

Desertification and Salinization of the Mesopotamian Plain: A Critical Review

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Abstract

Most of the Mesopotamian Plain is covered by Quaternary sediments among which the flood plain sediments of the Tigris and Euphrates rivers are the most dominant parts. Aeolian sediments; however, also cover considerable areas at different parts of the plain in forms of sand dunes, sand sheets and Nebkhas. The dunes are the most common form and they are creeping as well as sand sheets in vast areas causing desertification. The main reasons causing this is climate change, abandoning of agricultural areas. Salinization is another significant problem in the plain whereby the affected areas are growing in size and the concentration of the salt in the soil, as well as the groundwater is increasing rapidly. The increase in salinization is due to miss- management of water resources, and the increasing salinity of the surface and ground water which due to the use of irrigation water supplied from Al-Tharthar Depression (lake) and the Main Outfall Drain.

Keywords: Desertification, Sand dunes, Groundwater, Salinization, Solonization.

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1. Introduction

Mesopotamia is a historical region in West Asia situated within the Tigris–Euphrates river system. In modern days it is roughly corresponding to most of Iraq, Kuwait, parts of Northern Saudi Arabia, the eastern parts of Syria, Southeastern Turkey, and regions along the Turkish–Syrian and Iran – Iraq borders (Collon, 2011) (Figure 1). Mesopotamia means "(Land) between two rivers" in ancient Greek. The oldest known occurrence of the name Mesopotamia dates to the 4th century BCE, when it was used to designate the land east of the Euphrates in north Syria (Finkelstein, 1962). In modern times, it has been more generally applied to all the lands between the Euphrates and the Tigris, thereby incorporating not only parts of Syria but also almost all of Iraq and southeastern Turkey (Foster and Polinger Foster, 2009). The neighboring steppes to the west of the Euphrates and the western part of the Zagros Mountains are also often included under the wider term Mesopotamia (Canard, 2011, Wilkinson, 2000 and Matthews, 2003). A further distinction is usually made between Upper or Northern Mesopotamia and Lower or Southern Mesopotamia (Miquel et al., 2011). Upper Mesopotamia, also known as the Jazira, is the area between the Euphrates and the Tigris from their sources down to Baghdad (Canard, 2011). Lower Mesopotamia is the area from Baghdad to the Persian Gulf (Miquel, 2011). In modern scientific usage, the term Mesopotamia often has a chronological connotation also. In modern Western historiography of the region, the term "Mesopotamia" is usually used to designate the area from the beginning of time, until the Muslim conquest in the 630s, with the Arabic names Iraq and Jazira being used to describe the region after that event (Foster and Polinger Foster, 2009 and Bahrani, 1998).

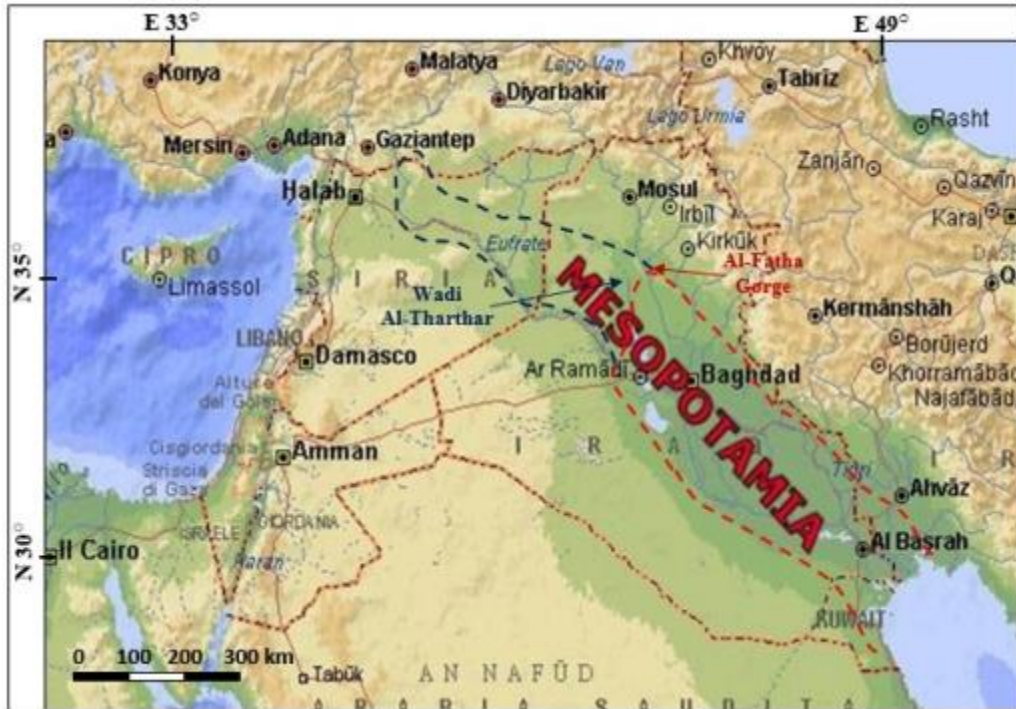


Figure 1: Geographical extension of Mesopotamia (Approximately limited by the dashed blue line including the Mesopotamian Plain) showing the Mesopotamian Plain (Approximately limited by the dashed red line). (Internet data, 2013) (Limits are added by the authors).

The Mesopotamian plain; however, is different geographically, geologically and historically from Mesopotamia. The Mesopotamian plain represents part of Mesopotamia, and nowadays it represents the existing plain between the Tigris and Euphrates rivers, which is limited to south of Al-Fatha gorge in the north, and the alluvial plains along the Iraqi – Iranian borders in the east. From the west, it is limited by wadi Al-Tharthar and the eastern limits of the Western Desert; then it extends to the northern limits of the Southern Desert (almost parallel to the Euphrates River); forming the southern limits of the plain. From the southeast, it is limited by the upper reaches of the Arabian Gulf (Figure 1).

The majority of the published information about Mesopotamia is related and concerned with the historical data about the different civilizations that rose here; since it was the cradle of the civilizations. Therefore, the available published data is related to the late Holocene Period (less than 10,000 years). The majority of the available data is related to irrigation canals, changing of the river courses, dams' construction and flood control works.

The age of the Mesopotamian plain dates back to the Pleistocene (2.558 Ma), and because the alluvial sediments of the plain are not of concern to oil explorations; therefore, very limited data is available from the drilled oil wells in this plain. The

same is true for the water wells; since the water wells very rarely encounter the Pleistocene sediments. Moreover, there is a large similarity between the alluvial sediments of the plain and the underlying Pre-Quaternary sediments (Yacoub, 2011); especially, when the Bai Hassan Formation underlies the Mesopotamian plain sediments.

2. Desertification of the Mesopotamian Plain

Quaternary sediments cover the whole plain (Figure 2), which suffers from high rate of desertification as the creeping sand dunes and sand sheets are increasing in their coverage areas.

2.1 Type of the Sediments

The Mesopotamia plain is totally covered by Quaternary sediments (Figure 2); the older formations below these sediments are Injana, Mukdadiya, Bai Hassan, and Dibdibba (Yacoub, 2011 and Sissakian and Fouad, 2012). The beds of all pre-Quaternary formations show dip towards the basin from all peripheral parts; however, some of the formations are exposed along the periphery of the plain (Figure 2). The exposed rocks at the western and southern sides of the plain have a gentle dip, while those exposed in Makhoul and Hemren Mountains, at northeast and east, have steep dip toward the plain. Both Makhoul and Hemren anticlines have axial trend of NW – SE. Hemren Mountain continues further along the eastern border of Iraq to the area east of Amara city. The presence of Quaternary sediments surrounded by pre-Quaternary rocks in the plain has contributed in the development of sand dunes at different parts of the plain, besides, other factors have contributed in the development and increasing of the coverage areas of the sand dunes.

2.2 Aeolian Sediments

The Aeolian sediments of different forms and types are characteristics of the arid and semi-arid climatic conditions, which prevailed during Holocene Epoch in the Mesopotamian plain and near surrounding. Their influences have increased, especially during the Late Holocene, and recently became more effective (Sissakian et al., 2013 and Al-Quraishi, 2013). The Aeolian sediments cover wide areas in the Mesopotamian plain in the form of large sand dunes fields, thin discontinuous sand sheet, and Nebkhas (Figure 3). In the Mesopotamia plain, sand dune fields are developed along the eastern, northern, southwestern and the central part of the plain (Figures 2 and 4). They are different in grain size, mineral constituent and source of sediments. The thickness of the sand sheets does not exceed one meter with wide extensions, whereas, the thickness of Barchan fields reaches 5m, and exceptionally may attain (25 – 30)m in southwest of Samawa. The sand dunes had accumulated during the late Holocene, or may be slightly earlier. Two stages of Aeolian sediments' development can be observed:

1. The relatively old stage represented by the fixed sand dunes. These are coated by thin mantle of soil with small native vegetation which helped in

fixing the dunes and

2. The young stage where the dunes are still active. The sediments of the marginal parts; however, seem relatively older than those deposited in the central part of the plain (Yacoub, 2011).

The orientation of the sand dune fields is usually NW – SE coinciding with the trend of the basin, which is bounded by high topographic terrains having the same directions. The windward slopes of individual Barchans dune indicate that the prevailing wind is N – S and NW – SE. The influences of the wind activities have intensively increased during the last four decades, due to increased drought environmental conditions, less precipitation and higher temperatures (Sissakian et al., 2013). The sediments of the main sand dune fields are described briefly hereinafter.

Sand dunes along the eastern margin: These are represented in the form of large fields along the Iraqi – Iranian borders west of Ali Al-Gharbi town in Al-Teeb and Chlat (Figures 2 and 4). They consist of fine to medium grained sand, with small amounts of silt and clay fraction.

The dunes are composed mainly of quartz, chert, limestone, and small amounts of heavy minerals; which are derived from the exposed Miocene and Pliocene rocks in Hemren Range and Quaternary sediments.

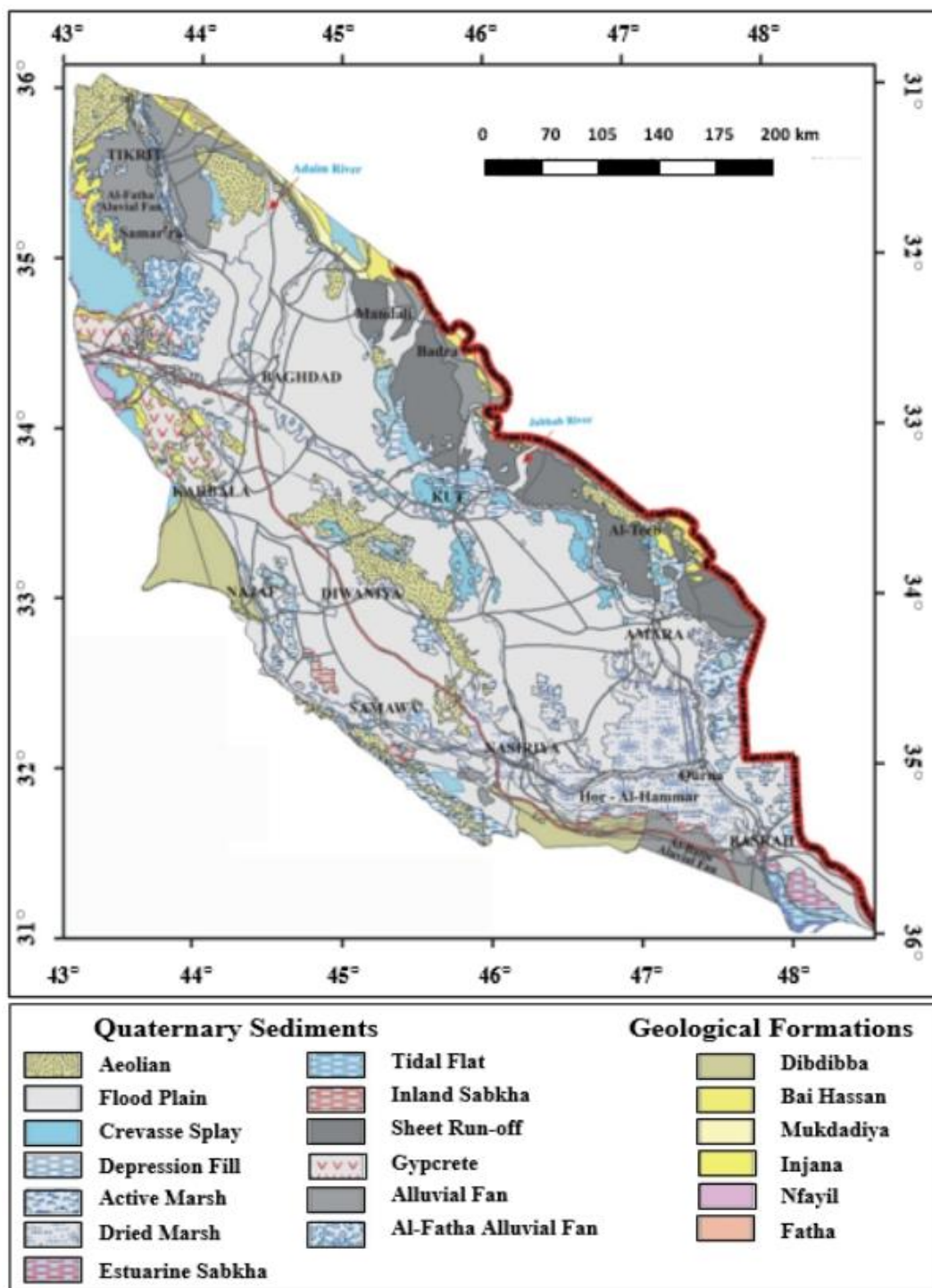


Figure 2: Geological map of the Mesopotamian Plain (After Yacoub, 2011).



Figure 3: Typical Nebkha developed due to sand accumulation around shrubs

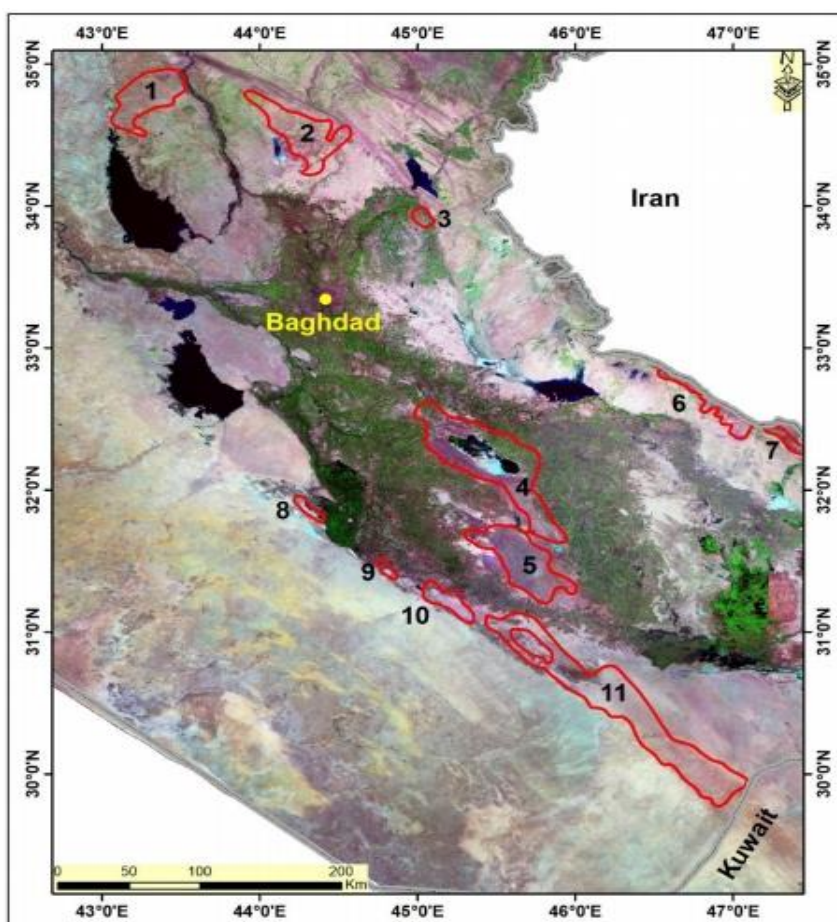


Figure 4: Satellite image showing the main sand dune fields in the Mesopotamian Plain.

Sand dunes: 1= Baiji, 2= Shari, 3= Baladrooz, 4= Hilla - Diwaniya, 5= Diwaniya – Samawa, 6= Al-Teeb, 7= Chlat, 8, 9 and 10 = Abu Jir active Zone Depression, and 11= Al-Slaibat – Al-Batin

Sand dunes along the northern margin: Three large sand dune fields are developed along the northern margin of the Mesopotamian plain, these are:

1. Baiji,
2. Shari, and
3. Baladrooz (Figures 2 and 4).

They generally consist of fine to medium grained sand. The sand grains are composed mainly of quartz, chert, limestone, and few amount of heavy minerals; the main source of these sediments is the exposed Miocene and Pliocene rocks in Hemren Range and Quaternary sediments. For Baiji sand dunes, only the part which is within the Mesopotamian Plain is considered in this study and presented in Figure 4.

Sand dunes of the southwestern margin: These sand dunes are developed mainly along the depression located within Abu Jir active fault zone (Figures 2 and 4). They consist mainly of fine to medium grained sand, with few coarse admixtures, and subordinate amount of clay and silt fraction. The sand is composed essentially of quartz, carbonate and less amount of feldspar, and rock fragments. The percentage of quartz grains often exceeds 50% and the carbonates reach up to 27.5%, in Samawa area (Yacoub, 2011). The main source of the sand dunes is the Late Neogene and Pleistocene rocks, which are exposed in the Western and Southern Deserts, and along Tar Al-Najaf and Tar Al-Sayed, besides the local Quaternary sediments.

Sand dunes of the central part: The sand dunes of the central part are developed between the Tigris and Euphrates Rivers (Figures 2 and 4), overlying the abandoned flood plain sediments. They are associated with dense anthropogenic sediments littered with pottery and brick fragments. The sediments of this field consist essentially of silt and clay in form of very tinny clay balls; locally rich with mud flakes and mollusk shell fragments, which are deflated from the surrounding dry marshes and lake sediments. The main sources of these sediments are the flood plain sediments of the Tigris and Euphrates Rivers and their related branches, in addition to the ancient irrigation canals.

Beside the sand dunes, sand sheets and Nebkhas form also part of the Aeolian sediments in the Mesopotamian Plain. Sand sheets are usually developed in between sand dune fields and/ or south wards from the active sand dunes where they are spread due to wind action. The thickness of the sand sheets ranges from less than one meter up to 1m and very rarely exceeds that. Some small rock fragments and/ or pebbles, not more than 1 cm in size, can be seen in the sand sheets. Their main constituents depend on the original sand dunes from where they are originated. The presence of sand sheets covering vast areas is good indication of desertification.

Nebkhas are also type of Aeolian sediments (Langford, 2000). A Nebkha is a sand dune that forms around vegetation with thickest part being in the wind main direction. It is an aeolian landform, i.e. a structure built and shaped by the action of wind. The development of Nebkhas within sand dune fields and/ or sand sheets is very common.

3. Salinization of the Mesopotamian Plain

Salinization is the process by means of which a non-saline soil becomes saline, as by the irrigation of land with brackish water (Oosterbaan, 1988). During last decades, salinization became one of the major problems in the Mesopotamian plain which suffers from increasing salinization. Problems with salinization are most commonly associated with excessive water application, rather than with too little. All irrigation water contains dissolved salts which are acquired as it passes over and through the land. Rain water also contains some salts, but these are generally in very low concentration in the water itself. However, the used irrigation water is highly contaminated from two main sources: 1) Al-Tharthar Depression (lake), and 2) Main Outfall Drain (Al-Mus'sab Al-Am) which collects the drainage water from all the drains in central and southern parts of Iraq. In the Mesopotamian plain, mismanagement of water resources and the prevalence of primitive irrigation systems and methods of irrigation are the main reasons for increasing the salinization of the soil (Figure 5). Before construction of the dams in Turkey, Syria, Iran and Iraq, the huge amounts of running water during floods in the rivers were washing out the accumulated salts in the agricultural lands and supplying new silty clay cover; therefore, salinization was less.

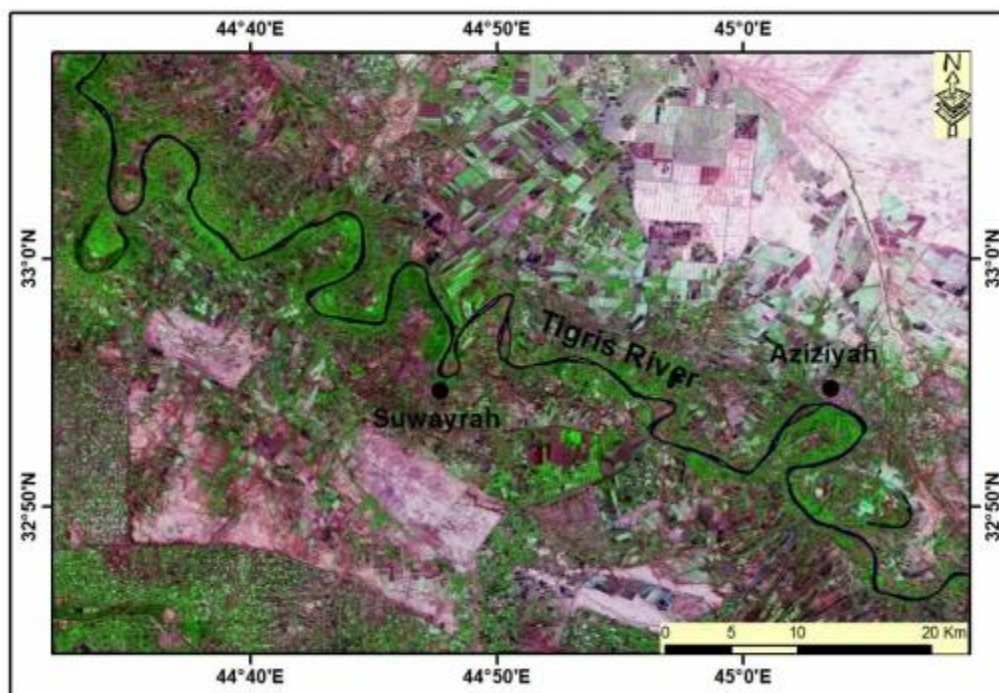


Figure 5: Satellite image showing salinized soils (the light pink colored polygons) along the Tigris River.

4. Discussion

The desertification and salinization in the Mesopotamian Plain is discussed hereinafter.

4.1 Desertification

Desertification is a type of land degradation in which a relatively dry area of land becomes a desert, typically losing its bodies of water as well as vegetation and wildlife (Geist, 2005). In the Mesopotamian plain, the desertification is a serious problem which is increasing rapidly and covering large areas; among them are agricultural lands (Figure 6). In order to indicate the change in coverage areas of the sand dunes within the Mesopotamian Plain, the coverage areas of each main dune was calculated from the geological map (Sissakian and Fouad, 2012) (Figure 2) and compared with the current coverage area (Figure 6). The results are presented in Table 1. The indicated years in Table 1, refer to the year in which geological mapping was performed at the areas under consideration. It is clear that the periphery and coverage area of each sand dune has increased significantly. The current periphery and coverage area of each sand dune were calculated from satellite images, whereas the original periphery and coverage area of each dune (Figure 2) were calculated through matching the geological maps with satellite images; after being digitized at accuracy of 1:100,000 scale.

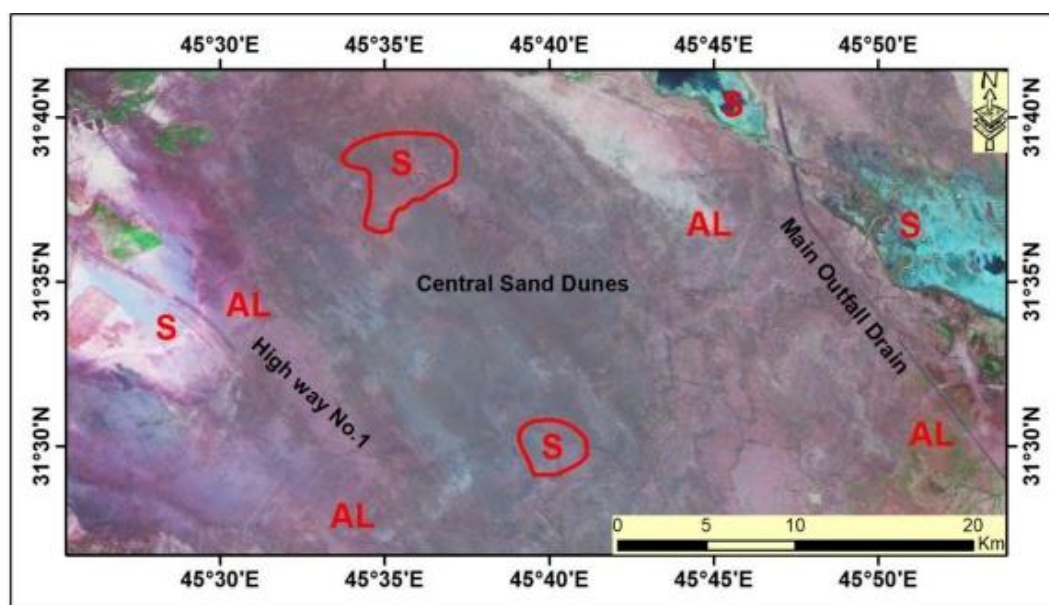


Figure 6: Satellite image of the Central Sand Dunes. AL means abandoned agricultural lands, S means salinized soils (Sabkha). Note the special embankments along the high way to stabilize the sand dunes. The two polygons are depressions in which the salinization (Sabkha) increases.

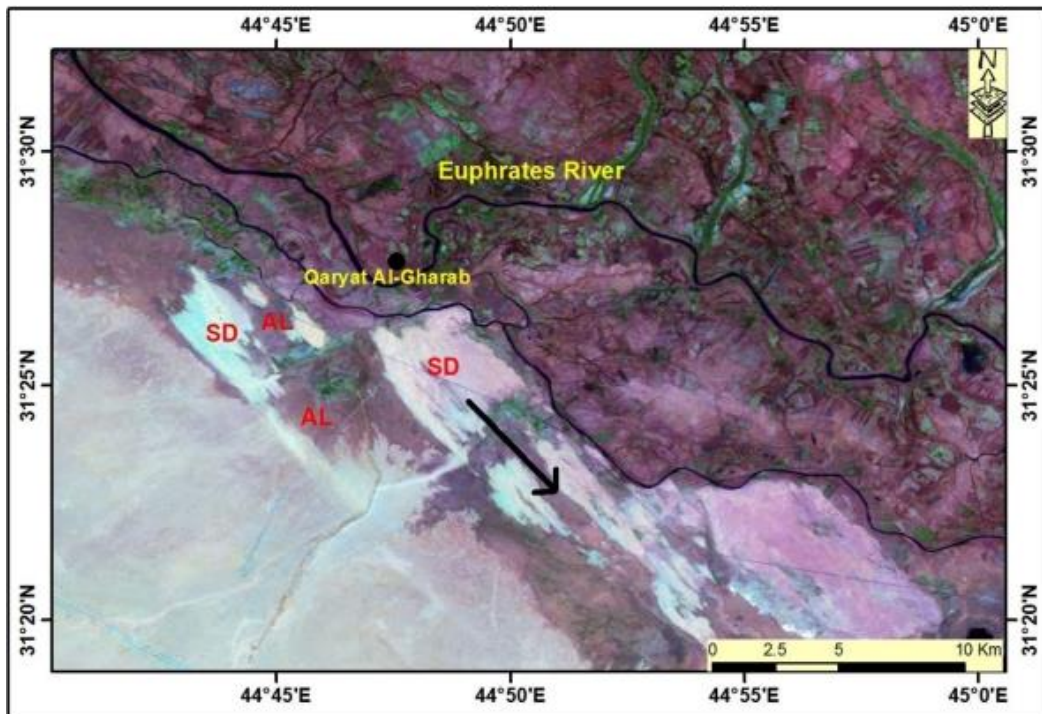


Figure 7: Satellite image of the sand dunes (SD) south west of Samawa city. AL means abandoned agricultural lands, the arrow points to the creeping direction of the dunes.

Table 1: Comparison between the peripheries and coverage areas of main sand dunes in the Mesopotamian Plain

Year	Name	Periphery (km)	Area (km ²)	Remarks
1974	Baiji	104	492	Only the part which is within the Mesopotamian Plain
2019		188	1159	
1977	Shari	154	1056	
2019		244	1304	
1983	Baladrooz	63.8	161	
2019		84.2	174	
1984	Central part of the Mesopotamian Plain	222	1127	On the geological map (Figure 2) these two main sand dune fields are combined together
2019		252	1683	
1982	Hor Al-Dalmaj	301	3014	
2019		316	3057	
1978	Abu Jir Sand Dunes	42	49	The small dunes are either neglected or combined together during digitization
2019	No. 1	53	68.6	
1978	Abu Jir Sand Dunes	22	23.3	
2019	No. 2	40.2	71.9	
1978	Abu Jir Sand Dunes	72.8	173	
2019	No. 3	108	355	
1979	Al-Slaibat – Al-Batin	386	1474	Including 214 km of Al-Slaibat Depression
2019		464	3117	
1980	Chlat	95	591	
2019		117	659	
1980	Al-Teeb	81	101	
2019		85.4	177	

The factors which causes the increase desertification; directly and / or indirectly in the Mesopotamian plain are briefed hereinafter.

4.1.1 Climate changes

The annual rainfall over the plain has been decreasing as a result of the global climate change impacts; accordingly, the amount of surface water is decreasing drastically. This is also leading to the decrease of the area of the agricultural lands, since farmers are abandoning their lands (Figures 6 and 7). The continuous abandonment of lands will in its turn increase the erosion capacity of the soil, especially so as they are ploughed lands. As a final result new sand dunes will develop increasing the creeping of dunes over the cultivated areas.

4.1.2 Abandoning of agricultural lands

Beside the above mentioned reason for abandoning of agricultural lands, many other reasons also exist, these are:

- i) The increase of salinity in surface water. This is due to the increase of the salt concentration in the waters of the rivers. This is attributed to the saline water supplied from Al-Tharthar reservoir to augment the Tigris and Euphrates rivers flow during draught seasons.
- ii) Unwise water management. This is leading to the increase of the salinity in the surface water; accordingly, the salinity of the soil is also increasing and the fertility is decreasing.
- iii) Using for irrigation the drainage water from the Main Outfall Drain (Figure 6) which runs in between the Tigris and Euphrates rivers from west of Baghdad and pours out in the Arabian Gulf. This drainage water is highly saline and its reuse for irrigation without mixing with good quality water is increasing the salinity of the soil.
- iv) Shallow Ground water level: The ground water level is rising continuously as a result of excessive water application (Figure 8 Left); which is mainly due to miss-management of both surface and groundwater. At the same time this is also causing the increase of salinity in ground water itself, (Figure 8 Right) which will make it not be suitable for irrigation also. Social and community issues. Thousands of people are migrating from rural areas to cities and especially to the Capital for better living conditions and for better job opportunities.
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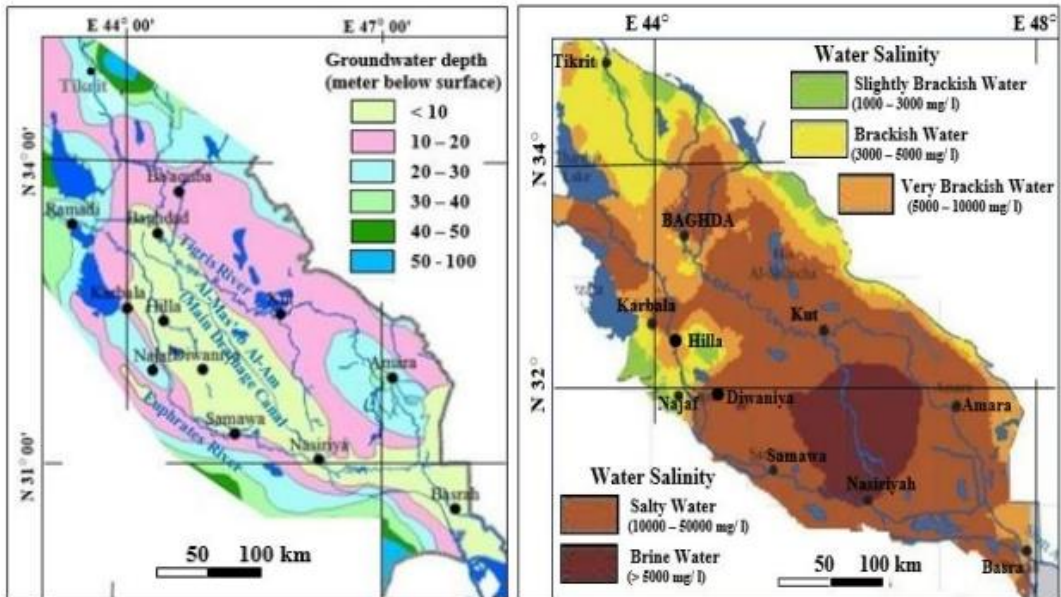


Figure 8: Left) Groundwater depth map, Right) Water Salinity map. (Modified from Al-Jiburi and Al-Basrawi, 2015).

4.1.3 Haphazard Driving

In rural areas, the majority of roads are earth roads and unpaved, so when local people drive their cars and other trucks on these roads, they cause the rise of heavy dusts which damage the vegetative cover, likewise when they use their heavy cultivation on the dry land they accelerate soil erosion and cause the degradation of its structure as the coherence of the top soil is destroyed. Accordingly, the top soil is easily weathered and changed to fine clayey particles developing new sand sheets and/ or sand dunes.

4.1.4 Farming Practices

Many of the farmers are not familiar with the correct land management practices and are ignorant of how to use their lands effectively. In many cases they essentially clear the land of everything on top of one plot of land nutrients, desertification becomes more and more of a reality for the cultivated areas. Moreover, the majority of farmers use the fallow method of cultivation whereby they cultivate one half of their lands in one year and leave the other half to be cultivated in the next year which means large tracts of land remain barren with no vegetation cover and completely dry especially during draught seasons. This will accelerate degradation of the soil and accordingly accelerate desertification.

4.2 Salinization

Salinization of soil is another main problem in the Mesopotamianp, it is mostly accompanied with desertification, and both processes are considered to be forms of soil degradation (Slavikova, 2019). Large parts of the plain are severely salinized with many parts which are even totally salinized and with increasing salt content in the groundwater (Figure 9).

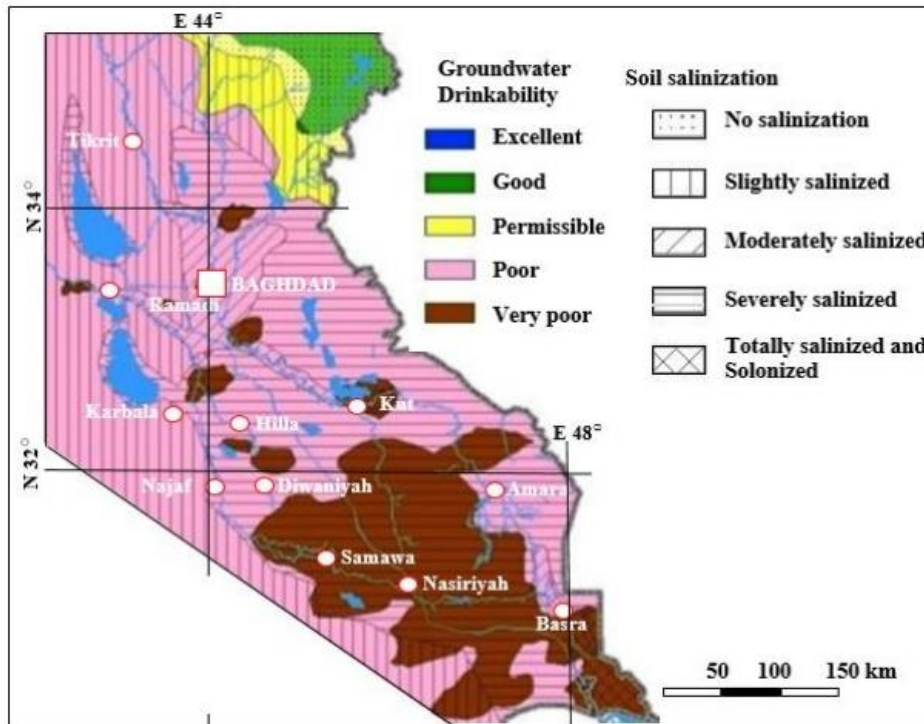


Figure 9: Map od Drinkability of water and soil salinization (Modified from Al-Jiburi and Al-Basrawi, 2015)

Some of the factors which increase salinization in the plain are mostly the same as those which increase desertification such as climate change, unwise water management, bad farming practices and abandonment of agricultural lands. However, some other factors also play significant roles in increasing salinization of the soil, these are:

- i) The Mesopotamian plain is a closed basin which retards the free flow of the groundwater into the Arabian Gulf. This is contributing to the precipitation of the salts in the ground water.
- ii) The construction of many storage dams on the rivers has decreased the possibilities of flooding. Accordingly, there is no provision of new supply of silt to the flood plains
- iii) So, no more washing out of the accumulated salts is done.

5. Conclusions

The following conclusions can be drawn from this study; Large rural and agricultural lands of the Mesopotamia plain are affected by desertification; especially major parts of the cultivated area. This is causing one of the most serious desertification problems in the whole of the Mesopotamian plain. Many factors play significant roles in this desertification process, which are: climate change, abandoning of the agricultural land for various reasons, unwise water and land management, and haphazard cars and trucks driving. Salinization of soil in the Mesopotamian plain is also another significant problem which is increasing continuously due to a multitude of reasons which are also leading to cause desertification. However, the main reason is being the use of the storage water of Al-Tharthar Depression (lake) to overcome water shortage in the Tigris and Euphrates rivers during draught seasons. The fresh water which is diverted to Al-Tharthar Depression for storage there becomes polluted by the dissolved salts from the exposed gypsum beds in the depression, and when it is returned back to both rivers it is contaminated with salts, and it is used for irrigation by the farmers in their very primitive irrigation methods, then will cause the salts to be precipitated in the soil after the evaporation of water. Using the water of the Main Outfall Drain (Al-Mas'sab Al-Am) for irrigation has also contributed to the increase of salinity in the soil. Moreover, the shallow saline groundwater which migrate upwards by capillary action is causing and increased salinity of the soils of the cultivated lands causing its deterioration.

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