



## Geomorphological Characteristics of Sand Dunes in the Area Extending Between Al-Diwaniyah, Al-Muthanna, and Nasiriyah

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### Abstract:

The study showed that sand dunes are formed as a result of the interaction of the north-west winds with dismantled sand deposits in a flat and dry steppe environment, which led to a variety of forms and patterns such as Crescent, longitudinal and transverse dunes. the results also showed that the weakness of vegetation cover and sedimentary surface characteristics contribute to an increase in the activity of wind processes. the study confirms that sand dunes represent a dynamic phenomenon with environmental effects and geomorphologically important in the study area.

**Keywords:** Sand Dunes, Al-Diwaniyah, Al-Muthanna, and Nasiriyah.

المستخلص:

تهتم هذه بدراسة الخصائص الجيومورفولوجية للكثبان الرملية في المنطقة الممتدة بين الديوانية والمنثى والناصرية وتحليل العمليات والعوامل المؤثرة في نشأتها وتطورها أظهرت الدراسة أن الكثبان الرملية تتشكل نتيجة تفاعل الرياح الشمالية الغربية مع الرواسب الرملية المفككة في بيئة سهلية منبسطة وجافة مما أدى إلى تنوع أشكالها وأنماطها مثل الكثبان الهلالية والطولية والعرضية كما بينت النتائج أن ضعف الغطاء النباتي وخصائص السطح الرسوبي يسهمان في زيادة نشاط العمليات الريحية وتؤكد الدراسة أن الكثبان الرملية تمثل ظاهرة ديناميكية ذات تأثيرات بيئية وجيومورفولوجية مهمة في منطقة الدراسة.

### Research Introduction:

The sand dune is, perhaps, the most easily recognizable form of aeolian geomorphology in drylands and semiarid environments. They are directly created by an interaction between climatic elements — particularly wind — and loose sediments at the surface. There is good reason to support why studying sand dunes is critical; sand dunes are constantly changing, and thus can significantly impact land use, infrastructure and human activities in the surrounding environment. The study area is located within the alluvial plain of southern Iraq, and includes the governorates of Diwaniyah, Muthanna and Nasiriyah. This area is defined by its mostly flat, dry climate and lack of plant cover, making way for wind activity (aeolian) processes and making it easier for sand to develop into distinctive sand formations. The prevailing winds blowing from the northwest lead to the formation, transportation, and deposition of sand sediment, thus forming different patterns of sand dune formation. The goals of this project are to study the geomorphology (characteristics and formation) of the sand dunes in the study area; to gain insight into the geologic processes and geomorphic factors that affect the formation, growth, and spatial

distribution of the sand dunes; and to demonstrate the impact of the sand dunes upon the environment and geomorphology. The sand dunes between Diwaniyah and Muthanna (Nasiriyah) display a diversity in their geomorphological characteristics due to their distinctively unique shapes, sizes, and areas. Crescent, longitudinal, and transverse dunes dominate the region, depending on the wind's direction and how it interacts with certain types of environmental conditions. The information gathered from this analysis will provide an overall understanding of how the surface of the southern region of Iraq is shaped through time and space due to aeolian processes (wind processes) within the context of the geomorphic features of the area.

### First: Research Problem:

The research problem was represented by the following questions:

What are the geomorphological characteristics of the sand dunes in the area extending between Diwaniyah, Muthanna, and Nasiriyah?

What natural and geomorphological factors influence the formation, development, and distribution of sand dunes in the study area?

### Second: Research Hypothesis:

The answers to the research problem questions are as follows:

The sand dunes in the area extending between Diwaniyah, Muthanna, and Nasiriyah are characterized by a clear diversity in their geomorphological characteristics in terms of shapes, sizes, and spatial extent. Crescent, longitudinal, and transverse dunes predominate, depending on the nature of the prevailing environmental and wind conditions.

The study hypothesizes that the development of sand dunes is linked to the dominance and speed of northwesterly winds, along with the sparse vegetation cover, the nature of the loose sediments, and the flat topography, all of which contribute to activating wind processes and the encroachment of sand dunes.

Third: Research Objectives:

This research aims to:

- 1- Identify the geomorphological characteristics of sand dunes in the study area.
- 2- Analyze the aeolian processes (erosion, transport, deposition) affecting dune formation
- 3- Study the dominant sand dune patterns and their spatial distribution
- 4- Investigate and explain the interrelationship between the parameters of the natural elements of climate, wind, and topography, which have an effect on the formation of the sand dunes found in the region being studied.

5- Analyze the geographical distribution of sand dunes in the region.

6- Demonstrate the geomorphological impacts of dunes on the natural and human environment.

Fourth: Methodology:

The study adopted a descriptive analytical geomorphological approach based on:

A precise description of natural phenomena (sand dunes), analysis of the geomorphological processes influencing their formation, interpretation of the relationship between natural factors and morphological results, and correlation between the spatial distribution of dunes and environmental conditions.

The study also relied on:

Spatial analysis of maps, satellite imagery, and climatic data (wind).

Fifth: Research Structure:

The research is structured as follows:

Section One: The Natural Framework of the Study Area

This includes:

Geological structure, surface and topography, slope, climatic characteristics, winds and their directions

Section Two: Geomorphological Characteristics of Sand Dunes

This includes:

The concept of sand dunes, their formation, and geomorphological

processes (erosion, transport, deposition)

Factors affecting formation, types of sand dunes, geographical distribution, movement, morphometric characteristics, and geomorphological influences

-1 Natural Characteristics:

Introduction:

1-1 The Geological Structure of Iraq and the Study Area:

The geological structure of Iraq shows a complex geological history formed as a result of the interaction of tectonic and sedimentary factors over different geological eras. Iraq has gone through long stages of development since ancient times, in which its sedimentary layers were affected by the major tectonic movements that resulted from the collision of tectonic plates in the Arabian Peninsula, Iran and Anatolia. These processes contributed to the formation of the Zagros fold belt in the northeast, the wide alluvial plain in the south and center, and the stable desert in the west and southwest (1).

Modern geological studies in Iraq began at the start of the 20th century and developed with the expansion of oil and mineral exploration. This facilitated geological mapping and the identification of sedimentary formations and intrusive rocks. The Basequius Iraq Surveys eventually aided in establishing compositional and morphological aspects of the region and clarified the regional tectonic processes that formed the area's geological unit basis for

studying geomorphological features by providing basic scientific evidence for studying important geomorphological features like sand dunes and modern surface deposits. The oldest Quaternary deposits are some of Iraq's most common geological units, covering the western and eastern alluvium and parts of central and southern Iraq. Quaternary deposits accumulated from exposure, transposition; deposition of material has taken place as a result of large river systems like Tigris and Euphrates, and due to climate transition at the onset of the Holocene and Pleistocene. Compositional layers of clay, silt, and sand are a result of rivers (fluvial) or wind (aeolian) transporting materials to the surface of the earth and layering successive layers over time.

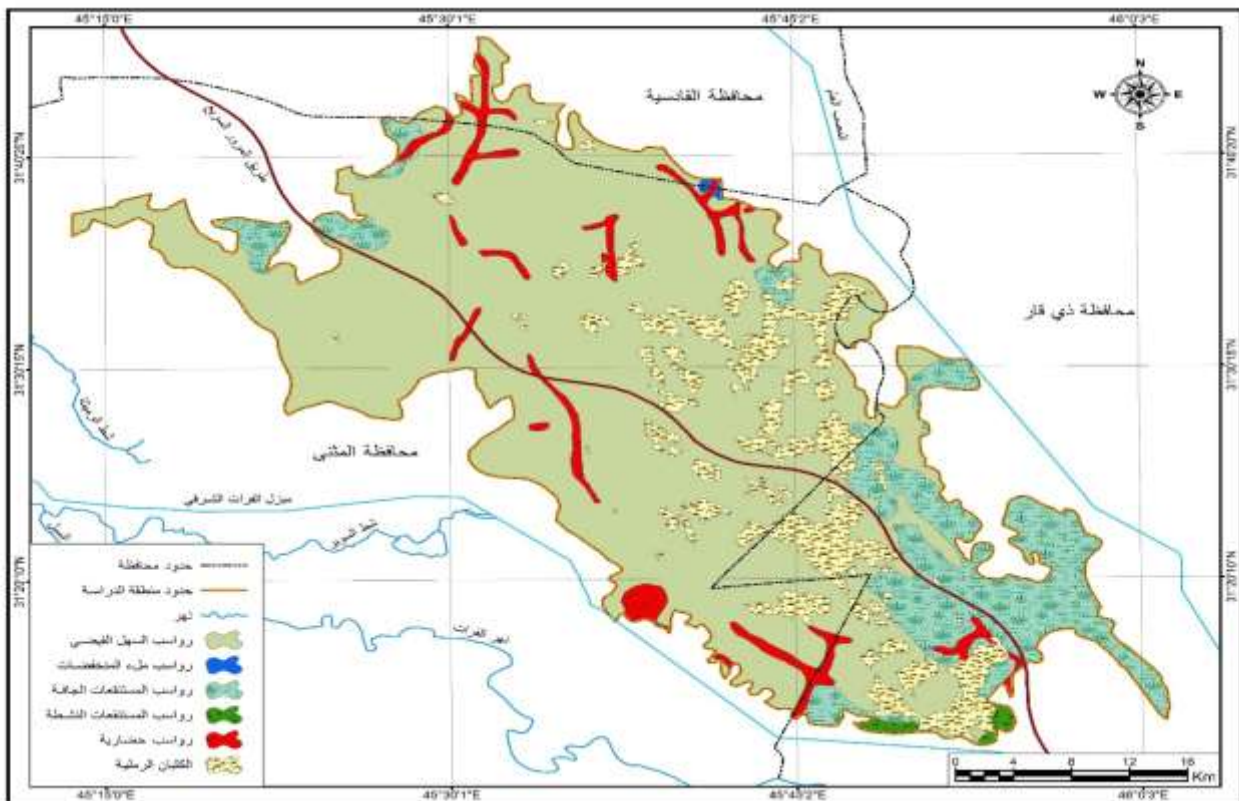
. The study area is located within the southern part of the Iraqi alluvial plain, extending between the governorates of Muthanna, Dhi Qar, and Qadisiyah. It is characterized by relatively flat terrain interspersed with salt flats. Topographic depressions and scattered sand dunes, most of which are oriented with the prevailing wind direction from west to east. The region also shows a diversity in surface formations due to the different depositional environments and depositional conditions during recent geological eras, which makes it a suitable field for studying geomorphological changes and their impact on the stability of roads and

infrastructure. Thus, the geological structure of this region is a crucial factor in understanding the nature of sand dune formation and its environmental and economic risks, given its close connection to the characteristics of recent sedimentary rocks and the active surface processes in the arid and semi-arid environment (2).

most prominent sedimentary units in modern fluvial environments. They are formed as a result of seasonal fluvial deposition on the banks of rivers and streams. These deposits are predominantly a mixture of sand, silt, and clay. The size of the sand ranges from fine to medium grains, and its color tends towards gray, while the silty clay appears in the upper layers of the flood plain, forming clear horizontal accumulations.

1 - Flood Plain Deposits (Holocene):  
Flood plain deposits are among the

Map (1-1) Geological Structure



1-Source: Ministry of Industry and Minerals, General Authority for Geological Survey and Mining, Geological Map of Nasiriyah, Plate NH-38-31994, scale 1:250,000, Baghdad

2- The United States Geological Survey's (USGS) Landsat 9 satellite in Nevis Earth Analysis Center

(NOAC) light wavelengths (24-3-4 and 30-meter pixel resolution) was acquired in 2025. Using this satellite image (1) to create a geomorphologic map of the area (study area), we find that the largest area of sedimentary material in the study area is found in the alluvial plain, estimating at an area of

approximately 1158.26 km<sup>2</sup>, or approximately 69.05% of the study area's total area. The study of these sediments is essential to establish the process of sediment deposition from rivers and recent topographic changes, ascertain their effect on use and stability of land, and determine how these sediments contribute to the formation of dunes and geomorphologic hazards in the alluvial plain (3).

#### 2- Depression Fill Deposits (Holocene):

The most recent sedimentary units created during the Holocene era, referred to as fill deposits in depression areas, are created in low-lying or flat parts of the Earth's surface where water accumulates after rainstorms or seasonal flooding. Fill deposits are made up of the smallest sized clastic materials (e.g., clay, silt, sand) to a medium size, which form distinct granules that reflect the nature of the calm conditions under which they were deposited. Using a geological map of the study area from Al-Qadisiyah Governorate shows that depressions cover about 1.63 km<sup>2</sup> in an extensive area of the northern region of Al-Qadisiyah Governorate, equivalent to 0.1% of the total area in the study area.

Characteristics of these deposits suggest that they are associated with hydrologically deposited materials through semi-enclosed areas during the humid periods of the Holocene epoch; therefore, they can be regarded as significant

geomorphological indicators of recent activity at the surface and their role in changing the alluvium in the region (4).

#### 3- Dry Marsh Deposits (Holocene):

Dry marsh shingle deposits are made from silty clay or clayey silt with calcareous aggregates and organic material. They are greenish-grey in colour and contain small pieces of shells and marine molluscs; these materials indicate what sort of environment these deposits came from.

The geomorphological map of the study area shows that there are various densities of these deposits across the study area, with lower density in the northern area and higher density in the eastern part of the area. The southeastern area has the highest concentration of these types of deposits, amounting to an area of 240.34km<sup>2</sup>, which is about 14.31% of the total area of the study area. Studying these deposits is important to understand the dynamics behind the deposition of clays as well as the accumulation of organic material in low-lying areas, and to assess these deposits' effects on the geomorphological environment, their possible relationship to sand dune formation, and land surface change hazards in the alluvial plain (5).

#### 4- Aelian Sand Dunes (Holocene):

Sand dunes represent a common geomorphological feature of desert areas. Dune development by the process of wind erosion can occur when loose sands are transported to exposed parts of the landscape.

Dune deposits consist of either silt or sand. Dunes are shaped by the prevailing wind direction (and speed), and the location of deposition (e.g. vegetated). Dunes can exist in the form of discontinuous sand sheets or as areas of eroded sand surrounded by vegetated areas. In areas adjacent to vegetation, dunes can develop in the form of silty dunes; in some cases, these silty dunes will be crescent-shaped, dictated by the wind direction and the prevailing dynamics of the environment. The geomorphological mapping of the study site reveals a total area of approximately 197.14 km<sup>2</sup> of dune area or approximately 11.76% of the total study site. The spatial analysis of the dune area demonstrates that the sand dunes are located at a higher density in wind-exposed areas. Conversely, there is a reduction in sand density where vegetation has accumulated or in depressed areas. Studying the surface of these deposits and the processes causing their formation provides crucial scientific information for understanding wind erosion dynamics and recent topographic changes in the study area, as well as for evaluating geomorphological hazard associated with migration of sand dunes and their effect on infrastructure and roads in desert regions (6).

#### 5. Anthropogenic/Cultural Deposits (Holocene):

Manmade Deposits are sedimentary layers formed as a result of human activities, either directly or

indirectly, on the Earth's surface, which encompasses all forms of construction as well as destruction of buildings, farming activities, industries creating waste products, and moving soil and sediment by various types of human activities (7). The map of the physical features of the site reveals the location of these manmade deposits; 3,914 manmade deposits have been located in the northern, western, and southern portions of this property covering approximately 71.64 km<sup>2</sup> (i.e., 4.27%) of the total property area. These manmade deposits vary in nature consisting of silt, fine sand, organic materials, and Construction and Demolition debris include both new and old manmade materials and are evidence of the effects of human beings on the Earth's surface and soil characteristics. Research on manmade deposits is important in assessing the effects of human activities on the terrestrial environment and current topography. It also helps distinguish between natural and human-induced changes and provides a basis for planning sustainable land uses in urban and rural areas within the study area (8).

#### 6. Active Wetland Deposits:

Active swamp deposits are formed in humid environments that are subject to continuous or repeated water saturation with surface and groundwater, such as marshes, swamps, and poorly drained low-lying areas. These deposits are characterized by the accumulation of significant amounts of organic

matter as a result of the slow decomposition processes under anaerobic conditions, in addition to containing fine sedimentary materials such as clay and silt. These deposits also contain varying proportions of dissolved minerals, especially iron, magnesium, and sulfate compounds, which reflect the nature of the prevailing depositional environment and long-term hydrological activity. Active swamp deposits are recent (Quaternary) deposits and contribute to documenting the development of the sedimentary surface of low-lying areas. They also affect the geomorphological and environmental characteristics of the surrounding areas, including surface stability and susceptibility to erosion or deposition. These deposits cover an area estimated at about 8.59 km<sup>2</sup>, and a percentage of 0.51% of the total area of the study area, which indicates their limited spatial distribution and their association with low-lying areas with poor drainage (9).

#### Topography:

##### 1- Surface:

The area extending between the governorates of Al-Muthanna, Dhi Qar and Al-Qadisiyah is characterized by topographic features that are predominantly almost completely flat. This flatness is a result of the formation of the southwestern alluvial plain of Iraq, which was formed over long periods by the activity of the Euphrates River and its tributaries. This

continuous river activity led to the accumulation of fine silt and sand deposits, forming a low-sloping surface whose slopes in most parts of the region do not exceed 1%, which made the surface largely smooth and free of features of sharp ruggedness. This wide flatness contributes to creating a natural environment suitable for the movement of sand by the prevailing northwest winds, as the absence of topographical obstacles leads to the wind energy remaining high for long distances, which explains the spread of linear and crescent sand dunes in large parts of the region (10). As for the southwest of Al-Muthanna Governorate, a group of local topographic depressions stand out, which are due to the interaction of dissolution processes in gypsum formations with ancient wind erosion. Geological studies have revealed that the spread of gypsum soils in the Samawah desert makes the surface susceptible to shrinkage and subsidence processes as a result of the dissolution of gypsum under the influence of changes in humidity and groundwater, which leads to the formation of cavities and surface subsidences that may develop over time into clear depressions. These depressions are effective areas for sand accumulation, as the winds lose some of their speed upon entering due to the sudden change in the surface shape, thus increasing the susceptibility to sedimentation and forming semi-stable dunes within those basins (11). In the southwest of Al-Muthanna Governorate, a

group of local topographic depressions stand out, which are due to the interaction of dissolution processes in gypsum formations with ancient wind erosion. Geological studies have revealed that the spread of gypsum soils in the Samawah desert makes the surface susceptible to shrinkage and subsidence processes as a result of gypsum dissolution under the influence of changes in humidity and groundwater, which leads to the formation of cavities and surface subsidence that may develop over time into clear depressions. These depressions are effective areas for sand accumulation, as the wind, upon entering, loses some of its speed due to the sudden change in surface shape, thus increasing the susceptibility to sedimentation and forming semi-stable dunes within these basins (12). Recent studies in aeolian geomorphology indicate that these depressions play an important role in the redistribution of sand within the alluvial plain. Areas with topographic depressions act as natural wind speed reduction zones and become accumulation centers for shifting and mobile sand, especially in areas characterized by a thin sedimentary cover and ancient wind activity. This is confirmed by soil and sediment analysis in the Muthanna and Dhi Qar deserts. Sedimentary analyses have also revealed the spread of active and semi-stable dunes that vary in size and direction depending on wind intensity and the shape of the land surface. Based on the above, it can

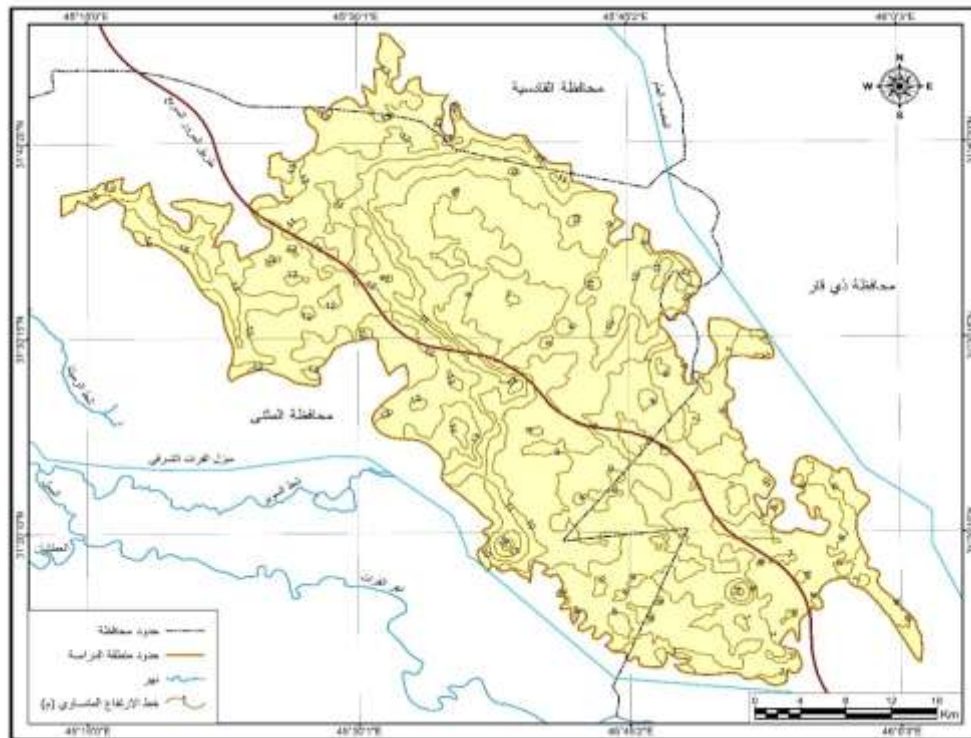
be said that the topography in the region extending between Muthanna, Dhi Qar, and Qadisiyah is the product of a complex interaction between the geological structure (especially gypsum) (13) and aeolian activity (wind and dune formation). And ancient riverine activity. This interaction produced a flat surface that allows for the spread of sand dunes, with local depressions acting as effective sand deposition zones. This makes topography one of the primary explanatory factors for the spread of sand dunes and their geomorphological risks to infrastructure and roads passing through the area (14). The study area is part of an alluvial plain characterized by its relative flatness and lack of severe ruggedness.

Flatness is the dominant characteristic, with the highest point, as shown on the map, reaching 14 meters and the lowest 7 meters. The topographic map of the study area shows a series of contour lines with values ranging only between 7 and 14 meters above sea level in the southern and southeastern parts of the area. This confirms that the surface is characterized by its wide flatness and limited topographical variation, with the most recent sedimentary surfaces being the lower elevations (7–10 m), while the medium elevations (10–12 m) represent the majority of the stable alluvial plain. Relatively speaking, and the most widespread in the region, the relatively higher elevations (12–14 m) appear as

simple hills or slight protrusions, remnants of previous sandy or sedimentary accumulations, and are scattered in the central and northeastern parts of the region. The flat area that consists of new river sediment with little noticeable height differences and very little steep

changes in terrain has a maximum slope (i.e., gradient) of about 1.0 percent. Because of this, the elevations of the area have been categorized into four separate categories, as shown in (2-1):

Topographic map (1-2)



Source: Researcher using 30m DEM and ArcGIS 10

software.

**Category 1(7.0m-8.0m):**

The lowest elevation in the study area (concentrated in the southwest and southeast end of the study area). Fine sediment and moving sand deposits will be visible throughout this classification. In addition, rural areas were used as old drainage channels, which lead to an increase because of water accumulation raising the water table to the ground;

therefore, also increasing this area’s sensitivity or vulnerability to sand moving in or encroaching on that same area in an active way.

**Category 2 (9–10 m):**

Regions that fall in this category consist of flat or somewhat sloped sites with moderate rainfall. They are characterized by relatively deep and fertile soils (usually consisting

of either clay or silt), but they do have some potential for being overwatered during certain parts of the year from seasonal flooding. There is generally moderate surface runoff because of moderating area slopes due to surface runoff and water infiltration; however, these sites remain quite susceptible to annual sand movements due to their proximity to large bodies of fast-moving rivers, etc.

#### Category 3 (11–12 m):

This classification encompasses both low hills and slight elevations, which represent an area between the lowland regions and the far northern upland regions. The relative height above sea level in this category facilitates better drainage than in lower elevation areas, as well as a lower accumulation of salts than in all others. Additionally, lower rates of active sand accumulation occur due to the flatter slope of the terrain, which provides for greater access to lower elevations (by sand) through a channeling mechanism (i.e., gentle slope).

#### Category Four (13–14 m):

This represents the highest areas studied and includes the high hills and small ridges in the north and northwest. Its relative elevation and gentle slope reduce its vulnerability to transported sand accumulation, and this category also helps direct sand flow towards lower elevations.

#### 2- Slope:

Slope is one of the most important landforms that receives widespread attention in geomorphological studies because it represents the spatial link between areas of elevation and depression and directly reflects the nature of the Earth's surface and its degree of stability. Slope refers to the inclination of the Earth's surface from the horizontal plane, i.e., the amount of vertical change that occurs between two points on the surface over a specific horizontal distance. This inclination may be pronounced in foothills and slopes or almost nonexistent, as in flat surfaces (15). The area extending between the governorates of Muthanna, Dhi Qar, and Qadisiyah is characterized by topographic features predominantly of near-complete flatness. This flatness is a result of the formation of the southwestern alluvial plain of Iraq, which was formed over long periods by the activity of the Euphrates River and its tributaries (16). This continuous river activity led to the accumulation of fine silt and sand deposits, forming a low-sloping surface whose inclinations do not exceed 1% in most parts of the region. This has made the surface largely smooth and devoid of sharp rugged features. This wide expanse contributes to creating a suitable natural environment for sand transport by the prevailing northwesterly winds. The absence of topographical obstacles allows wind energy to remain high for long distances, which explains the

prevalence of linear and crescent-shaped sand dunes in large parts of Climatic Characteristics:

the region (17).

Climate is a fundamental characteristic in physical geographical studies. It reflects the prevailing atmospheric conditions in a specific area over a long period and thus differs from short-term weather. It also contributes to explaining environmental variations between geographical regions and influences the formation of natural features and geomorphological processes (18). Climate results from the interaction of several geographical factors, such as geographical location, topography, elevation, air mass movement, and pressure systems, leading to a diversity of climatic patterns. Its importance in geomorphological studies is highlighted by its connection to weathering, erosion, and sediment transport processes (19). Based on this, this study relies on analyzing wind as the most influential climatic element in the study area, using data from the Diwaniyah, Muthanna, and Dhi Qar stations for the period (1994–2024) To demonstrate its role in the formation and movement of sand dunes (20)

Table (1-1) Averages and Monthly Annual Wind Speed (m/s) at Study Area Stations for the Period (1994-2024)

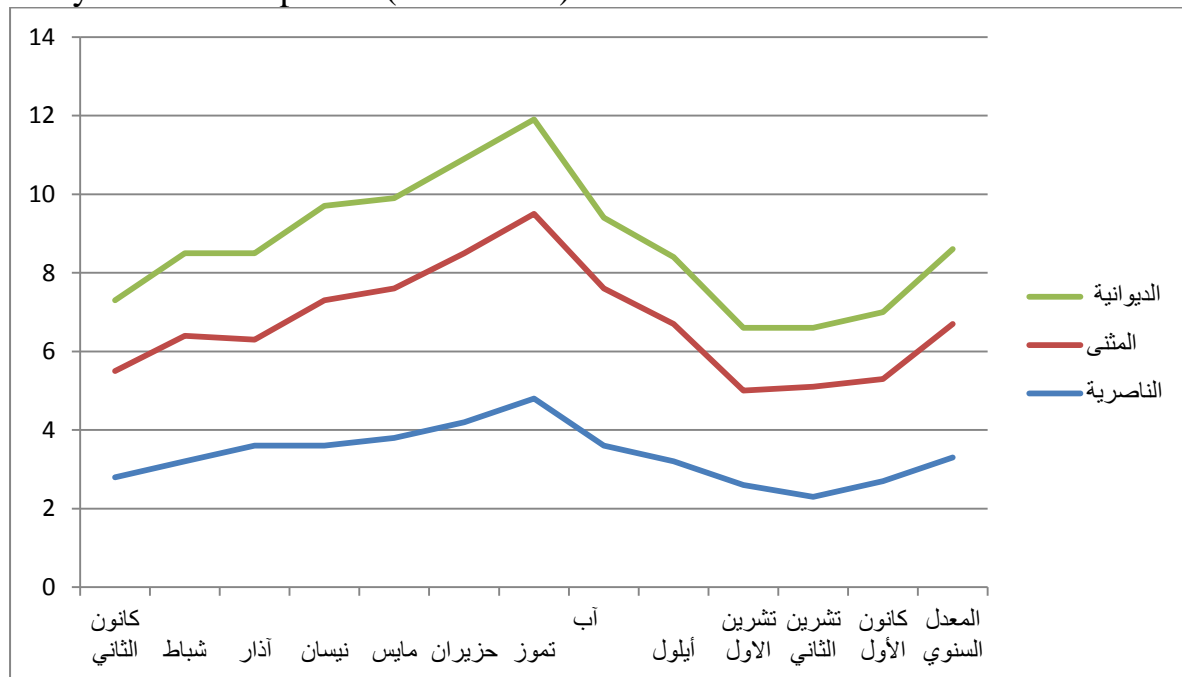
Source: Republic of Iraq, Ministry of Transport, Iraqi General Authority for Meteorology and Seismic Monitoring, Climate Department, Unpublished Data, 2024.

Nasiriyah Station	Al-Muthanna Station	Diwaniyah station	months
2.8	2.7	1.8	January
3.2	3.2	2.1	February
3.6	2.7	2.2	March
3.6	3.7	2.4	April
3.8	3.8	2.3	May
4.2	4.3	2.4	June
4.8	4.7	2.4	July
3.6	4.0	1.8	August
3.2	3.5	1.7	September
2.6	2.4	1.6	October
2.3	2.8	1.5	November
2.7	2.6	1.7	December
3.3	3.4	1.9	Annual Average

Wind: Wind is defined as the movement of air in the atmosphere relative to the Earth's surface. It arises from atmospheric pressure differences resulting from temperature variations between different areas of the Earth's surface and moves from high-pressure to low-pressure areas. Wind plays a significant role in transporting heat and moisture between regions and directly influences geomorphological processes, particularly wind erosion and the formation of sand dunes in arid and

semi-arid environments (21). Wind is a fundamental climatic element linked to atmospheric pressure differences, controlling air movement and the distribution of climatic patterns at both local and regional levels. It also contributes to modifying temperatures and precipitation patterns and affects the environment by regulating the distribution of heat and moisture, as it is part of the major atmospheric pressure systems that determine prevailing weather conditions (22).

Figure (7-1) Monthly and annual averages of wind speed (m/s) at stations in the study area for the period (1994-2024)



Source: Republic of Iraq, Ministry of Transport, Iraqi Meteorological Organization and Seismological Monitoring Authority, Climate Department, Unpublished Data, 2

As shown by the data from Figure 1-1 and Table 1-1, the wind speed is impacted by season (i.e., wind speeds at each of the stations studied displayed a distinct annual cyclic pattern) across all of the stations examined. The wind

speed exhibits its greatest value during summer months (i.e., June and July) and the least amount during winter (December through February) and fall (September through November). Wind speeds were measured at roughly 2.4 m/s at Diwaniyah, 4.3 m/s at Muthanna, and 4.2 m/s at Nasiriyah (all measured in June, which represents the start of the summer wind season). Wind speeds reached their annual peak (i.e., 2.4 m/s at Diwaniyah, 4.7 m/s at Muthanna, 4.8 m/s at Nasiriyah) during July.

In contrast, wind speeds decrease during winter and autumn, with the lowest values recorded in November at (1.5 m/s) in Diwaniyah, (2.8 m/s) in Muthanna, and (2.3 m/s) in Nasiriyah. This is reflected in the decrease in the graph curves, and the spatial variation in wind intensity between stations is also evident, with Muthanna recording the highest annual averages (3.4 m/s), followed by Nasiriyah (3.3 m/s), and then Diwaniyah (1.9 m/s)

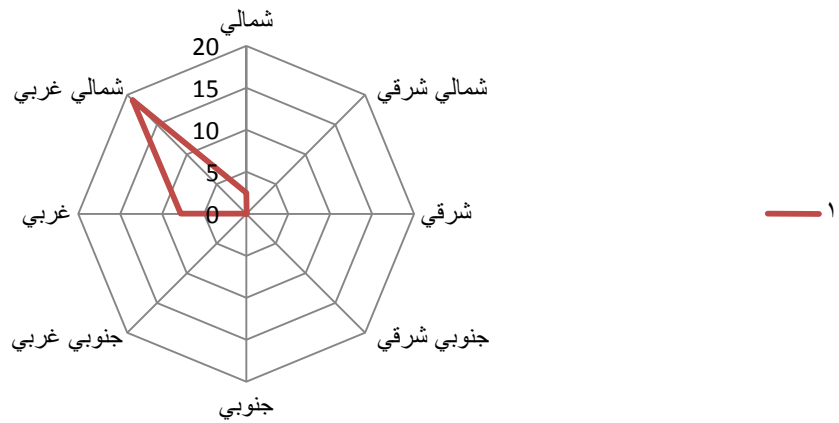
Table (1-2) Frequency of wind directions at stations in the study area for the period (1994-2024)

Source: Republic of Iraq, Ministry of Transport, Iraqi Meteorological Organization and Seismological Monitoring Authority, Climate Department, Unpublished Data 2024

Nasiriyah Station	Al-Muthanna Station	Diwaniyah station	Trends
<b>2.5</b>	<b>3.8</b>	<b>5.7</b>	North
<b>0.1</b>	<b>0.1</b>	<b>0.1</b>	Northeast
<b>0.1</b>	<b>0.1</b>	<b>1.5</b>	East
<b>0.1</b>	<b>–</b>	<b>3.1</b>	Southeast
<b>–</b>	<b>2.5</b>	<b>1.7</b>	Southwest
<b>–</b>	<b>0.1</b>	<b>–</b>	West
<b>7.8</b>	<b>2</b>	<b>2.4</b>	Northwest
<b>19.1</b>	<b>23.7</b>	<b>15</b>	Northwest
<b>67.7</b>	<b>70.3</b>	<b>70.5</b>	Percentage of Settlement
<b>%100</b>	<b>%100</b>	<b>%100</b>	Total

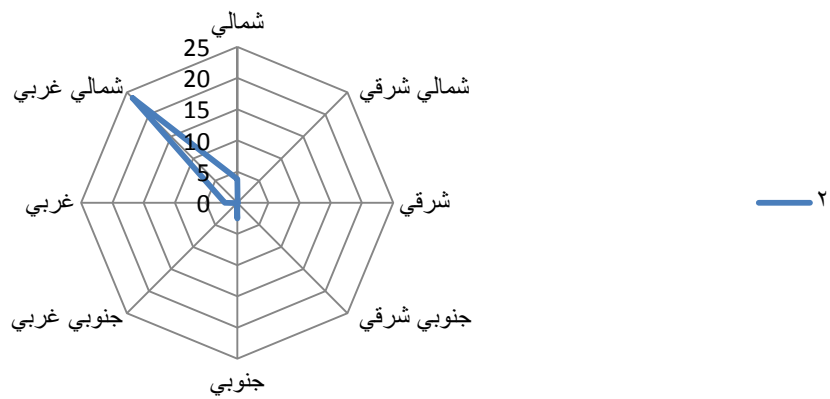
Nasiriyah Station

### اتجاه الرياح



Al-Muthanna Station

### اتجاه الرياح



Diwaniyah station

### اتجاه الرياح

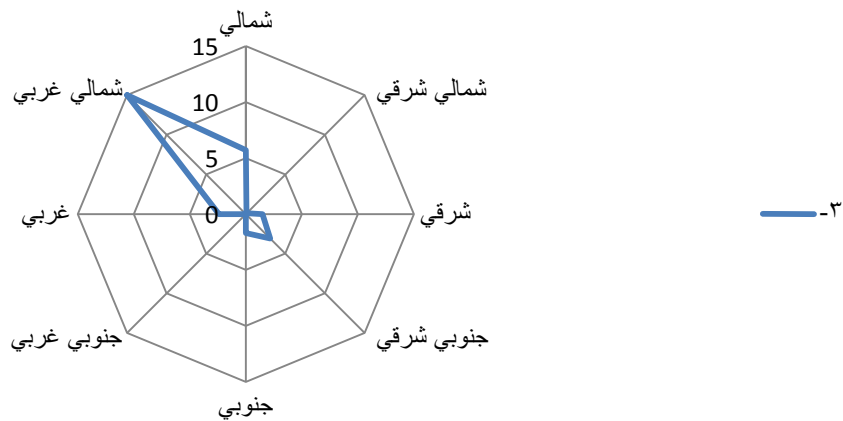


Table (1-2) and Figures (1-2, 1-3, 1-4) show the relative distribution of wind direction frequency at stations in the study area during the period (1994–2024). Northwesterly winds prevailed at all stations, recording the highest frequency rates: (23.7%) in Al-Muthanna, (19.1%) in Al-Nasiriyah, and (15%) in Al-Diwaniyah. This indicates their dominance in the region's wind system. Northerly winds came in second place with lower percentages: (5.7%) in Al-Diwaniyah, (3.8%) in Al-Muthanna, and (2.5%) in Al-Nasiriyah. Easterly and northeasterly winds recorded very low percentages, not exceeding (0.1–1.5%), reflecting their limited influence. The weak or nonexistent frequency of southerly, southeasterly, and southwesterly winds was also observed, particularly at the Al-Nasiriyah station, confirming their lack of significance in the region's wind system.

An examination of the wind speed and direction data shows a clear seasonal pattern in wind behaviour in this area. Winds are strongest during the summer months (particularly June and July) and weakest during the winter and fall. In addition, there are significant differences in wind intensity based on location. For example, the Al-Muthanna weather station had the highest average wind intensity across the whole year, followed by Nasiriyah and thereafter by Diwaniyah. The findings also confirm that northwesterly winds

predominate, followed by northerly winds (the other directions have low average intensities). The results indicate that wind characteristics in this region are influenced primarily by long-term climate patterns.

Section Two: Geomorphological Characteristics of Sand Dunes. This section focuses on the geomorphological analysis of dunes, their patterns, and their impact. It includes:

The Concept and Formation of Sand Dunes: Sand dunes are hills or chains of loose sand formed by wind. Their size ranges from over one meter to several kilometers. They may appear as vast sand fields or isolated chains and are found in various geographical environments. They are classified according to their geographical location into inland and continental dunes, coastal or beach dunes, riverbank dunes, and lake shore dunes (23). Sand dunes are considered aeolian geomorphological features, as they arise from the wind transporting sand grains and depositing them when its speed decreases or when there are natural or topographical obstacles that facilitate their accumulation. Their shapes and sizes vary according to wind direction and speed, the amount of available sediment, the nature of the surface, and the degree of vegetation cover. They are also dynamic, moving phenomena that constantly change according to wind transport and deposition processes (24).

Dunes are formed Sand dunes are formed as a result of the interaction of wind with transportable sand deposits. The formation process begins with small, isolated sand accumulations formed by aeolian transport and deposition. Wind transports and deposits sand grains in specific areas, and these accumulations gradually develop into more complex dune formations as the sand supply and wind influence continue (25). Sand dunes also form in self-organizing patterns that evolve over time in response to wind direction and changes, the amount of available sediment, and the impact of climatic changes and sea level on sand movement, development, and expansion, particularly in arid and semi-arid environments (26).

Geomorphological processes affecting their formation:

Wind Erosion:

Wind erosion is related to the movement of soil particles by wind. Soil movement begins when the wind pressure on the surface soil particles is greater than the gravitational forces acting on those same particles. At this point, the soil particles move across the Earth's surface in a series of hops (saltation) or creeps. The greater the height of the hop or creep, the more wind energy is required (27). Wind Erosion: Its Concept and Formation Factors: Wind is defined as the movement of air from areas of high atmospheric pressure to areas of low

atmospheric pressure, carrying with it its physical properties such as heat and humidity.

It is considered one of the active geomorphological factors in reshaping the Earth's surface.

Wind erosion is a series of processes that wind causes on the surface layer of the soil. These include abrasion, transport of surface particles, and deposition, whereby the soil or rock breaks down and the wind carries its fragments from one place to another, contributing to changes in the Earth's surface features and the formation of various sand formations. The factors that control the intensity of wind erosion on the Earth's surface are: Wind Speed Wind speed is one of the main factors for the start of wind erosion, as the wind's ability to move surface grains increases proportionally with the cube of its speed, which means that a slight increase in speed may lead to a large increase in the ability to erode. The equations developed by Chepil showed that wind speed is one of the most important factors affecting wind erosion, as it is a fundamental factor along with the climatic susceptibility to wind erosion.

a) Suspension method: This involves the transport of fine and microscopic sediments such as clay, fine sand, and silt, which remain suspended in the air for long distances before settling when wind speed decreases.

B- Jumping Method: In this method, medium-sized sand grains that

cannot remain suspended in the air for long distances are transported. They move in short, successive jumps across the Earth's surface due to wind pressure. Upon impact with the Earth's surface, they move other grains, thus increasing the process of transport and wind erosion (28). Wind Deposition and Sand Dune Formation: Wind deposition is the final stage of wind-driven geomorphological processes. Deposition occurs when wind speed falls below the capacity required to carry sand grains, causing them to fall and accumulate in specific locations. Geomorphological studies show that sand dunes form as a result of the continuous accumulation of wind-transported sand in arid and semi-arid environments where loose, poorly consolidated sediments are available (29).

Geomorphological literature indicates that sand accumulation is gradual due to repeated wind transport processes (jumping, creeping, and suspension). Heavier grains are deposited first, while finer grains continue to move for longer distances, resulting in a gradation in the size of the sediments. Within the dunes (30), the presence of natural obstacles or changes in surface roughness slows wind speed, thus initiating the deposition process and the formation of various sand formations (31). Factors affecting the formation of sand dunes: Sand dunes are affected by several natural factors, the most important of which is wind speed. Wind speed is the

primary factor in initiating the movement and transport of sand, and the wind's ability to carry grains increases with its speed (32). The size of the sand grains is also an important factor, as fine grains are easier to transport than coarse ones. Additionally, the degree of dryness increases the soil's susceptibility to erosion (33). Vegetation cover reduces wind speed and limits sand movement, while its absence increases the activity of aeolian processes. The prevailing wind direction also determines the direction of sand dune extension (34). Aeolian geomorphological processes clearly contribute to the formation of sand dunes in the area extending between Diwaniyah, Muthanna, and Nasiriyah, due to natural conditions such as relative aridity, high temperatures, and sparse vegetation cover (35). The dominance of northwesterly winds also plays a role. It contributes to the transport and redistribution of large quantities of sand, leading to the continuous formation and development of sand dunes (36).

#### Types of Sand Dunes in the Study Area:

The sand dunes located in this study area differ significantly not only in their shapes but also in their sizes. Each type of sand dune develops differently depending upon natural environmental factors that affect its creation. Among these are wind speed and direction; both of which play an important role in the transport and depositing of the sand

grains that create the various shapes of dunes. The other factor affecting the size, extent and spacing of the sand dunes is the sand source and the type of land surface from which the sand comes. The types of differences between sand dunes relate not just to their shape but also to their morphometric dimensions: length, width and height. The morphological characteristics of a dune remain the same for all dunes within the same type: a crescent shaped dune for example may range in size from one location to another, yet will still possess the same basic morphological characteristics. A typical dune is composed of two main sides, the windward side and the leeward side. The windward side slopes gradually to the ground with a convex slope; while the leeward side has a steep slope. Wind-driven dunes that are formed by winds blowing at a rate of 100 kilometers per hour or greater usually have a very steep leeward slope, known as a concave or slip-face dune and will have two arms or wings that extend in the same direction as the wind.

Various types of landforms occur in the study area where the dunes have formed in different ways due to the conditions of the wind, amount of sand that was deposited, and the characteristics of the surface on which they are located. Following is a list of these landforms, grouped according to their morphology, or nature of construction:

- 1. Barchan Dunes:

Crescent dunes are the most frequent type of sand dune found in the

research area. They occur in open areas that are continuously subjected to the dominant northwesterly winds, where there is no vegetation and ample loose sand available for accumulation. When sufficient sand is available and the direction of the wind flow is constant, the conditions for the formation of crescent dunes are met. A crescent dune consists of a longer, gradually sloped windward side and a nearly vertical slip face. The two arms of the dune extend out toward the direction of the prevailing winds. The dunes' arms point towards the direction of the dunes' movement and sand drift as a result of ongoing wind impacts on areas of sand deposits that have formed in those areas. The outer edge of the dunes generally moves faster than the centre of the dune because the edges are thinner and have less resistance (37). The link between the crescent dunes in the area between Diwaniyah, Muthanna, and Nasiriyah is due to the flat topography, low precipitation, large amounts of loose sand and northwesterly winds allowing sand to move easily and continue drifting across the landscape. The dunes are oriented in a southeast direction, and the crescent dunes will continue to have their characteristic shape as long as the prevailing winds remain relatively consistent and do not change in speed or direction. The dunes are forming in a southeasterly direction, and the crescent shape of the dunes will remain largely unchanged as long as the prevailing

winds remain relatively stable in direction and speed

#### -2 Longitudinal Dunes:

Longitudinal dunes are a common geomorphological feature in arid and semi-arid environments. They form as a result of sand accumulation along a longitudinal line, roughly parallel to the prevailing wind direction. These dunes often develop in areas exposed to consistently oriented winds, with the lateral influence of secondary winds or eddies that help redistribute sand on either side of the dune. Longitudinal dunes may also form as a result of the merging or overlapping of crescent dunes. The growth of one wing of a crescent dune increases more than the other due to the influence of lateral winds, leading to the connection of adjacent dunes and their gradual transformation into long sandy extensions. Secondary winds also contribute to pushing sand into the spaces between the dunes, leading to their filling and the formation of continuous sand chains with a clear longitudinal extension (38). In the region extending between Diwaniyah, Muthanna, and Nasiriyah, longitudinal dunes are associated with the dominance of northwesterly winds, with seasonal or local variations in wind direction contributing to their formation. The presence of a series of long, narrow sand channels that extend a range of lengths, with a distinctive longitudinal alignment and moderate elevation, provides important geomorphological characteristics

that influence the stability of both land and roadways in the study area, due to their function as conduits for sand movement across alluvial plains. These dunes are characterized by their clear longitudinal extent and moderate heights, in addition to their role in guiding sand movement within the alluvial plain.

#### -3 Transverse Dunes:

Since transverse dunes form at right angles (perpendicular) to the direction of wind flow and therefore block the passage of wind, they get their name. They occur in an area with plenty of loose sand and not much (or any) vegetation to interfere with the ability for sand to be constantly and consistently moved and deposited (accumulated). There are two major surfaces of a transverse dune; the windward side has a gentle, gradual slope and the leeward side has a steep slope which is called the slip face, where sand accumulates after being deposited over the crest of the dune (39). The shape formed by the transverse dune is due mainly to the constant wind movement of sand being moved and deposited on a "step by step" method, thus resulting in the creation of long, parallel chains of sand (how are these formed.?)

The creation of transverse dunes in the study area is related to an abundance of sand accumulation sites and relatively flat areas of land where sand can move (transfer) through the action of the wind. The predominant northwesterly winds in

the area are also responsible for the formation of the transverse dunes and their direction of growth (extension). Transverse dunes represent significant geomorphological features as they indicate the actions of many geological processes and demonstrate how wind patterns in the area alter the Earth's surface on a continuous basis.

#### - 4. Nebkha Dunes:

Nebkha dunes are formed when sand-laden winds encounter fixed elements such as shrubs, rocks or other objects that cause the wind to slow down. As a result, the wind loses its ability to carry sand and will eventually deposit and build up loads of sand around these objects.

Due to their smaller size than various types of dunes, Nabkiya Dunes grow continuously with the imminent supply of sand and/or wind's influence. When wind flows over a solid obstacle, it splits into two lateral ways of flow; after the wind has passed, some of the air has formed an eddy at the solid object and has diminished in velocity. Because of these wind eddies, sand accumulation will generally occur on the front face and the side faces of the object. Over time, as transport and deposition continue to occur, the size of the sand deposits grow eventually developing distinct Nabkiya Dunes (40). Throughout the area encompassing Diwaniyah, Muthanna, and Nasiriyah, Nabkiya Dunes can be widely found in locations where vegetation cover is

limited or small in surface features. These limited factors help to some degree hold and stabilize the wind-driven sand. The characteristics of the sand dune's appearance reflect the interaction between aeolian processes and surface characteristics of the local area, as well as indicating areas of sand movement activity and dominant wind direction in the study area.

#### -5 Wind Ripples:

Wind ripples are small scale geomorphological features that develop on smooth, dry sandy surfaces due to intense deposition of sand from wind activity. They appear as small, repeating waves of sand that indicate the direction of movement and the amount of sand blown by the wind. Ripples will vary in size depending on how fast the wind is blowing (wind speed) and how big/dense the particles being tracked (size of grains of sand). For example, the spacing from crest-to-crest becomes greater as the speed of the wind increases or when the size of the particles becomes larger - while the crest-to-crest distance becomes shorter as the wind slows down or when the size of the particles reduced. The high density/abundance of wind ripples located between Diwaniyah, Muthanna, and Nasiriyah is strong evidence that aeolian processes are actively shaping and moving the sand across the sediment surface of the sandsheets in arid and semi-arid regions.

Figure 1: Al-Hilaliyah dunes in the southern part of the study area



Source: Field study dated 26/12/2025

Photo (2) nabak dunes south of the study area



Source: Field study dated 26/12/2025

Image (3) Longitudinal dunes in the study area



Source: Field study dated 26/12/2025

Image (4) Neem wind in the study area



Source: Field study dated 26/12/2025

#### Geographical Distribution of Sand Dunes in Southern Iraq:

The sand dunes and sand flat formations exist in great quantities in the dry and semi-dry parts of southern Iraq due to the presence of materials that can be easily blown into these forms as a result of outdoor atmospheric conditions and little plant growth. Furthermore, the prevailing northwesterly winds continuously transport and redistribute sand. Sand dunes are more concentrated in areas with flat surfaces and gentle slopes, as the nature of the alluvial plain facilitates

the movement and movement of sand over long distances. The distribution of dunes varies from one area to another depending on the surface characteristics, the amount of available sand, and the intensity of wind activity. This has led to the emergence of sand belts and fields of varying density and extent within the study area, particularly in its western and southwestern parts. This distribution is clearly evident in the area extending between Diwaniyah, Muthanna, and Nasiriyah, due to the influence of arid climatic conditions and the dominance of northwesterly

winds, which are the primary factor in sand movement and the direction

#### Morphometric Characteristics of Sand Dunes:

These dunes are characterized by Sand dunes possess a range of morphometric characteristics, including height, length, width, direction of extension, and angles of slope. The morphology and location of the dunes will be influenced by the environmental conditions and winds dominating the area of study. In addition to the relationship between wind speed, sediment supply, and land surface characteristics, they all play a strong role in influencing the dimensions and orientation of dunes from an environmental and ecological standpoint. The morphology of dunes also provide a significant amount of information about the dynamics of dunes and how they developed over time as they correlate to erosion, movement, and aeolian deposition processes (a combination of the two) through time. In addition, the dune morphology and how it is distributed throughout the region of Diwaniyah, Muthanna and Nasiriyah will vary based on different natural and wind conditions (42).

#### Sand Dune Movement and Creep:

Sand dunes are dynamic landforms subject to continuous movement and creeping due to the influence of wind. Sand grains are transported from windward slopes to leeward slopes. The steeper background causes the dune to gradually move in

of dune expansion (41).

the direction of the prevailing winds. The speed of dune encroachment varies depending on wind speed, sand grain size, surface type, and degree of cohesion. Small dunes and fine sand are more mobile than large dunes. Weak vegetation cover and high aridity levels increase sand encroachment activity in the area between Diwaniyah, Muthanna, and Nasiriyah. This contributes to the continuous movement of sand and the changing positions of dunes over time, in addition to its direct impact on roads, infrastructure, and various land uses within the study area (43).

#### Geomorphological Impacts of Sand Dunes:

Sand dunes lead to a range of geomorphological impacts that are clearly reflected in the nature of the land surface and its various uses. The continuous movement of sand contributes to reshaping surface features and changing the morphological characteristics of the areas where it is found. Sand encroachment also leads to the burial of parts of agricultural lands, roads, and infrastructure, in addition to increasing desertification and soil degradation due to the removal and transport of the fine topsoil by the wind. These effects are evident in The effects are greater in arid and semi-arid environments

characterized by sparse vegetation cover and high wind activity, making sand dunes a significant geomorphological phenomenon that impacts the stability of the natural and human environment within the study area, particularly in areas near active sand movement paths in the region extending between Diwaniyah, Muthanna, and Nasiriyah (44).

#### Results:

- 1- The study showed that sand dunes in the region extending between Diwaniyah, Muthanna, and Nasiriyah vary in their shapes, sizes, and orientations according to the prevailing climatic and geomorphological factors in the region.
2. The study revealed that northwesterly winds are the primary factor in the formation and movement of sand dunes, leading to their spread in converging directions across most of the study area.
3. The research showed there was a definite link between surface characteristics, scattered vegetation, and increased erosion by wind and accumulation of sand.
4. Of loose soil and dry soil, loose soil was found to have more sand dunes than any other soil type.
5. Human actions such as overgrazing and the removal of vegetation have increased problems associated with desertification and the expansion of sand dunes.

6. The study showed that sand dune movement may threaten roads, utilities, and farm property in the area studied.

7. The research indicated that dry climate conditions, high rates of evaporation, and little rainfall have contributed to increased sand dune activity in the area studied.

#### Recommendations:

1. Establishing green belts and planting desert-hardy and drought-resistant vegetation will help stabilize the soil on the sand dunes.
2. To fight desertification and limit the encroachment of sand dunes between Diwaniyah, Muthanna, and Nasiriyah, integrated environmental programmes are being implemented .
3. Using Geographic Information Systems (GIS) and remote sensing systems, we can continuously monitor the movements of dunes and assess the spatial variations of those dunes.
4. Establishing windbreaks and vegetation belts along main roads to reduce sand encroachment and mitigate risks to transportation.
5. Conducting future studies on sand dune movement rates and the impact of climate change on their development.
6. Raising awareness among local communities about the importance of preserving vegetation cover and reducing human activities that contribute to the degradation of the desert environment.
7. Supporting research institutions and universities to conduct specialized research in desert

geomorphology and sand dunes in southern Iraq.

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