26- April	24- March	Ripening Stage

Table (2). Climatic requirements for wheat according to [13].

Evaluation scale, degree of limitation, and suitability classes						Climatic Characteristics
N2	N1	S3	S2	S1		
4		3	2	1	0	
0	25	40	60	85	95 100	
>30 <8	- -	25-30 10-8	23-25 12-10	20-23 15-12	18-20 18-15	Mean temp.of the growing cycle(C°)
<2 >28	-	4 -2 24 -28	6 - 4 18-24	8 - 6 12- 18	10- 8 10-12	Mean temp.of the vegetation stage (C^{o})

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<8 >36	-	10 - 8 32- 36	12-10 26-32	14 -12 22 -26	18-14 18-22	Mean Tem.of the flowering stage (C°)
<10 >42	-	12-10 36- 42	14-12 30-36	16-14 24-30	20-16 20-24	Mean temp.of the Ripening stage (C°)
- - -	- - -	18-19 if - >21	<8 if - <21	- -	<8 if <21	Average daily min.temp. clodest month combined with average daily max.tep.clodest month (C°)

Table (3). Climatic suitability classification based on climatic factor values and final climatic ratings [13].

Climatic Rating(K)	Climatic Index (C)	Limitation Level For Climatic (Over all evaluation)	Classification	Symbol
100-98	100-76	No	suitable	S1
98-85	75-51	Slight	moderate suitable	S2
85-65	50-26	Moderate	marginality suitable	S3
65-45	25-12	Severe	non suitable	N1
<45	<12	Very severe	non suitable	N2

Results and Discussion

- Climate

The minimum temperature ranged from 5.61 to 27.88 °C,(Table 5) , with the lowest average in January and the highest in July. The maximum temperature ranged from 17.97 to 45.64 °C, with the lowest average in January and the highest in August. Summer months experience high temperatures, reaching 43.07, 44.97, and 45.64 °C in June, July, and August, respectively. Temperature plays a pivotal role in soil formation in arid and semi-arid regions, as it accelerates chemical and biological reactions, leading to faster decomposition of organic matter and soil formation [15].Sunshine duration ranged between 6.3 and 11.5 hours per day, with the shortest durations in December and January and the longest in July. The results indicated that the total annual precipitation is low, amounting to 105.25 mm, corresponding to low relative humidity during the hot summer months, reaching 56.17%, 50.53%, and 45.93% in June, July, and August, respectively. The highest relative humidity was observed in January at 73.35%, with an annual average of 53.85%. Low rainfall affects soil properties, increases susceptibility to wind erosion, and reduces organic matter content, thereby limiting microbial activity and leading to the formation of loose soil [4]. As a result, the data showed increased evaporation, particularly during the summer months, reaching 322.26, 355.11, and 320.96 mm in June, July, and August, respectively, with an annual total of 2237.39 mm. Wind speed also significantly affects soil particle redistribution and transport, with a maximum wind speed of 2.6 $m\,s^{-1}$ recorded in July and an annual average of 1.84 $m\,s^{-1}$. Based on the climatic data presented in Table 1, and since the difference between average summer and winter soil temperatures exceeds 5 °C, and the annual mean temperature exceeds 22 °C, the soil temperature regime of the study area is classified as Hyperthermic, while the soil moisture regime is classified as Torric, indicating that the soil remains dry for more than three consecutive months [13].

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Table 4. Monthly and annual averages of climatic elements in Babylon Governorate for the period 2001–2023.

Months	Temperature (°C)			Sunshine Duration (hours)	Precipitation (mm)	Relative Humidity (%)	Evaporation (mm)	Average Wind Speed (m/s)	Wind Direction
	Minimum Temperature (°C)	Maximum Temperature (°C)	Monthly Mean Temperature (°C)						
January	5.61	17.97	11.79	6.3	20.46	73.35	53.251	1.5	NW
February	7.62	21.08	14.35	7.1	15.61	64.46	77.00	1.9	NW
March	11.57	26.36	18.97	7.6	11.20	70.83	132.01	2.2	N
April	17.00	32.24	24.62	8.4	12.18	62.24	181.53	2.1	N
May	22.42	38.65	30.54	9.4	2.77	68.47	258.73	2.1	N
June	25.94	43.07	34.51	10.9	0	56.17	322.26	2.5	N
July	27.88	44.97	36.43	11.5	0	50.53	355.11	2.6	N
August	27.66	45.64	36.65	11.2	0	45.93	320.96	2.0	N
September	23.99	41.62	32.81	9.9	0.15	37.03	243.01	1.5	N
October	19.17	35.23	27.2	8.1	4.29	37.63	158.38	1.2	N
November	11.83	25.81	18.82	6.6	20.42	36.37	79.41	1.2	N
December	7.28	19.18	13.23	6.3	18.17	43.23	55.74	1.3	N
Total	-	-	-	-	105.25	-	2237.391	-	-
Average	17.33	32.65	24.99	8.61	-	53.85		1.84	N

*Source: Iraqi Meteorological and Seismological Monitoring Authority – Unpublished data

- Assessment of Climatic Suitability for Wheat Cultivation

Climate is one of the most important factors determining the productivity of field crops, including wheat, as it directly affects plant growth, the development of physiological stages, and the efficiency of physiological processes. Since wheat is relatively sensitive to temperature fluctuations, any deviation from the optimal climatic conditions can lead to reduced yield. According to the classification and evaluation by [13].which relied on selected climatic indicators in an assessment model to determine the degree of suitability for cultivation, the climatic data for the study area (Table 6) showed that the Climatic Index reached 84.4%, placing it within the high suitability class (S1) in terms of climatic conditions for wheat cultivation. The overall climatic evaluation was 98.7%, indicating a highly favorable climatic environment. This implies that climate does not act as a limiting factor for wheat production.The results in the table indicate that the mean temperature throughout the complete wheat growth cycle was 16.64 °C, with a suitability rating of 97.7%. This temperature provides ideal conditions for seed germination and vegetative growth without exposing the plants to heat stress [10]. During the vegetative growth stage, the average temperature was 14.22 °C, with a suitability rating of 91.3%asw. This temperature is

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suitable for vegetative growth and enhances photosynthetic efficiency, being close to the optimal range for this stage [9].At the flowering stage, the average temperature was 18.97 °C, with a suitability rating of 98.8%. This is an ideal value for completing fertilization and grain formation, as moderate temperatures stimulate enzymatic activity and accelerate nutrient translocation to the grains without affecting pollen viability [6] .During the maturity stage, the average temperature was 23.42 °C, with a suitability rating of 95.7%.

This temperature is appropriate for grain drying and reducing moisture content, thereby minimizing the risk of fungal diseases [6].The results in the table also show the winter cold index, calculated based on the minimum temperature of the coldest month (5.61 °C) and the maximum temperature (17.97 °C). This range allows the accumulation of the required water for breaking dormancy and ensures regular spring growth [11].

Table 6. Assessment of Climatic Suitability for Wheat in the Study Area [13].

Rating	Degree of limitation	Temp. C	Climatic condition for different development period with wheat growing cycle
97.7	0	16.64	Mean temp. of growing cycle (C)
91.3	1	14.22	Mean temp. of the vegetation stage(C)
98.8	0	18.97	Mean temp. of the flowering stage (C)
95.7	0	23.42	Mean temp. of the Ripening stage (C)
100.0	0	5.61 17.97	Average daily Min. temp. coldest month combined with average daily Max. temp. coldest month (C)
84.4	Climatic Index (Ci)		
S1	Suitability class of climate		
98.7	Over all climate rating		

Conclusions

The high climatic suitability for wheat cultivation highlights that the main limiting factor lies in soil properties and management rather than in climatic conditions.

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