RESEARCH ARTICLE

The role of geographic information systems in selecting the best places for wheat production (Tal Afar district as a model)

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ABSTRACT

The overlay (Overlay/Union) process is considered one of the most important functions of Geographic Information Systems (GIS), as it relies on inputting data related to the studied phenomenon in the form of layers, each representing a specific factor to build an integrated geographic database. In this research, a set of maps related to wheat cultivation and the environmental factors affecting it—such as climate, soil type, and soil productivity—were used as digital layers within the GIS environment. The study adopted the principle of equal weighting among the factors, due to the absence of detailed and accurate data that would allow for assigning different weights to each factor, and because the primary objective was to develop a practical and simple model that could be applied locally. This method provides a preliminary yet reliable analysis of the overlap between environmental factors and areas of wheat cultivation. The spatial analysis results indicated the potential to identify the most suitable areas for wheat production in the Tal Afar District, Nineveh Governorate. A map was prepared to reflect the relationship between various environmental factors and production sites. These results highlight the value of using GIS in supporting agricultural planning and decision-making based on land suitability.

KEYWORDS: **Wheat, matching, Geographic Information Systems (GIS), layers, maps.**

مقالة بحثية

دور نظم المعلومات الجغرافية في انتخاب أفضل الأماكن لإنتاج القمح (قضاء تلعفر أنموذجا)

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الملخص :

تعد عملية التطابق(Overlay/Union)) من أهم وظائف نظم المعلومات الجغرافية ، حيث تعتمد على إدخال البيانات المتعلقة بالظاهرة المدروسة على شكل طبقات، يمثل كل منها عاملاً محدداً، لتشكيل قاعدة معلومات جغرافية متكاملة. في هذا البحث، تم استخدام مجموعة من الخرائط الخاصة بمحصول القمح والعوامل البيئية المؤثرة فيه، مثل المناخ، نوع التربة، والقابلية الانتاجية للتربة ، على شكل طبقات رقمية ضمن بيئة نظم المعلومات الجغرافية . اعتمدت الدراسة على مبدأ تساوي الأوزان بين العوامل نظراً لغياب بيانات تفصيلية دقيقة لتحديد أوزان مختلفة لكل عامل، ولأن الهدف الرئيس هو بناء نموذج عملي وبسيط قابل للتطبيق محلياً. وتتيح هذه الطريقة إجراء تحليل مبدئي وموثوق لتطابق العوامل البيئية مع مناطق زراعة القمح. أظهرت نتائج التحليل المكاني إمكانية تحديد المناطق الأكثر ملاءمة لإنتاج القمح في قضاء تلعفر بمحافظة نينوى، حيث تم إعداد خارطة تعكس العلاقة بين العوامل البيئية المختلفة ومواقع الإنتاج. وتشير هذه النتائج إلى قيمة استخدام نظم المعلومات الجغرافية في دعم التخطيط الزراعي واتخاذ القرارات المبنية على أساس ملاءمة الأراضي.

الكلمات المفتاحية : القمح ، التطابق ، نظم المعلومات الجغرافية ، طبقات ، خرائط.

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Introduction

Geographical studies focus on spatial relationships between geographical phenomena within a given space. Geography is concerned with these relationships in order to reach a scientific explanation for a group of phenomena, which is emphasized by the structuralist approach that addresses elements based on their relationships, or by starting from the principle of the relationship between things.

The fundamental idea behind Geographic Information Systems (GIS) is based on the same principle as matching (manual) maps, albeit with different methods and execution. This involves creating several types of thematic maps for the same area and then extracting information derived from them through manual skills after comparing the topics of these maps. In light of this simple concept, the overlay technique used in GIS programs works by entering data related to the studied phenomenon—represented by environmental soil factors—in the form of layers (shapefiles), where each layer contains a specific subject. This forms a Geographic Database (Geodatabase) where overlay operations are performed for the factors affecting the studied phenomenon, represented in map form. When the distribution of any factor aligns with the distribution of the studied phenomenon, it indicates a connection and match between the phenomenon and its influencing factors. In the current study, the Tal Afar district in Nineveh Governorate was selected for research and application, creating several thematic map layers to be overlaid using the ArcGIS program.

Research Objective:

The objective of this study is the prepare of an environmental overlay map for wheat cultivation using GIS techniques. Using geoprocessing tools in ArcGIS Desktop10.8 , this was achieved through overlaying multiple maps that illustrate various aspects of the environmental factors that impact the productivity of wheat in the area in question, resulting in a presentation of the environmental matching process through map overlays.

Research Problem:

Research problem occurs because traditional methods of processing and analysing agricultural investment criteria, forming spatial patterns of agricultural investment and measuring spatial variation are ineffective. Which calls for the need for automated geographic information management of large systems such as GIS. They improve the geographers' ability to understand the spatial processes in a scientific, efficient, and precise way, enabling more precise measurement of spatial variation of geographical phenomenon.

Research Hypothesis:

The creation of environmental Overlay map, using GIS techniques, can help us classify lands environmentally suitable for wheat cultivation, as in the case of Tal Afar district.

Research Methodology:

The research employed the inductive method as the primary approach in the study, which begins by examining specific details and proceeds toward generalizations. This started with preparing maps of the natural characteristics affecting wheat production, followed by assessing land suitability for wheat cultivation, and finally identifying the most suitable locations for wheat production within the district. The study employed the environmental overlay process (Overlay/ Union) in the GIS environment as the principal analytical tool, intending to determine the optimal sites for wheat production in the Tal Afar District.

Data Sources:

The quantitative approach and GIS are suited to a range of geographic data, also known as spatial data, showing aspects of geography and the descriptive information of different kinds associated with the phenomenon. There are two types of geographic data:

1. **Spatial data:** These are linked to a location within some spatial or geographic reference system that exemplifies the geographic phenomena like maps, aerial photo, satellite data, etc. The maps used during the current study were of Tal Afar district.
2. **Attribute data:** They are numerical data that is associated with the phenomena that are represented on the maps and defining the type of database. These data are qualitative data (place names) or quantitative data (values showing the areas of agricultural land use).

Structure of the Research:

The structure of the research is an introduction, three chapters, and a conclusion. Chapter One deals with the factors that affecting wheat crop production in Tal Afar, including climate, soil and soil productivity. It also informs about the location of the study area.

Chapter 2: Covers GIS overview, the overlay concept and different types of topological overlays.

Chapter 3 focuses on the processing and analysis of different layers of the geo-database and preparation of the environmental overlay map of wheat cultivation. Then, the conclusion and results are presented, followed by the references.

1. Factors Affecting Agricultural Production in Tal Afar

1.1 Location of the Study Area

Geographic location is a key feature in the study of geography, since the region studied will determine its characteristics. For a geographer, "location" has many connotations, including the astronomical location, [1/p13].

administrative location within the district and governorate, and the location in relation to the country. The size of the study area is 774 km². In order to give a holistic picture of the study area further discussion is on:

1.1.1 Astronomical location of the District

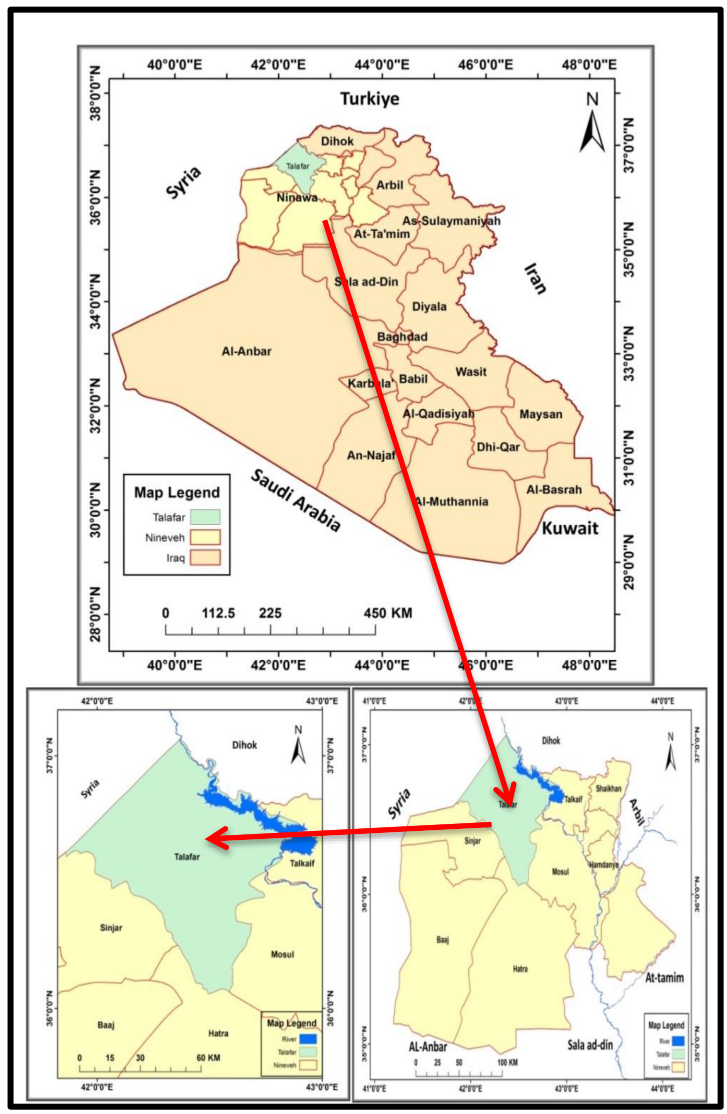
1. Astronomical position is important since it mainly determines the nature of the area. Tal Afar is situated between 36° and 37° North latitude, leaving it generally within a hot steppe climate region suitable for wheat production. Tal Afar is located between the longitudes of 41° and 43° East[2/p16].

1.1.2 District Administrative Location

2. Tal Afar is a strategically located city in Nineveh Governorate located in the western part of the governorate. It is bordered to the north and northwest by Syria, Duhok Governorate to the east and northeast, al-Hadar district to the south, and Sinjar district to the west. Geographically, Tal Afar district occupies a strategic administrative location in the study area. In terms of its geographical location in Nineveh Governorate, it is situated in the northwest part of the Nineveh Governorate administrative borders. Since it lies in the north-western corner of Iraq, it is also the same when it comes to its location in the country. As illustrated in Map (1-1). Its population numbers around 280,000, and the primary language spoken is Turkmen with Arab and Kurdish minorities nearby. The population is predominantly Muslims. [3/p3-4].

Tal Afar is about 30 miles west of Mosul, 38 miles south of Iraq's border with Turkey and 40 miles east of the border with Syria.Tal Afar district has four sub districts, which include Rabiah, Hamidat (Badosh), Zummar, and Ayadiya (Afkhah Ne).

Map (1-1): Location of the Study Area within Iraq and Nineveh Governorate



Source: [22].

2. Natural Factors in Tal Afar District

1.2.1 Climate of the Study Area

As wheat is vulnerable to the climate, the climate indirectly impact the growth of wheat. From a climatic point of view,Tal Afar district is classified as a semi-arid region and it has sensitive and delicate ecological system. The study area covers the latitudes of 36°–37° North and longitudes of 41°–43° East. It falls in the hot steppe climate,[4/p119]. which distinguishes it from desert climates mainly by the higher amount of annual rainfall.The steppe areas receive about twice as much rainfall as the desert areas, are semi-arid, and have an average annual rainfall between 350 and 400 mm. Temperature, rainfall, humidity, and wind are all environmental determinants that play a crucial role in the successful cultivation of wheat. The most important climatic variables include rainfall and temperature among them.

Rain is the region's most important form of precipitation, and the region's wheat-growing land relies on the winter rains. During the growing season, rainfall averages more than 350 mm and is fairly evenly distributed (Table (1-1).

Rainfall in the study area is associated with low-pressure systems originating from the Mediterranean Sea with several peaks between late December and mid-February. The early autumn and spring rains are predominately convectional rains, where the earth's surface heats up and as the ascending thermal buoyancy mixes with the descending polar air masses from the Anatolian Plateau, the rains are produced. This causes the production of cumuliform (CU) and cumulonimbus (CN) clouds. Rainfall, which is abundant, normally falls when temperatures are low, vary with fluctuation, both at annual and monthly totals.

1. Rainfall

Table (1-1) Monthly Rainfalls average from (mm) (2014 to 2024)

Months	July	June	May	Apr.	Mar.	Feb.	Jan.	Dec.	Nov.	Oct.	Monthly Total
Tal Afar Station	0	0.6	15	19	22	65	179.4	0	72	0	373

Source: [17].

The seasonal water requirement for wheat is divided into four stages such as the 92.4 mm and 76.65 mm water requirement in the germination and vegetative growth stage respectively while the 32.35 mm and 19.4 mm requirement occur during flowering and grain formation and ripening respectively. As seen in Table (1-2), the excess water exceeds the water deficit, and precipitation is adequate for wheat production during the growing season in the study area.

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Table (1-2): Water Needs for Wheat and Water Surplus or Deficit at Different Times of Crop Growth in

the Study Area

Growth Stage of Wheat		Germination	Vegetative Growth	Flowering	Grain Formation & Ripening
Growth Period		**November**	**January-March**	**April**	**May/June**
Tal Afar Station	**Water Requirements**	92.4	76.65	32.35	19.4
	Available Rainfall	72	266.4	19	15.6
	Surplus or Deficit	-20.4	189.75	13.35-	-3.8

Source:.[5/p50]

Rainfall Zones in the Study Area

The region has three separate rainfall zones:

a. Guaranteed Rainfall Areas: These are areas that lie on a rainfall line of 400 mm. Rainfall in these areas is regular every winter, making them most suitable for wheat cultivation. They are found mainly in the northern and north-eastern part of the study area.

b. Semi-Guaranteed Rainfall Areas: This is where the 350-400 mm rainfall line falls, and they receive year-round precipitation depending on the low-pressure systems. By definition, these regions provide an interface between regions with guaranteed and non-guaranteed rainfall. In some years, part of the area is in guaranteed rainfall, and in some years in non-guaranteed rainfall depending on the amount of precipitation. .[5/p50].

c. Non-Guaranteed Rainfall Areas: In these areas, it is not certain that there will be rainfall, and agriculture in these areas leads to desertification, especially in seasons when the land is plowed and no rainfall occurs. The soil becomes subject to erosion — desertification. (These terrains are generally set over untilled land using artificial irrigation techniques.) .[5/p50]. As shown in Map (1-2).

2. Temperature:

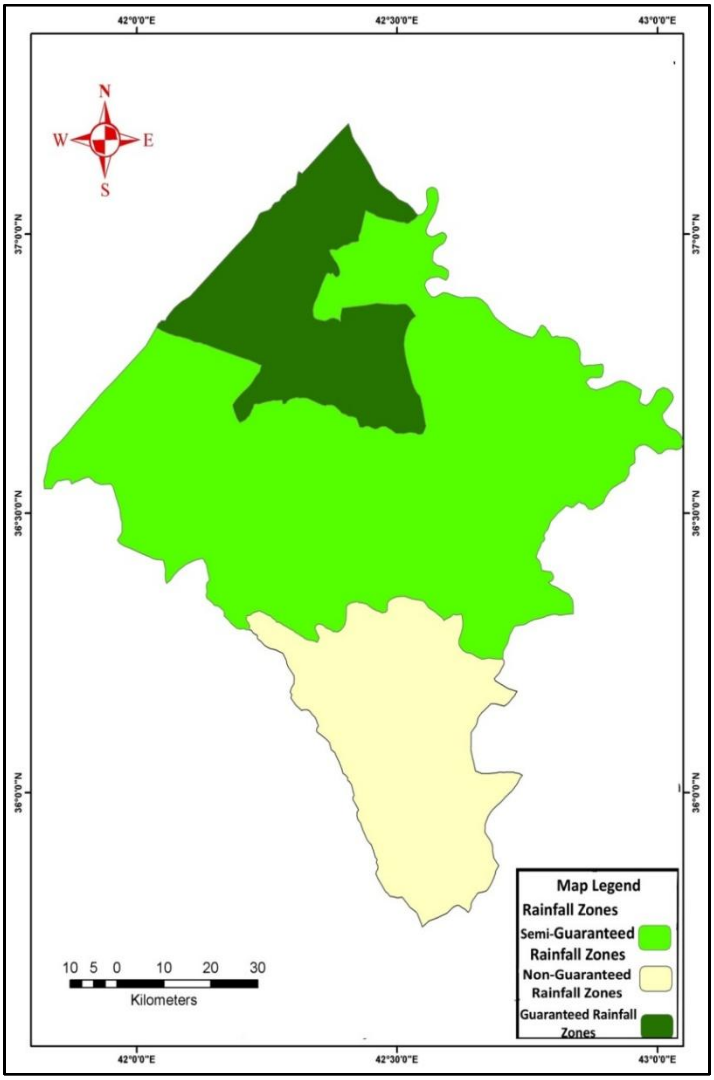
Table (1-3) Monthly Average Temperature Rates of Tal Afar Station during the Years of Observation (1980-2024)

Months	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Average
Tal Afar	**49.7**	**8.71**	**12.37**	**18.57**	**26.02**	**31.5**	**35.9**	**34.6**	**29.19**	**22.9**	**15.0**	**9.1**	**20.85**

Source: [17].

The atmosphere temperature is determined by the type of reciprocal relationship between solar and terrestrial radiations. The annual average temperature at the Tal Afar climate station and the monthly average are.[5/p50]. As shown in table (1-3).

Map (1-2): Rainfall Zones Map of Tel Afar District



Source: [19].

(unpublished data)

Wheat is planted in the autumn and matures in late spring or early summer. Wheat seeds, for instance, germinate when temperatures reach less than 3°C or more than 32°C, with the utmost being 25°C. The minimum temperature for seedlings is 5°C and maximum is 37°C, with 28°C being ideal for this growth stage; with an ideal flowering temperature of 25°C, and a gradual increase toward maturity. (see table 1-4).

Table (1-4) shows that the temperature of the study area is the closest to the temperature required for wheat germination, the minimum temperature is 3.5°C, and the maximum temperature for the same month is 23°C, and wheat is a cool-season crop, so it requires such temperatures for germination. The minimum temperature is between 2-6°C in December, and the maximum temperature is between 12-14°C, which is favourable for vegetative growth. The minimum temperature is 12°C and the maximum temperature is 22°C during the flowering phase in April, very close to the ideal temperature for flowering. The progressive rise of degrees starting from the first day of May to sixth day of June, contributed to the development of crops and the success of the wheat harvest in Tal Afar.

1-2-2 Soils

The soils, which blanket the plains of the region, belong to one of the two major groups known scientifically as Chromoxerets. Typically, these are brown and reddish-brown soils, the thickness of which varies with surface characteristics. Soils are thick, where slopes are gentle; whereas soil thickness decreases on steeper slopes and hilltops (Map (1-3)). Tal Afar has four major soil types:

1. Brown Soil:

This type has a depth of between 60 to 200 cm. It rests above the Al Fars formations and is typically draped by the windblown Loess soil. The topsoil has a loamy, soft, and fine texture similar to the texture of the deeper soil layers. .[7/p65]. The composition of the soil is cloddy or granular; soft when wet, hard when dry. In general, surface and deep soil water permeability is good, which is suitable for wheat

Table (1-4): Maximum and Minimum Temperature Rates for Tal Afar Station for 2024 by Month

Months	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Max Temperature	12	13.5	14	22	30	39	40	40	30	28	23	14
Min Temperature	2.5	3.5	6	12	16	20	24	22	20	12	3.5	2

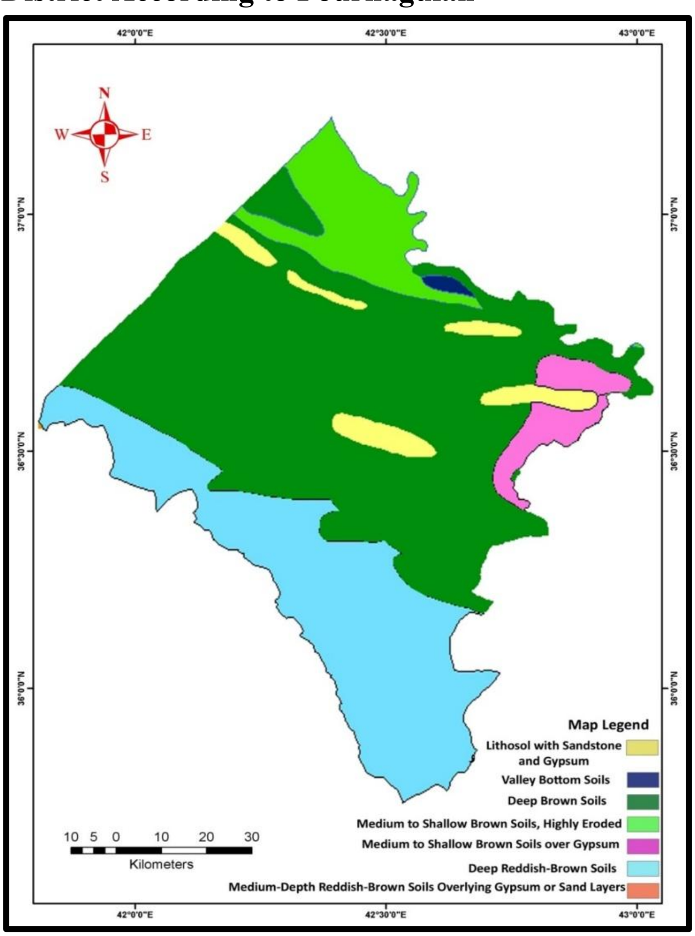
Source: [18].

cultivation. The areas, with deep soils, are highly suitable for wheat farming, whilst medium-depth and shallow soils are less so, due to erosion, especially when found over gypsum layers. .[8/p52]. **Red-Brown Soil:**

This soil type originates from Upper Fars gypsum formations mixed with anhydrite rock, shale, and clay. The cover is thin, and its texture is coarser than brown soil, interspersed with pebbles, sandy rocks, and limestone. The soil depth reaches 50 cm. It is cloddy, or granular, soft when wet, hard when dry. Compared to brown soil, wheat cultivation is less suited to this soil type. .[8/p85].

When cracked, the deep red-brown soils are unsuitable for cultivation, but good when intact. The moderate depth red-brown soils overlying gypsum or sandy layers are considered good for cultivation, however, they represent a small part of the study area.

Map (1-3): Soil Classification Map of Tel Afar District According to Pournaguian



Source: [20].

Lithosol with Sandstone and Gypsum:

This type includes those mounds of gravel and stone that accumulate in various places because of soil erosion processes. These include the northern regions, due to which these soils are not ideal for agriculture.

2. Valley Bottom Soils:

Newly-formed sedimentary soils containing clay, silt, and sand, with calcareous and gravel materials. They develop in low-lying regions such as valleys and depressions, accounting for a small portion of the north-eastern portion of the study region. [6/p115].

1-2-3 Soil Productivity Capacity.

Soil fertility and productivity are affected by a number of interlinked factors including: mineral and organic content, soil texture, and the presence of air and water. The absence of these factors affects productivity, as crops have different nutritional needs from the soil. Map (1-4) shows four types of land in the study area.

Very Good Agricultural Land:

Characterized by high fertility and suitability for wheat and barley cultivation, though their clayey texture may limit productivity. These lands are found in the Rabia sub-district, particularly in the areas of Tel Asmeer, Tel Talab, Misherfa, Tel Al-Hawa, Kani Attar, Alakana, and Tel Wardan.[9/p22].

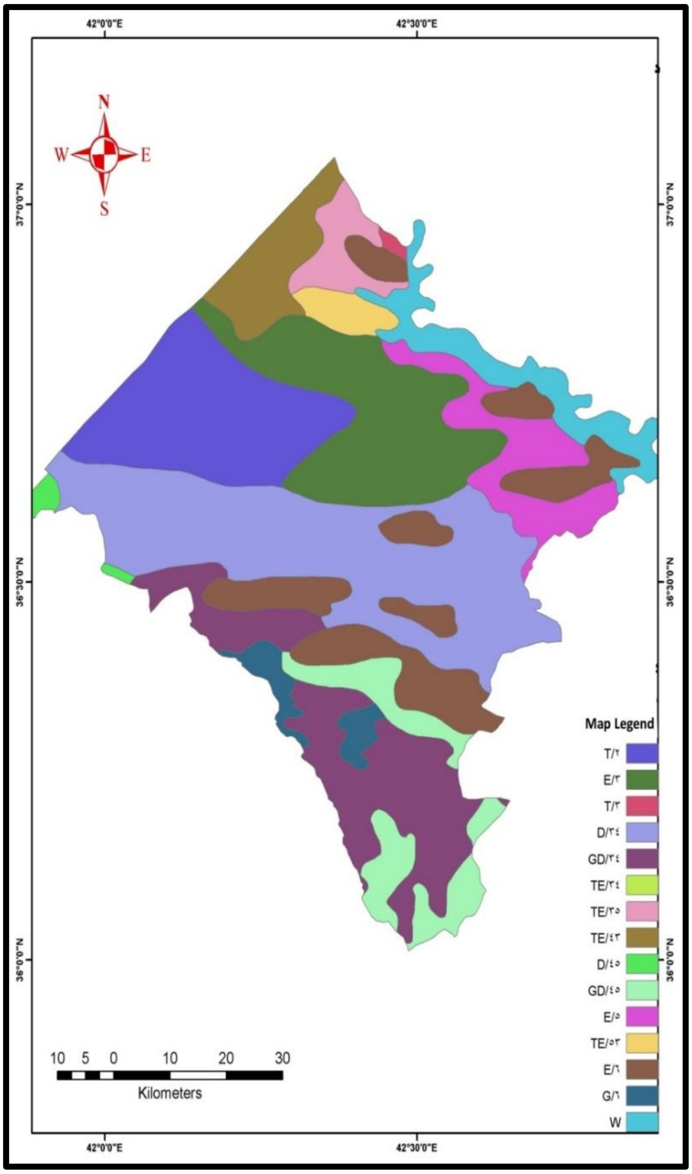
Good Agricultural Land:

Rainfall makes the heavy clay soils susceptible to water erosion; however, the soil is well-suited to wheat and barley production. They are distributed in the northern and eastern parts of (Dabshiya, Karan, Asliya) Rabia, and in the area of Zammar (Karkafr, Karqouj, Al-Aziziya, Ein Zala, Karfr, Al-Amleh).

Moderate Agricultural Land:

Noted for unpredictable and variable rainfall but classified as fair therefore productivity may vary significantly between wet and dry years. These lands are located in the southern Rabia area (Kharai'j Abd Bilal, Kharabat Saeed, Al-Kharija Al-Khazna) and in the Ayyadhiya sub-district (Mamat Haloum, Bir Al-Helu, Al-Bugha, Sahl Al-Malih, Qabak, Afkani

Map (1-4): Map of Soil Productivity in Tel Afar District



Source: [21].

Non-Arable Land:

Involves rocky slopes, low-fertility gypsum (silt) soils, or areas affected by sand dunes or high moisture due to Mosul Dam reservoir. They are located in Ayyadhiya and Zammar (Karbir, Ein Habash, Kharabat Kabir, Balbala Tapa Si) and Tal Afar (Al-Abra Al-Kubra, Ein Afr).

The Al-Tai land productivity classification study states that the region has large areas of good and moderately arable land, and suits the cultivation of wheat and barley. On the other hand, certain regions are unsuitable as they comprise steep slopes, shallow soil depth, or excessive gypsum content, hindering effective crop growth. [10/p73].

The present study focused on analyzing the natural factors (climatic, soil, and productive capacity), as they constitute the primary basis for determining land suitability for agriculture. In contrast, the economic factors (production costs, proximity to markets) and social factors (availability of labor, land ownership) were not included in the current model due to the absence of up-to-date detailed data. Nevertheless, they were highlighted as important dimensions that should be incorporated in future studies to provide a more comprehensive assessment of land suitability for agriculture.

2-1 GIS Overlay in Geographic Information Systems

Data processing is the backbone of Geographic Information System (GIS). Merging, overlaying, or combining layers is arguably one of the greatest functions that GIS excels at. It means layering multiple datasets together from varied places so analysis and processing can be conducted. This takes a considerable amount of computational resources and available specifications. This technique has been used to generate new maps, combining datasets and performing mathematical or relational operations that may highlight the best locations for agriculture, areas of higher productivity or environmental suitability for specific crops. .[11/p135].

By allowing disparate data sets to coincide spatially, GIS overlay can provide critical information for answering analytical questions about relationships between variables and spatial realities. It can, for instance, know where is the most appropriate place on the farm to plant wheat or it can identify the best farming zones. In GIS overlay, we use different layers of data, like soil types, agricultural regions, and climatic factors, and use layers to see how these factors relate to each other and help with spatial variation and eco-compatibility. .[12/p306].

Concept of Overlay In cartography, overlay is the mapping of a variety of data sets to produce a unique map made up of different components. In other words, it is a process of area overlap of a map that show a certain phenomenon with another map that holds separate information about other phenomenon(s). Overlay is the process of creating a composite map which contains all the phenomena to be analysed or identified, along with their spatial relationships to each other. Merging data from different sources allows for data analysis and processing and is at the very heart of Geographic Information Systems (GIS). GIS has enabled the ability to take different phenomena or principal elements of the same region and superimpose one over the other to create a new phenomenon or composite. While GIS techniques perform less like a sieve for maps, it makes maps more transparent, as if they were printed on transparent sheets and placed on a light table. While overlay is generally considered two-dimensionally, tending to use geographic math, it is also applicable in multiple dimensions. Overlay: Using a combination of different sets of information or data to create maps made up of multiple components.**[13/p300].** The vector overlay process (overlay in linear system) is based on geometry, topology and a branch of mathematics that examines the placement of items in relation to one another. **.[14/p100].**

2.3 Types of Topological Overlay

1. Point-in-Polygon Overlay

This method involves matching a dataset containing point data with another dataset of the same phenomenon that contains areal data. This concept, known as "Point-in-Polygon Overlay," is illustrated by overlaying a map of various agricultural regions with another map that includes, for example, the locations of wells (as shown in Figure 2-1). The process involves merging the attribute tables of the two datasets into a single table. **.[15/p106]..**

2. Line-in-Polygon Overlay

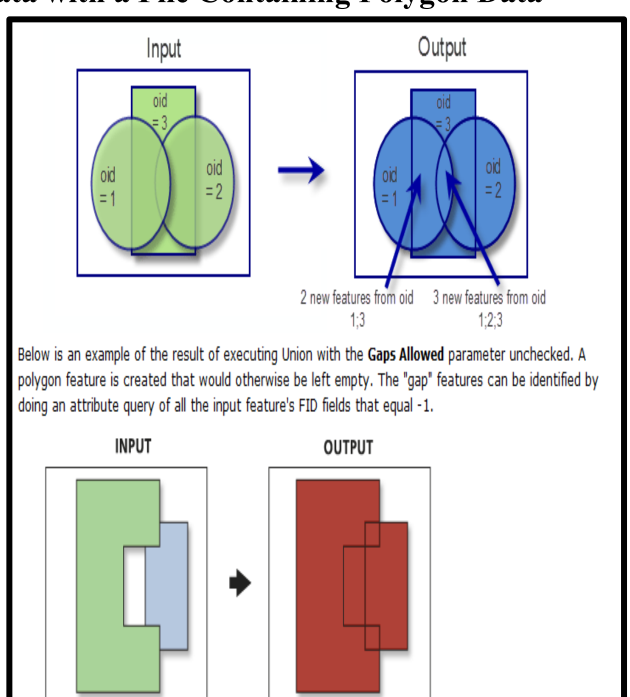
3. This approach associates a dataset with linear features to another one that comprises areal data. Called "Line-in-Polygon Overlay" .it overlays linear data with areal data. **Polygon-in-Polygon Overlay**

This technique relates to overlaying two areal datasets—for example, one that shows various soil types, and one that shows agricultural areas. This type of overlay is called "Polygon-in-Polygon Overlay" because it is an aggregation of different patterns of soils in large agricultural areas .This requires two areal datasets to be matched19.**[16/p86]..**

In light of this simple conceptualization, the overlay process used in GIS software is based on inputting the study's data as layers, with each layer representing a specific subject. These layers are input in the form of files, as described in the previous example. The collection of files for these layers forms a database (Data Base) that is used in any study employing a GIS.

The study adopted the principle of equal weighting among environmental factors, due to the absence of detailed data that would allow for deriving precise weights using methods such as AHP or MCE. This assumption is consistent with the research objective of developing a practical and simplified model that can be applied within a local context with limited resources. Nevertheless, we recommend conducting future studies that employ multi-criteria analysis methods (MCE/AHP) to examine the impact of varying weights on the results."

Figure (2-1): Matching a File Containing Linear Data with a File Containing Polygon Data



Source: Generated by the researcher using ArcGIS software

In our study, a set of layers with different themes will be overlaid, including:

1. Rainfall distribution layer
2. Soil classification layer
3. Soil productivity layer

This is done to produce or generate a set of new themes (i.e., new maps) using geoprocessing to achieve an environmental overlay model for wheat production, utilizing intersection or union commands.

3.1 Processing and Analysis of the Geographic Data Set and Preparation of the Environmental Overlay Map for Wheat Production

The process of analysis and processing is one of the most important functions of GIS. It is distinguished by the creation of new maps and new databases based on both spatial and descriptive data. In this study.

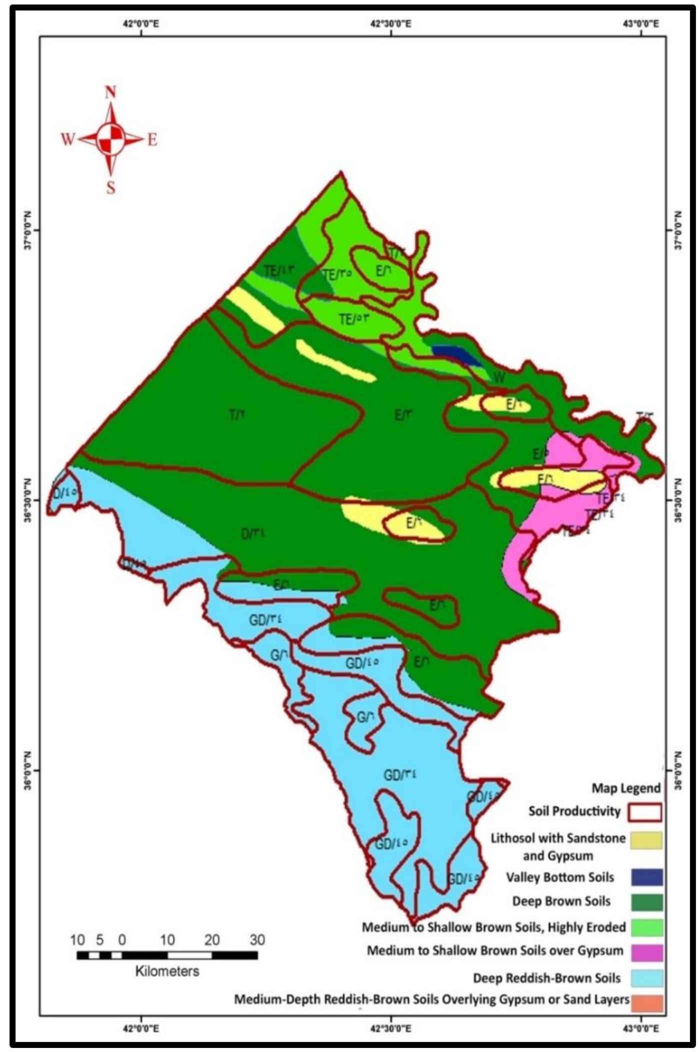
Although advanced analytical tools are available in the GIS environment, such as Fuzzy Logic and AHP, this study relied on conventional spatial analysis tools (Overlay/ Union) for two main reasons: first, to simplify the analytical process, making it replicable by local institutions; and second, due to the limited availability of precise data required for applying more complex models. Nevertheless, we emphasize that adopting more advanced tools in the future would contribute to enhancing the accuracy and reliability of the results.

the ArcMap GIS program was used for overlay operations through the Arc Toolbox, which represents one of the key analytical tools in GIS. Factors influencing the suitability of areas for wheat production and the productivity per unit area were overlaid. Two layers were combined using the "Union Two Themes" command to produce a new layer, which was then further overlaid with another layer to produce yet another new layer, and so on. Below is an outline of the overlay operations and the analysis of results

- **Step one:**

In Arc Toolbox and the "Union" command, certain factors influencing the suitability for wheat cultivation were overlaid. More specifically, soil type map (figure 1-3) was overlaid with soil productivity map(figure 1-4), resulting in new map(figure 1-5) with new attribute and table—generated by a merge of the attribute tables from each of original maps. The new map shows different soil types and their potential productivity, identifying new areas that can be classified by soil type and productivity.

Map (1-5)Matching the Soil Type Map with the Soil Productivity Map in Tel Afar District



Source: Generated by the researcher using Soil Type Map (1-3) and Soil Productivity Map (1-4).

The new descriptive data table confirms that most of the study area is described as deep brown soils. As indicated on the map, the soil classifications are E/3, T/2, E/6, and D/34. Previously, we described the properties of deep brown soils and their locations within the study area, emphasizing their aptitude for wheat cultivation. Moderate wheat productivity land–as shown by the presence of land types E/3 and D/34. As shown in Figure (6), most of the northern, central, western, and eastern regions of the study area are covered by these soils.

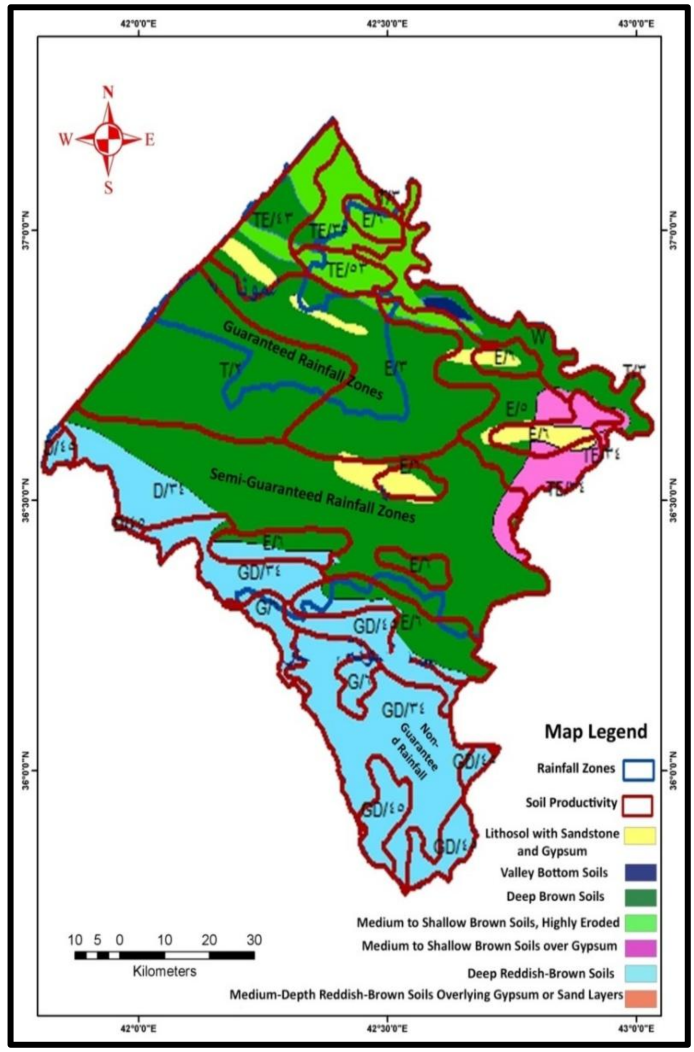
- **Step Two:**

To conduct this step, a match between map (1-2), where rainfall zones are delineated, and the new map derived in step one as map (1-5) was executed. The above process created a new layer with new specifications and also created a table of what the old and new maps were. Map (1-6) gives us a summary of the intersection between the soil types and productivity map with the rainfall zones map, where we can see the rainfall areas associated with the corresponding soil types and their productivity. The new map clearly identifies the spatial distribution of rainfall zones in the region, categorizing them as assured rainfall areas, semi-assured rainfall areas, and non-assured rainfall areas.

This map further explains the characteristics of precipitation in the study area and highlights the most promising agricultural development—mostly located in the north of the area. The northern part of the study area is classified in assured rainfall zones with moderate agricultural productivity on deep brown soils, with moderate constraints due to water and wind erosion. Conversely, the southern part of the study area is predominantly covered with non-assured rainfall zones, where the red-brown soils are mainly found, which are considered less favourable for agricultural purposes (compared to the brown soils).

Additionally, the new matching process uncovers the spatial elasticity of wheat cultivation at district level, using the agricultural variables like soil type and its productivity. Since the rainfall and temperature , and consequently, other influencing factors are fairly homogenous in the region, (clearly illustrated by the soil and productivity maps), the distribution pattern becomes obvious.

Map (1-6): Matching the Soil Type Map with the Soil Productivity Map with the Rainfall Zones Map in Tel Afar District



Source: Generated by the researcher using Rainfall Zones Map No. (1-2) and the previously created composite map No. (5-1)

This comprehensive matching effort enabled us to create an Environmental Suitability Map for wheat farming within Tal Afar district using GIS. The land where agriculture is sustainable under the best environmental conditions is indicated by the new layer that was added with the new database.

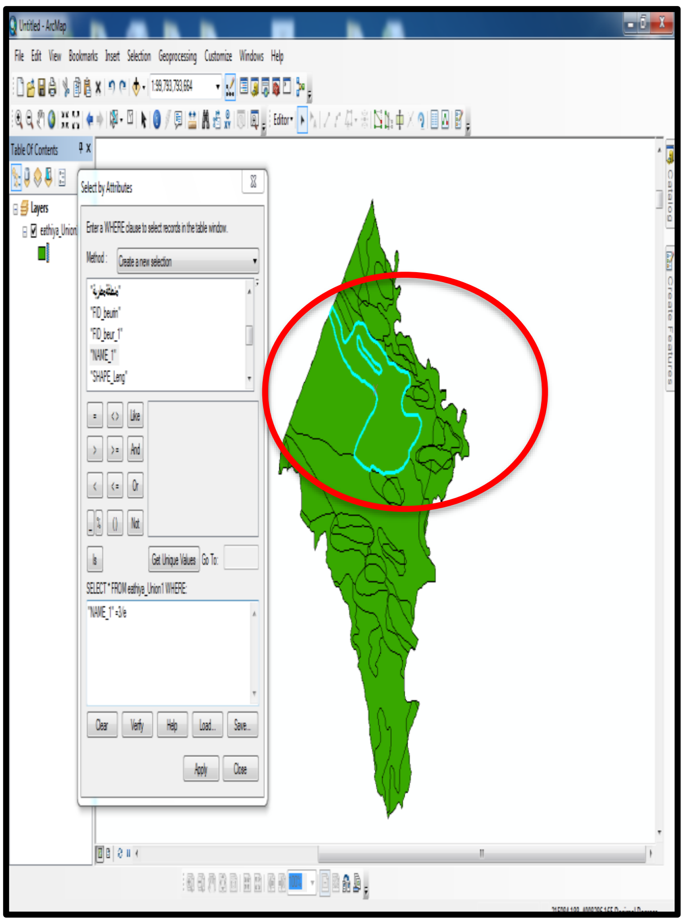
The study based its final results on equal weights for the input factors, which makes the results relatively stable without testing their sensitivity to changes in weights or classification criteria. Using such methods would have added significant value in terms of assessing the stability of the results under potential variations. Due to data limitations, this type of analysis was not applied here; however, it is recommended for future studies to enhance the credibility of the conclusions.

As a result, the study area can be classified into two agriculture regions:

1. **Highly Productive Zone:**This zone includes the districts of Tel al-Matar, Wasfiya, Tel al-Hawa, Kran, and Karsour, and is located in the northern part of the study area, as shown in Figure (1-3).

2. **Less Productive Zone:**This zone comprises the remaining districts, which are situated to the south of the highly productive zone.

Figure (3-1): Environmental Matching Map for Wheat Crop within the ArcMap Environment



Source: Generated by the researcher using ArcGIS software

Conclusions

1. The study demonstrated that Geographic Information Systems (GIS) represent an effective tool for analyzing and integrating environmental data to produce maps that identify the most suitable locations for wheat cultivation in the Tal Afar District.

2. The spatial analysis results revealed that the interaction of natural factors contributed to identifying areas with high suitability for agriculture, reflecting the strength of GIS in supporting the agricultural sector.

3. The study's reliance on equal weighting among factors provided a practical and simplified model applicable in local contexts with limited data, although this may reduce the accuracy of the results compared to more advanced methods such as AHP or Fuzzy Logic.

4. The findings confirmed that generating a spatial suitability map helps guide agricultural efforts toward areas that are more efficient in utilizing natural resources.

5. It was observed that the study was limited to natural factors, meaning the results reflect only the natural dimension, while economic and social factors remain to be integrated in future studies to provide a more comprehensive picture.

Recommendations

1. Incorporating multi-criteria analysis methods (MCE/AHP) in future studies to determine precise weights for the influencing factors, thereby enhancing the accuracy of the results.

2. Integrating economic and social factors (production costs, proximity to markets, availability of labor) in future analyses to provide a more comprehensive perspective.

3. Conducting field validation by comparing the results with actual production data or through field visits to strengthen the credibility of the generated maps.

4. Encouraging local agricultural institutions to adopt the research outputs in order to guide agricultural policies toward the optimal use of lands suitable for wheat cultivation.

5. Regularly updating agricultural and climatic databases to facilitate the use of GIS techniques in supporting long-term decision-making**.**

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