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Classification of Drought Indicators for the Southern Hamrin Hills Area – Diyala Using Palmer (PDSI)

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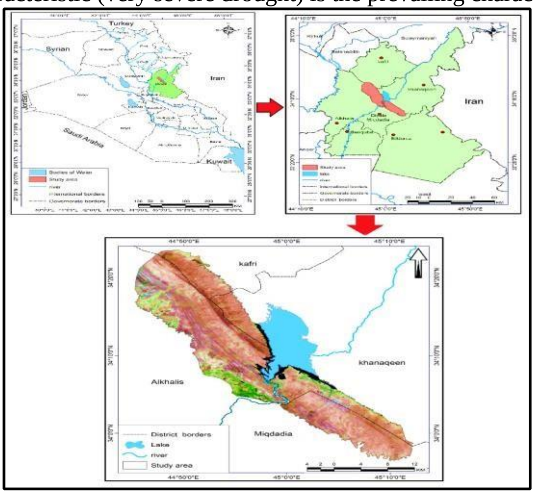
Abstract

Drought is defined according to Palmer as a lack of moisture supplies over a period of several months or years within a specific area (1). The study aims to classify and determine drought patterns using the PDSI drought index, in the Hamrin Hills and the extent of their exposure to drought for the period (1999-2023) through remote sensing data, to produce drought type maps for the region and the possibility of updating their data. The problem is determined by the possibility of employing geographical technologies to detect drought patterns using the Palmer drought severity index. The region is located astronomically between longitudes (44.45.1645.23.26) east and latitudes (34.23.31- 33.56.30) see Figure (1). Data from satellite stations were relied upon for the period (1991-2023) from the website https://climate.northwestknowledge.net. After using the Palmer index, it became clear that the characteristic (very severe drought) is the prevailing characteristic of the region.



Map (1) Location of the study area

Source: Digital Elevation Model (DEM) 2- General Authority for Survey, Administrative Map of Iraq, at a scale of 1/500,000 and on the satellite image of the Lanasat8 satellite 2024/8/7

Keywords: PDSI, geographical technologies, Diyala.

1. Introduction

The region is tectonically located within the unstable continental shelf affected by folding processes caused by Alpine movements (2), within the scope of low folds within the Hamrin belt - and the Tikrit Al-Amara belt (3). The region is described by its continental climate according to the Köppen classification (4), which is characterized by the dominance of semi-arid climate due to high temperatures and the wide daily and annual thermal range with seasonal rainfall and its fluctuations. The spatial effects of drought vary according to its severity and duration, and specific indicators contribute to monitoring drought. Many previous studies have relied on (temperature and rainfall) to identify dry and semi-arid areas, but all of them have been criticized for relying on specific climatic elements without considering other elements. The Palmer drought severity index was used for its high accuracy as it includes most of the climate elements (5).

2. Programs and websites:

Table (1) Tools used in the study.

Source	Sunnah	volume	Program & Websites
https://www.esri.com/enus/arcgis/about-arcgis/overview	2014	Data processing, presentation and analysis	Arc GIS 10.8
http://nic.fb4.noaa.gov/products/ana lysis_mo nitoring/	2023	Many U.S. government agencies rely on it to activate drought relief programs.	https climate: northwestknowledge. Net
https://earthexplorer.usgs.gov /	2024/2/18	30 * 30	Visual satellite (LandSat .8)
https://www.usgs.gov/centers/eros/s cience/usgs-	2014	30 * 30	Digital Elevation Model DEM
Ministry of Water Resources, General Authority for Survey, Administrative Map of Iraq	2022	1:500000	Topographic map
Ministry of Industry and Minerals	2022	1:500000	Geological Map

Table (2) Equations and indicators used.

description	Standards	Equation	Name
The amount of moisture needed in the topsoil layer and the basic soil layer needed is not usually charging the soil with water	PE> P	PR= AWC – S1- S2))	Soil recharge
The amount of moisture that soil can lose due to evaporation	P=0	PL= PLs + PLu	Possible loss of moisture
Possible rainfall minus soil recharge	AWC = PR	PRO = AWC - PR	Possible Flow
Calculates the difference for each month between actual		P - (a, PE + PR + PRO -)	Monthly rain incoming difference

rainfall and appropriate rainfall depending on the climate of the region			
Humidity period intensity index and dry period intensity	0.5 ، 0.5-	$X_i = 0.897X(i-1)+Z(i)/3$	PDSI Monthly Index Value
Determine the end of the dry season and the end of the rainy season	$Z=-2691X_{i-1}+1.50$	$Z(i)>Ze(i)$ -0.15	Measure the percentage of moisture needed to end the drought

1. The Palmer Drought Severity Index: Limitations and Assumptions, William M. Alley, U.S. Journal of Climate and Applied Meteorology, volume 23,1984, Geological Survey, Resion, VA

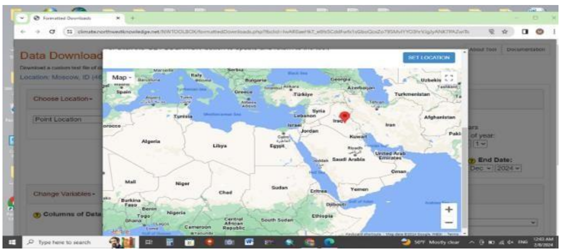
Practical procedures:

-Data for two climate space stations for the study area to determine the severity of drought from the site:

//https climate: northwestknowledge. net)):

-First step: Download climate data for two virtual stations within the study area from the link above, Image (1)

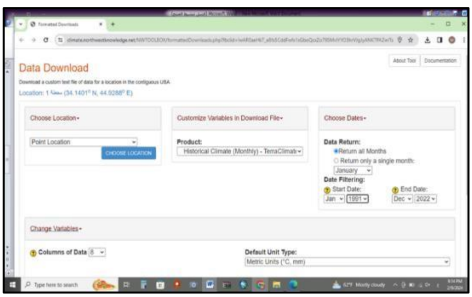
Image (1) Selecting the location of the study area from the climate site.



Source: Based on the website //https climate: northwestknowledge. net))

Step 2: Determine the study period for extended climate data (1/9/1991 – 1/9/2023) Image (2)

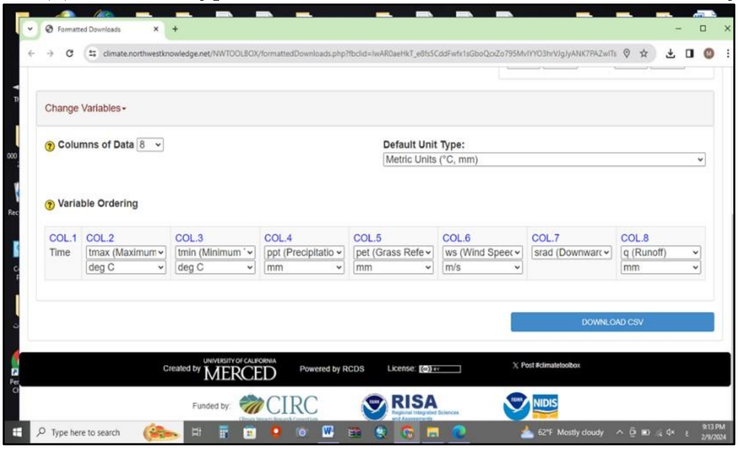
Image (2) Determine the date of the required climate data.



Source: Based on the website //https climate: northwestknowledge. net))

Step Three: Determine the type of climate data and then download the climate elements, Figure (3).

Figure (3) shows the type of climate data to be downloaded for the study area



Source: Based on the website //https climate: .northwestknowledge.net

Step 4: After downloading the data for the purpose of processing it and extracting the monthly and annual rates of climate elements according to the Palmer Standard Index (PDSI)

3. Application of the standard Palmer Drought Severity Index

The Palmer Index is one of the standard drought severity indexes using algorithms created by meteorologist Wayne Palmer in (1965) with the aim of providing data on humidity and making comparisons between selected sites and the same site in different seasons in response to drought and humidity conditions without taking into account water levels in reservoirs, lakes and hydrological conditions. He made modifications to the index (1984) to include the duration of drought with the idea that an abnormally rainy month in long drought periods does not significantly affect the results of the index (6). He relied on climatic elements calculated according to the Thornthwaite method (7) in building these algorithms. The construction of these algorithms was developed by (welis) and others by calculating climatic constants in a dynamic manner that varies according to the station (8). All climate elements and available water content (groundwater levels, soil moisture and its ability to retain water, stream flow, etc.) are used in this study to determine drought and determine wet years. The standard Palmer Index was applied for the severity of drought or what is called the Palmer Drought Severity Index (PDSI).

The Palmer Drought Severity Index is a tool used to assess the drought status of a given area based on the moisture balance in the soil. This index is based on measuring the amount of rainfall compared to the requirements of plants, and takes into account several factors such as:

1. Evaporation and transpiration: the amount of water lost from the soil and plants.

2. Rainfall: the amount of rain falling during a specific period of time.
3. Plant water requirements: the amount of water needed for healthy plant growth.

The importance of using the Palmer Index is as follows:

1. Determining the level of drought: The index can be used to determine whether the area is experiencing mild, moderate, or severe drought.
2. Agricultural planning: Helps farmers make decisions about planting and irrigation dates.
3. Water resource management: Contributes to guiding water management policies in droughtprone areas.3

Palmer classifies drought into three levels:

1. Mild drought: The soil moisture level is slightly below the required level.1
2. Moderate drought: A significant lack of soil moisture.2
3. Severe drought: A severe lack of moisture that affects agricultural production

The Palmer Index is a valuable tool in climate and agricultural studies and is useful in making informed decisions about natural resource management. The Palmer Index has proven its effectiveness in identifying drought periods in the long term with specific values, positive values indicating semi-humid and humid seasons, and negative values indicating dry and semi-dry seasons (9). This index is more accurate and more comprehensive and is characterized by its calculated numerical representations that aim to measure the specific drought condition on the ground using weather data and hydrological data. The numerical representations used have enabled the identification of drought locations, timings, severity and duration, and interpretation of the potential loss of moisture due to the effect of temperatures. It also enables decision-makers to plan, design, model and evaluate risks, and determines the deficit in the moisture supply by representing the groundwater balance in the long term (10.

For the purpose of analyzing drought patterns in terms of the Palmer Index and producing digital drought maps, data specific to the study area for the period (1991-2023) were represented for two virtual space stations, the first station at an astronomical location (34.0625 -45.1042) and the second station is at an astronomical location (34.2708-44.8958), and positive numbers indicate semi-humid and humid seasons, negative numbers indicate moderately dry and very dry seasons as in Table (3).

Table (3) Drought categories for the Palmer Drought Severity Index (PDSI)

Result of the equation	Season adjective	t
+4	Very humid	1
+3	Very humid	2
+2	Average humidity	3
+ 1	low humidity;	4
+ 0,5	Very little humidity;	5
0,0	Close to average	6
- 0,5	Very little dehydration	7
- 1.0	Slightly dehydrated	8
- 2.0	Moderate dryness	9

-3.0	Severe dehydration	10
-4	Very severe dehydration	11

The Drought Of 1988 and Beynd, Proceedings of a strategic Planning Seminar co-sponsored with the National Academy of Science and Resources for the Future October 18, 1988, Washington, D.C.,6pp

By comparing Table (3) with the results of Table (4) and Table (5), the temporal and spatial variation of the Palmer index in the selected virtual satellite stations within the region becomes clear, as the highest drought index reached a repetition of (12) years for both stations with a value of (-4) and the season characteristic was (very severe drought), while both stations recorded the characteristic (severe drought) with a variation in the repetition of the characteristic with a repetition value of (6) seasons in (Station 1) and a number of repetitions of (3) (Station 2), while the characteristic (moderate drought) was repeated with a number of (8-11) seasons in Stations (1 and 2) respectively, and the season characteristic was close to the average that indicates the end of the drought characteristic and the beginning of the humidity characteristic or vice versa. 11) The two stations recorded only one season, while the highest humidity characteristic within the Palmer index recorded the characteristic (moderate humidity) that extended for one season in (Station 1) and for two seasons in (Station 2), followed by the season characteristic (low humidity - very low humidity) for one season for the two stations, and the season characteristic (wet) was not recorded Very-very humid) Palmer index within the study area indicates the prevalence of drought and low humidity, Map (2).

Table (4) Palmer Standard Drought Index (PDSI) classification in the study area for the period (1991-2023)

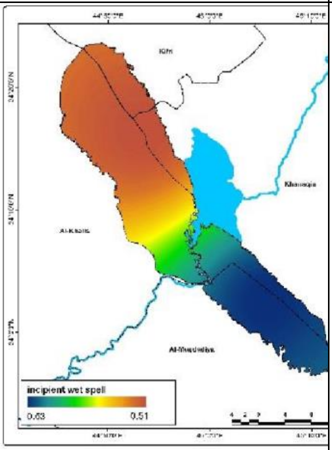
Season adjective	Station 2	Season adjective	Station 1	Sunnah	t
Severe dehydration	-2.98	Moderate dryness	-3.11	1991	1
Average humidity	2.82	Average humidity	2.37	1992	2
Very little humidity;	0.53	Very little humidity;	0.51	1993	3
Close to average	-0.26	Close to average	-0.26	1994	4
Severe dehydration	-3.08	Severe dehydration	-3.04	1995	5
Moderate dryness	-2.59	Moderate dryness	-2.72	1996	6
Moderate dryness	-2.86	Moderate dryness	-2.94	1997	7
Slightly dehydrated	-1.24	Slightly dry	-1.38	1998	8
Very severe dehydration	-5.23	Very dry	-5.54	1999	9
Very severe dehydration	-5.82	Very dry	-6.09	2000	10
Very severe drought	-5.22	Very severe dryness	-5.62	2001	11
Severe drought	-3.73	Severe dryness	-3.93	2002	12
Moderate drought	-2.21	Moderate dryness	-2.15	2003	13
Mild drought	-1.68	Low dryness	-1.81	2004	14
Moderate drought	-2.46	Moderate dryness	-2.77	2005	15
Moderate drought	-2.11	Moderate dryness	-2.48	2006	16
Very severe drought	-2.35	Moderate dryness	-2.58	2007	17
Very severe drought	-5.07	Very severe dryness	-5.2	2008	18
Very severe drought	-6	Very severe dryness	-6.12	2009	19
Very severe drought	-5.51	Very severe dryness	-5.6	2010	20
Very severe drought	-4.53	Very severe dryness	-4.58	2011	21
Very severe drought	-5.63	Very severe dryness	-5.63	2012	22
Very severe drought	-3.72	Very severe dryness	-3.67	2013	23
Very severe drought	-2.57	Very severe dryness	-2.74	2014	24

Moderate drought	-6.51	Moderate dryness	-6.44	2015	25
Very severe drought	-4.07	Very severe dryness	-4.04	2016	26
Moderate drought	-2.97	Very severe dryness	-3.03	2017	27
Low humidity	-2.73	Severe dryness	-3.11	2018	28
Near average	1.59	Low humidity	1.77	2019	29
Very severe drought	-0.15	Slight dryness	-1.5	2020	30
Very severe drought	-6.67	Very severe dryness	-6.68	2021	31
Moderate drought	-8.53	Very severe dryness	-8.45	2022	32
Very severe drought	-2.92	Moderate dryness	-2.62	2023	33

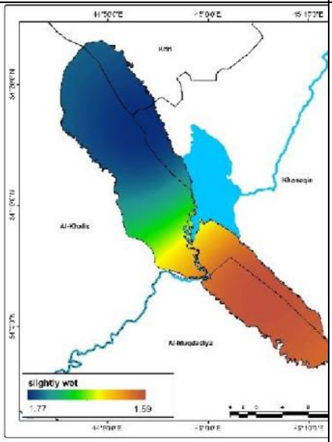
Source: Based on the website ((https://climate.northwestknowledge.net

Map (2) Drought patterns of the Palmer Drought Severity Index (PDIS) for the study area for the period (1991-2023)

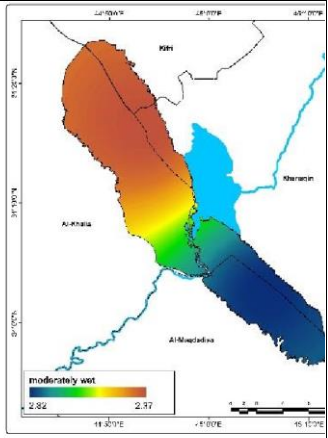
incipient wet spell



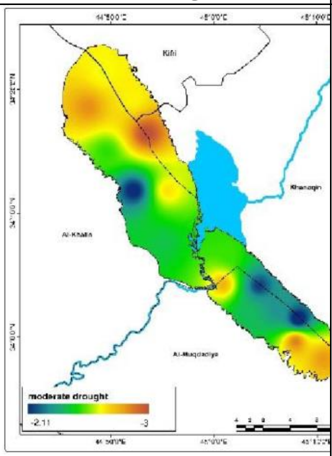
slightly wet



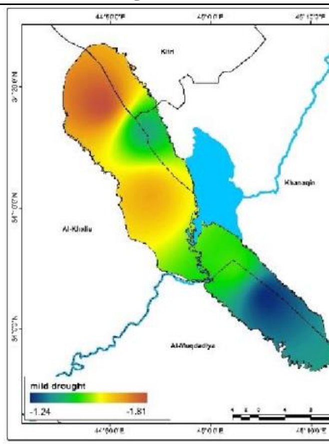
moderately wet



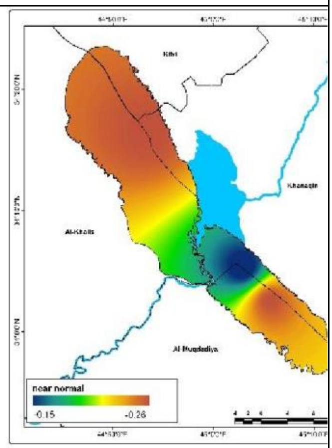
moderate drought



mild drought

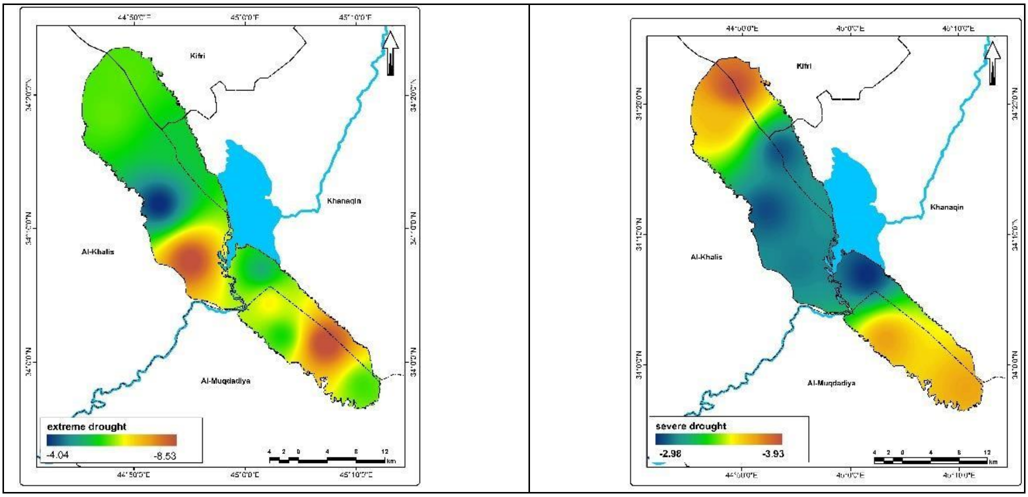


near normal



extreme drought

severe drought



Source: Table (4) and Table (5) and Arc GIS 10.8 program outputs

Table (5) Seasonal characteristic frequency for Palmer index for the study area

Repeat the season adjective in Station 2	Repeat season adjective in Station 1	Season adjective
There isn't any	There isn't any	Very humid
There isn't any	There isn't any	Very humid
1	1	Average humid
1	1	Low humid
1	1	Very low humid
2	1	Near average
There isn't any	There isn't any	Very slightly dry
2	3	Low dry
11	8	Average dry
3	6	Severely dry
12	12	Very severely dry

Source: Based on the website ((https://climate.northwestknowledge.net and Results of Table (3)

Results Analysis

The Palmer Index deals with the severity and duration of drought. Its methodology is based on very sensitive values that may end the drought characteristic in a region if it is exposed to rainfall during a certain period of time that greatly affects the values of the PDCI index for several months to come. Thus, the time series models are limited in pattern for an entire rainy season. Here, the high potential of this index to identify sudden climate changes becomes clear. The Palmer Index is also one of the regional drought indicators, and decision-makers can develop a clear picture to predict short-term changes in plant water needs in addition to long-term forecasts for crop production and protection from weather disturbances. It also provides an image of the drought that the region has been exposed to in the past. The region witnessed humidity ranging from very low to low humidity (Map 2-B and 2-C) and medium humidity (Map 2-A) at a repetition level of (1 season) for all sites. The region did not witness the season characteristic (very wet - very wet). The region witnessed a season characteristic close to the average at a repetition level of (1) season for the first site and a repetition level of (2 seasons). For the second site, the region suffered from a slight drought at a frequency level of (3 seasons) within the first site and (2 seasons) at the second station, map (2-E and 2-F), and a very severe drought at a frequency level of (12 seasons) within the study period for all stations, map (2-H). It also requires developing drought indicators and conducting more climate studies to determine drought patterns and types. The study clarified the importance of satellite stations in revealing the spatial variation of climate elements for each station.

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