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GEOMORPHOLOGY OF SAND DUNES AND THEIR IMPACT ON HUMAN ACTIVITY IN NASIRIYAH GOVERNORATE

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Abstract:

Geomorphological processes prevalent in arid and semi-arid regions are detrimental as they lead to ecosystem degradation. Therefore, geomorphological studies are crucial for development projects, as they assess available resources and propose appropriate methods to combat the degradation of existing natural environmental resources.

This research aims to study the geomorphology of sand dunes and their impact on human activity in Nasiriyah Governorate. Sand dunes are a widespread feature in the study area and are geomorphological formations resulting from natural and climatic conditions related to wind erosion. Given the impact of this phenomenon on human activity, the research hypothesized that natural factors play a significant role in influencing the dunes. The Nasiriyah station was used to monitor the impact of climatic elements that influence this phenomenon. The research findings revealed that sand dunes have a significant impact on human activity in the study area. This impact encompassed numerous aspects, including agricultural lands, residential areas, transportation, tourist and archaeological sites, air quality, and public health.

This study comprised four sections. The first section presented the theoretical framework, the concept of sand dunes, their formation, and the factors influencing them. The second section addressed the natural characteristics of the study area. The third section examined the different types of sand dunes. The fourth section explored the impact of sand dunes and strategies for mitigating their risks. The research concluded with a set of findings and recommendations.

Keywords: Sand dunes, human activity, Nasiriyah Governorate

INTRODUCTION

Iraq is one of the countries whose land is affected by the problem of sand dunes, which are widespread in many areas. The study area is one of the regions where this phenomenon is prevalent. Sand dunes have formed due to various natural conditions, including the prolonged occurrence of wind erosion, creating suitable natural conditions. These conditions can result in the formation of sand dunes ranging in height from 20 to 50 feet. The presence of sand dunes reflects a climate characterized by long periods of drought, low rainfall, high summer temperatures, and strong, persistent winds throughout the year. Human activities, such as overgrazing, deforestation for fuel, and agricultural expansion, also contribute to the formation of sand dunes. This creates vast areas of barren land. Additionally, there are areas occupied by ancient archaeological mounds and sites where regulations prohibit cultivation within 500 meters of these sites, according to the Directorate General of Antiquities. All these factors have contributed to the formation and expansion of sand dunes, primarily driven by the dynamic force of the wind. The Pathways of Transport, Deposition, and Sand Dune Formation in the Study Area

From the above, we conclude that several factors have influenced the formation of sand dunes in the study area, leading to their presence. Therefore, we can say that the study area is a suitable and ideal environment for the formation and spread of sand dunes.

SECTION ONE - THEORETICAL FRAMEWORK

First - Research Problem:

The main research problem is represented by the following question: (What are the reasons that led to the formation of sand dunes in Nasiriyah Governorate?) This will allow the researcher to address the research in detail.

1. What are sand dunes? What are the factors that cause them to form?
2. Do the natural characteristics of the study area play a role in the formation of sand dunes?
3. What are the geomorphological features of wind origin in the study area?
4. What is the extent of the impact of sand dunes? What are the strategies for mitigating their risks?

Second - Research Hypothesis:

The research hypothesis represents an independent answer to the problem. The main research hypothesis is that several factors have led to the formation of sand dunes in the region. The research can be explained as follows:

1. It is a topographical phenomenon consisting of sand grains originating from an environment where sand is readily available. Several factors have contributed to its formation.
2. Natural characteristics, namely the surface and climate, play a significant role in the formation of sand dunes.
3. The geomorphological forms are represented by sand dunes of various types (crescent, elongated, and ridge)
4. It has an impact on many aspects, including agriculture, transportation, and tourism. It can be addressed by using methods to reduce its impact and stabilize it in a way that preserves the natural environment and promotes future vegetation development.

Third - Research Objective:

The current research aims to reveal the geomorphology of sand dunes and their impact on human activity in Nasiriyah Governorate, as well as the possibility of mitigating their risks. Fourth – Importance of the Study:

The importance of this topic lies in the fact that it is a geomorphological phenomenon prevalent in the study area. Furthermore, it is particularly relevant now, especially given the increasing periods of drought and the expanding areas affected by sand dunes across Iraq. Therefore, the study's significance lies in identifying effective means to mitigate the economic and environmental impacts of this phenomenon.

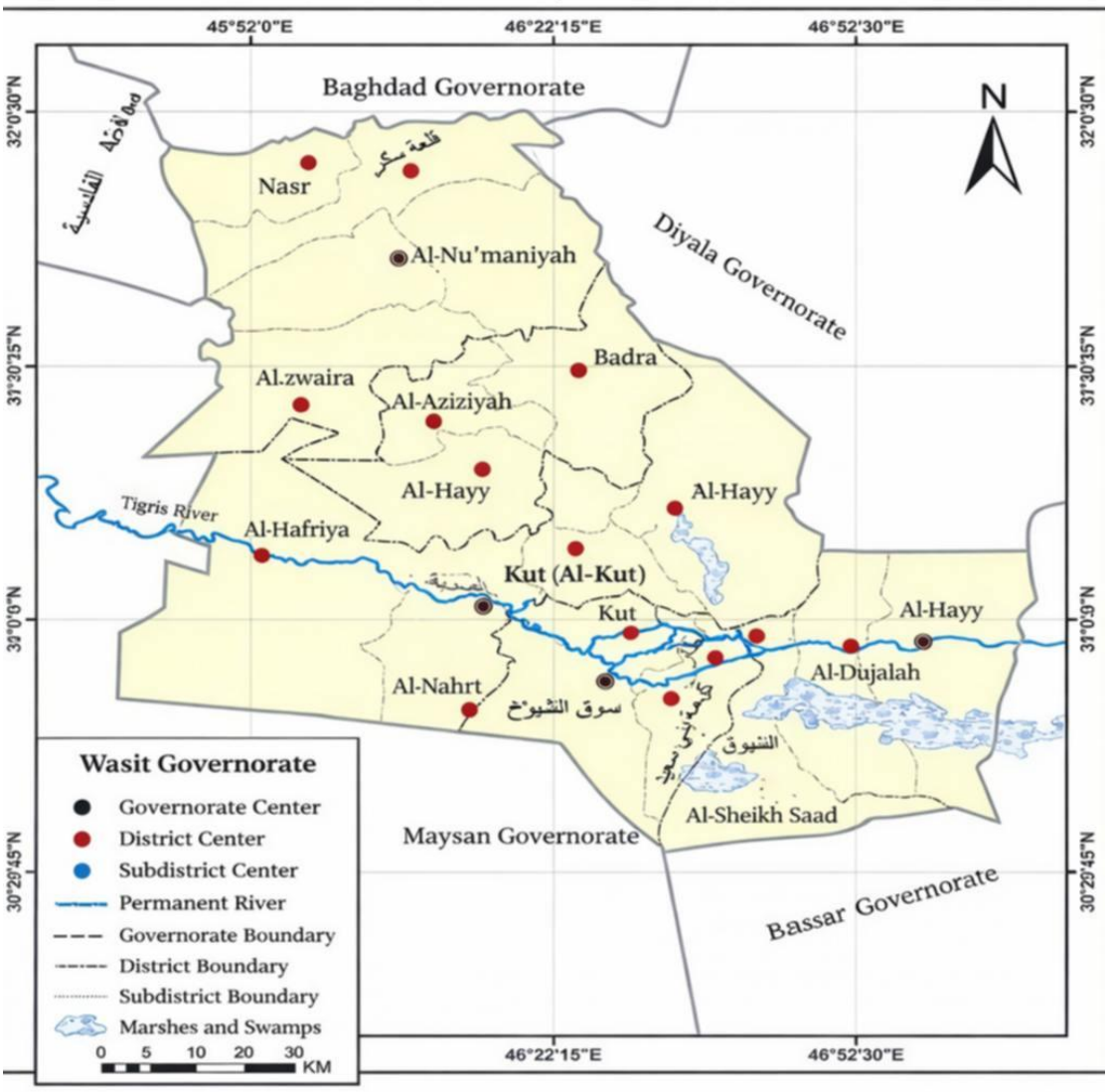
Fifth – Research Methodology:

The research employed a descriptive-analytical approach to describe the sand dune phenomenon. The study also utilized an experimental approach based on quantitative analysis of the study area. Sixth - Scope of the Research:

Nasiriyah Governorate is located in the southern part of Iraq, extending between latitudes 30°33' and 32°5' North and longitudes 12°47' and 45°27' East (Map 1). It is bordered to the north by Wasit Governorate, to the south and southeast by Basra Governorate, to the northwest by Qadisiyah Governorate, to the west and southwest by Muthanna Governorate, and to the east by Maysan Governorate. Administratively, the governorate consists of five districts and fifteen sub-districts.

The area of the governorate is (13810 km2), which constitutes a percentage of (2.9%) of the total area of Iraq, which is (434128 km2).

Administrative Units of Nasiriyah Governorate(Map 1)

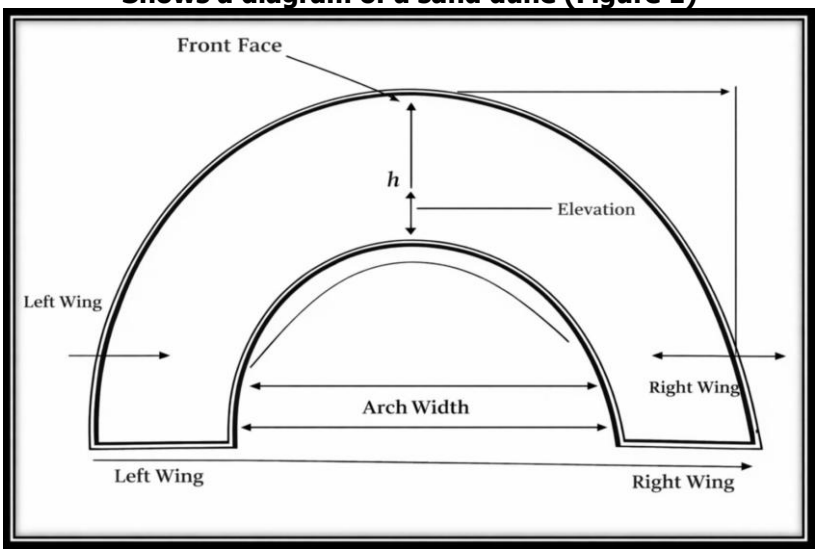


Source/Republic of Iraq, Ministry of Water Resources, General Survey Authority, Map Production Department, Digital Unit, Map of Nasiriyah Governorate, at a scale of 1:2500000.

The Concept of Sand Dunes:

Longwell defined sand dunes as rock debris blown by the wind, which then turns into sand and accumulates to form small, circular or elongated hills. Johan defined them as hills of sand formed by wind when it is active (i.e., devoid of vegetation) and inactive when vegetation is present, preventing the sand from being transported from one area to another (Al-Jawdhari & Jaber, 2014, p. 414). Holm believed that dunes are a topographical phenomenon of wind origin, composed of sand grains from a natural source that are freely mobile. Kellen described dunes as series of deposits blown by the wind, usually with a gentle slope facing the wind and a steeper slope on the side sheltered from the wind, called the slip face. Thus, we find a difference in researchers' opinions regarding a comprehensive definition that can capture the meaning of sand dunes. Despite the differences in definitions, this difference is not significant because the scientific reality of dunes is that they are a form of landform composed of loose sediments formed by processes. Geomorphic processes include weathering, erosion, and carving of rocks. The most important geomorphic factor is wind, which transports the resulting rock fragments and deposits them in other areas, whether near or far from their source. This depends on two factors: first, low wind speed weakens its ability to carry sedimentary particles, causing them to fall to the ground; second, the presence of obstacles impeding the wind's energy, leading to the deposition of its load in the form of accumulations. With continued deposition, these accumulations form dunes. Dunes vary in size, from a few meters in height to several meters in width, with some exceeding 200 meters in height. Most sand dunes are around 5 meters high (Figure 1). Geomorphic processes influence rocks and the landforms they form, encompassing physical and chemical variables that contribute to the formation of the Earth's surface. The geomorphic factor, where the process becomes... Geomorphism is influential (i.e., a medium capable of eroding, transporting, and depositing the material that makes up the Earth's crust and rocks). Wind erosion contributes two phenomena (abrasion and erosion), as winds laden with sedimentary material attack the different shapes of the Earth's surface, thus eroding the rocks, changing their shape, and transporting the products of the sedimentary rock from their source to their depositional areas when there is no obstacle, forming sand dunes (Abdul Hassan: 2013, 4-5).

Shows a diagram of a sand dune (Figure 1)



Source: Hussein Aab Khalaf Al-Mousawi and Safa Ghani Abdul Wahid, Landforms Affected by Winds in Western Wasit Governorate, Issue 22, Journal of the College of Education, Wasit University, 2016, p. 358.

How Sand Dunes Form

Sand dune formation begins when there is a change in the topography of the Earth's surface, or when the area is devoid of or limited in vegetation cover, both in quantity and type. The formation of a sand dune occurs in several stages. In the first stage, when the wind weakens, its load of sand falls over itself and accumulates on the windward side. Some remains at the top of the dune, while other sand rolls down the windward side. The process of sand particles rolling and sliding is caused by gravity. Consequently, the wind flattens the windward side, while the slope of the windward side ranges between 20 and 30 degrees. Thus, in the first stage of dune formation, sediment accumulates more on the windward side than on the windward side, leading to an increase in the dune's height. In the second stage, the sand slopes down from the top of the dune due to gravity at the foot of the windward side, creating a steep slope. In the third stage (Figure 2), the difference between the gentle windward slope and the steep windward slope becomes clear. Sand accumulates on one side and at the top, then gradually slopes downwards due to gravity on the other side, which is characterized by the influence of wind eddies and cross currents. These currents contribute to some sand grains settling on top of the dune, preventing them from sinking below the slopes shaped by the wind direction (Al-Jawdhari & Jaber, 2014, p. 415).

Factors Affecting Sand Dune Formation

1. **Wind:** This is the primary factor in soil erosion. Sand grains begin to move when wind speeds range between 9 and 12 km/h. The movement of sand grains occurs in three ways (Al-Jawdhari & Jaber: 2014, p. 416): Jumping, in which

sand grains ranging in size from 1 to 5 mm are carried to a height of about 30 cm from the ground surface; Creeping, which is the movement of sand grains ranging in size from 2 to 5 mm, transported across the ground surface by wind; and Suspension, which is the movement of very fine sand grains, less than 0-0.5 mm, into the upper layers of the atmosphere, where they remain suspended for a period and are transported in this manner. For a considerable distance (3000-4000 m), the sand accumulates, forming a clayey deposit. These lands are known as loess.

Wind is a major climatic factor, characterized by its powerful movement, which depends on both direction and speed in the formation of sand formations. Northwesterly and southeasterly winds are prevalent in the study area. Furthermore, most winds oscillate in different directions throughout the year. This creates variations in the axes of the dunes between these directions. Wind speed is also of great importance; increased speed leads to greater capacity for carrying sand over long distances. Variations in wind speed, and the resulting transport and deposition of grains, are conducive to the formation of different types of aeolian deposits (Al-Farghali, 2007, p. 56).

2. **Natural Vegetation:** This is a specific type of factor that increases surface roughness, similar to gravel. Therefore, it contributes to the formation of sandy formations, especially sand dunes, in the study area. The interaction between the wind and the vegetation barrier reduces wind speed, causing it to deposit part of its load in a form that depends on the size and density of the vegetation. Among the most important plants that play a role in the formation of sand dunes are wild jujube and tamarisk. Low humidity leads to the deterioration and disappearance of natural vegetation, which affects the formation of sand dunes, transforming them into undulating sand covers that become a source of sand. Natural vegetation significantly hinders wind erosion through the density of its cover. This is achieved through plant roots, which affect wind erosion by holding the soil in place. Since these lands are located within arid and semi-arid regions characterized by low winter rainfall and high temperatures, the wind transports soil particles from one place to another. When this sand encounters an obstacle, the wind deposits its load of sand due to the barriers that weaken wind speed, forming a sand accumulation around the sand. Obstacles, and the ongoing process of erosion and deposition, cause these accumulations to grow and form sand dunes (Shawer: 1995, 240).
3. **Moisture:** When rain falls during the winter months, the moisture content inside the dunes increases. The weight of the particles is heavier when wet than when dry. Due to the high permeability of the dune soil, it retains this moisture for a long time. With a small percentage of silt and clay flakes, this contributes to limiting its movement until that movement stops. The opposite occurs during the dry month, as long as the soil is free of moisture content due to the lack of rainfall. It is clear that the movement of the dunes in the study area does not retain large amounts of moisture during the summer months (June, July, August, and September), and the opposite is true during the rainy winter months. This is reflected in the process of wind erosion and the movement of sand dunes (Al-Jumaili: 2010, p. 284). The presence of moisture in the sand causes its grains to stick together, so the wind is unable to transport them. Seasonal rainfall in the study area plays a role in the presence of water in the surface layer to a depth of about (30 cm), which leads to the cohesion of the sand grains, and thus reduces the ability of the wind to remove and transport the sand. The rate of sand movement decreases.

SECTION TWO - NATURAL CHARACTERISTICS OF THE STUDY AREA

First: Surface

The flatness and absence of obstacles impeding wind movement facilitate wind movement. Therefore, its impact on the dunes is significant, and this factor influences the movement of sand dunes. The transport and accumulation of particles increases on flat surfaces, while the opposite occurs on rugged terrain (Al-Jumaili: 2010, p. 284). The dunes in Nasiriyah Governorate are distributed across two regions: the alluvial plain and the western plateau (Al-Samarrai: 1994, p. 1). The surface of the first region, located in the north and northwest, is characterized by flatness, as it forms part of the alluvial plain, which is predominantly flat. This is due to the geological characteristics of the region, formed from alluvial deposits that resulted in its leveling. The region is distinguished by the presence of a 10-meter elevation line that runs along the beginning of the region at the riverbanks east and west of the Al-Gharraf River in the Al-Fajr district. This elevation leads to several factors, including increased wind erosion activity. The sand dunes extend from the northwest to the southeast. The second area, located in the western part of the study zone, is characterized by its flatness, being part of the alluvial plain formed from the deposits of the Tigris and Euphrates rivers. This flattening resulted in a northwest-southeast direction, starting from the Al-Fajr area and extending to the Al-Bathaa area. The 5-meter line of equal elevation is the only elevation line representing the highest point in the area.

Secondly, Climatic Factors:

Climatic factors are among the most important factors influencing the diversity of geomorphic processes, which significantly affect the formation of landforms. A direct and indirect relationship exists between climate and geomorphic processes in determining the characteristics of these processes in terms of frequency and type (Karbal, 1986, p. 82). This means that climate is a variable factor, changing from one period to another for any region on Earth's surface.

This leads to a clear change in the types of weathering and erosion factors that shape landforms and geomorphic processes (Al-Bahri: 2001, 36). Iraq's climate is characterized by several climatic patterns, including warm and cold, as well as fluctuations in temperature, which in turn affect rainfall. Based on the climatic characteristics of this era, it is evident that the climate of the study area was characterized by aridity, thus facilitating wind erosion and deposition processes. The most prominent feature of these processes is the sand dunes found in the study area. Each climatic

element has a clear significance in the formation of landforms. The data available at the Nasiriyah station was used, as follows (Abdul-Hussein: 2016, 229-230).

1. **Solar Radiation:** This is the radiant energy falling on a unit horizontal area of the Earth's surface and is measured in calories per square centimeter (kcal/cm²). It is responsible for heating the Earth's surface, evaporating water, melting snow, and warming soil layers (Al-Yasiri: 2013, p. 36). The intensity of heating is related to the angle of incidence of solar radiation and the length of the day. Therefore, it is considered one of the elements responsible for weather fluctuations (Jawda: 1988, p. 16), which are characterized by their high intensity and extreme variation, with monthly and annual changes, and the degree of their extreme fluctuations that determine the severity of the climate. It is also an important geomorphological factor in the formation of landforms. The climate is no different from that of Iraq because the amount of incoming solar radiation is perpendicular or nearly perpendicular. As a result, Iraq's climate is characterized by a clear increase in monthly and annual temperatures with a long hot season that reaches (10 months), in contrast to the winter season, where the value is lower. In addition, solar irradiance is the duration of theoretical and actual sunshine hours, where the theoretical radiation duration reached (14) hours in July, while the daily radiation duration in January was (11.9) hours. Therefore, summer became hotter, with the theoretical number of hours of solar radiation in August and September being (13.1-12.2 hours/day) (Table 1). This, in turn, affects the activity of mechanical weathering of the rock types responsible for soil formation. This, in turn, affects the formation of landforms, including sand dunes, which primarily reflect weathering through wind erosion.

Climatic Elements of the Study Area(Table 1)

Element/Month	K 2	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	T1	T2	K1	Average
Theoretical temperature / s	11,9	11,0	12	12.5	13.4	12,1	14	13,1	12,2	11,2	10,3	10,0	12.98
Actual temperature / s	5,4	6,2	6,4	7	7,8	8,4	8,8	8,6	8	7	6,0	5,4	7.33
Minimum temperature °C	6,2	8,5	12,8	18,9	24	27	28,8	28,4	23,9	19,9	12,6	7,9	25.50
Maximum temperature °C	17	20,7	26	32	39	43,4	45,6	44,2	40,9	35,9	25,5	18,9	28.50
Dust storms	0,2	0,7	1,3	2,1	2,4	5,2	5,3	3,3	1,2	0,5	0,3	0,2	22,7
Wind m/s	3,3	3,6	4,1	4,3	4,4	5,8	5,8	5,1	4,5	3,2	3,2	3	3
Rainfall / mm	27,8	18	21,2	13,3	4,3	0	0	0	0,7	5,4	14	22,9	6.40
Relative % humidity	68,7	59	49,8	42	31	23,5	22,2	23,4	27	37,3	52,9	66,8	39.75
Evaporation / mm	74,9	105,6	180,9	259,3	381,9	494,5	554	506,8	383,6	247,7	129,7	76,8	554

Source: Iraqi General Authority for Meteorology, Water and Agricultural Resources, Unpublished Data, 2022.

2. Temperature: High temperatures, especially in summer, lead to increased evaporation from the soil surface. The minimum temperature in July reached 28.8°C, while the maximum temperature for the same month reached 45.2°C. This leads to a decrease in soil moisture content, making it susceptible to drying and disintegration. It also facilitates wind erosion, thus altering soil properties, particularly in the western plateau region, which is characterized by its vast expanses, maximizing wind speed. In the alluvial plain, characterized by fine-textured soil and gentle slope, high temperatures lead to increased evaporation and enhanced capillary action (Al-Asadi, 1998, p. 162). Temperature thus affects soil aeration in two ways: firstly, through heat within the soil and between layers, by the contraction and expansion of air within the pore spaces; and secondly, because soil and atmosphere typically have different temperatures. This temperature difference necessitates exchange between the atmosphere and soil at the intermediate surface (Al-Yasiri, 2013, p. 38). Therefore, temperature is one of the most effective climatic elements in activating weathering processes and has a significant impact on soil diversity. The Earth's surface forms as a result of temperature variations, which cause rocks to heat up and cool down through the daily cycle of expansion during the day and contraction at night. Because rocks are composed of several minerals, varying pressure forces are generated within the rock body due to the different rates of expansion and contraction. This leads to the rocks breaking down into small sheets that are easily eroded as a result of the heating and cooling of the rocks (Al-Rawi: 1990, 226). In addition, the color of the rock greatly affects the weathering process, as black minerals are more susceptible to heat and heating than white minerals.

3. Wind: This is the horizontal movement of air parallel to the Earth's surface, resulting from pressure differences between two regions. Air moves from an area of high pressure to an area of low pressure. Wind is the cause of many weather phenomena, such as temperature fluctuations, various forms of condensation, and precipitation. It is the primary means by which the atmosphere distributes heat and humidity across the Earth's surface. It is the moving image of the atmosphere (Al-Yassiri, 2013, p. 40). Increased wind speed leads to higher temperatures during the months of June, July, and August, and stirs up dust, causing dust and sandstorms in the summer. During winter, these winds are cold, dry, and dust-raising, especially when high-pressure systems prevail (Al-Barrak, 2010, p. 34). Wind is a geomorphological factor, being one of the important climatic elements. It plays a significant role in shaping the Earth's features, particularly during periods of drought. It erodes the Earth's surface, carries away particles, transports them, and then deposits them in one place to another. This is evident in sand dunes, which demonstrate the role of wind as a significant geomorphological factor (Al-Subaihi, 2006, p. 73). The wind's ability to transport rock fragments increases when aridity intensifies and the land surface becomes loose, unconsolidated sand. Wind operates in two ways: abrasion and scraping. Wind speed is highest during the day and lowest at night. This is due to the high daytime temperatures and the resulting convection currents caused by the mixing of air layers near the Earth's surface with the upper atmosphere, particularly during midday. Wind speeds can be at their peak during this time. Conversely, wind speeds begin to decrease during autumn (September, October, and November) and continue to decline until winter (December, January, and February). The average wind speed is 3-3.3-3.6 m/s (Table 1). Furthermore, the prevailing wind direction has an impact on the study area. Due to its arid climate and lack of natural vegetation, the area has a finely textured surface prone to wind erosion, making it a source of sand dune formation, particularly crescent-shaped dunes, as their formation requires continuous winds blowing in a specific direction throughout the year (Abdul-Hussein: 2016, p. 234).

4. **Dust Storms:** These are defined as strong winds carrying enormous quantities of dust. They are a common climatic phenomenon in arid and semi-arid regions. Dust storms rise when the wind blows, stirring up dust particles that are carried long distances (Al-Masoudi & Al-Jassani: 2010, p. 3). Their size and diameter vary depending on wind speed and the nature of the terrain over which the wind passes, causing a significant decrease in visibility, sometimes to just a few meters (Hadid: 1992, p. 153). Dust storms are influenced in their formation by low-pressure systems (Ghanem: 2003, p. 98). Dust storms cause significant environmental pollution and damage, sometimes leading to human suffocation, in addition to burying irrigation canals, damaging crops, and halting air traffic at airports due to reduced visibility on runways. These storms are most intense south of latitude 35 degrees north, due to the favorable natural conditions for their formation, namely their geographical location at the edge of the desert. The absence of vegetation due to low rainfall and the flatness of the arid land is linked to dust storms (Al-Yassiri: 2013, 4). Dust storms are strongly connected to the local environment through temperature. When the air temperature rises in an area due to exposure to sunlight during the day, significant changes occur in the atmospheric pressure of that area. This leads to tremendous disturbances in air masses, causing them to move along multiple paths towards low-pressure areas with high temperatures, carrying with them fine dust particles. Wind speed plays a major role in activating wind erosion processes, which contribute to the formation of dust storms. The frequency of dust storms increases starting from March until it peaks in July, with the total monthly and annual average frequency of dust storms reaching (22.7 days). July recorded the highest rate of dust storms.

   The dust storm frequency was (5.3 days) (Table-1). Therefore, there is a direct relationship between the frequency of dust storms and the formation of sand dunes. The low frequency of dust storms at that station is due to the nature of the soil, which is characterized by fertility and the density of agricultural land, which hinders wind erosion. The dust storms occurred for (5.3 days) (Table-1).

5. **Rainfall:** Rainfall is of great importance in the study area for two reasons. The positive aspect is its geomorphological and hydrological impact, as it is the primary source of seasonal surface runoff in the region, especially during the rainy season. This is due to the study area's location within the arid and semi-arid regions of Iraq, which are characterized by fluctuating rainfall during the winter, while the region remains dry throughout the year. The negative aspect is that rainfall is often short, lasting only a few hours or a single day, and sometimes occurs as sudden downpours. This is a result of Iraq's location on the edge of cyclonic rainfall. Rainfall plays a significant geomorphological role in erosion processes, as the flowing water transports sediments and debris to low-lying areas. The volume of sediment varies depending on the amount of rainfall, the slope, the nature of the rocks, and their porosity. This leads to a complete depletion of these areas, rendering them barren and devoid of any vegetation. The scarcity of vegetation cover, coupled with a hot summer, loosens the soil and prepares it for erosion, resulting in a continuous increase in wind erosion activity and the formation of sand dunes. The rainy season begins... In Iraq, during October, the region is affected by low-pressure systems originating from the Mediterranean Sea, causing rainfall. This rainfall is characterized by its cyclonic nature and extends until May. Monthly and annual rainfall rates fluctuate, with high amounts recorded in December, January, February, and March. Average rainfall for these months was 22.9 mm, 27.8 mm, 18 mm, and 21.2 mm respectively (Table 1). The amount of rainfall in these months exceeded the amount of evaporation, negatively impacting the movement of sand dunes due to soil moisture, which in turn reduced wind erosion.

6. **Relative Humidity:** This is the percentage of water vapor actually present in the air. The amount of water vapor depends on the air's ability to hold it, which is determined by its temperature and constant pressure. Humidity ranges from 0% when the air is hot and dry to 100% when the air is saturated with vapor, meaning it can hold no more water vapor. The higher the air temperature, the greater its ability to hold water vapor (Al-Hussaini, 2013, p. 211). Humidity is important in geomorphological processes, particularly chemical weathering. High atmospheric humidity

increases soil moisture, and this higher humidity in the air leads to soil cohesion and protects it from erosion and wind erosion. It also reduces the water requirements of natural vegetation, as occurs in winter. Conversely, during summer, an inverse relationship exists between relative humidity and temperature. Humidity decreases as temperatures rise, leading to increased wind erosion due to the lack of cohesion in soil particles. This results in the formation of sand dunes in the study area Relative humidity is observed in the study area.

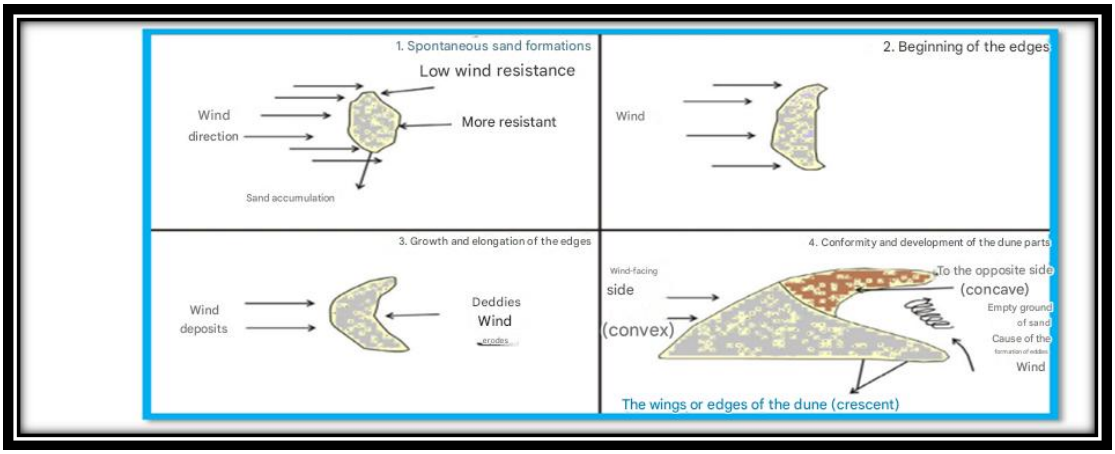
7. Evaporation: This is the transformation of water from a liquid to a gaseous state, at which point the air can carry the vapor molecules. Evaporation is a factor that directly and indirectly affects hydrological and climatic processes. Several factors contribute to this process, including solar radiation, temperature, and wind. The higher the values of these factors, the greater the amount of evaporation, as there is a direct relationship between them. Evaporation is inversely related to humidity. Evaporation affects the actual rainfall, as it helps activate weathering processes and increase wind erosion, in addition to its direct impact on surface water runoff and the amount of water replenishing groundwater. The annual average evaporation rate reached 554 mm (GDZL-1). However, there is a variation in the total evaporation rates on a monthly and seasonal level throughout most of the year. This general increase in evaporation rates during those months of the year stems from the higher temperatures in winter. The data shows that variations in relative humidity and wind speed have a positive impact on wind erosion processes due to the increased evaporation rate at the expense of the amount of water lost. Rainfall, with its low actual value, has a negative impact on the low density of vegetation cover, which has made the soil drier and more fragmented, making it a suitable environment for wind erosion and the accumulation of sand dunes (Al-Yasiri: 2013, 47-48). The high amount of evaporation in central and southern Iraq, which includes the study area, explains the fragmentation of the soil and its ease of being carried by the wind.

SECTION THREE - SAND DUNE SHAPES

Sand dunes are characterized by different shapes and sizes. Their formation depends on the speed and direction of the wind, which transports the grains and then deposits them in an accumulating manner, thus forming different shapes of sand dunes. In general, the size of a dune varies from one to another, but the basic design of the dune is somewhat similar and falls within a certain category of diverse dune shapes. For example, the sizes of crescent sand dunes may vary, with some being small and others large, but the basic design of the crescent dune is constant in the study area. Sand dune types differ in their formation methods and shapes, depending on the source of the sand and the size of its deposits. Wind is considered the most influential geomorphic factor in the formation of sand dunes, especially in the study area, because it is primarily responsible for removing sediments that have been weathered and transporting them to other areas (Al-Farghali: 200, 54). What contributes to wind erosion is the scarcity of vegetation cover in the study area, which is related to Inversely related to wind speed, where wind speed increases with sparse vegetation, this directly impacts its geomorphic capacity for erosion and deposition (Mahasoub: 199, 381). Sand dunes can be classified into the following shapes:

1. Crescent Dunes: These arise from the movement of dry, loose particles on flat land. Their formation is influenced by the prevailing wind direction and its increased speed during dry periods when soil particles are readily transported. The sand that forms these dunes can be local or transported by wind, depositing and forming the dunes. This type is associated with a crescent shape because the dune's ends form a crescent-shaped dune. The direction of the dune's movement indicates the direction of the prevailing wind towards the ends of the arc (Abdul Kadhim: 2019, 286). When the wind blows in one direction, providing a sufficient quantity of sand, crescent dunes, also known as "barchans" (Abdul Hussein, 2016, 10), are formed. Crescent dunes form when a sand accumulation reaches maturity and begins to move with the prevailing winds. During this movement, the slender edges of the dune experience less wind resistance than the center. Thus, the edges of the dune extend with the wind, forming two wings that provide wind resistance equal to that of the central part of the dune (Figure 3). The volume of a crescent dune consists of two sides: the windward side, which is gently sloping and convex, and the leeward side, which is concave and steep (Al-Jawdhari & Jaber: 2014, p. 321). This type of dune is found in the study area due to the availability of conditions conducive to its formation, including the prevalence of northwesterly winds throughout the year, which increase in frequency during the dry season, the flatness of the surface, and the scarcity of vegetation. However, crescent dunes generally maintain a balance among all their parts, with the sand blown from their upper parts compensating for the sand blown away from their edges. The amount of sand lost through blowing is proportional to the amount of sand gained. Through sedimentation, the size of crescent dunes, in terms of height and area, depends on the abundance or scarcity of sand in the region. Crescent dunes are clearly present in the study area in the northwestern part of Al-Rifai district. Two types of crescent dunes are found in the study area. The first type is the simple crescent dune, which is more widespread. These are isolated dunes with a crescent shape and two sloping wings in opposite directions, indicating the direction of the prevailing wind. One wing is often longer than the other due to the irregularity of the wind direction. The side facing the prevailing wind is gently sloping and has a convex shape, while the other side of the dune is relatively steep. A number of factors contribute to the formation of crescent dunes, including prevailing winds from a specific direction for most of the year, gentle slopes, and local topography. These conditions are present in the study area. The region is exposed to crosswinds blowing from the southeast, which remove sand from the windward side and transport and deposit it on the upper part of the windward side. This has contributed to the formation of crescent sand dunes, but in a specific direction. Contrary to the prevailing wind direction, it creates crescent-shaped dunes with a northwesterly direction above the crescent-shaped dunes with a northwesterly direction. This is a phenomenon that characterized the Umm al-Aqareb area in the west of the Rifa'i district. As for the second type, the composite crescent

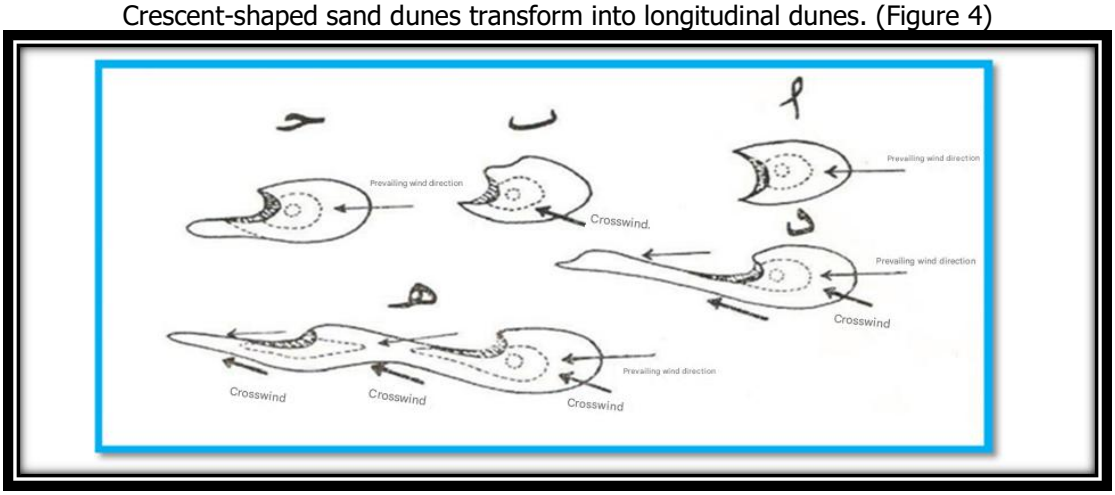
sand dunes, this type of dune is widespread in the Rifa'i district and the Qati'ah area. It is created by the joining of several dunes together, and the joining is at one of the sides of the dune. It is known that the sand that moves from one dune to another comes out from the sides, not from the side facing the wind (Al-Jawdhari and Jaber: 2014, 421).



Source: Ali Hamza Al-Jawdhari and Zainab Saleh, Spatial Analysis of Sand Dune Distribution in Al-Samawah District, Issue (2), Volume (22), University of Babylon Journal of Human Sciences, College of Arts, University of Babylon, 2014, p. 421

2. Longitudinal dunes are sand accumulations formed by their elongated shape, sometimes resulting from the overlap or merging of crescent dunes. This occurs because one end of the crescent dune is larger than the other (Abdul Kadhim, 2019, p. 286). Longitudinal dunes have axes that extend parallel to the prevailing wind direction. They are a result of changes in crescent dunes (Figure 4) caused by opposing winds. These winds cause wind erosion at one end and sediment accumulation at the other when wind intensity varies across the crescent dune (Al-Mousawi & Abdul Wahid, 2016, p. 369). These dunes can take on an elongated shape that may extend for several kilometers. Balgenold suggests that these dunes may be a result of air currents associated with strong, persistent winds. However, he emphasizes that strong winds carry the remnants of these dunes, causing the edges to lengthen and form... Longitudinal dunes take on a long shape, extending for meters (Al-Jawdhari & Jaber: 2014, pp. 421-422). These dunes are widespread on the western side of the main estuary in the Al-Rifai and Suq Al-Shuyukh districts.

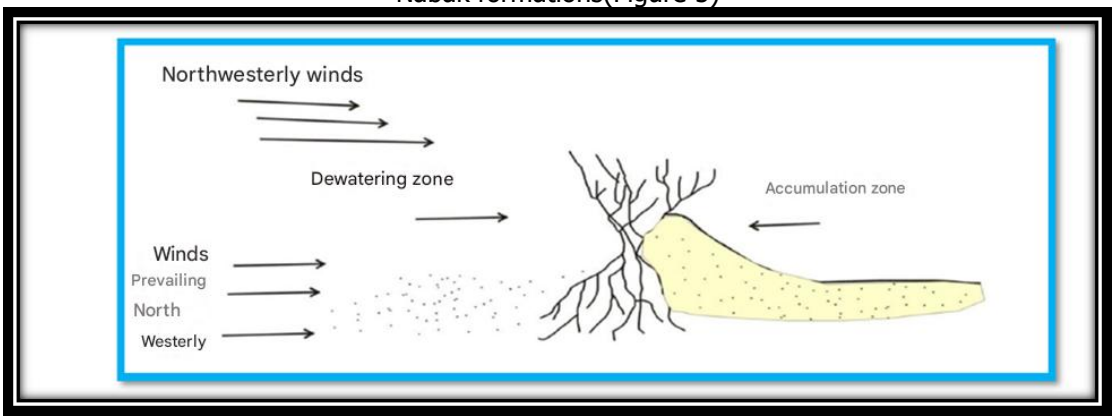
Crescent-shaped sand dunes transform into longitudinal dunes. (Figure 4)



Source: Ali Hamza Al-Jawdhari and Zainab Saleh Jaber, Spatial Analysis of Sand Dune Distribution in Al-Samawah District, Issue (2), Volume (22), University of Babylon Journal of Human Sciences, College of Arts, University of Babylon, 2014, p. 422.

3. Sand dunes (also known as sifting dunes) are accumulations of sand around plants. These plants act as a barrier, intercepting winds laden with sedimentary debris. This leads to deposition as the wind, carrying sand particles, is obstructed, reducing wind speed and its ability to carry the particles. Consequently, the sand accumulates behind the plant barrier (Figure 5). This demonstrates a direct relationship between the plant (Al-Farghali, 2007, p. 70) and the size and height of the dune. The plant's branches act as a windbreak, contributing to sand deposition, while its roots, organic remains, and added moisture help stabilize the sand accumulations (Al-Jawdhari & Jaber, 2014, p. 424). The plants reached a height of 1.5 meters, but their vegetative content was minimal. Therefore, the sand dunes associated with these plants were of medium size. This indicates that the more vibrant and green the plants, the greater their ability to trap sand particles, resulting in larger dune sizes. The dimensions of the sand dunes varied in the study area, as it became clear that... The Nabak dunes are widespread in the Suq al-Shuyukh district in the southwestern part of the region. Their height ranges between 30 cm and 2 m, and their width between 60 cm and 3 m (Abdul-Hussein, 2016, p. 253).

Nabak formations(Figure 5)



Source: Ali Hamza Al-Jawdhari and Zainab Saleh Jaber, Spatial Analysis of Sand Dune Distribution in Al-Samawah District, Issue (2), Volume (22), Journal of Babylon University for Human Sciences, College of Arts, Babylon University, 2014, p. 424.

SECTION FOUR - THE IMPACT OF SAND DUNES AND STRATEGIES FOR REDUCING THEIR RISKS

First - The Impact of Sand Dunes on Human Activity

1. **The Impact of Sand Dunes on Agricultural Lands:** The encroachment of sand dunes on agricultural lands is one of the most serious problems, as it leads to the burial of arable land, changes in soil properties, the spread of dry soils over it, the destruction of vegetation cover, and its exposure to various erosion factors. This ultimately transforms the land into unsuitable land for agricultural production, after it acquires the characteristics of dry soils, eventually turning it into a desert. Therefore, the phenomenon of sand dune encroachment on productive lands is commonly referred to as "desert creep," as it transforms land into unproductive land resembling desert soils. The encroachment of sand dunes on arable land is also described as severe desertification, considered one of the most dangerous manifestations of desertification, according to the United Nations Commission on Desertification (UNCCD) at the World Conference on Desertification held in Nairobi in 1977. Arable lands in the study area face this problem. A serious problem arises from the significant increase in the area of sand dunes, their movement, and their encroachment upon agricultural lands, especially since agriculture is the primary occupation of the study area's inhabitants, with 65% of the population engaged in this activity. Recently, the Agricultural and Agrarian Reform Authority has focused on mitigating this phenomenon and finding effective ways to control the dunes, employing several methods to limit their spread (Abdul Hassan, 2013, p. 16).
2. **The Impact of Sand Dunes on Residential Areas:** Sand dunes are a natural threat to residential areas. Winds, blowing from the northwest, carry sand, depositing it at obstacles and forming sand dunes that encroach upon residential areas. Some areas suffer from this encroachment, and many houses in the study area are affected by the accumulation of sediment near them. When winds blow, they pass towards areas where sand dunes are prevalent, causing some sediment to be deposited on the facades of houses they obstruct. Sand dune areas may be close to residential buildings, causing them to encroach and creating significant damage, including making walking difficult (Al-Asadi, 2011, p. 125). Studies have revealed a strong correlation between wind erosion and the expansion of the area affected by sand dunes. In some governorates, the area has more than doubled; in 2000 it was 453 km², while in 2018 it reached 804 km².
3. **The Impact of Sand Dunes on Transportation Routes:** Transportation routes are the cornerstone of development projects of all kinds, everywhere, and they serve as a means of connecting all regions. This study highlights the impact of sand movement on roads, especially paved and unpaved roads. One of the dangers arising from the effect of sand movement on roads is the encroachment of sand dunes onto them. In this case, the road disappears beneath the official surface because such destruction leads to its cancellation or replacement with another, resulting in economic losses, financial losses, and delays in completing the road. Perhaps the reason for this is the lack of a strategic plan for constructing roads that align with the prevailing wind direction, taking into account areas with sand dunes or those that penetrate large areas of uncultivated land due to natural causes. The road should run parallel to the dunes, allowing them to advance as they do with the wind. It would only be necessary to cut the road when the area is exposed to headwinds, causing some sand to accumulate on the sides of the road in quantities that can be easily removed by bulldozers belonging to the road maintenance authorities. The danger of sand encroachment during sandstorms and its accumulation on roads leads to accidents on highways, especially since visibility is limited during sandstorms and fog. This causes parts of the road to be buried, and while the movement of vehicles stirs and removes the sand, it remains a danger because it can cause speeding vehicles, which are more likely to overturn during sandstorms, to crash (Al-Moussawi & Abdul Wahid: 2016, pp. 386-387). The study area is intersected by the international highway, which is one of the most important roads in Iraq in general and in the study area in particular. This highway extends from 80 km northeast of the study area, at the beginning of the administrative borders of Al-Muthanna Governorate, to the Al-Masab Al-Aam Bridge, which crosses the study area at 120 km south, a distance of 40 km. Due to its size, its construction requires extensive excavation work and heavy machinery. The road is 32 meters wide, with two lanes, each measuring 130 square meters. Reducing the sand dunes and utilizing them for road paving is a viable option. This reduces its impact, but it does

not preclude the formation of dunes due to climatic conditions. Furthermore, soil aridity makes it susceptible to erosion (both water and wind) due to the sparse vegetation cover in the study area.This is because the lack of vegetation in the study area reduces its impact.

4. **The Impact of Sand Dunes on Tourist and Archaeological Sites:** The encroachment of sand dunes is burying all the tourist sites scattered throughout the study area and its extension, such as the archaeological site of Tell Umm al-Ajaj, which covers an area of (15 dunams) in the northern Kar district, and Tell al-Tarmah, which covers an area of (3 dunams) located in the Abu Hawn district, as well as Tell al-Mansuriyah, which covers an area of (2 dunams) located in the eastern Kar district, and the archaeological sites of Umm al-Aqarib and Tell Jukha, located in the northern Kar district, the center of the Rifa'i sub-district, as well as Tell Badhikh in the al-Salihiyah district, Qalat Sukkar sub-district, and Tell Ajil and Tell Abu Dhiba' in the Ramliyah district. Furthermore, the sites of Eridu and Ur are affected by the encroachment of sand dunes, as are the archaeological sites located in the Tell al-Ham area. This widespread geomorphological phenomenon is covering archaeological sites with sand dunes, in addition to cutting off transportation routes to these sites, unless specialized engineering efforts intervene to remove the dunes from the roads, especially since most of the roads that The roads leading to the archaeological sites are unpaved**.**
5. **-5The impact of sand dunes on air quality and public health:** Humans need clean air, and the cleaner the air, the greater a person's ability to resist diseases and feel healthier. When a person breathes polluted air, it affects their health and weakens their resistance to disease. When people are exposed to dust storms, they are more susceptible to illnesses, including eye diseases, lung diseases, allergies, and asthma, in addition to the discomfort they experience due to the increased dust levels in the air and the accompanying spread of disease-causing viruses (Al-Mousawi: 2014, p. 7). The danger of this phenomenon lies in the fact that sand dust contains particles capable of penetrating the respiratory system, as well as carrying biological and chemical pollutants from contaminated sand surfaces.

Second - Strategies for Reducing the Risks of Sand Dunes

Iraq began stabilizing sand dunes in the 1970s and established several stations, including the sand dune stabilization station in Baiji and the Al-Nu'maniyah station (1974). A sand dune stabilization station was also established in Nasiriyah Governorate. To stabilize sand dunes, it is essential to address the root causes of the problem and the reasons for their degradation in order to find effective ways to eliminate this issue and achieve integrated development in the region, transforming it into productive land suitable for human use (Abdul-Hassan: 2013). Sand movement, along with the movement of sand dunes, is one of the most dangerous natural phenomena threatening most human activities in the study area. Its encroachment threatens roads, especially the international highway linking Nasiriyah Governorate to Baghdad Governorate in the northern part of Al-Bathaa district, which is subject to significant dune encroachment during the summer. It also threatens agricultural reclamation areas in Al-Rifai district on the eastern bank of the General Outfall River, in addition to the risk of wells being filled in. Therefore, the state has increased its focus on stabilizing the dunes, mitigating their damage, and utilizing the areas that... This process occupies the area, and therefore it was necessary to find the most suitable methods for stabilizing sand dunes in an attempt to reduce the severity of the problems resulting from sand movement. Among these methods are:

1. **Clay Covering:** This involves leveling the surface of the sand dune using vehicles capable of traversing sand, called bulldozers. Afterward, the dune surface is covered with a layer of clay soil, ranging in thickness from 15 to 25 cm. The clay particles become embedded between the sand particles, forming a cohesive layer. When it rains, this layer stabilizes the sand grains, thus halting the movement of the dunes. Some natural vegetation may even grow on top of it, further contributing to its permanent stabilization. This method has been widely used in Iraq to stabilize dunes in the Nasiriyah Governorate. This method has yielded good, inexpensive results and achieves the desired purpose, especially for dunes located on both sides of the main drainage canal. It promotes the growth of natural vegetation and afforestation by retaining water, thus yielding positive results in plant growth and transforming areas dominated by encroaching sand into productive agricultural land. Furthermore, the movement of heavy machinery compresses the dunes. It is used during the covering process and is characterized by its ease and speed of completion, not requiring extensive expertise, and its low cost compared to other methods, as it has given good results. Clay soils were used to stabilize the dunes that obstruct irrigation projects carried out by the authorities responsible for stabilizing the dunes north of Al-Rifai district and stopping the encroachment of sand dunes for a maximum period of (4 years). (10,000 dunams) were actually covered and (50,000 dunams) were covered in total in Nasiriyah Governorate, with the study area's share being approximately (605 dunams) starting from Al-Fajr sub-district to the north of Al-Nasr sub-district (Abdul Hussein: 2016, 263).
2. **Earthen Dikes:** These are defensive lines to stop sand encroachment, ranging in height from (3-4 m) and in width from (5-8 m). The earthen dam is located (2-3 km) away from the nearest dune and is constructed perpendicular to the prevailing wind direction in the area to obstruct its paths, reduce wind speed, and prevent sand accumulation on the windward sides of the dams. The primary purpose of constructing earthen dikes is to limit and stop sand encroachment towards the structure being protected, such as irrigation projects, cities, and roads. It is preferable to construct two or three lines of these dikes with a suitable distance between them. Relying on a single line of earthen dikes leads to the dikes becoming filled with sand accumulating on the windward side, which gradually increases over time and then crosses to the other side. Furthermore, using loamy soils near the sand dunes that contain a percentage

of clay creates climatic conditions for the growth of natural vegetation, especially during the winter when it rains, which helps bind the particles of the earthen dikes. (Muhammad: 2010, 20).

3. **Use of Chemicals and Petroleum Substances:** Some chemicals are used to stabilize sand dunes, such as calcium chloride. This solution increases soil cohesion. Corosol is also used for dune stabilization. When mixed with water, it forms a colloidal plastic solution, creating a transparent, plant-friendly, and porous layer that allows seeds to breathe and access water. Additionally, lithium emulsion is used, which has a high capacity for binding soil surface particles and protecting them from various erosion factors. These chemicals are applied by spraying them onto the surface of the sand dunes after being mixed with water in specific proportions to form a material with a high binding capacity for soil surface particles for a period not exceeding three years. Limitations to using this method include the high cost of these chemicals and the negative environmental impacts of using large quantities (Abdul Hassan: 2013, 22). Therefore, the use of these materials is limited, with trials confined to stabilizing sand dunes in Baiji and Al-Nu'maniyah, after spraying the dunes with Corosol. When diluted with water at a ratio of (8:1), it forms a solid, cohesive layer on the dune surfaces, maintaining the cohesion of the sand grains and resisting wind erosion for three years. This material also possesses a permeability that allows water to penetrate, retaining moisture in the dune sand and reducing evaporation. This, in turn, promotes the growth of various native plants on the dune surface during this period. As for the poly-ceramic material, results have shown that it is highly effective in stabilizing sand dunes when diluted with water at a ratio of (38:1) and then sprayed onto the dune surfaces. This helps to bind the sand particles together, increasing the amount of sand resistant to wind erosion. Furthermore, the permeability of rainwater through this solution helps to increase moisture content and improve the properties of the dune soil by supplying it with nitrogen, thus increasing its fertility. This has a positive impact on the growth of plants.

Plants cultivated to mitigate sand dune movement, while effective in stabilizing sand dunes, face challenges due to their unavailability within the country and the need for importation, as well as their high cost. Therefore, their use in dune stabilization is only feasible if funds are allocated to support the agricultural sector and purchase these materials. Petroleum-based materials, on the other hand, are used in oil-producing countries struggling with sand dunes due to their lower cost and effectiveness in stabilizing them. Furthermore, the use of machinery in the spraying process reduces the need for manpower, allows for rapid application, and enables the coverage of large areas of sand dunes in a short time. One such petroleum-based material is bitumen, which has proven successful in stabilizing sand dunes after dilution with water. This material does not require heating. When the solution is sprayed onto the sand dune surfaces in the Sheikh Saad area, it forms a cohesive layer of sand grains with an increased percentage of non-stabilizing aggregates. For erosion, it allowed rainwater to penetrate, increasing soil moisture and improving soil properties. This contributed to the successful cultivation of millet. Meanwhile, crude oil and black oil are used to stabilize sand dunes near roads to prevent their encroachment onto the roads. Spraying the dunes with these substances and removing them from the roads, causing them to accumulate in one place, prevents them from being blown away by the wind. However, there are reasons that prevent the use of these materials: they do not allow rainwater to penetrate and they do not promote the growth of natural vegetation on the surface of the sand dunes sprayed with black oil.

4. **Making hedges from plant materials:** Plant materials such as reeds, palm fronds, tamarisk, tree branches, and some other natural plants suitable for making hedges are used. These hedges extend lengthwise, perpendicular to the wind direction, in multiple lines spaced 3-4 meters apart. This method is characterized by its simplicity and does not require expensive materials, relying instead on readily available plants. However, it is preferable for farmers to use this method to surround agricultural areas with these hedges to protect them from sand dune encroachment, or to plant these plants on the dunes themselves as hedges, especially those near farms and residential areas. This is because it is easy for any farmer to implement, in addition to stabilizing dunes near their farms to prevent sand particles from reaching and moving towards their agricultural lands when wind speeds increase (Abdul Hassan, 2013, p. 20). The selected trees should have a high resistance to wind, and in arid and semi-arid areas, trees that act as windbreaks should be planted at a distance of 30-45 meters. From the field and the same distance from transportation routes, and they are planted according to specific engineering methods along the areas, in addition to securing irrigation water during their planting season for the purpose of their growth and continuity. Among the shrubs that are suitable for stabilizing the sand and can be used as windbreaks are (tamarisk and thistle), which are planted on the surface of the dunes following the dry planting method. Millet grasses, which are characterized by rapid growth, can also be planted, and they need irrigation during the dry season at a rate of twice during the month. Water from the general and Dutch drainage canal can be relied upon after installing pumps to transport water to the northwestern region. Meanwhile, water from the Dutch can be relied upon in the northwestern region of Al-Bathaa district after relying on pumps to transport water during the summer season. The process of permanently stabilizing the dunes is not limited to reducing the encroachment of the dunes, but it leads to the utilization of the areas that were covered by those dunes, and they can be invested in, in addition to creating a beautiful environment that is considered one of the areas that attract people (Al-Quraishi: 1988, 97).

CONCLUSIONS:

1. The research demonstrated that wind erosion and deposition processes have a significant impact on sand dune formation. The scarcity of natural vegetation has led to increased wind erosion in areas characterized by fine, sandy soil.

2. Natural factors, specifically the arid climate of the study area, with its high temperatures, low rainfall, and high evaporation rates, which result in limited natural vegetation, have facilitated soil erosion and degradation due to wind, leading to sand dune formation.
3. The research concluded that sand dunes have significant impacts on human activity in the study area. Their encroachment threatens agricultural lands, residential areas, transportation routes, tourist sites, and archaeological sites, in addition to impacting public health.
4. Several types of sand dunes are found in the study area, including crescent, long, and sand dune types.

RECOMMENDATIONS:

1. The spread of sand dunes in the study area necessitates financial allocations to mitigate this phenomenon.
2. Given the scale of this problem and its significant and widespread impact on human activity, it is imperative to expedite the implementation of both temporary and permanent solutions.
3. Encourage farmers to cultivate the land by providing them with assistance and facilities, supplying them with modern and advanced agricultural machinery, and raising awareness among farmers and developing their agricultural skills.
4. Construct windbreaks that move against the prevailing wind direction.

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