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SOIL TYPES AND EROSION IN IRAQ: A CRITICAL DISCUSSION

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Abstract

Iraq includes different tectonic zones and different physiographic provinces; accordingly, different types of soils, and erosion types and intensities are developed in different parts of Iraq. There were many attempts to compile a map of soil types in Iraq by different authors, which we mentioned very briefly. The main soil types are alluvial, colluvial, residual, and eolian. Also, a brief description of the physiographic provinces is given. We have presented the active erosion types in Iraq, with a discussion of the reasons for soil erosion and degradation in different parts of Iraq excluding the northern and northeastern parts that belong to the Kurdistan Region of Iraq (KRI). The main erosion agents are water and wind. The active erosion types are sheet, rill, and gully erosion; respectively; however, wind erosion cannot be ignored. We also discussed the factors that control soil degradation in Iraq. Moreover, we presented different relevant maps and field photos, which express relevant data about erosion types and damages.

Keywords: Soil types; Erosion types; Erosion agents; Soil degradation; Iraq.

1. Introduction

According to Buday (1980), the Qulqula Radiolarian Formation (QRF) (Jurassic Early Cretaceous) was defined by Bolton (1955), along Qulqula Gorge at the foothill of the Qandil mountain between Kozina and Baqiawa villages. He indicated its outcrop as a very thick sequence of bedded chert, siliceous shale, and cherty limestone. Buday (1980) explained that the lower and upper contacts of the formation are uncertain due to the intense deformation of the outcrop folding, faulting, and thrusting. Many authors such as (Aswad & Elias, 1988), (Jassim & Goff, 2006), (B. Al-Qayim et al., 2012), (Omar et al., 2015) and (Ali et al., 2017)

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mentioned the Qulqula Radiolarian Formation as a Group (Qulqula Group) based on the fact that the latter formation is overlaid by Qulqula Conglomerate Formation (Cenomanian). Recently (Baziany, 2014) studied it in detail QRF and divided it into several units, and indicated 24 thrust faults inside it.

Iraq possesses diverse physiography: mountains, rolling hills, alluvial plains, and desert plains. This diversity has formed different physiographic provinces, and in each province, usually, one soil type prevails. However, more than one soil type occurs in each province but does not cover large areas as the main soil type.

Harmonized World Soil Database (HWSD) (Nachtergaele et al. 2012) is one of the sources of the Soil types, that cover the world. This database consists of a 1 Km (or 30 arc-second) raster image, with a very good database. However, the HWSD deficiency is its resolution, which is ~1:3,500,000. Abbreviations should be defined at first mention and used consistently thereafter. Abbreviations should not be used only once unless it seems necessary for clarity.

1.1. Previous works

In Iraq, different attempts were carried out to compile a soil map by soil survey and classification with different authors; the majority of them were for agricultural purposes. However, some of the compiled soil maps emphasize gypcrete and other mechanical properties for civil constructional purposes. The number and type of soil units are incomplete; hitherto this is attributed to the lack of semi-detailed or detailed surveys of soil covering the whole area of Iraq. Only 35% of Iraq is covered by a semi-detailed survey work with 1:50,000 to 1:25,000 soil maps (Muhaimeed et al. 1997). Gibbs (1954) compiled a soil conservation map. He made a general soil conservation survey at a scale of 1:2,000,000 for the whole area of Iraq. Moreover, a more detailed survey has been conducted for an area near Chem Chemal, northeast of Kirkuk City. He mentioned that water and wind erosion are much more important as 52570 Km^2 have serious water erosion, 78894 Km^2 have serious wind erosion and the rest of Iraq has slight to moderate water or wind erosion. However, after seven decades, a lot of changes happened in soil types and their coverage areas; besides the erosion intensity and agents.

The pioneer exploration work of Buringh in 1960 also emphasized soil classification for agricultural purposes using the 1938 system, through which he recognized 18 great soil groups. However, Buringh (1960) mentioned in detail soil erosion and conversation and the written book can be considered as the most comprehensive book about the soil types, soil erosion, and soil conservation in Iraq; hitherto. Barazanji (1973) compiled a soil map of Iraq in his postgraduate study. He emphasized the gypsiferous soils in different parts of Iraq. He recognized different types of gypsiferous soils. Al-Agidi (1976) performed a soil classification for Iraqi soils, especially alluvial soils. The study was also forwarded for agricultural purposes. FAO (1977) compiled the Soil Map of South Asia as a part of the Soil Maps of the World. The presented soil classes are those, which belong to the agricultural uses. However, gypsiferous soils were shown on the maps too. Iraq Geological Survey (GEOSURV) mapped different types of soils during the regional geological mapping of Iraq (1972 – 1984). A series of geological

maps at a scale of 1:250,000 was published during 1992 – 1998. The compiled maps show different types of soils, which were classified depending on geological terms. Moreover, the mentioned series was used in compiling the geological map of Iraq (Sissakian and Fouad, 2015). Azeez and Rahimi (2017) compiled a map that shows the distribution of gypsiferous soil using geoinformatics techniques for some Aridisols in the Garmian area; northeast of Kirkuk City. They compiled two maps to show the distribution of gypsiferous soils in the Garmian area. The first one shows the output of supervised classification and maximum likelihood for specific soil types, and the second map shows the thermal-based classification. The thermal-based map can predict the gypsiferous area in a better way, than the classification based only on the spectral properties of non-thermal bands. Muhaimeed (2019) compiled a general soil map of Iraq, following USDA soil Taxonomy, 300 pedons representing all soil types in Iraq were collected from the previous works. A digitized soil map at a scale of 1:500,000 was compiled. The maps show five soil orders; each one shows some variations with the common properties reflecting the effect of the dominant soil formation factors. The soil orders are arranged according to their dominance as follows: Aridisols (62.2%), Entisols (16.2%), Inceptisols (12.6), Mollisols (3.8%), and Vertisols (1.2), respectively. Muhaimeed (2019) studied the available soil information in Iraq and concluded that among the total coverage of the area (438,317 Km^2), he found 94,500 Km^2 of agricultural land and 8,230 Km^2 of forest land. Moreover, he mentioned that 39% of Iraq is Desert, 10% is terrain land, 21% is mountains, and 30% is plains, including marshes and lakes.

1.2. Aim

The current work aims to explain the main soil types in different parts of Iraq; excluding KRI. To discuss the main erosion types and agents, and the reasons for soil degradation in different parts of Iraq. Besides, explaining briefly each physiographic province in Iraq.

2. Materials and Methods

The authors have reviewed tens of published papers, maps, and books and reviewed all existing maps that show soil types and erosion in Iraq. Different satellite images were interpreted manually to achieve the aims of the current study. The main sources of the used data about the soil types are the regional geological mapping reports (1972 – 1984), and the published geological maps at a scale of 1:250000 with the enclosed geological reports of the Iraq Geological Survey (GEOSURV). Moreover, the geological map of Iraq, scale 1:1000000 (Sissakian and Fouad, 2015) with its Explanatory Booklet is used to quote relevant data about soil types in Iraq. Many field photographs are added to illustrate erosion types and their effect on soil degradation, besides some relevant maps. The authors have reviewed the Physiographic Provinces in Iraq and presented a brief explanation for each province.

3. Physiographic Provinces in Iraq

Different physiographic maps were compiled in Iraq with different concepts; therefore, the terminology of the physiographic provinces and/ or units is quite different in different maps. The most common is that prepared by Buringh (1960) when he used agricultural terms rather than physiographic ones. The most recent physiographic map is that compiled by Sissakian and Fouad (2015), we have adopted the provinces and described them briefly; hereinafter (Excluding KRI).

3.1. Western Desert Province (WDP)

It occupies the western part and a portion of the southern part of Iraq (Figure 1). It is gently sloping land, increasing southwestwards, starting from about 300 m (a.s.l.), in its eastern margin to 998 m (a.s.l.), in Jabal An'aza (Figure 1). This province is dissected by long valleys; more than a few hundreds of kilometers, some of them are canyon-like. In the western part, isolated hills and plateaus form outstanding geomorphological features. Ga'ara Depression is another outstanding feature, with its well-known three isolated hills "Al-Afayif", and others. The exposed rocks have a wide age range. Vast parts in the west are covered by residual soil, which is reddish-brown silty clay with a thickness of up to 3 m. Gypcrete is well developed, especially in Al-Ga'ara Depression indicating a wet climate during the Pleistocene. Sheet and wind erosion are the most effective; however, rill erosion acts on slopes and very rarely gully erosion in deep canyon-like valleys. The northeastern part is a highly karstified area, with different types of karst features, especially in the Haditha vicinity.

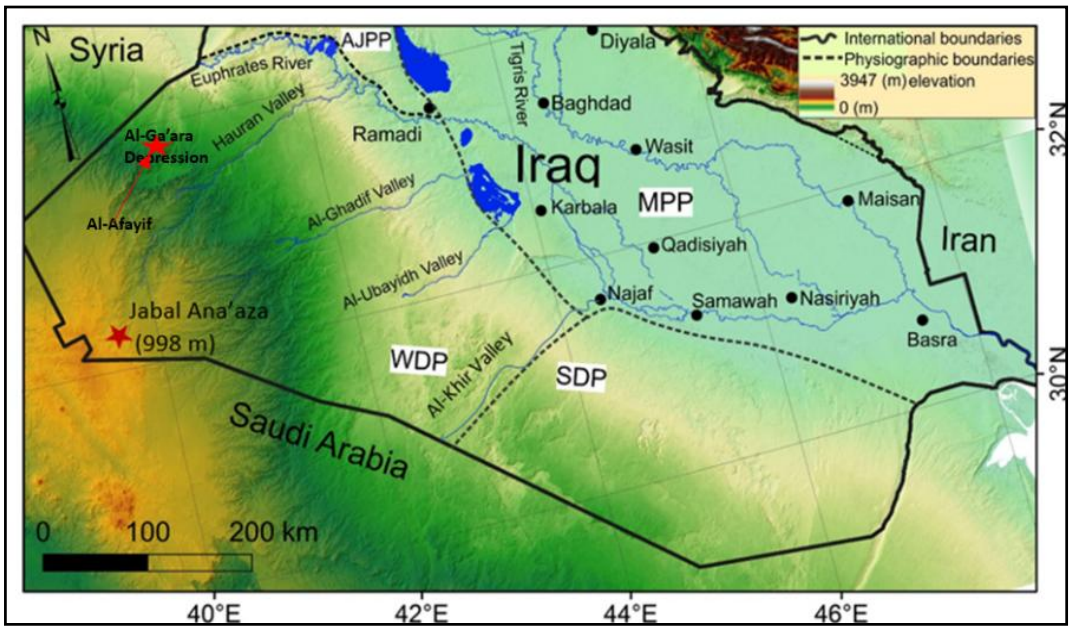

Figure 1. The Western Desert (WDP) and Southern Desert (SDP) provinces over the shaded relief.

3.2. Southern Desert Province (SDP)

It is the southeastern continuation of the Western Desert Province, being divided by Al-Khir Valley, and extends south of the Euphrates River to the Iraqi – Saudi Arabian borders (Figure 1). It is flatter as compared to the Western Desert, dissected by a very complex drainage system, in the form of shallow and wide valleys, which commonly open in circular depressions of karst type inform of blind valleys. The elevation of the land ranges from (100 – 300) m (a.s.l.). The main soil type is residual soil with alluvial soil filling the shallow and wide valleys and karst depressions, alluvial fans are also developed locally. The soil is silty and sandy with a thickness of up to 2 m; with rock fragments mainly of chert, which are covered by desert varnish. The main erosion types are sheet, rill, and wind erosion; however, in main valleys, galley erosion is active, especially during floods. This province is characterized by the presence of dens karst phenomenon in the form of sinkholes or shallow circular depressions. Al-Salman Depression is an outstanding geomorphological feature, it is a karst depression, and the floor is covered by a thick gypcrete indicating a wet climate during the Pleistocene.

3.3. Mesopotamian Plain Province

It forms the central part of Iraq (Figure 2), being of flat nature, with an elevation of 150 m (a.s.l.) in the extreme northern parts, which is limited by Himreen and Makhoul ranges, and zero elevation along the Arabian Gulf. The western limits are almost represented by the Abu Jir–Euphrates Fault Zone.

The province is covered by Quaternary sediments, mainly of alluvial plains of the Tigris and Euphrates Rivers and their tributaries. In the eastern part, alluvial fans are developed, followed by sheet run-off plain. The main soil type is alluvial and Aeolian. The main erosion types are sheet and wind erosion. The latter is increasing widely causing desertification, especially around the main sand dune fields like Baiji, Shary, Central part of the Mesopotamian Plain. Moreover, sabkhas are developed in many places. In the southeastern part; coastal sabkha is developed and covers a large area. Gypcrete is also developed in some parts like Karbala – Najaf plateau, the cupping Al-Fatha alluvial fan in the north, and parts of the alluvial plains alongside the eastern borders of the province.

3.4. Al-Jazira Plain Province

It occupies the central western part of Iraq (Figure 3). It is almost a flat plain, with elevation ranges from 100 m to 600 m (a.s.l.). The land slopes from its central part towards east, south, and west, however, its northwestern parts slope towards west, south, and east. The soil cover is of the residual type being highly gypsiferous due to the exposures of gypsum within the Fatha Formation (Sissakian and Fouad, 2015). The province is characterized by a very dense karst phenomenon and the presence of salt marshes; like Snaisla, Ashqar, Albu Gharis, and Al-Taweel. The sheet, rill, and gully erosions are very active, besides the wind erosion.

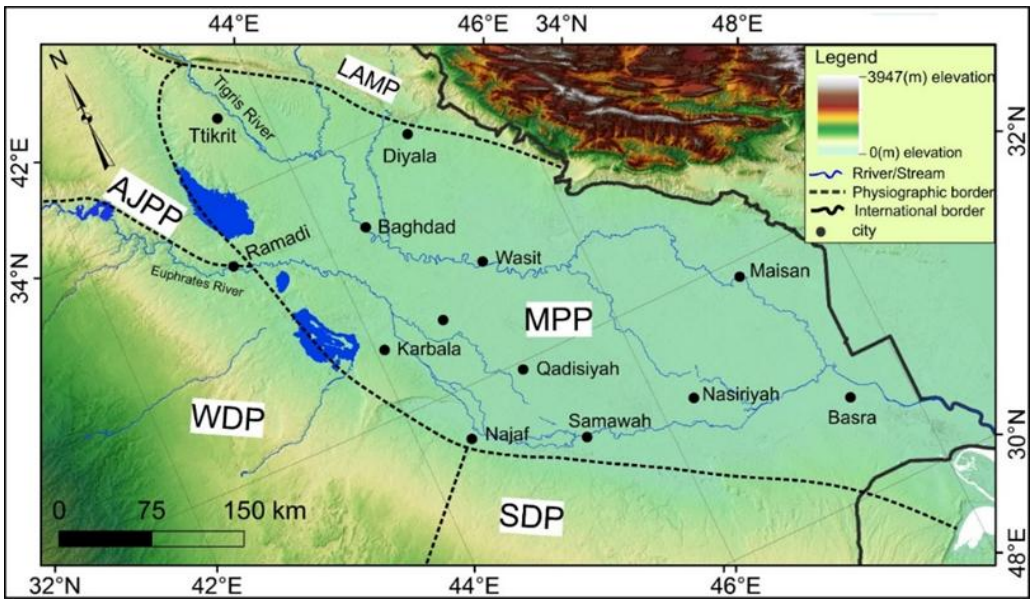

Figure 2. Mesopotamian Province (LAMP = Low Amplitude Mountainous Province, and AJPP = Al-Jazira Plain Province) over the shaded relief.

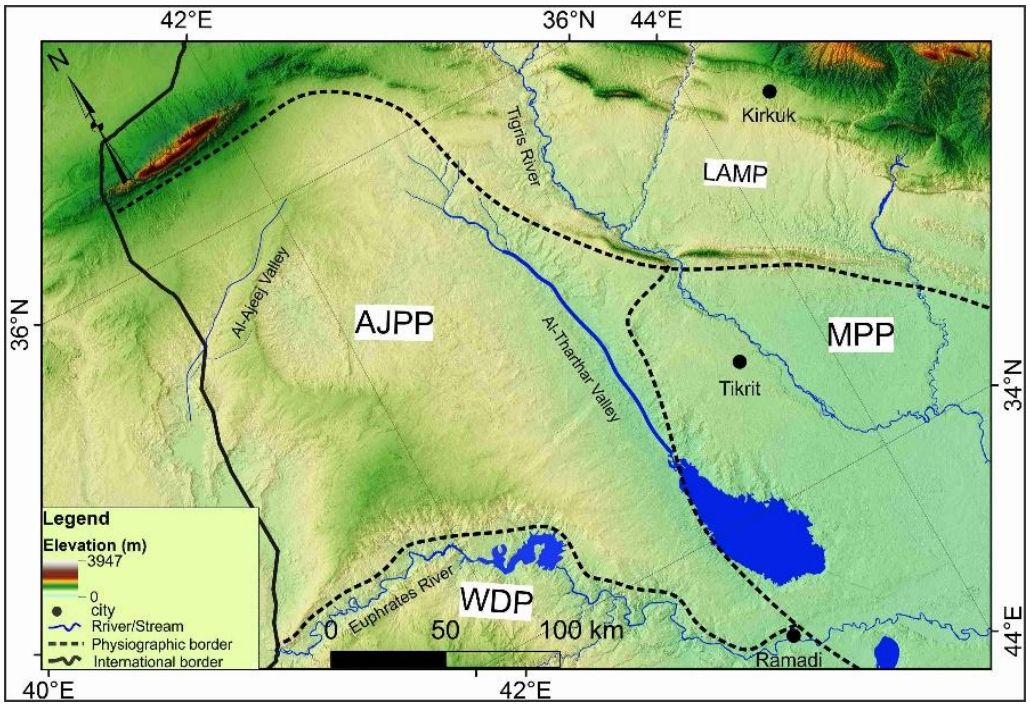

Figure 3. Al-Jazira Plain Province (AJPP) over the shaded relief.

3.5. Low Amplitude Mountainous Province

It extends from the east, along the Iraqi – Iranian borders, to the northwest along with the Iraqi – Syrian borders (Figure 4). It forms hilly and mountainous areas; ascending towards the north. The elevation ranges from (150 – 1000) m (a.s.l.), with different sloping directions due to the presence of longitudinal anticlines, separated by wide and shallow synclines. The developed

soils are: 1) Residual, 2) Colluvial, and 3) Polygenetic. The constituents of the soils are highly variable depending on the parent rocks and structural position. In synclines, the polygenetic soil prevails with a thickness attaining (1 – 8) m, whereas in anticlinal areas, the residual and colluvial soils prevail with a thickness attaining 3 m. Gypcrete is developed as belts surrounding the anticlines. The rill, sheet, and gully erosions are the main types, besides wind erosion.

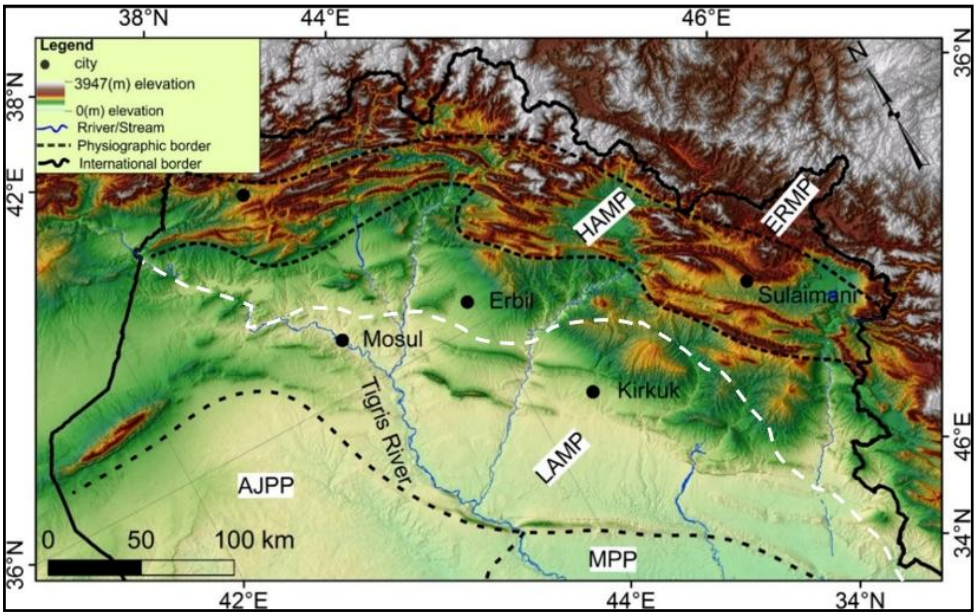

Figure 4. The Low Amplitude Mountains (LAMP), High Amplitude Mountainous Province (HAMP), and Extremely Rugged Mountainous (EHMP) Province over the shaded relief. The white dashed line represents a tentative southern boundary of the KRI.

3.6. High Amplitude Mountainous Province and Extremely Rugged Mountainous Province

Both provinces are within the KRI (Figure 3). Therefore, they are excluded from the current work.

4. Soil Types

We presented a brief description of the soil types in different parts of Iraq based on their morphological position and main constituents. The used data depends on Yacoub (2011), Sissakian and Fouad (2015), and Sissakian et al. (2020). The main soil types are briefed hereinafter.

4.1. Alluvial Soils

Alluvial soils cover the whole Mesopotamian Plain (Yacoub, 2011) with all subtype details sediments like; flood plain, depression fill, valley fill, crevasse splay, sheet runoff, alluvial plain; both old, which includes in some locations, five stages and recent types, river terraces (Sissakian and Fouad, 2015). The thicknesses of alluvial soils are highly variable and depend on 1) The subtype of the soil, 2) The morphological position, 3) The distance from the source

area, and 4) The coverage area. The constituents of the subtypes also are highly variable and depend on the same factors that control the thicknesses. Apart from the valley fill and terraces, sheet erosion is very active in other alluvial soil types; especially in depression fill and flood plain sediments.

In the Western and Southern deserts, Al-Jazira Plain, and the Low Mountainous Province, alluvial soils are rare and occur usually in valleys as valley-filling sediments, with very limited flood plain sediments, terraces, and alluvial fans. The thicknesses and main constituents are also highly variable and controlled by the same factors as in the Mesopotamian Plain.

4.2. Aeolian Soils

The main occurrences are in the Mesopotamian Plain and cover vast areas (Figure 5), for example, the Baji dunes, Shari dunes, Central dunes and Southern dunes of the Mesopotamian Plain, and Al-Teeb dunes such as Jabal Mishdakh. However, in the Western and Southern deserts, Al-Jazira Plain, and the Low Mountainous Province, small sand dunes occur with very limited coverage areas, besides Nabkha deposits (Figures 6, and 7).

The main types of dunes are Barchan; other types like Transverse, Elongated, Climbing, and Falling are rare. The accumulation of aeolian sand as sand sheets occurs either on slopes or even flat areas (Figures 6, and 7) in the previously mentioned areas. The constituents of all existing sand dunes; apart from those in the central and southern parts of the Mesopotamian Plane are the same and consist of fine sand and silt; mainly of quartz, carbonate, and less amount of feldspar, and rock fragments. Whereas, those of the Mesopotamian Plain consist mainly of clay particles associated with dense anthropogenic sediments. The thickness of the dunes is generally up to 5 m but occasionally may reach 25 m, whereas the sand sheets are generally less than 1 m (Yacoub, 2011).

4.3. Residual Soil

Large areas of the western part of the Western Desert are covered by residual soil. The soil is brown to reddish brown, silty, and clayey with small rock fragments, which increase in size and abundance depth wards. The thickness ranges from (0.5 – 1.5) m but exceptionally may reach a few meters. In the Southern Desert, and Al-Jazira Plain, the residual soil is not well developed like in the Western Desert. In the former case, the residual soil contains a lot of chert fragments and sand sheet cover (Figure 7a), whereas in the latter case, the residual soil is highly gypsiferous due to the wide exposures of the Fatha Formation that includes thick gypsum beds (Sissakian and Fouad, 2015). The thickness ranges from less than one meter up to 1 m.

In the Low Amplitude Mountainous Province, the residual soil has a special development, it is mixed with colluvial and alluvial soils and is called Polygenetic soil; usually filling the synclinal roughs as wide undulatory plains. The composition is highly variable depending on the exposed rocks in the area. The thickness may reach a few meters. In the Mesopotamian Plain, there is no residual soil.

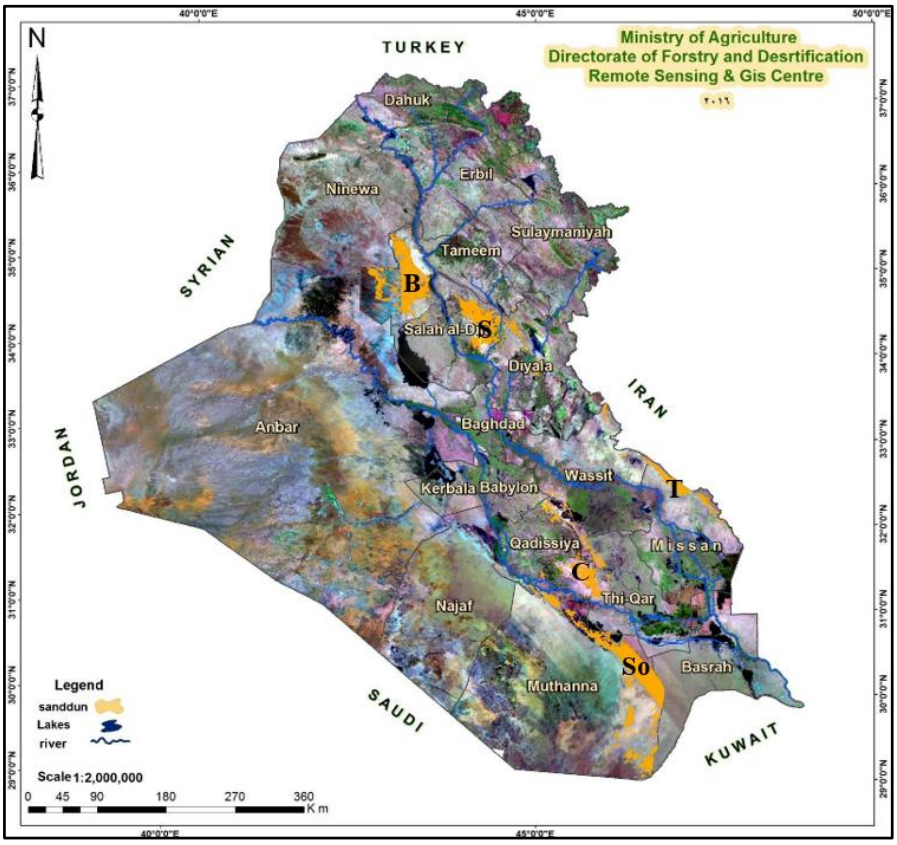

Figure 5. Landsat image (2006) showing the distribution of sand dunes in Iraq (Modified from Al-Farraji, 2016), B = Baiji dunes, S = Shari dunes, C = Central dunes, So = Southern dunes, T = Al-Teeb dunes.

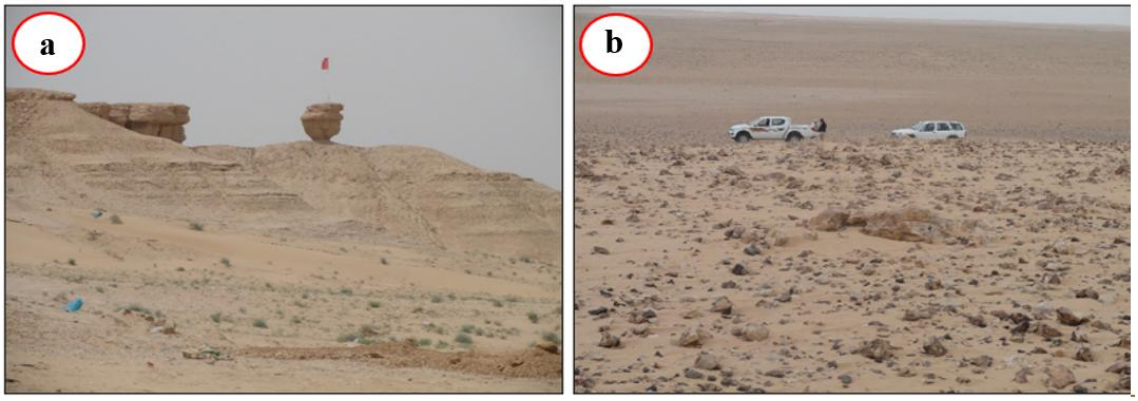

Figure 6. a) Mushroom form at Al-Najaf vicinity, note the accumulated aeolian sand on the slopes, b) Disintegrated very hard rocks including chert at the south of Al-Nasiriya city forming Serir morphology with dense aeolian sand accumulation.

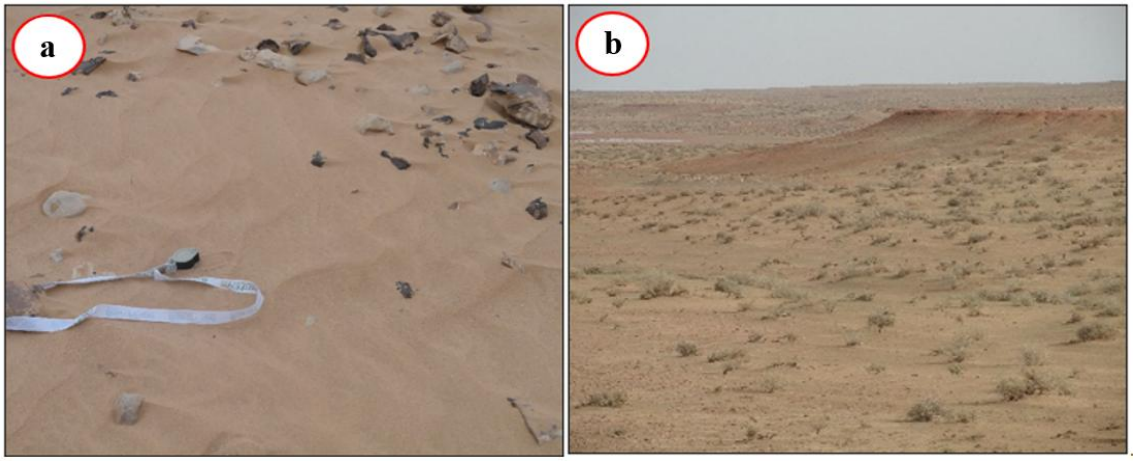

Figure 7. a) Accumulated sand sheet with chert fragment south of Al-Nasiriya city, and b) Combined rill, wind, and sheet erosion at slopes and floor (Left upper corner) of Al-Slaibat Depression (SW of Al-Nasiriya city).

4.4. Colluvial Soils

Colluvial soils are well developed in the Low Mountainous Province around mountains (anticlines) forming narrow belts with gentle slopes where rill erosion is very active. In The Western and Southern deserts and Al-Jazira Plain, colluvial soils are developed on the banks of the main valleys, along the main cliffs (Figure 7b), also forming continuous belts with gentle to steep slopes depending on the size of the valley or the height of the cliff. In both cases, the rill erosion is very active. Locally, the colluvial soils are partly covered and/or contaminated with the aeolian soil (Figure 6a), especially those slopes that face northwest because the prevailing wind direction is NW – SE. In the Mesopotamian Plain, colluvial soil is very rarely developed on the rims of elevated areas and archeological hills; with a thickness of less than 1 m.

4.5. Gypcrete

The gypcrete is well developed in the Low Amplitude Mountainous Province, especially where the Fatha Formation is exposed forming continuous belts around the anticlines. It is a highly gypsiferous soil, locally very hard. The thickness is highly variable and may reach a few meters (Sissakian and Fouad, 2015). It is also well developed in the eastern part of the Western Desert, and the western margins of the Mesopotamian Plain, especially in Fallujah, Habbaniyah, Karbala, and Najaf vicinities. Locally, they are covered by a thin veneer of sand sheets and scattered pebbles. The percentage of the gypsiferous materials is highly variable, the thickness ranges from (0.5 – 2.0) m.

4.6. Sabkha

The main sabkhas are restricted to the shallow depressions and playas; particularly those situated along the western and southern margins of the Mesopotamia Plain (Yacoub, 2011). Different types of Sabkhas are developed; such as Inland, Tidal, and Estuarine depending on

the morphological position. However, small sabkhas are also developed in the Western and Southern deserts, the Low Amplitude Mountainous Province; filling shallow depressions. In Al-Jazira Plain, Sabkhas are well developed in many large depressions, like Bawara, Al-Taweel, Snaisla, Ashqar, Geziz, and Taweel, they all are large salt pans filled by sabkhas. The thickness generally varies between a few meters (Sissakian and Fouad, 2015).

5. Erosion Types and Agents

5.1. Erosion Types

Erosion is one of the primary causes of land degradation. It is responsible for about 84% of land degradation worldwide (Toy et al. 2002; Blanco-Canqui and Lal 2008). It is a result of the combined effects of tectonic uplift, erosion, and different rock strengths. Besides, man-made causes like deforestation, overgrazing, haphazard constructions, road cuts, land use changes, unorganized agricultural effects, haphazard quarrying, and off-road driving.

The majority of Iraq has a gently sloping and horizontal nature, especially in the Mesopotamian Plain (Figure 8a); however, the relief increases north, northeast, and southwestwards. Therefore, the erosion intensity is not high depending on the rainfall amount (Figure 8b), which increases mainly north and northeastwards.

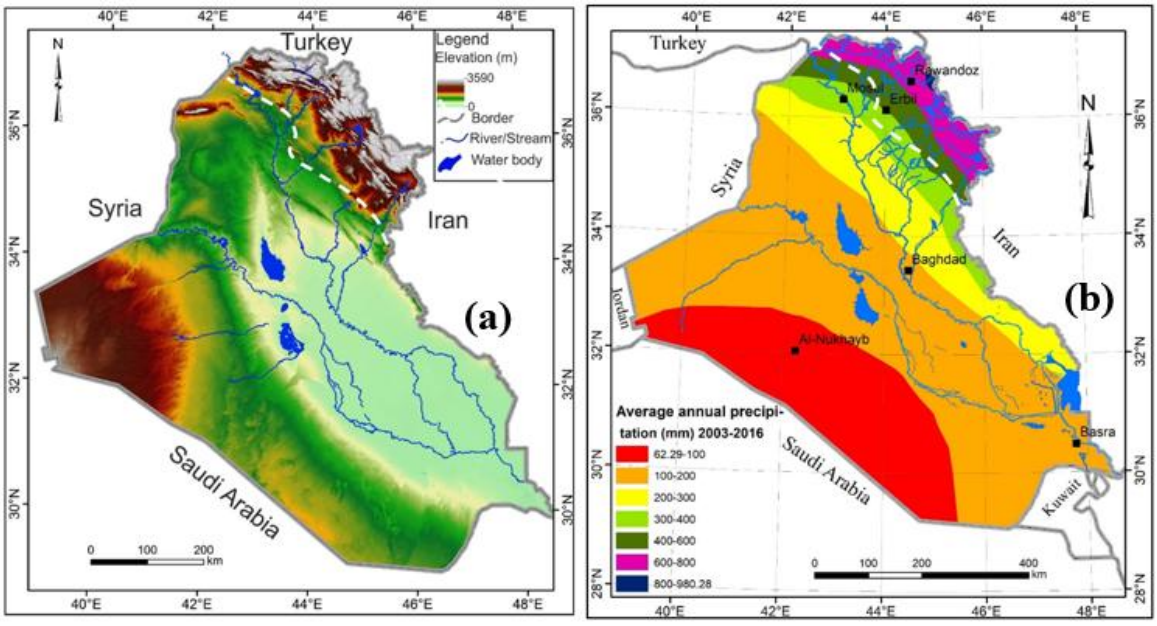

Figure 8. a) Shaded height and relief map of Iraq, the dashed white line represents the tentative southern boundary of the KRI, b) Average annual precipitation map of Iraq for the period (2003 – 2016) using Tropical Rainfall Measuring Mission (TRMM) data (Othman et al., 2020a and b). The dashed white line represents the tentative southern boundary of the KRI.

The vegetation cover (Figure 9) also plays a significant role in erosion intensity and erodibility of existing soil, which covers different parts of Iraq. However, occasionally very intensive erosion may take place during heavy rain showers. These are restricted to the eastern parts of

Iraq where the seasonal streams and valleys flow from the Iranian side into the Iraqi side causing severe damage to infrastructure and inundation of agricultural fields.

Some main valleys in the Northern and Southern deserts, and Al-Jazira Plain also exhibit severe erosion during floods causing soil degradation and severe damage to existing infrastructure; although the number of flood occurrences is highly decreased due to global warming and climate change. Due to global warming and climate change, the amount of rainfall and duration are highly changed causing seasonal floods in different parts of Iraq and during different parts of the year. Such unexpected floods have severe destruction forces and cause soil degradation, especially in flat areas like the Mesopotamian Plain. Three main erosion types are occurring in Iraq; these are 1) sheet erosion, 2) rill erosion, and gully erosion.

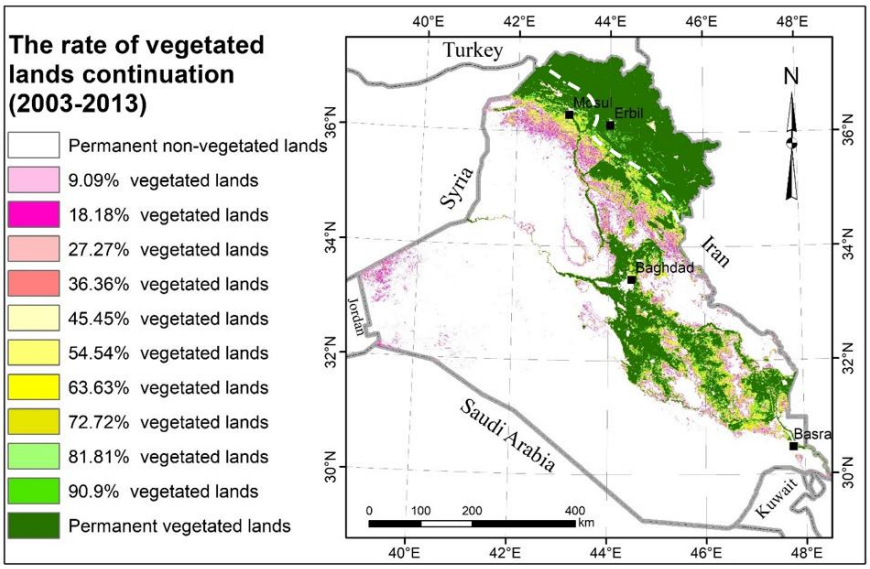

Figure 9. The rate of vegetated lands continuation (2003 – 2013) for Iraq in 2013 of EROS Moderate Resolution Imaging Spectroradiometer (eMODIS) (USGS, 2020). The dashed white line represents the tentative southern boundary of KRI.

5.1.1. Sheet Erosion

In the Western and Southern deserts, the Sheet Erosion is the most active than other parts of Iraq because of its flat nature, which is covered by residual soil. The traces of the erosion are in the form of crescent-shaped groves, the height, length, and spacing of the grooves depend on 1) the type of the soil and its hardness and compactness, 2) the thickness of the soil, 3) the gradient of the slope, 4) the amount of the water running as sheet flow, and 5) the duration of the running water as sheet flow.

In Al-Jazira Plain area where the terrain is almost flat with very gentle sloping (Figure 8a), the main erosion type is sheet erosion, where thick layers of residual soil and/ or soft green marl beds of the Fatha Formation (Sissakian and Fouad, 2015) are washed out forming step morphology, which extends for few hundred meters with a height of up to one meter.

In the Mesopotamian Plain, especially in the eastern parts, sheet erosion is very active during heavy rainfall and causes extreme damage to infrastructure (Figures 10 and 11), agricultural fields, and soil degradation due to huge amounts of flooded water and weak soil.

In the Low Amplitude Province, areas suffering from sheet erosion are rare because flat areas in the province are rare. In restricted areas like south of Kirkuk where the land is covered by polygenetic soil, sheet erosion is active as in the Mesopotamian Plain.

Figure 10. Flooded streams in the eastern part of Iraq (Mesopotamian Plain). a) An eroded embankment, b) A damaged culvert.

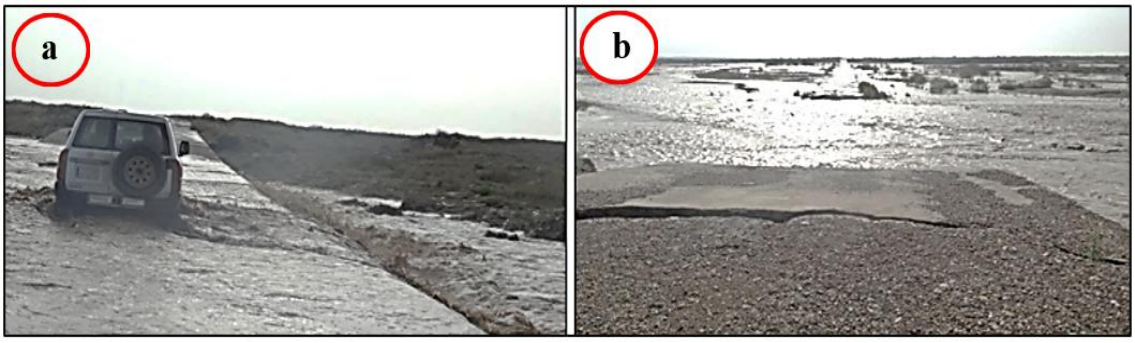

Figure 11. Flooding in the eastern part of Iraq, a) An over-flooded road, and b) Sheet flood causing inundation of agricultural fields and the main road.

5.1.2. Gully Erosion

Gully erosion is very active in the Western and Southern deserts during floods, especially in large valleys like Wadi Hauran (Figure 12) and Wadi Al-Aqrawi (Figure 13a), respectively, which occasionally happen during the rainy seasons. The height of the flood front may reach 2 m, with great destruction ability (Figure 13a), and may last a few days.

The Gully erosion also is active in the mountainous and hilly parts of Iraq (Low Amplitude Mountainous Province) where deep valleys exhibit gully erosion causing landslides (Figure 13b) and locally forming badland topography (Figure 14a).

Figure 12. Flood in Wadi Hauran in the Western Desert, a) In Rutbah town, b) East of Rutbah town.

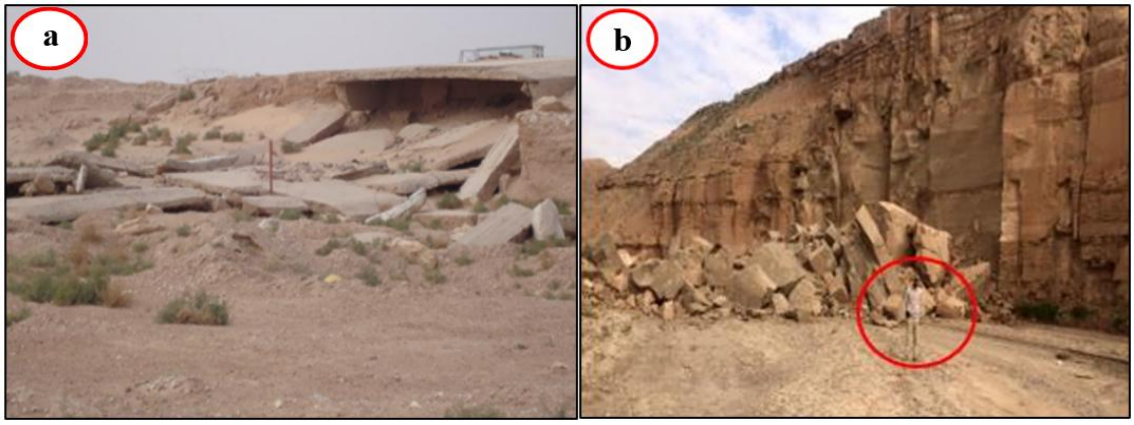

Figure 13. a) Damaged culvert due to the flood of Wadi Al-Aqrawi in the Southern Desert south of Al-Samawa city, b) Gully erosion and a rock fall in Shishireen Valley (Low Amplitude Mountainous Province).

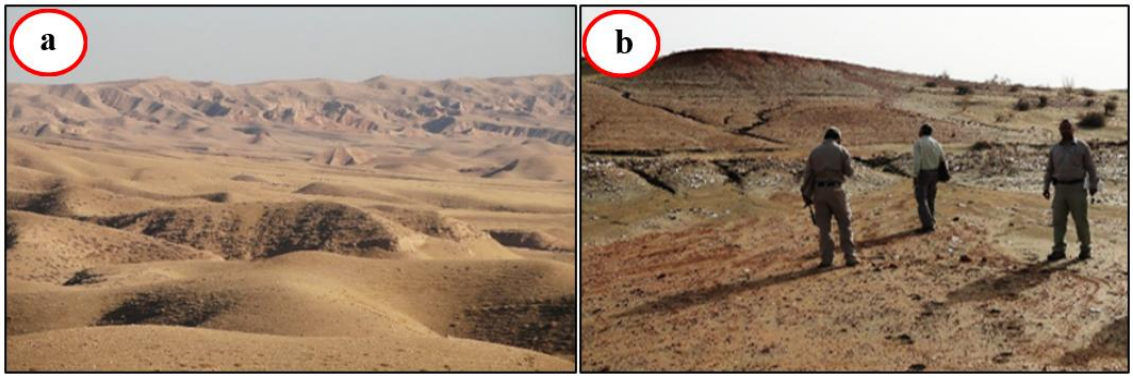

Figure 14. a) Badland terrain developed northeast of Kirkuk City (Low Amplitude Mountainous Province), b) Rill erosion on soft claystone and marl in Al-Slaibat Depression at the Southern Desert (SW of Al-Nasiriya city).

5.1.3. Rill Erosion

Rill erosion is very active in different parts of Iraq, usually acting on slopes, especially when covered by soil and/or weak rocks. It is restricted to road cuts, embankments, channels, railway embankments, and natural ground slopes (Figure 14b). The depth and spacing between the rills depend on: 1) the type of soil and its compactness, 2) The type of the rocks and their hardnesses, 3) The thickness of the soil, 4) The gradient of the slope, 5) The amount of the water flowing on the slope, 6) The height of the slope, 7) Duration of the running water, 8) Presence or otherwise of top and side ditches (on road cut slopes), and 9) Presence or otherwise of vegetation cover.

The most active areas of rill erosion are within the Low Amplitude Mountainous Province, where mountainous and hilly topography prevails; followed by the Western and Southern deserts. In the former case, the rill erosion is active in areas covered by soil or where weak rocks are exposed, whereas in the latter case, the rill erosion is active along the banks of the main valleys and the hilly terrain, which is developed in between the main valleys and/ or between the branches of the main valleys. In Al-Jazira Plain area, rill erosion is active along the banks of the main valleys and in areas where the marl and claystone beds of the Fatha Formation are exposed.

5.1.4. Wind Erosion

Wind erosion is also very active in both Western and Southern deserts; eroding even hard rocks forming mushrooms (Figure 6a), disintegrating very hard rocks (Figure 6b) with a combination of sheet erosion (Figure 7b), and forming isolated hills in form of Butte and Mesa (Figure 15a). The height of the isolated hills ranges from a few meters up to 25 m and rarely exceeds 50 m, whereas the width and length are highly variable within tens of meters and may exceed very rarely 100 m. Moreover, the combination of wind, sheet, and rill erosion in gently sloping and flat areas has developed a special landscape (Figure 15b) with a lot of shrubs that may form "Nabkhas" (Figure 15b).

In Al-Jazira Plain area where the terrain is almost flat, wind erosion is less active as compared to the desert areas. It acts on the soft marl and claystone beds of the Fatha Formation causing their disintegration into small rock chips and/ or aeolian sand, which is accumulated around shrubs and other small vegetation plants forming small Nabkhas.

In the Mesopotamian Plain, the activity of wind erosion is lesser as compared with other areas in Iraq. It acts on the rims of the shallow and wide depressions, which are developed within the alluvial sediments causing deflation of the topsoil and/ or salt crust, which cover the depressions. Accordingly, small sand dunes and Nabkhas are developed.

Figure 15. a) Combination of wind, sheet, and rill erosion at Al-Slaibat Depression forming small Buttes, b) Combination of wind and sheet erosion at a small depression east of Kut city forming Nabkhas.

5.2. Erosion Agents

The main erosional agent in the main types of erosion in Iraq is the water. However, wind erosion cannot be ignored; although its effect is mainly in the Western and Southern deserts, and partly affects the remaining parts of Iraq. Hereinafter is a brief description of the two erosion agents in each physiographic province.

5.2.1. Water

Water is the main erosional agent in different parts of Iraq. However, the intensity and mode of the erosion are different in different parts of Iraq. In the Western and Southern deserts, the quantity of rainfall in the southern parts is less than 100 mm/year, and it increases northwards to reach 200 mm/year; as a maximum (Figure 8b). Therefore, the main erosion occurs along the valleys (Figure 13) and less effectively as sheet erosion, where a lot of residual topsoils is eroded annually; especially in the Western Desert where the earth's surface is flatter as compared to the Southern Desert (Figure 8a). Moreover, in the Southern Desert, the drainage system is highly affected by karst forms, which form very complicated blind drainage systems and hundreds of karst depressions. The blind drainage system and karst depressions act as retarders for erosion because the water cannot flow freely as in the Western Desert. However, in both deserts, the depressions are filled by rainwater, which acts as an erosional agent (Figure 16).

In the Low Amplitude and Al-Jazira provinces, the rainfall intensity ranges between (300 – 500) mm/ year (Figure 8b) and reaches 600 mm/year in the Sinajar vicinity; therefore, the erosion is more active as compared to the Western and Southern deserts. Moreover, the relief differences are higher due to the existence of mountain chains; therefore, the erosion rate will also be higher. The presence of soft rocks like claystone and marl increases the erosion intensity in this province. In the Mesopotamian Province, the intensity of the rainfall ranges between (100 – 300) mm/year (Figure 8b); however, mainly it is 150 mm/year but the erosion

rate is high because the majority of the province is covered by soft alluvial plain sediments. Moreover, the amount and speed of the flooded water in valleys running towards Iraq from Iran have high destruction and erosion capabilities as sheet erosion, especially in abandoned agricultural fields.

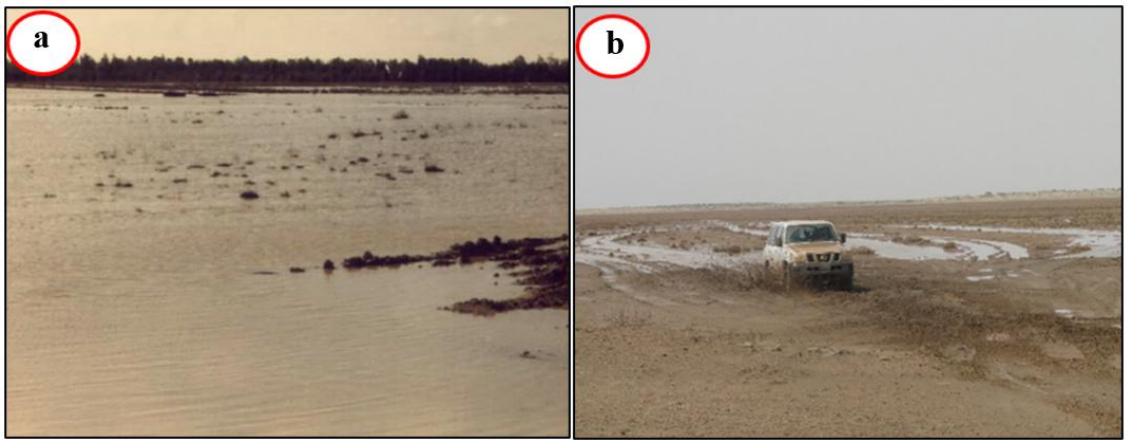

Figure 16. Inundated depressions by rainwater, a) The Western Desert (Al-Fhaida Oasis), south of Al-Qaim town, b) Al-Slaibat Depression; south of Al-Samawa City.

5.2.2. Wind

Wind is the second main erosion agent after water. Wind erosion is very effective in the Western and Southern deserts (Figures 6a and 15). Because the earth's surface in both deserts is almost flat (Figure 5), with low annual rainfall (Figure 6) and scarce vegetation cover (Figure 7); therefore, the blown wind can remove the topsoil easily. Moreover, the blown wind can carry sand particles and even small pebbles that will increase the abrasion ability or the erodibility. In Al-Jazira Plain, wind erosion is almost the same as in both deserts because the surface topography, annual rainfall, and vegetation cover are almost the same. However, large sand dunes are developed; called Baiji Sand dunes in the northeastern parts of Al-Jazira Plain (Figure 5).

In the Mesopotamian Plain, the blown wind attacks the alluvial plain sediments and disintegrates the topsoil; accordingly, sand dunes are developed at different parts of the plain, such as in the central and northern parts (Figure 5).

In the Low Amplitude Mountainous Province, the wind action is very low because of the hilly and undulatory topographic nature (Figures 8a and 14a), which includes long mountains (anticlines), considerable vegetation cover (Figure 7), and the hardness of the exposed rocks (Sissakian and Fouad, 2015).

6. Discussion

The interaction between the relief, amount of rainfall, and vegetation cover is the main effective process in soil erosion and degradation. Soil erosion is very effective, especially in the

Mesopotamian Province, where annually the topsoil is eroded due to sheet floods which cause sheet erosion. The abundant agricultural lands due to different reasons like social, increases the intensity of the soil erosion. Accordingly decreases food security because the cultivated areas are decreased and the crop yield is decreased, which will increase desertification, not only in the Mesopotamian Province but also in Al-Jazira Province.

Soil retrogression and degradation are two regressive evolution processes associated with the loss of equilibrium of stable soil. Retrogression is mainly due to soil erosion and is related to a phenomenon where succession returns the land to its natural physical state. Whereas, degradation is an evolution, different from natural evolution, related to the local climate and vegetation (Sims, 2023). Soil degradation may also be viewed as any change or ecological disturbance to the soil perceived to be deleterious or undesirable (Johnson et al., 1997).

Iraq is covered by rocky exposures and different types of soils; mainly alluvial (The Mesopotamian Plain), residual (the Western and Southern deserts, and Al-Jazira Plain), and partly colluvial (the Low Mountainous Province). The residual soil is usually developed on top of rocky exposures; especially when the topography is almost flat and/ very or gently sloping and the bedrock is hard. The main erosional type is the rill and gully erosion (Figure 14b), and very rarely sheet erosion; only when the surface area is wide and allows for water to move as sheet flow and accordingly sheet erosion will be in action. However, when the bedrock is not hard, then sheet, rill, and gully erosion types will actively disintegrate the weak rocks forming a topsoil with different thicknesses, which may range from less than 1 m up to a few meters. Accordingly, badland morphology is developed (Figure 14a), which accelerates the erosion of topsoil cover in combined sheet, rill, and gully erosion types. Residual soil is also developed on the top of river terraces with considerable thickness, which allows sheet erosion to start; however, on the outer rims of the residual soil, rill erosion and locally, gully erosion will start too.

The colluvial soils are usually developed on slopes and around mountains (anticlines). The thickness, size of the fragments, their composition, and compactness (cementation) depend on: 1) Their Morphological position, 2) The lithology of the bedrock from where they are derived, 3) The moved distance from the source area, 4) The gradient of the slope, and 5) The amount of rainfall through which they are deposited. The thickness may range between less than one meter up to a few meters and the cementation and compactness also may differ depending on the morphological position, type of cementing material, and the lithology of the fragments. The main erosion types are rill and gully, and the intensity of the erosion depends on: 1) The thickness of the soil, 2) The gradient of the rills and/ or the valleys, 3) The cementation or compactness of the soil, 4) The morphological position of the soil, and 5) The amount of the flowing water on the soil.

Alluvial soils cover the whole Mesopotamian Plain and are under the action of sheet erosion (Figure 11), which has severe damaging ability (Figure 10), especially during heavy rainy showers. In the Western and Southern deserts, Al-Jazira Plain, and the Low Mountainous Province.

Alluvial soils are restricted to large valleys as valley-filling sediments (Figure 13b), flood plain sediments of the Upper Zab River and large streams and valleys, river terraces of the Upper Zab River and main streams, and alluvial fans' both old and recent. In all cases, rill and gully erosion are very active, whereas sheet erosion is very rarely acting on these soil types.

Although the mentioned three main soil types occur in different parts of Iraq depending on their morphological position; however, locally two (Figure 15a) or three types are developed. In such cases, different types of erosions act depending on their morphological position; however, rill and gully are the most abundant and very rarely sheet erosion.

The man-made action cannot be ignored as an erosional agent. In haphazard road cuts and construction of other civil structures, plowing of farms, grazing of animals, abandoning of quarries. In all such cases, different types of erosion and soil degradation are the main outcomes, which either accelerate the natural erosional types or facilitate erosion intensity and soil degradation.

7. Conclusions

The main conclusion from the current study is that four main soil types are developed, these are alluvial, residual, colluvial, and aeolian, besides gypcrete (gypsiferous soil) and sabkhas.

Whereas the main erosion types are sheet, rill, and gully. However, wind erosion plays a significant role in different parts of Iraq. The main erosion agents are water and wind besides, man-made actions (like deforestation, overgrazing, haphazard constructions, road cuts, land use changes, unorganized agricultural effects, haphazard quarrying, and off-road driving) are very significant after the climate factors (Rain, and wind). The intensity of erosion and soil degradation is quite different in different parts of Iraq. However, soil erosion is active during heavy rain showers, which will cause flooding of valleys; the floods have a very high destruction ability. Sheet and Gully erosion are also very active. Rill erosion is the second most active erosion type.

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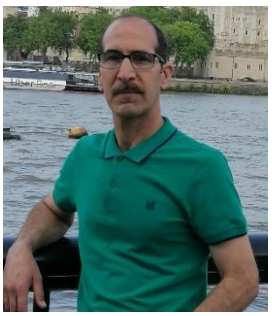

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