JJEES

JJEES (2026) 17 (3): 324-337
ISSN 1995-6681

Jordan Journal of Earth and Environmental Sciences

Desertification and its Effects in Iraq: A Review

Emad Telfah Abdel Ghani[1*], Wael F. A. Alshamary[2], Husam Naji Mukhlif[3], AbdulKarem A. M. Alalwany[3], Atheer Saleem Almawla[1], M S Jumaah[4], Bilal Muayad Abdulrahem Alalosy[1]

[1] The Upper Euphrates Centre for Sustainable Development Research, University of Anbar, 31001, Iraq.
[2] The College of Agriculture, University of Kirkuk, 36001, Kirkuk, Iraq.
[3] Higher Institute of Desert Sciences, University of Anbar, Ramadi, 31001, Iraq.
[4] Department of Soil Science and Water Resources, College of Agriculture, University of Anbar, Ramadi 31001, Anbar, Iraq.

Received on 3 May 2025; Accepted on 30 March 2026

Abstract

Desertification is an environmental process in the world which leads to degradation of land, decrease in agricultural productivity and biodiversity. In Iraq, 55.5% of the territory (≈96,500 km²) would be desertified or undergoing such process/state, while 23.2% would be classified as experiencing full desertification (≈40,400 km²). This growth has been fostered by climate change, mismanagement of water, and unsustainable land use. Effects include decreased food security, rural to urban migration, and increased frequency of sandstorms damaging both public health and economic activities. Efforts to halt desertification, including afforestation, better irrigation and sustainable farming, have made a difference but are not enough in the absence of more robust policy measures and international co-operation. This review compiles recent (2023–2024) developments and the growing significance of the desertification situation in Iraq, as well as its requirement for sustainable connected action that not only slows down/combats desertification but also ensures a stable socio-ecosystem.

Keywords: *desertification, drought, sand dunes, Geographic Information Systems (GIS), Remote sensing, Iraq.*

1. Introduction

Global desertification is one of the world's dilemmas, exacerbated by water shortage as well as climate change. The United Nations Convention to Combat Desertification (UNCCD, 2024), indicated that globally over one-third of our planet's land is affected (Awadh S.M. 2024).

Desertification is closely associated with rainfall variability and climate change in arid and semi-arid regions, leading to a redistribution of potential for land productivity and the development of soil erosion (Salahat & Al-Qinna, 2015).

Wind erosion is one of the notable processes in the desertification phenomenon that occurs in arid environments, resulting in the removal of fine particles and organic matter from soil structure which deteriorates fertility and water retention capacity of soil (Abdelwahab ve Mustafa, 2021, Ide vd., 2025). As a result, desertification is not just an environmental issue; it represents a development concern that impacts upon food security and the sustainable utilization of natural resources.

Destruction of the vegetation cover by drought and over-grazing results in an increase in the susceptibility of the soil to wind erosion and water. It is conducive to the loss of fertile topsoil and threatens the long-term sustainability of ecosystems (Al-Sababhah & Al-Maqablah 2023)

The crisis in Iraq is even more severe. The Iraqi Ministry of Planning (2024) indicated that 55.5% of Iraq is desertified or under threat of desertification, as well as 23.2% already totally deserted in iraq shafaq. com). This indicates a marked increase from the previous year, 2021, in which the total desertified area was found to be 27,200 km² (Alkhateeb et al., 2019; Al-Shamary et al., 2021). The spread of the desertified areas is associated with decreasing water levels in Tigris and Euphrates rivers, increasing temperatures, and soil salinization resulting from inefficient use of irrigation waters (Lateef et al., 2024).

Quantitative analyses indicate that vegetation degradation has rapidly intensified in, for instance, the provinces of Babil and Al-Qadisiyah in the period between 2000 and 2023 under land-use change impact and climate stress (Alsultan et al., 2023; Alobaidy et al., 2024).

In this context, a detailed framework in the form of an integrated scientific investigation is direly needed in Iraq. The purpose of this review is to offer a synthesis up-to-date on the topic of desertification, including its causes, impacts and potential countermeasures, with an emphasis on sand dunes as a crucial defacing aspect in Iraq.

2. Methodology

As a review paper, this study performs systematic literature research and analysis to synthesize the recent research on desertification in Iraq. The approach is based on three main parts:

2.1 Databases and Sources

Relevant literature was searched from international

* Corresponding author e-mail: emadabdulghani@uoanbar.edu.iq

databases (Scopus, Web of Science, Google Scholar), as well as local journals and reports issued by Iraqi entities (UNCCD, 2024; Iraqi Ministry of Planning, 2024).

2.2 Search Strategy

Search keywords were "desertification Iraq", "sand dunes Iraq", "climate change Iraq", and "soil degradation Iraq", and the OR Boolean operators were used to focus the search results. Publications from 2000 to 2024 were considered, with an emphasis on studies from recent years (2023–2024) to ensure contemporariness (Alkhateeb et al., 2019; Al-Shamary et al., 2021).

2.3 Inclusion and Exclusion Criteria

- Inclusion: Peer-reviewed articles, government reports, and conference papers addressing desertification drivers, impacts, or mitigation strategies in Iraq.
- Exclusion: Non-English publications without translation, non-peer-reviewed sources, and articles lacking methodological transparency.

2.4 Analytical Framework

The selected studies were categorized into thematic clusters:

- Drivers of desertification (climatic, anthropogenic, geological).
- Impacts (agricultural, ecological, socio-economic).
- Mitigation strategies (afforestation, water management, sustainable agriculture).
- Comparative synthesis was conducted to highlight regional variations within Iraq and to evaluate the effectiveness of current policies (Safriel, 2009; Rasul, 2016).

3. Desertification concept

Desertification is when an area that was fertile is eroded into a desert because of human actions (Becerril-Pio and Mastachi-Loza, 2021). Sivakumar (2007) and Reynolds (2013) claim this is an ongoing global concern and severely affects nature and productivity in the contemporary world, which seems to have become a reason for concern for many people. Other countries, including Iraq, are also facing this environmental challenge (Al-Obaidi et al., 2022). In a statement by the UNCCD (United Nations Convention to Combat Desertification) on desertification, they estimate that it surpasses 1/3 the total surface area of land, which is the reason behind land degradation, which in itself is an astonishing loss or reduction in biologically productive land or economically useful land. This phenomenon usually leads to the degradation of biodiversity and plant and animal life, in addition to the depletion of social value, poverty, and unrest (Eltaif et al., 2024).

This takes place in arid and semiarid regions which is caused by climate changes along with overgrazing and inappropriate land utilization (Sombroek & Sene, 1993).

A section is also described as becoming increasingly more arid, which makes the area susceptible to maximum land degradation, termed desertification.

Desertification is defined by (Vogt et al 2011) "as a process of land degradation in which a region becomes increasingly arid, resulting in loss of biological productivity and economic value"- it's a biological problem which has complex causes linked to human and natural factors. Climate change, overgrazing, and poor land management also contribute to emerging deserts (Wairiu, 2017). Desertification has become a serious environmental problem worldwide due to its havoc caused environmentally and humanly (Thomas, 1997).

3.1 Factors of Desertification

The causes of desertification are multifaceted and include climate change, overgrazing, deforestation, and irrigation practices that deplete water resources (Darkoh, 2018). These factors often act in combination, and it may be impossible to determine a single cause.

The loss of arable land is one of the major effects of desertification. This can be disastrous for agriculture, as it limits the quantity of space available for crops and increases the risk of crop failure. This can also cause food insecurity to become more intensified and problematic in this area, with growing difficulties to produce enough food required by the local population (Tokbergenova et al., 2018).

Besides the influence on agriculture, desertification can bring severe consequences for the environment. Reduction in plant cover can result in erosion and soil degradation, subsequently encouraging the expansion of desertification. It may also cause loss of biodiversity as most plant and animal species cannot survive the harsh environment resulting from desertification (Kassas, 1995).

There is a number of initiatives to tackle desertification. The UNCCD has initiated a variety of programmes and projects to address desertification and encourage sustainable land use. These include the Great Green Wall Initiative to plant a barrier of trees across Africa as part of an effort to reverse desertification, and enhance food security, and the Land Degradation Neutrality Fund that financially supports projects for land restoration initiatives (Reynolds et al., 2007).

Sustainable management of water resources is crucial in arid countries, and the importance of flood hazard mapping using dam break scenarios is highlighted for reducing risks (Al-Weshah, Al-Salahat, & Al-Omari, 2024).

Even then, desertification is still widespread across the globe. In order to effectively deal with desertification, holistic solutions will be required that can address the multiple factors contributing to desertification and the particular circumstances of communities experiencing this phenomenon (Safriel, 2009).

In Iraq, desertification is a major issue as it has an arid and semi-arid climate that suffers from drought and soil degradation. The issue is compounded by factors such as population explosion, urbanization and environmental deterioration. These have resulted in the depletion of flora, disturbance of soil, and lower productivity of soil that has eventually affected local people's lives negatively as well as

decreasing environmental health (Al-Kasoob et al., 2024).

Other significant reasons for the desertification of the land in Iraq include overgrazing. This is a widespread phenomenon in many areas of the nation, especially northern and central regions, where there are limited water points and pasture. Overgrazing results in soil and vegetation degradation, can contribute to soil erosion, and decrease biodiversity (Al-Turaihi et al., 2023).

Another significant reason for desertification in Iraq is bad land use management. Improper land use is forced on many parts of the country - for example, crops that are planted in areas that cannot or should not bear agriculture. This can contribute to soil degradation and erosion, as well as loss of vegetation and habitats for wildlife (Maitima et al., 2009).

Several measures have been tried to solve the problem of desertification in Iraq, such as land management and conservation practices, sustainable agriculture, and irrigation projects. Nonetheless, a lot more must be done to reduce the fundamental reasons for the issue and make sure that its natural resources are not only protected but also compatible with long-term management and use (Rasul, 2016).

Evidence from Jordan on urbanization and its sustainability implications reveals that the changes in land use/land cover have significant relevance for environmental change (Abusmier & Al-Kofahi, 2024).

3.2 Types and forms of desertification:

There are several types of desertification, including:

- Climatic desertification: This type of desertification is caused by changes in the climate, such as prolonged drought or extreme temperatures. These changes can lead to the loss of vegetation and soil erosion, making the land less productive and more vulnerable to further degradation.
- Anthropogenic desertification: This type of desertification is caused by human activities, such as overgrazing, deforestation, and poor land management practices. These activities can lead to the loss of vegetation, soil erosion, and salt accumulation in the soil, making the land less productive and more vulnerable to further degradation.
- Geological desertification: This type of desertification is caused by geological factors, such as tectonic activity or the erosion of mountains. These factors can lead to the loss of vegetation and soil erosion, making the land less productive and more vulnerable to further degradation.
- There are also several forms of desertification, including:
- Physical desertification: This form of desertification is characterized by the loss of vegetation, soil erosion, and the accumulation of salt in the soil. It can lead to the formation of sand dunes, which can reduce land productivity and increase vulnerability to further degradation.
- Biological desertification: This form of desertification is characterized by the loss of biodiversity, which can have negative impacts on the ecosystem and the communities that rely on it. It can be caused by the loss of vegetation, soil erosion, and the introduction of invasive species.
- Chemical desertification: This form of desertification is characterized by the accumulation of pollutants and other harmful substances in the soil, which can make the land less productive and more vulnerable to further degradation. It is associated with human activities such as the use of insecticides and fertilizers, and industrial and agricultural pollution.
- All things considered, desertification is multidimensional problem and can cause many adverse effects to the natural environment and local communities. Policy makers and communities alike should therefore seek a solution to the cause, while employing effective solutions to mitigate against it (Pal et al., 2023).

3.3 Desertification's landforms:

There are some landforms related to desertification. Certainly the most prolific is the sand dune. Dunes A dune is a mound of sand that wind has blown into. They may be as small as several feet high or as tall as hundreds of feet in height and are typically located in dry or semi-dry areas.

3.3.1 Sand dunes:

The most common problem in desertification areas is sand dunes, which obstruct roads and prevent people from reaching water resources and other resources (El Gamri, 2020).

Salt pans are also a feature of desertification. Salt pans are flat lands with deposits of salt and other minerals, usually found in arid regions. They form when water from a salt lake or sea evaporates, leaving behind a crust of salt. Salt direns are a significant issue in the regions going through desertification as they may render the soil infertile and very challenging for any plant growth (Zade et al., 2021).

A related landform type is the playa, which is a wet basin that forms in arid environments, either through drying of an alkaline lake or accumulation and concentration of bleached silts. Playas are level, dry areas located in deserts. They tend to be salt- and mineral-coated, and are typically located at the bottom of valleys or in basins. Playas are a serious concern for the process of desertification because they cause land to be non-cultivable, and due to environmental contamination, plant and animal habitats become both ecologically harmful and hazardous (Abdelfattah et al., 2009).

In conclusion, desertification is one of the key environmental and economic problems facing millions of people worldwide. It is attributed to a number of factors, including global warming, overgrazing, deforestation and bad land management. Desertification.

The landscape in desertified areas includes sand dunes, salt pans, and playas, all of which can render soil infertile and unsuitable for the support of plants and animals Logsdol & Klopcic, 2017).

3.3.2 Desertification landforms in Iraq:

Environmental Situation Desertification is a serious issue for Iraq with long-term effects on the natural environment and the human population of that country. Desertification has had a great effect on the Iraqi natural environment, and its people. Desertification in Iraq. From a UNDP report, desertification in Iraq is driven by overgrazing, deforestation, and sub-optimal irrigation techniques (Chasek etal, 2019).

Among the most visible effects of desertification in Iraq are dunes that reach a maximum height of fifty meters. These sand dunes, called "ergs," form when the wind blows loose sand from the floor of the desert into piles. Ergs are most common in Western and Southern Iraq, and have the effect that they force out agricultural land and make access to water and resources difficult for people (Shahid & Alsumaiti, 2022).

Loss of vegetation cover is another effect of desertification in Iraq, resulting in soil erosion and low water retention in the soil. This has, in fact, hindered farmers from cultivating crops, increasingly contributing to food insecurity and economic crisis in a large number of rural areas (Minelli, 2016).

Efforts to combat desertification in Iraq have involved reforestation and afforestation projects, along with sustainable land management schemes. Yet the UNDP report adds that these initiatives have been undermined by continued conflict and insecurity in the country, as well as inadequate funding and resources (Chasek et al., 2019).

Overall, it can be argued that desertification has always been a major issue in Iraq, affecting the natural landscape and the livelihood of Iraqi people. Addressing these will require coordinated action by government, non-government organizations (NGOs), and other agencies to implement sustainable land management practices (WHO 1992).

Sand dunes:

Sand dunes are active, dynamic land forms that constantly shift and change under the influence of wind and water. Natural distribution in Iraq Dwaras of sand dunes are distributed in various thrust-sanders, including the western desert, eastern desert, and the south desert of Manifesto.

These sand dunes can move in a variety of ways, including through the process of saltation, which is the bouncing and hopping movement of grains of sand as they are blown by the wind (Sissakian et al., 2013). Sand dunes are among the main features of the earth's surface and are a prominent presence in arid and semi-arid environments in different regions of the world, due to the availability of appropriate environmental conditions for their formation in these environments, as arid and semi-arid ecosystems are characterized by fragile systems that are vulnerable and respond to various degradation factors, especially after the climatic changes that the planet is witnessing due to the erosion of the ozone layer by the impact of greenhouse gas emissions, or the so-called (global warming phenomenon), and the resulting increase And the recurrence of drought years, the lack of rainfall, and a rise in the temperature of the earth, which affected its natural system and disrupted its ecological balance, and then its degradation, and the activity of wind erosion processes from transport, sedimentation and formation of sand dunes in different regions of the world (Agam & Berliner, 2006).

Sand dunes in Iraq are primarily controlled by the wind and one of its main features is force and direction. Dunes generally come about in the direction of the prevailing wind and move with a similar size and shape, which is impacted by periodicity and the strength of gusts. For instance, dunes in the Western desert of Iraq are predominantly formed under the influence of the northwest wind that prevails over the region during winter seasons (Jourdain et al., 2006).

Another cause that may affect the advancing desertification in IRAQ is the existence of vegetation. Vegetation in the form of vegetation cover on sand dunes stabilizes the dune and prevents of further erosion. Dry, non-vegetated dunes are easier to shape by wind and erode with less resistance (Goudie & Middleton, 2006).

Dyani Brown Climate change can contribute to shifting sand dunes in Iraq. Wind and water regimes in the area might be altered by temperature increase or changes in precipitation patterns, this could also affect how the sand dune system is formed and works (Eklund & Pilesjö, 2012).

Several research works have been done on the dynamics of sand dunes in Iraq. The results of one such study appeared in the journal "Geomorphology," and looked at sand dunes' shapes in western Iraq, reporting that the dynamics of these landforms depend on wind direction, vegetation cover, and topography. In addition, the research identified locations susceptible to sand dune advance and transport and suggested that understanding these dynamics might be helpful for interpreting predictions about how such advances could affect infrastructure and human habitation (Al-Naji & Al-Shammery, 2019).

Desertification Desertification has reached to one of the study material that has been drawn attention of humans all over the world, and concern by international organizations that have made a lot of efforts to reduce it and try to find appropriate solutions for soil, water and natural vegetation This is due to lack of effective sources Which can be defined as limited natural wealth with importance in global level experiencing steady population growth throughout recent years (Adamo et al., 2018).

Overall, sand dunes in Iraq are active landforms under the influence of multiple factors, including wind, water, and vegetation. As such, they can pose a threat to infrastructure and human settlements, and understanding the patterns and processes that drive their movement can be crucial for mitigating these risks (Goudie, 2018).

3.3.3 The concept of sand dunes:

The definition of sand dunes varied from one world to another and from one group to another, where it is defined as the wind blowing rock debris to then gather to form small shapes, circular or longitudinal shape sometimes, irregular shape at other times, known as sand dunes (Longwell, 1949). On the other side, Bagnold (1954) defined sand dunes (a mound of sand rising to a single peak), while Rasmussen (2024) defined sand dunes as a collection of sand-sized materials blown by the wind. Furthermore, (Stone, 1967) believed that sand dunes are a topographic phenomenon of air origin consisting of grains of sand from a natural source deposited on the side far from the direction of the wind. While Steven Fryberger et al. 1979) defined sand dunes as (collected in the form of a series of deposits blown by the wind), they have a slight slope facing the wind and another steep slope on the obscured side, called the façade of the slide (Al-Jashaami et al., 2024).

3.3.4 Hazards of sand dunes:

1. People migrate to other places to search for a source of livelihood and life, which leads to instability.
2. Lack of visibility when walking on the roads during sandstorms and various disasters.
3. Disruption of air traffic and the resulting fatal and tragic accidents.
4. Damage to agricultural crops and filling irrigation canals and drains with sand, and the resulting losses.
5. Ecological imbalance in the sand dune area in everything related to man and the biosphere.
6. Health problems that result from the inhalation of air loaded with dust and dust by humans, and the deaths that occur.

3.3.5 Benefits of sand dunes (Ati, 2021):

1. Sand dunes are used in the manufacture of glass.
2. Mixing sand with clay produces fertile soil for planting.
3. They act as groundwater reservoirs because they have high permeability.

3.3.6 Forms of sand dunes in Iraq:

3.3.6.1 Barchan (Crescent) Dunes

Crescent dunes arise when the wind blows in one direction and a sufficient amount of sand is available, and this type of dune is similar in general shape to the crescent with the two arched ends pointing in the direction of the wind departure, as they indicate the direction of movement of the dune and the direction of the prevailing winds (Al-Trabulsy, 1993). Crescent sand dunes are formed when the sand piles or sand gathering reach maturity, and then begin to move with the direction of the wind, as they begin to form the ends of the thin dune that are less resistant than the centre of the dune in the form of two wings up to their length and arch to the degree that the wind resistance is equal to the degree of resistance of the middle part of the dune and when the crescent dune is formed, it remains in its shape as long as the prevailing winds remain in the same direction (Figure 1).

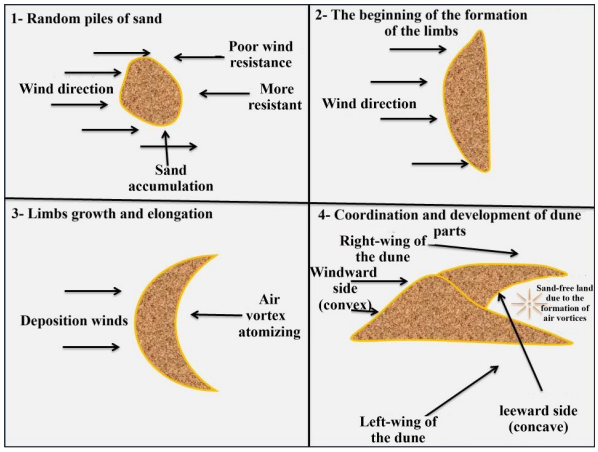

Figure 1. Stages of formation of the crescent dune (Barkhan)

3.3.6.2 Longitudinal sand dunes (composite):

The basis of these dunes is the crescent dune, which, when exposed to winds intersecting the prevailing winds in the region, can cut the wings of the crescent dune, making one longer than the other. Wind eddies carry the remnants of these dunes, causing the edges to lengthen and the formation of longitudinal dunes from the previous crescent shape. Bagnold saw that these dunes may be the result of air currents associated with strong winds that blow permanently in one direction and extend their axes parallel to these winds, but he stressed that the compound dunes begin their life cycle as crescent dunes due to their exposure to side winds that intersect with the permanent direction of them, which leads to the elongation of one of the sand dune sides (Al-Jashaami et al., 2024).

When studying this type in the field, it is observed that compound dunes result from the merging of crescent dunes. The merging of dunes aligned in a longitudinal orientation is also observed, creating a wind barrier in the dune-merger area, leading to sedimentation and the filling of these areas with sand particles (Figure 2).

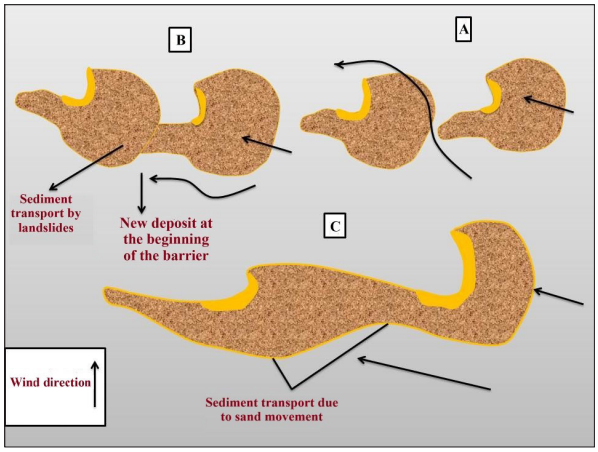

Figure 2. Stages of formation of the longitudinal dune (composite)

3.3.6.3 Nebkas sand dunes:

This type of sand dune forms when a sand-laden wind encounters an obstacle, such as plants, especially desert shrubs, or a massif, which acts as a barrier. This causes the wind to deposit its sediment load around the plant or massif (Wang et al., 2002). Continued accumulation of sand grains

on the plant leads to cohesion, forming a triangular shape whose head points in the direction of the wind. It grows until it becomes a dune known as a Nebka. The plant is eventually covered, leading to its death and decay, especially in annual plants. The sand grains then become loose and are easily winnowed, carried, and transported by the wind again. These dunes move slowly and cohere with the roots of plants (Sabah Baji Diwan, 2013) (Figure 3).

Figure 3. A picture showing the formation of the dunes of Nebkas

Wide sand dunes:

The reason why this type of dune is called by this name is because it intercepts the movement of the prevailing winds as they are perpendicular to them. This type arises when there is an abundance of sand, and the area is devoid of vegetation. The transverse dunes consist in two sides (as in the crescent dunes), extending in opposite directions. The first is a slope and takes a concave shape at an angle ranging between (15-32) (Gaur et al., 2023).

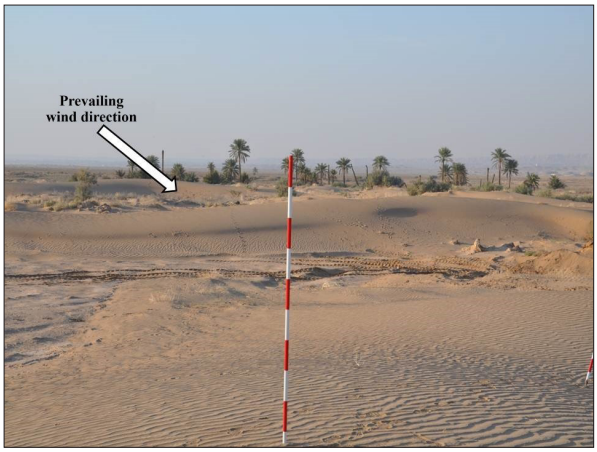

Figure 4. A picture showing the formation of the wide dunes

3.4 Movement of sedimentary particles of sand dunes

Grains and sand sediments move in three ways, which are chemical:

1. Creeping: Moving in this way, coarse grains that cannot be carried by the wind, rolling grains moving on the surface of the earth for short distances, and when moving, may collide with other grains lead to their movement is the other, and the size of the grains that move in this way ranges from (1 – 2 mm) (Baas, 2019).
2. Saltation: The grains move in this way to close distances from the surface of the soil, due to direct wind pressure on the grains. As the grains rise to the top, then down, then to the top again after blowing new air again, and the size of the grains that move in this way ranges between (0.05 – 1 mm) (Bass 2019).
3. Suspension: very fine grains of sand, less than 0.05 mm in diameter, which are very soft, are carried in this way in the upper layers of the atmosphere and can travel very long distances, up to 3000 – 4000 km. They remain suspended in the air for a long time and are then deposited when wind speed and strength weaken due to low atmospheric pressure (Al-Gurairy & Al-Zubaidi, 2023).

3.5 The negative effects of sand dunes and ways to control them:

Sand sediments affect when they move and sedimentation on many human facilities, especially agricultural and industrial activity, services, and conductor roads, as well as having a role in the activity of dust phenomena, suspended dust, and rising dust, which have negative effects represented in the following:

3.5.1 Effects on soil:

Sand dunes lead to the loss of large amounts of soil, the change in its properties, and a decrease in its ability to retain organic matter, which leads to the loss of soil fertility and thus a lack of plant growth. The process of wind splashing repeats, splashing small particles, and then desertification begins, which leads to a change in the properties of the soil and a decrease in its productivity, and thus the loss of large areas of agricultural land.

3.5.2 Impact on agricultural lands, irrigation channels, and natural pastures:

The encroachment of sand dunes on agricultural land is one of the most serious problems, as it leads to the landfilling of arable land, altering the characteristics of its soil, spreading loose, dry soils over it, eliminating its vegetation cover, exposing it to various erosion factors, and ultimately converting it into land unsuitable for agricultural production by transferring the characteristics of dry desert soils, and over time converting it into a desert.

Figure 5. Showing the landfilling of irrigation channels due to the movement of sand dunes

3.5.3 Impact on transport and connectors ways:

Sand dunes are one of the factors affecting transport routes in areas near the sand dunes, as they affect the main tiled roads and other unpaved secondary roads.

Figure 6. The encroachment of sand dunes on land roads

3.5.4 Impact on the industrial facility (gravel and sand quarries in the region):

The effect of sand dunes on these quarries is in two forms: The first is a direct effect where the sand dunes crawl on these quarries, which leads to the difficulty of controlling them, while the second form has an indirect effect through the creep of sand dunes on the road that leads to the quarries and thus the difficulty of reaching the load cars to the quarries that transport gravel and sand from these quarries and thus stop working in them.

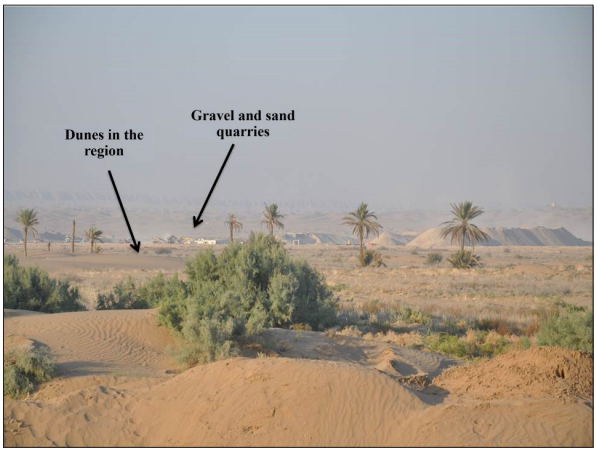

Figure 7. The effect of sand dunes on quarries directly

3.5.5 Impact on residential villages in the region:

The neighboring villages near the sand dunes suffer from sand creeping toward their homes, with sand grains and rising dust colliding with their doors and windows, leading to the deposition of sand particles inside. In some cases, this may lead to residents migrating or leaving their homes during the summer due to the intensity of the winds and the dryness of the region, as well as the mental health damage it causes, such as feeling suffocated and not opening the doors because of sand particles entering the house. This can leave a person feeling as if they are living an abnormal life, as if they are in the middle of a barren desert.

3.6 Ways to reduce the effects of sand dunes

Several methods are used to stabilize the sand dunes, including mechanical and other biological methods, which are as follows:

3.6.1 Mechanical methods (temporary methods):

1. Earth mounds: The main purpose of establishing earth mounds is to establish defensive lines and barriers that resists sand encroachment towards the facility to be protected, such as irrigation projects, roads, cities, agricultural lands, etc. In addition to stopping the sand creep and preventing its access to the facility to be protected, the berms are intersecting with the prevailing wind direction in the region, The distance between one berm and another depends on the density of the sand dunes in the region, where the distance is low if the sand dunes are dense, and earthen mounds help to create suitable conditions for the growth of natural plants and the success of afforestation due to hindering the creep of the sand dunes. They also work as fences that prevent the entry of animals for grazing in the region and are often at a height of (2-3 m). Mechanisms are used in the work of these berms (Hereher, 2010).

2. 2- The work of fences: It is the work of fences made from plant residues, such as palm fronds, reeds, and papyrus, that act as bumpers to reduce wind speed in front of the sand dunes. However, because of the limited capacity of the area that contains the sand dunes in the study area, this method has become useless, as it requires large quantities of plant residues, a long time, and high labor costs.

3. Modification and levelling of sand dunes (mechanical potential): It is a method used in areas where the sand dunes are newly formed, provided that they are planted with agricultural crops, as they must be close to water sources, as the windbreaks were established in them after they were modified and ploughed deep tillage through which the sand mixes with agricultural soil, and then it is planted and afforested and this process takes place in the winter, where the movement of sand is almost stopped.

4. Mulching: The sand dunes are covered with a heavy layer of clay from the areas adjacent to the sand dunes by machinery (bulldozer), where the thickness of this layer is (20-30 cm), As it works to stop the movement of the dunes completely, because it is a heavy soil (clay) that is difficult to transport by the wind and when rain falls, it holds together and works to protect the sand underneath, as well as its pressure due to heavy machinery on it during the covering process. This method is characterized by its ease and speed of completion and does not need extensive experience and low costs compared to other means, as well as it helps to develop vegetation cover for water retention (Figure 8). But if the areas

are vast, it is necessary to switch to coverage, using oil (black oil) to treat the movement of sand dunes in lands where agricultural activities cannot be used, because oil derivatives have a negative impact on agricultural land, and this method is rehabilitated and defects are repaired after a period not exceeding five years (Scherr & Satya Yadav, 1996).

3.6.2 Biological methods (permanent means of prevention):

This method is one of the approaches that provide sustainability in the stabilization of sand dunes, and the presence of vegetation means the permanent stability of the sand dunes. The removal of vegetation cover by humans helped form sand dunes, and the re-vegetation of such areas can eliminate the problem of moving sand dunes, if managed in ways that suit the special environmental conditions of those areas, such as exploiting types of trees that tolerate drought and soil salinity and using trees in the study area (Tamarisk, eucalyptus) for easy propagation, as well as their ability to withstand drought and salinity. These methods in the study area are as follows:-

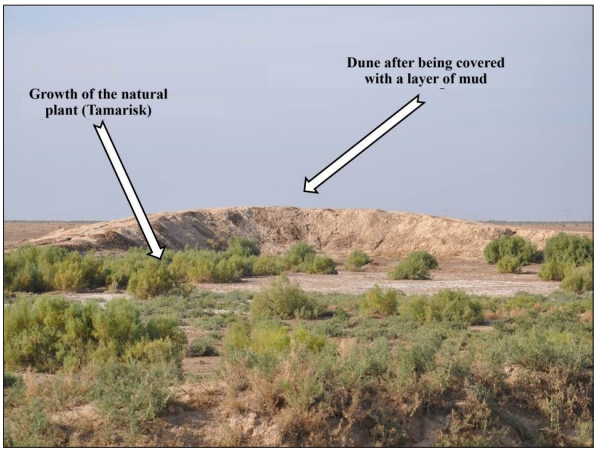

Figure 8. The dunes covered with a layer of clay

1. Development of natural herbs:

It is a method that comes naturally after the sand dune is covered with clay soil, where vegetation is grown on it when appropriate conditions are available, and it is also important to protect it from overgrazing, because the presence of animals on the sand dune removes vegetation cover and destroys the clay layer, which leads to its deterioration again. This requires preventing the entry of animals for grazing purposes. The most important of these plants are Tamarisk, Anabasis, and Saltwort.

2. Cultivation of windbreaks (green belts):

Planting trees in areas with moving sand dunes is important because they act as bumpers to reduce wind speed and improve natural conditions for the growth of native plants in these areas. If planted systematically, they further reduce wind speed and soil erosion. After completing mechanical methods, green belts and windbreaks are planted in sand dune areas, with trees selected for their ability to withstand drought and soil salinity, as mentioned earlier. In the study area, tree types such as Tamarisk and Eucalyptus are planted, among others, and then irrigated only in the first year.

3.6.3 The use of remote sensing and geographical information systems to monitor desertification:

In a study of spatial extensions of the sand accumulations significantly for the years (2000-2005-2013-2019), on the pastoral lands of two regions in the Western Desert of Iraq, depending on the techniques of remote sensing and geographic information system, this covered an area of (1826.5 km^2) (harbi Ibrahim & Said, 2023). The researcher (Alalwany et al., 2021) explained in his study the patterns of sand movement in the Western Desert in Egypt and its impact on the environment in the study area, where the accumulations move 40 meters in three broad directions during the year. The movement of these sand accumulations is related to the prevailing wind system within the region. (Hereher, 2010) Studied the economic risks of sand dune movement and its impact on agricultural development in southern Siwa Oasis in Egypt, he also calculated the area affected by sand dune movement has arrived 50,629 acres, and the cost of economic losses from the seriousness and effects of sand accumulation movement has arrived L.E 3206.7 million. The researcher (Abo, 2015) pointed out in his study of the Ratqa Valley basin, which is part of the Hammad Basin, it can be agriculturally exploited, and the lands of the basin of this valley suffer from the problem of gathering dunes that threaten agricultural areas within the basin of this valley, as well as agricultural lands in the district of Al -Qaim.

Figure (9) illustrates the time trend of the decline in the vegetation cover index (NDVI) in Iraq during the period 2000–2023, reflecting the deterioration of vegetation cover associated with the increasing severity of desertification, drought, and climate change.

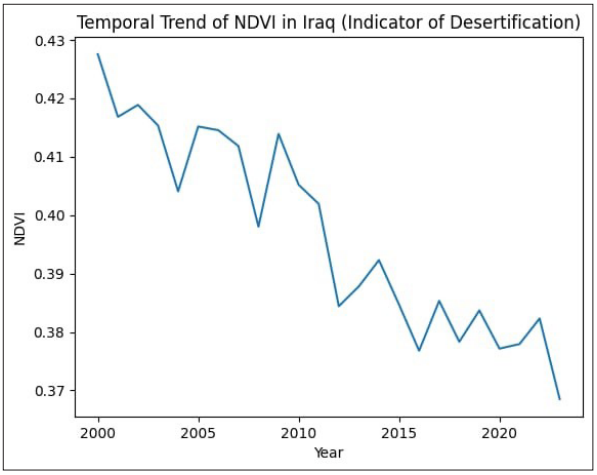

Figure 9. Temporal trend of NDVI in Iraq as an indicator of desertification. Source: MODIS satellite data; adapted following land degradation monitoring approaches by Al-Ansari et al., 2021 reported in JJEES.

Desertification was incorporated into the Sustainable Development Goals outlined in the 2030 Agenda for Sustainable Development in order to address its possible effects on the economy, ecology, and society. The main objective of Sustainable Development Goal 15 is to safeguard, restore, and promote the sustainable use of land-based ecosystems, effectively manage forests, prevent desertification, and halt and reverse land degradation

and biodiversity loss (Yousef et al., 2025). According to projections of future climate change, desertification will increase globally due to changes in temperature, precipitation, carbon sequestration, and atmospheric carbon dioxide levels. Sustainable Development Goal 15.3 aims to rehabilitate land and soil degraded by desertification, drought, and floods. The primary objective is to attain a state of balance by 2030, when restoration activities effectively offset the adverse impacts of land degradation. Addressing desertification is essential for reducing global poverty and mitigating the negative impacts on biodiversity and climate change resulting from human activities (Mukhlif, 2015). Remote sensing technology, by analyzing multispectral images, allows you to monitor climate, soil, and vegetation dynamics of a territory. By means of spectral indices NDVI (Normalized Difference Vegetation Index), MSAVI (Modified Soil-Adjusted Vegetation Index), NDMI (Normalized Difference Moisture Index), NBR (Normalized Burn Ratio), Spectral Albedo values (BRDF) of Liang, BSI (Bare Soil Index), LST (Earth's surface temperature), and the GIS technology, is possible to accelerate the acquisition of spatial-environmental data. The authors started out with research about the use of the aforementioned spectral data, considering the study area Mussomeli Municipality (Caltanissetta Province, Sicily), to evaluate the sensitivity of the area to desertification, in a short period (year, season). In this study, the satellite data are considered in MEDALUS (Mediterranean Desertification and land use) protocol, which adopts data attributable to four Macro factors: protection, soil, climate, and land management (Bolch et al., 2021). The use of geospatial data and Geographic Information Systems (GIS) technologies for monitoring and mapping desertification processes has become essential for understanding landscape dynamics, assessing environmental change, and informing strategies for sustainable land management (Mussumeci et al., 2024).

The Mirzachul was chosen as a desertification monitoring case study. To identify the soil types present in the case study area, Landsat imagery for 1994-2024 and the Soil Map of Uzbekistan served as auxiliary data. We concentrated on the NDVI, SAVI, and WDVI. The trends of sandy bare soil and steppe were also significantly different in 1994, with approximately 830 ha and 3800 ha (Yuan-he et al., 2016), respectively. However, by 2024, the area of sandy bare soil had decreased sharply by about 50% to 1.5 million hectares, while the area of steppe had increased to 2 million hectares (Abdimuminov et al., 2024).

Using information drawn from remote sensing, various aspects of desertification can be analyzed, monitored, and predicted. Over –the years, there have been several approaches to studying desertification using RS. This paper explored the global-scale prevalence and chronology characteristics of research that applied RS to study desertification. Moreover, the research also considered the main methods and elements used to study desertification through remote sensing data analysis. 1991 Desertification Research on the Theme of RS and Application in Desertification Research began from 22.The early application of remote sensing in the research on desertification originates from 22. From 2015 to 2020, more than 40 papers were published on average annually, and this represents a significant increase in the use and availability of remote sensing (RS) technology for desertification assessment (Abdimuminov et al., 2024).

Assessment of Land Degradation Risks. Remote sensing and GIS, as well as tools, are powerful for assessing such risks in different fragile ecosystems, for example, Al Gadeer. The methodology is tested in A by using this combination of remote Sensing, where (Mazahreh et al., 2012). 2019) applied different data and maps as an input to (GIS) to generate potential suitability for various Land Utilization Types (LUTs). Suitability assessment. Land suitability mapping has been developed by integrating soil and climate information within a novel approach.

The monitoring and prediction of desertification in arid areas are important for the solution of environmental and social problems. Supplemental to remote sensing for monitoring land surfaces and ecosystems. The objective of this research is to monitor and predict desertification in the Sistan Plain using raw data from remote sensing, based on a data screening method. The satellite data for the study included images from Landsat 5 and 8 captured in June each of 10 years (1990–2020). The remote sensing-based indices such as LULC map, normalized differential vegetation index (NDVI), enhanced vegetation index (EVI), VCI, TCI, MNDWI, and SI were utilized in the study. Central satellite data, SPI, and SDI environmental indices were also included for analysis (Yousef et al., 2025).

The researcher (Hashemi et al., 2024)pointed out in his study the role of modern technologies in monitoring desertification, as he used Remote Sensing (RS), Geographic Information Systems (GIS), and Global Positioning Systems (GPS) technologies, which have proven their importance in studying soil surveys, as they save time and effort and provide continuous information and values for soil characteristics and their spatial and temporal variations in a comprehensive manner, where risks can be predicted and then the necessary measures taken to reduce them and preserve resources.

Change detection is the process of determining the difference in observing the phenomenon over different time periods. Modern technologies have enabled monitoring and observation of changes in vegetation cover across very large areas at different times. To control and monitor the density and distribution of vegetation in desert environments with unlimited boundaries, repeatedly and continuously integrated by means of remote sensing, is considered important in the preservation of this ecosystem and its maintenance and the preservation of what is deteriorating for the purpose of developing implementation plans to maintain that wealth (Abdulhameed et al., 2022).

4. Desertification in Iraq

Desertification in Iraq is driven by multiple climatic and anthropogenic factors. To provide clarity and synthesis, the following tables summarize the main drivers and impacts across Iraqi regions, as well as the mitigation strategies currently applied and their effectiveness.

Figure 10 and Table 1 show the relative importance of the main factors causing desertification in Iraq, where low rainfall, high temperatures, and soil salinity are among the most influential factors, in addition to overgrazing and poor land management.

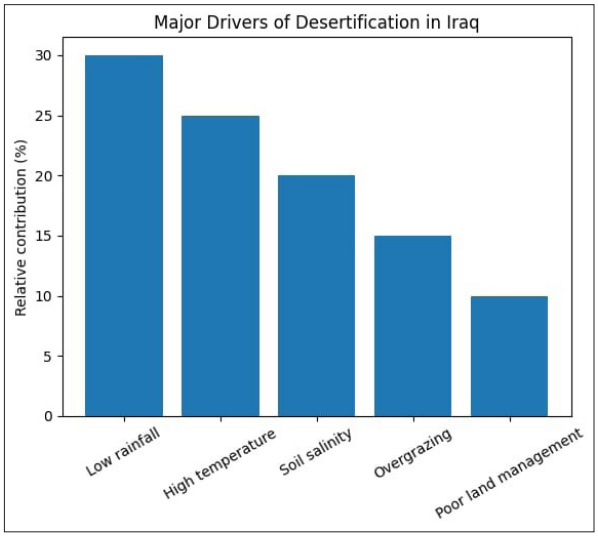

Figure 10. Major drivers of desertification in Iraq. Source: FAO (2020), UNCCD (2022), Salah and Salahat, 2020, JJEES.

Table 1. Main drivers of desertification in Iraq and their regional impacts. Adapted from Alkhateeb et al., 2019; Al-Shamary et al., 2021; Abdulrahman, 2025.

Driver	Most affected region	Main impact
Declining rainfall & rising temperatures.	Southern and central Iraq.	Loss of vegetation cover, increased sandstorms.
Mismanagement of water resources (salinization, evaporation).	Southern provinces (Basra, Dhi Qar).	Soil salinity, reduced agricultural productivity.
Overgrazing.	Northern and central Iraq.	Rangeland degradation, biodiversity loss.
Deforestation .	Anbar and Diyala.	Soil erosion, loss of vegetation.
Population growth & urbanization.	Baghdad and peri-urban areas.	Pressure on resources, unregulated urban expansion.

Several strategies have been adopted to mitigate desertification in Iraq, as shown in Table 2. This shows the effectiveness of each strategy.

Table 2. Mitigation strategies against desertification in Iraq and their effectiveness. Adapted from Rasul (2016), Safriel (2009), UNCCD (2024), Chasek et al. (2019).

Strategy	Application in Iraq	Effectiveness	Notes
Afforestation/reforestation.	Limited campaigns in Anbar and southern Iraq.	Moderate.	Lack of funding and sustainability.
Water management (modern irrigation, water harvesting).	Pilot projects in Kirkuk and Najaf.	High.	Requires scaling-up and government support.
Sustainable agriculture (biochar, soil amendments).	University research and small-scale trials.	Moderate.	Scientifically effective but not widely adopted.
International cooperation (UNDP, FAO projects).	Small-scale initiatives.	Low.	Hindered by instability and limited resources.

Desertification in Iraq is depicted in Figure 11, showing the areas most affected and the environmental impacts of climate change and water shortage.

- The government has launched efforts to address the problem, but is hampered by large hurdles.

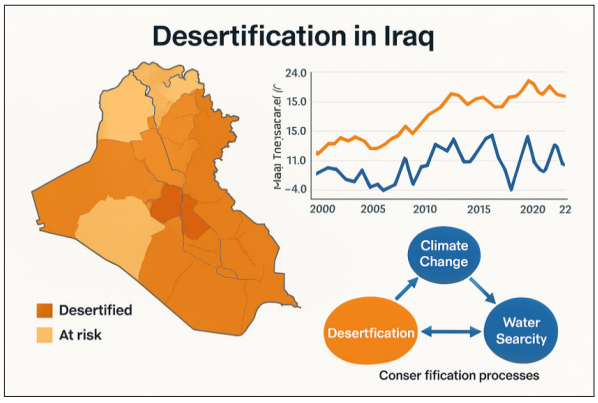

Figure 11. Desertification in Iraq. Adopted from https://masae-analytics.com/

5. Conclusions

The results in Tables 1 and 2, as well as Figs. 9–11, illustrate the intricate relationships of both climatic fluctuations and human activities in shaping desertification across Iraq. The data provided to us is evidence that desertification is a consequence not only of climate change, but also as a result of bad land use and water management … and due to the fact that the people seem to cut off the branch they sit on.

Policy Analysis

Existing policies in Iraq to combat desertification are not coherent and adequate. Reforestation programs remain meritorious but are handicapped by inadequate friend-foe identification, weak community involvement. Water management measures, such as dam building and traditional irrigation based on water-demanding crops, have frequently exacerbated soil salinity and declining groundwater recharge. Additionally, institutional harmonization is insufficient among the Ministries of Agriculture, Environment, and Water Resources, leading to duplication of roles and lack of effective implementation.

Drivers and Impacts

The distribution (Figure 11) shows that desertification hotspots are mainly located in the western and southern sides, where there is the most precipitation decline and temperature increase. These changes in climate, coupled with overgrazing and deforestation, have contributed to increased soil erosion and loss of vegetation.

Effectiveness of Mitigation Strategies

Table 2 indicates that although the strategies have been implemented in some cases – afforestation and sustainable agriculture, for instance – their implementation has low effectiveness due to insufficient funding and lack of farmer participation. While international cooperation (including with its neighbours on transboundary water management) is lacking, Iraq remains exposed to upstream states' water policies.

This assessment verifies that desertification in Iraq is not just an environmental problem, but a strategic issue which affects the ability of the country to ensure food security and sustainable development. The research identifies three main factors for the decline, including poor management of water resources, climate change, and unsustainable land use. Appropriate actions, consequently, effective responses also call for an integrated national policy on management of land and water, the launching of public-awareness campaigns, and the introduction of modern techniques to limit soil degradation. The results presented will be useful in the context of both scientific discussions on desertification and policy-making and development activities in Iraq. In addition, the present work pinpoints areas that would need further investigation in the future, especially technically and economically viable solutions which can enhance Iraq's ability to combat desertification and meet sustainable environmental development.

6. Recommendations

To face these challenges, Iraq needs to consider an integrated approach that encompasses environmental, social, and economic dimensions. Key recommendations include:

1. Establishing early warning systems for drought and desertification.
2. Promoting modern irrigation techniques (e.g., drip irrigation) to reduce water waste.
3. Enhancing regional cooperation with Turkey and Iran on shared water resources.
4. Empowering local communities to participate in afforestation and land restoration projects.
5. Aligning national strategies with UNCCD frameworks and the Sustainable Development Goals (SDGs).
6. Expansion in the studies of using remote sensing and geographic information system as early warning to monitor desertification especially in Iraq.
7. Using the recent technologies to mitigate the creeping of sand dunes towards agricultural lands.
8. Using all means to retain soil moisture which prevent sand particles from transport to other areas.
9. Appropriate use of water harvesting techniques to mitigate desertification.
10. Limiting pastoralists' overgrazing in places that are likely to turn into deserts.
11. Establishing laws to preserve desert plants.
12. Working on afforestation of desert areas with heat-tolerant plants.

References

Abdelfattah, M. A., Dawoud, M. A. H., & Shahid, S. A. (2009). Soil and water management for combating desertification: Towards implementation of the United Nations Convention to Combat Desertification from the UAE perspectives. Proceedings of the International Conference on Soil Degradation, Riga, Latvia. https://www.researchgate.net/publication/259178629_Soil_and_water_management_for_combating_desertification_-_towards_implementation_of_the_United_Nations_Convention_to_Combat_Desertification_from_the_UAE_perspectives

Abdimuminov, B., Mamatkulov, Z., Allanov, K., Abdunazarav, H., Umarova, M., & Choriev, A. (2024). Monitoring and mapping of desertification process using geospatial data and GIS technologies in Mirzachul area. E3S Web of Conferences. https://doi.org/https://doi.org/10.1051/e3sconf/202459003008.

Abdulhameed, I. M., Alhadeethi, I. K., Jabir, A. A., Fayyadh, A. S., Mohammed, A. S., Kamel, A. H., Ghani, E. T. A., Mutar, H. A., Al-Esawi, J. S. E., & Almafrchi, K. Y. (2022). Guideline of Iraqi valleys development. Upper Euphrates Basin Developing Center. https://www.researchgate.net/publication/361007080_Guideline_Of_Iraqi_Valleys_Development_1_Wadi_Horan

Abdulrahman, S. A. (2025). Iraq's Desertification: The Complication of Environmental Security Issues. Natural Built Social Environment Health, 1(01), 81-98. https://doi.org/10.63095/NBSEH.25.720252.

Abdelwahab, M., & Mustafa, M. (2021). A review Research on

Wind Erodibility of Some States and Their Interrelationships in Sudan. Jordan Journal of Earth & Environmental Sciences, 12(4). https://jjees.hu.edu.jo/files/Vol12No4/JJEES_Vol_12_No_4_P9.pdf

Abo, R. S. A.-S. (2015). Sand dunes movement and its impact on development plans, Siwa Oasis. International Journal of Research in Economics and Social Sciences, 5(11), 124–133. https://www.academia.edu/30072199/Sand_dunes_movement_and_its_impact_on_development_plans_Siwa_Oasis?auto=download.

Abusmier, S. A., & Al-Kofahi, S. D. (2024). Examining land use/land cover dynamics in Zarqa Governorate major districts: Implications for urban and environmental sustainability. Jordan Journal of Earth and Environmental Sciences, 16(1), 45–60. https://www.researchgate.net/publication/389891405_Examining_Land_UseLand_Cover_Dynamics_in_Zarqa_Governorate_Major_Districts_Implications_for_Urban_and_Environmental_Sustainability.

Adamo, N., Al-Ansari, N., Sissakian, V. K., Knutsson, S., & Laue, J. (2018). Climate change: Consequences on Iraq's environment. Journal of Earth Sciences and Geotechnical Engineering, 8(3), 43–58. https://iraqi-forum2014.com/wp-content/uploads/2018/05/Vol-8_3_3.pdf.

Agam, N., & Berliner, P. R. (2006). Dew formation and water vapor adsorption in semi-arid environments: A review. Journal of Arid Environments, 65(4), 572–590. https://doi.org https://doi.org/10.1016/j.jaridenv.2005.09.004.

Ahmed, A. D., Abdulhameed, I. M., Ghani, E. T. A., & Ibrahim, M. K. (2020). Selection of water harvesting sites in Horan valley. IOP Conference Series: Materials Science and Engineering. https://doi.org/10.1088/1757-899X/881/1/012183?urlappend=%3Futm_source%3Dresearchgate.net%26utm_medium%3Darticle.

Al-Gurairy, A., & Al-Zubaidi, A. (2023). Climate change and its impact on the expansion of the phenomenon of sand dunes and desertification of agricultural lands in Iraq for the period 1984–2022 (Governorates of Al-Qadisiyah, Al-Muthanna, and Dhi Qar). Israa University Journal of Applied Sciences, 7(1), 75–96. https://doi.org/10.52865/YJPI8019.

Al-Jashaami, S. H., Almudhafar, S. M., & Almayahi, B. A. (2024). Desertification and its impact on agricultural production in Iraq. Library of Progress – Library Science, Information Technology & Computer, 44(3). https://www.researchgate.net/publication/385291236_Desertification_And_Its_Impact_On_Agricultural_Production_In_Iraq

Al-Juboori, J. M. Y., Khairo, A. M., & AlShamary, W. F. (2023, April). The thermal conductivity and matric potential (moisture tension) relationships for soils of different gypsum content. In IOP Conference Series: Earth and Environmental Science (Vol. 1158, No. 2, p. 022007). IOP Publishing. https://doi.org/10.1088/1755-1315/1158/2/022007

Al-Kasoob, G. F., Al-Sulttani, A. H., Al-Quraishi, A. M. F., & Hussein, R. N. (2024). Monitoring drifting sand using spectral index and Landsat TM/OLI datasets in Bahr An-Najaf area, Iraq. In Natural Resources Deterioration in MENA Region: Land Degradation, Soil Erosion, and Desertification (pp. 241–260). Springer. https://doi.org/ https://doi.org/10.1007/978-3-031-58315-5_12

Al-Naji, A. J., & Al-Shammery, T. A. (2019). Mineralogical study of sand dunes fields in Najaf Governorate, Southern Iraq. Iraqi Journal of Science, 239–254. https://doi.org/10.24996/ijs.2019.60.2.6.

Al-Obaidi, J. R., Yahya Allawi, M., Salim Al-Taie, B., Alobaidi, K. H., Al-Khayri, J. M., Abdullah, S., & Ahmad-Kamil, E. (2022). The environmental, economic, and social development impact of desertification in Iraq: A review on desertification control measures and mitigation strategies. Environmental Monitoring and Assessment, 194(6), 440. https://doi.org/10.1007/s10661-022-10102-y.

Mazahreh, S., Bsoul, M., & Hamoor, D. A. (2019). GIS approach for assessment of land suitability for different land use alternatives in semi arid environment in Jordan: Case study (Al Gadeer Alabyad-Mafraq). Information Processing in Agriculture, 6(1), 91–108. https://doi.org/10.1016/j.inpa.2018.08.004

Al-Shamary, W. F. A., Alkhateb, B. A. A. H., Abd Al-Jabbar, M. S., & Kahlel, A. S. (2021, May). Impact of date residues, humic acid and the level of irrigation in growth and yield of onions (Allium cepa L.). In IOP Conference Series: Earth and Environmental Science (Vol. 761, No. 1, p. 012011). IOP Publishing. https://doi.org/10.1088/1755-1315/761/1/012011

Al-Shamary, W. F. A., Alkhateb, B., Ghani, E. T. A., Al-Antary, T. M., & Kahlel, A.-M. S. (2021). The influence of perlite and irrigation management on the properties of potatoes in gypsiferous soil. Fresenius Environmental Bulletin, 30(5), 4771–4778. https://www.researchgate.net/publication/352440377_THE_INFLUENCE_OF_PERLITE_AND_IRRIGATION_MANAGEMENT_ON_THE_PROPERTIES_OF_POTATOES_IN_GYPSIFEROUS_SOIL_CIRCADIAN_RHYTHMS_View_project_Agricultural_patterns_View_project_THE_INFLUENCE_OF_PERLITE_AND_IRRI

Al-Trabulsy, H. A. M. (1993). Investigation of some astronomical phenomena in medieval Arabic chronicles [Doctoral dissertation, Durham University. https://etheses.dur.ac.uk/5691/1/5691_3107.PDF?UkUDh:CyT.

Al-Turaihi, A. S., Al-Zubaydi, J. H., & Manii, J. K. (2023). Engineering and Minerological Characteristics of Sand Dunes of Babylon Governorate, Iraq. The Iraqi Geological Journal, 247-258. https://doi.org/10.46717/igj.56.1E.19ms-2023-5-29

Alalwany, A., Mukhlif, H., & Abdulkareem, B. (2021). A study of the distribution of sand sheet on some pastures in the Western Desert of Iraq. IOP Conference Series: Earth and Environmental Science. https://doi.org/10.1088/1755-1315/904/1/012002

Alkhateeb, B., Alshamary, W., & Aljumily, A. (2019). The role of perlite and irrigation management in water consumptive, growth and yield of potato (Solanum tuberosum L.) in sandy loam soil. Biochemical & Cellular Archives, 19(2). DOI: 10.35124/bca.2019.19.2.4063

Alobaidy, A. S., Tahir, H. T., & Alshamary, W. F. (2024). The role of the use of some soil enhancers and the type of subsurface drip irrigation tube in some of the physical properties of the soil and the efficient use of water for the growth and yield of eggplant crop under protected farming conditions. Sciences, 15(4), 40–51. https://iasj.rdd.edu.iq/journals/uploads/2024/12/03/699c811f25f990d82b10a2400f72e216.pdf

Alshamary, W., Aljumily, A., Ghani, E. T. A., & Alkhateb, B. A. (2021). The influence of binary irrigation (BI), humic acid (HA), and various saline water on water consumption (WC), water use efficiency (WUE) of corn (Zea mays L.). Ecology, Environment and Conservation, 27(1), 316–322. https://www.envirobiotechjournals.com/EEC/v27i121/EEC-46.pdf

Alsultan, R. M. H., Al-Shamary, W. F. A., Ibrahim, M. A., & Kahlel, A. S. (2023). Effect of biochar and amino acid (steam) on growth and green yield of onion (Allium cepa L.) variety (Karbala). IOP Conference Series: Earth and Environmental Science. https://doi.org/10.1088/1755-1315/1259/1/012047

Alsultan, M., Alobaidy, H., & Ahmed, S. (2024). Rainfall anomalies and temperature rise in Iraq: A 20-year analysis. Iraqi Journal of Environmental Science, 18(1), 33–47. https://doi.org/10.1007/s00704-022-03976-y

Al-Tameemi, N., Xuexia, Z., Shahzad, F., Mehmood, K., Linying, X., & Zhou, J. (2025). From Trends to Drivers: Vegetation Degradation and Land-Use Change in Babil and Al-Qadisiyah, Iraq (2000–2023). Remote Sensing, 17(19), 3343.

https://doi.org/10.3390/rs17193343.

Al-Sababhah, N., & Al-Maqablah, M. (2023). Integrated evaluation of soil erosion-prone areas and land degradation risk. Jordan Journal of Earth and Environmental Sciences, 14(2). https://jjees.hu.edu.jo/files/Vol14/No.2/JJEES_Vol_14_No_2_P8.pdf

Al-Weshah, R., Al-Salahat, M., & Al-Omari, S. (2024). Flood hazard mapping from dam break: A case study of King Talal Dam. Jordan Journal of Earth and Environmental Sciences, 16(1), 61–72. https://jjees.hu.edu.jo/files/Vol16/No1/JJEES_Vol_16_No_1_P4.pdf

Ati, A. A. S. S., Al-Daraji, R. A. H., & Al-Ghuraibi, I. M. (2021). Climate change and combating desertification. Methodological book. Ministry of Higher Education and Scientific Research – University of Baghdad – College of Agricultural Engineering Sciences. Unavailable online.

Awadh, S.M. (2024). Drought and Desertification Hazard in Iraq. In: Abd el-aal, A.ea.K., Al-Enezi, A., Karam, Q.E. (eds) Environmental Hazards in the Arabian Gulf Region. Advances in Natural and Technological Hazards Research, vol 54. Springer, Cham. https://doi.org/10.1007/978-3-031-71836-6_14.

Baas, A. C. (2019). Grains in motion. Aeolian Geomorphology: A New Introduction, 27-60. https://doi.org/10.1002/9781118945650.ch2.

Bagnold, R. A. (1954). Experiments on a gravity-free dispersion of large solid spheres in a Newtonian fluid under shear. Proceedings of the Royal Society of London. Series A. Mathematical and Physical Sciences, 225(1160), 49–63. https://royalsocietypublishing.org/rspa/article-media/9364/pdfviewer/48449

Becerril-Piña, R., & Mastachi-Loza, C. A. (2021). Desertification: Causes and countermeasures. In Life on Land (pp. 219–231). Springer. https://doi.org/10.1007/978-3-319-95981-8_81

Boer, B., & Hannam, I. (2021). Restoration of ecosystems and land degradation neutrality. In Fulfilling the Sustainable Development Goals (pp. 392–404). Routledge. https://doi.org/10.4324/9781003144274-30?urlappend=%3Futm_source%3Dresearchgate.net%26utm_medium%3Darticle

Bolch, E. A., Hestir, E. L., & Khanna, S. (2021). Performance and feasibility of drone-mounted imaging spectroscopy for invasive aquatic vegetation detection. Remote Sensing, 13(4), 582. https://doi.org/10.3390/rs13040582

Chasek, P., Akhtar-Schuster, M., Orr, B. J., Luise, A., Ratsimba, H. R., & Safriel, U. (2019). Land degradation neutrality: The science-policy interface from the UNCCD to national implementation. Environmental Science & Policy, 92, 182–190. https://doi.org/10.1016/j.envsci.2018.11.017

Darkoh, M. B. (2018). The nature, causes and consequences of desertification in the drylands of Africa. Land Degradation & Development, 9(1), 1–20. https://doi.org/10.4324/9781315192963-10?urlappend=%3Futm_source%3Dresearchgate.net%26utm_medium%3Darticle

Diwan, S. B. (2013). Spatial analysis of the distribution and forms of sand dunes in Maysan Governorate. Al-Ustad Magazine, 8(205), 113. https://search.mandumah.com/Record/466794

Eklund, L., & Pilesjö, P. (2012). Migration patterns in Duhok Governorate, Iraq, 2000–2010. Open Geography Journal, 5, 48–58. https://doi.org/10.2174/1874923201205010048

El Gamri, T. (2020). Sand dunes: Mechanisms, impacts and control measures in the Sudan. Environment and Natural Resources International Journal (ENRIJ), 5, 1–16. https://www.researchgate.net/publication/349378038_Sand_Dunes_Mechanisms_Impacts_and_Control_Measures_in_the_Sudan

Eltaif, N.I., Gharaibeh, M.A., Fadhil Al-Quraishi, A.M. (2024). Impact of Climate Change on Iraq: Severe Water Scarcity and Desertification. In: Al-Quraishi, A., Negm, A., Benzougagh, B. (eds) Climate Change and Environmental Degradation in the MENA Region. The Handbook of Environmental Chemistry, vol 136. Springer, Cham. https://doi.org/10.1007/698_2024_1100.

Gaur, M. K., Wadhawan, S. K., & Dhir, R. (2023). Geomorphological characteristics of sand dunes and evolution of aeolian landscape for sustainable future in western Thar Desert, Rajasthan, India. In Sand dunes of the Northern Hemisphere (pp. 246–277). CRC Press. https://doi.org/10.1201/9781003125426-19?urlappend=%3Futm_source%3Dresearchgate.net%26utm_medium%3Darticle

Steven Fryberger, Breed C.S., McKee E.D. (1979). A study of global sand seas: Glossary. Prepared in cooperation with the National aeronautics and Space administration, United States Department of Interior, Publisher: U.S. Geological Survey.

Goudie, A. S. (2018). Human impact on the natural environment: Past, present and future. John Wiley & Sons. https://tuannguyenweb.wordpress.com/wp-content/uploads/2017/04/andrew-s-goudie-the-human-impact-on-the-natural-environment_-past-present-and-future-wiley-blackwell-2013.pdf

Goudie, A. S., & Middleton, N. J. (2006). Desert dust in the global system. Springer Science & Business Media. https://doi.org/10.1007/3-540-32355-4

Harbi Ibrahim, I., & Said, Y. H. (2023). Food security policy in Iraq and the challenges of response after 2003. Tikrit Journal for Political Science, 3(pic4), 287–314. https://doi.org/10.25130/tjfps.v3ipic4.238

Hashemi, Z., Sodaeizadeh, H., Mokhtari, M. H., Ardakani, M. A. H., & Aliabadi, K. K. (2024). Monitoring and forecasting desertification and land degradation using remote sensing and machine learning techniques in Sistan plain, Iran. Journal of African Earth Sciences, 218, 105375. https://doi.org/10.1016/j.jafrearsci.2024.105375

Hereher, M. E. (2010). Sand movement patterns in the Western Desert of Egypt: An environmental concern. Environmental Earth Sciences, 59(5), 1119–1127. https://doi.org https://doi.org/10.1007/s12665-009-0102-9.

https://shafaq.com/en/society/Over-half-of-Iraq-now-at-risk-of-desertification-ministry-warns.

Ide, I., Abdourhamane Toure, A., Rajot, J. L., Marticorena, B., Noma Adamou, S., Pierre, C., ... & Garba, Z. (2025). Wind Erosion Dynamics Associated With Land Use on Sandy Soils Under Heavy Anthropogenic Pressure (Southwestern Niger). Land Degradation & Development. https://doi.org/10.1002/ldr.70037

Iraqi Ministry of Planning. (2024). Annual report on desertification and land degradation in Iraq. Baghdad: Government of Iraq. https://wfp.tind.io/record/130575/files/ELR%203541.pdf

Kassas, M. (1995). Desertification: A general review. Journal of Arid Environments, 30(2), 115–128. https://doi.org /10.1016/S0140-1963(05)80063-1.

Lateef, N. S., Ghani, E. T. A., Alnedawi, I. S., & Alshamary, W. F. (2024). Effects of binary irrigation and humic acid on maize yield in saline conditions. International Journal of Design & Nature and Ecodynamics, 19(5), 1725–1732. http://iieta.org/journals/ijdne

Longwell, C. R. (1949). Sedimentary facies in geologic history: Conference at meeting of the Geological Society of America held in New York, November 11, 1948 (Vol. 39). Geological Society of America. https://books.google.iq/books/about/Sedimentary_Facies_in_Geologic_History.html?id=rvGq4Ezu6fsC&redir_esc=y

Maitima, J. M., Mugatha, S. M., Reid, R. S., Gachimbi,

L. N., Majule, A., Lyaruu, H., Pomery, D., Mathai, S., & Mugisha, S. (2009). The linkages between land use change, land degradation and biodiversity across East Africa. African Journal of Environmental Science and Technology, 3(10). Website: https://www.researchgate.net/publication/228913785_The_linkages_between_land_use_change_land_degradation_and_biodiversity_across_East_Africa

Minelli, S. (2016). Land degradation neutrality target setting programme. United Nations Convention to Combat Desertification (UNCCD). Website: https://www.unccd.int/sites/default/files/2018-08/LDN%20TS%20Technical%20Guide_Draft_English.pdf

Mukhlif, H. N. (2015). Monitoring & evaluation status of land degradation in RATGA valley basin in west Iraq using RS & GIS [Master's thesis, University of Anbar].

Mussumeci, G., Mangiameli, M., Costa, R., Piccione, V., Schilirò, M., & Tomarchio, D. (2024). Remote sensing approach for monitoring of macrofactors climate, soil and vegetation (Me.DAL Us. protocol) in the desertification process in Sicily. AIP Conference Proceedings. https://doi.org/10.1063/5.0215558

Pal, S. C., Chatterjee, U., Chakrabortty, R., Roy, P., Chowdhuri, I., Saha, A., Islam, A. R. M. T., Alam, E., & Islam, M. K. (2023). Anthropogenic drivers induced desertification under changing climate: Issues, policy interventions, and the way forward. Progress in Disaster Science, 20, 100303. https://doi.org/10.1016/j.pdisas.2023.100303

Rasmussen, M. (2024). The influence of time, rock properties, and climate on mechanical weathering [Doctoral dissertation, University of North Carolina at Charlotte]. Linke: https://www.proquest.com/openview/8ad53193fbd2a435eefe7e0cfed0d864/1?pq-origsite=gscholar&cbl=18750&diss=y

Rasul, G. (2016). Managing the food, water, and energy nexus for achieving the Sustainable Development Goals in South Asia. Environmental Development, 18, 14–25. https://doi.org/10.1016/j.envdev.2015.12.001

Rasul, G. (2016). Managing the risks of climate-induced desertification in fragile environments. Environmental Development, 20, 1–10.

Reynolds James F. (2013) Desertification. In: Levin S.A. (ed.) Encyclopedia of Biodiversity, second edition, Volume 2, pp. 479-494. Waltham, MA: Academic Press.

Reynolds, J.F., Maestre, F.T., Kemp, P.R., Stafford-Smith, D.M., Lambin, E. (2007). Natural and Human Dimensions of Land Degradation in Drylands: Causes and Consequences. In: Canadell, J.G., Pataki, D.E., Pitelka, L.F. (eds) Terrestrial Ecosystems in a Changing World. Global Change — The IGBP Series. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-32730-1_20.

Safriel, U. (2009). Deserts and desertification: Challenges for sustainable development. Land Degradation & Development, 20(3), 221–239. https://doi.org/10.1002/ldr.907

Salahat, M. A., & Al-Qinna, M. I. (2015). Rainfall fluctuation for exploring desertification and climate change: New aridity classification. Jordan Journal of Earth and Environmental Sciences, 7(1), 27–35. Website: https://jjees.hu.edu.jo/files/Vol7N1/Vol7N1_HQ_P27-35.pdf

Scherr, S. J., & Yadav, I. S. (1996). Land degradation in the developing world: Implications for food, agriculture, and the environment to the year 2020. International Food Policy Research Institute. https://doi.org/10.22004/ag.econ.42280

Shahid, S. A., & Alsumaiti, T. S. (2022). Soil conservation practices and efforts made to combat desertification in the United Arab Emirates. In Global degradation of soil and water resources: Regional assessment and strategies (pp. 273–286). Springer. https://doi.org/10.1007/978-981-16-7916-2_19

Sissakian, V., Al-Ansari, N., & Knutsson, S. (2013). Sand and dust storm events in Iraq. Journal of Natural Science, 5(10), 1084–1094. https://doi.org/10.4236/ns.2013.510133

Sivakumar, M. V. (2007). Interactions between climate and desertification. Agricultural and Forest Meteorology, 142(2–4), 143–155. https://doi.org/10.1016/j.agrformet.2006.03.025

Sombroek, W., & Sene, E. H. (1993). Land degradation in arid, semi-arid and dry sub-humid areas: Rainfed and irrigated lands, rangelands and woodlands. Published by: Food and Agriculture Organization (FAO) of the United Nations, including articles, books, meeting reports, proceedings and studies published by FAO, or prepared in collaboration with FAO. Website: http://agris.fao.org/agris-search/search.do?recordID=XF9657077

Stone, R. O. (1967). A desert glossary. Earth-Science Reviews, 3, 211–268. https://doi.org/10.1016/0012-8252(67)90378-9

Thomas, D. S. (1997). Science and the desertification debate. Journal of Arid Environments, 37(4), 599–608. https://doi.org/10.1006/jare.1997.0293

Tokbergenova, A., Nyussupova, G., Arslan, M., & Kiyassova, S. K. L. (2018). Causes and impacts of land degradation and desertification: Case study from Kazakhstan. In Vegetation of Central Asia and Environs (pp. 291–302). https://doi.org/10.1007/978-3-319-99728-5_11.

UNCCD. (2024). Global Land Outlook – Regional Report: Middle East and North Africa. United Nations Convention to Combat Desertification. UNCCD. (2024). Global Land Outlook – Regional Report: Middle East and North Africa. United Nations Convention to Combat Desertification. https://www.unccd.int

Vogt, J., Safriel, U., Von Maltitz, G., Sokona, Y., Zougmore, R., Bastin, G., & Hill, J. (2011). Monitoring and assessment of land degradation and desertification: Towards new conceptual and integrated approaches. Land Degradation & Development, 22(2), 150–165. https://doi.org/10.1002/ldr.1075

Wairiu, M. (2017). Land degradation and sustainable land management practices in Pacific Island countries. Regional Environmental Change, 17, 1053–1064. https://doi.org/10.1007/s10113-016-1041-0

Wang, X., Dong, Z., Zhang, J., & Chen, G. (2002). Geomorphology of sand dunes in the Northeast Taklimakan Desert. Geomorphology, 42(3–4), 183–195. https://doi.org/10.1016/S0169-555X(01)00085-X

World Health Organization. (1992). Our planet, our health: Report of the WHO Commission on Health and Environment. WHO. https://apps.who.int/iris/handle/10665/37933

Yousef, G. S., Dibs, H., & Naje, A. S. (2025). A Review of Environmental Monitoring for Land Desertification Using Geospatial Analysis and Remote Sensing. Nature Environment & Pollution Technology, 24(2). https://doi.org/10.46488/NEPT.2025.v24i02.D1697

Zade, S., Gourkhede, P., Vaidya, P., Singh, R. S., Sinha, S., Kumar, A., & Kumar, V. (2021). Problem soils and their management practices. Publisher: Mr.Gajendra Parmar, Web Site:www.parmarpublisher.com, ISBN: 978-81-925878-3-5