Iraqi Geological Journal

Journal homepage: https://www.igj-iraq.org

Determination of Euphrates River Stability at Fallujah Area Using Spectral Reflectance

Ban A. Al-Kubasi[1]* and Omar B. Al-Jarrah[1]

[1] Department of Applied Geology, College of Science, University of Anbar, Ramadi, Iraq

* **Correspondence**: ban22s4001@uoanbar.edu.iq

Received:
25 June 2024

Accepted:
18 September 2024

Published:
31 January 2025

Abstract

Rivers generally try to be stable and compatible with the surrounding geological and climatic conditions. Any change in these conditions will affect the river and its activities. The Euphrates River in Fallujah is connected with theTharthar Channel, which means additional amounts of water and sediments enter the main course and change the profile or shape with some shifting location to be stable again. Some of these changes are dangerous if the channel moves towards villages or buildings, especially those on the river banks. To determine these changes, measurements for the river's reflectivity were made across two profiles situated before and after the connection point between the Euphrates River and the Tharthar Channel. A wavelength of 850 microns was chosen for the reflectivity measurements because it provides the best discrimination between water, soil, and vegetation. Reflectivity indicated islands and narrow widths during the dry and flood seasons during fieldwork for comparison. A series of Satellite images from 1972 to 2024 were utilized to identify river changes before and after this channel was built. Results demonstrated a 100-200 m., Meander shift. In a typical case, another place showed a shift of 900-1000 m, which is the most threatened by river shifting. It becomes clear that the Euphrates River although in recent low discharge and draught period still affects the surrounding areas.

Keywords: Euphrates; Reflectance; Stability; Fallujah; Mmeanders

1. Introduction

A river is a natural watercourse that flows towards an ocean, lake, sea, or another river, generally freshwater (Leopold, 1994). They will change coarse over time because of natural causes (geological or climate), also some human activities can accelerate change processes. This might significantly impact the local population and other buildings and constrictions within the river basin (Brookes, 1994). Rivers are stable in their natural state, but if any external influencing factor affects such as (an increase in discharge or percentage of suspended sediments, or engineering facilities). The river will begin to change its course and profile to accommodate these changes and attempt to return to its previous state of stability. Hangings can be as river meanders, lateral shifting, or deepening Some of these activities negatively or positively affect environmental impacts or human life. Any change in the shape of the river course and the changes will give different spectral reflections resulting from the appearance, disappearance, or transformation of landforms in the area, so determining these short or long-term changes will provide ideas and confirmations for the areas likely to be exposed to these river changes, especially if they have adverse effects, and to find safety arrangements. This study involved conducting field reflectivity measurements on specific river sections before and after the connection point between

DOI: 10.46717/igj.58.1A.16ms-2025-1-26

the Tharthar channel and the main Euphrates River. The measurements were taken in two different seasons to demonstrate these short-term changes were analyzed by comparing serial satellite images from 1972 to 2024. The aim was to understand the impact of this channel on the Euphrates River and surrounding areas, including the direction of shift and accurate distance calculations. The analysis of digital satellite images has become a useful approach to monitoring water quality (Syahreza et al., 2012), In addition to reducing maintenance costs for engineering projects threatened by shifting and determining how to identify potential morphological change in river channels, these tools provide a valid means to study river channel changes (Jaafar and Daliman, 2022). This research aims to determine the impact of the Tharthar -Euphrates artificial channel on the Euphrates River (channel and banks) in the Fallujah area.

2. Study Area

The located area between Habbaniyah- Fallujah region in Anbar governorate within the administrative boundaries of Fallujah city is between latitudes (33° 21 N"–33° 24' N) and longitudes (43° 33' E"–43° 39' E) (Fig.1).

The study area is in a hot and continental semiarid climate. It has two major seasons, hot and dry summer and cold with rare rain in winter, with two short transition seasons, spring and autumn. The temperature ranges from -350C in the winter at the headwater region to about (40- 50 OC) in the summer in Iraq (Abdul-Jabbar, 2013).

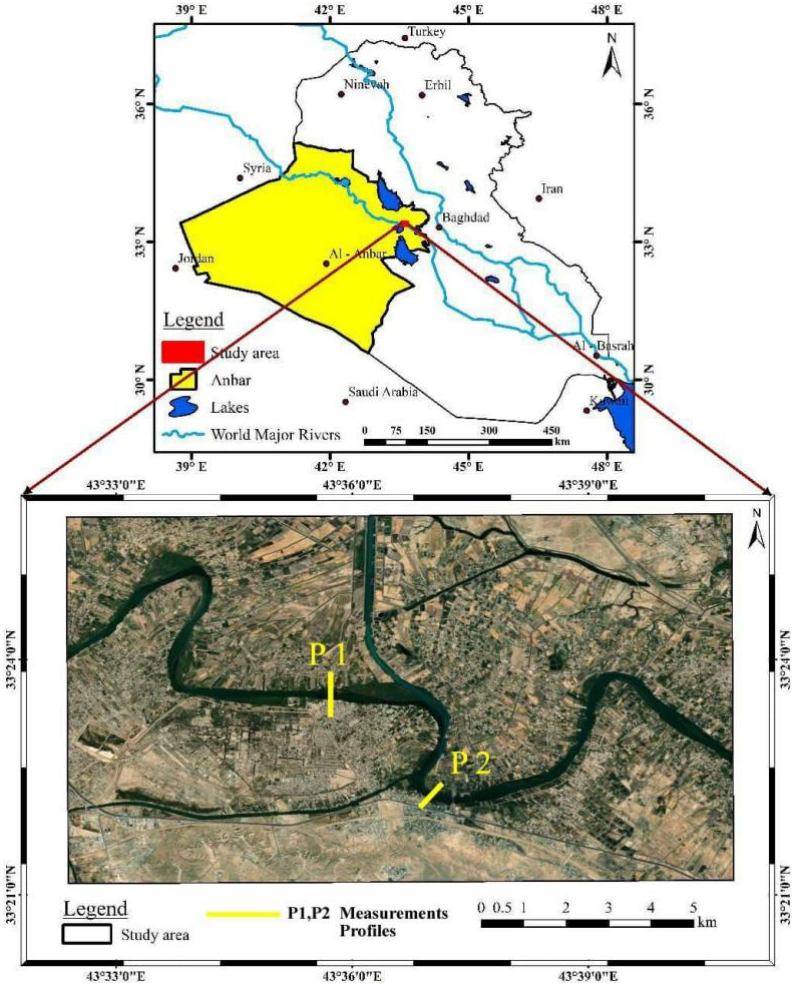


Fig.1. Study area and measuring profiles

3. River Meandering

River meandering is a common natural geomorphic feature and is one of the most dynamic actions. It is seen widely in alluvial plains, grasslands, tropical rainforests, and desert margins. Meandering rivers exhibit migration of the channel location in their floodplains with changing sinuosity due to outer bank erosion and inner bank deposition. The evolution of meandering rivers affects the exploitation and preservation of river systems, including flood alleviation, channel maintenance, riverbank erosion, land protection, and infrastructure resilience In general, due to the channel morphological characteristics and flow momentum, water and sediments converge in the concave banks and diverge in the convex banks. With the flow momentum redistribution, riverbeds in concave banks gradually degrade and deposit near convex banks until point bars form (Zhou and Tang, 2022).

4. Hydrology of Study Area

Distinct climate zones characterize the Euphrates and Tigris basins. In Turkey, the climate is predominantly Mediterranean and gradually transitions to a progressively hot, dry desert environment toward the southern regions. In the headwater region, the summer is characterized by aridity, while the winter is marked by intense cold and heavy rainfall. Precipitation is most prevalent throughout the autumn, winter, and spring season, During the winter seasons, snowfall occurs. The average yearly precipitation ranges from more than 1000mm in Turkey to about 150mm in Syria and about 75mm in the southern part of Iraq (Al-Ansari et al., 2019)

5. Geology of Study Area

The Euphrates River in the research area at its flood plain extends towards the south. Therefore its flow speed will be slower, and its width will be greater. Also, the water discharge has decreased significantly during the last decades due to drought seasons in the region and the dams and other irrigation projects established in neighboring countries. The mean discharge rate decreased from 26.6 BCM at the Hit station for the period between 1938–1998 to 184.3 BCM at the measurement period for this research 2023-2024, while the Tharthar channel discharge was 101.6 BCM for the same period of research measurements this means the channel brings to Euphrates River approximately 55% of its basic discharge after the point of connection between two channels the characteristics of Euphrates channel changed and began to show stability again after some time (Al-Ansari et al., 2018).

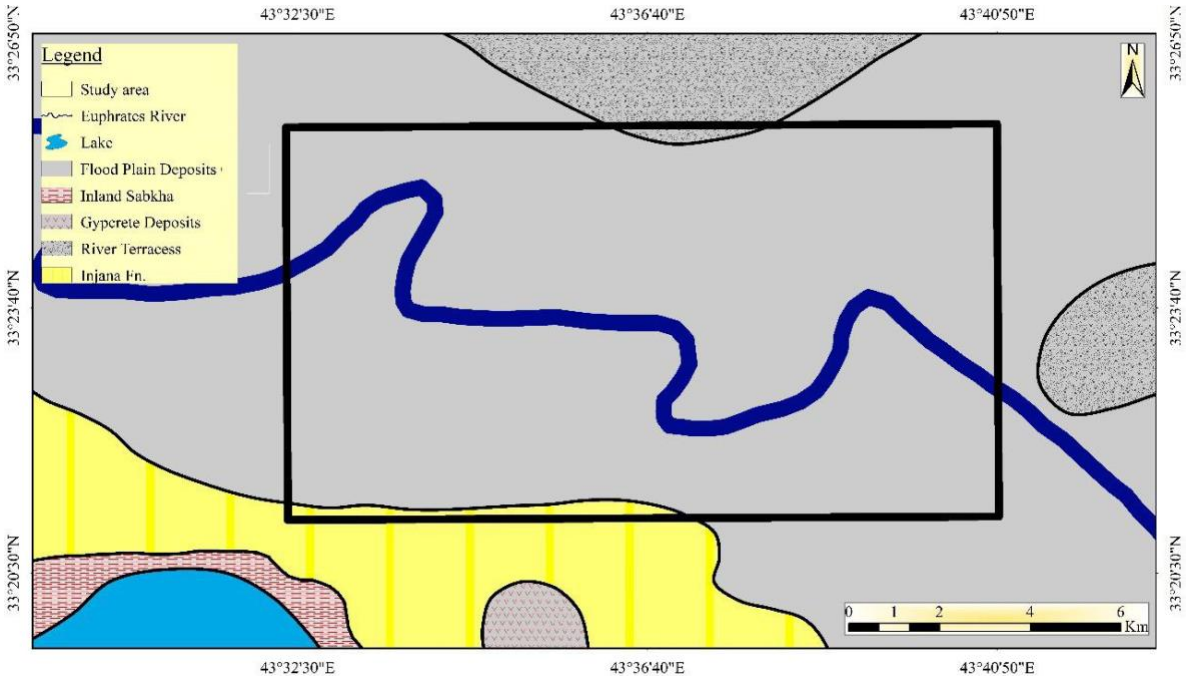


Fig.2. Geological setting of the study area

6. Materials and Methods

6.1. Field Work

Spectral measurements carried out by spectrum radiometer HOPOOCOLOR (OHSP-660T) measured spectral data in two periods, including low water level. Reflectance measurements were conducted on of 1/11/2023 and 24/4/2024 before and after joining the artificial Tharthar channel and main Euphrates River to assess its impact on the chosen river profiles (P1 and P2). The measurements were conducted at 850 µm wavelength for soil, plant, clear water, and turbidity. Measurement was included across the river's body width with a distance of 10 m. Between points (by using a boat) also the measurements continue at both banks of the river with a distance of 5 m. To show the reflection difference within areas adjacent to the river (maybe by the river's activates).

6.2 River Bed Depth Measurements

The depth of the Euphrates River was measured simultaneously using an instrument (Intelligent MGG/KL- DCB). During the reflectivity measurements obtained from the water surface (Fig.3).



Fig.3. River depth measurements

6.3. Bank Soil Samples

The soil samples of both banks of the Euphrates River were collected and distributed on Profiles P1 and P2. Samples were dried for their analysis using a sieving device to separate the sediment and using sieves with sizes that conform to the global tables to calculate ratios of sand (coarse and fine), silt, and clay using the proportion triangle to classify the soil (US Department of Agriculture soil textural triangle, 2022) and was as follows: (Clay<0.002 mm, silt 0.002-0.075mm, fine sand 0.075-0.42mm, medium sand 0.42-2mm, course sand 2-4.75mm. In many river systems, fine material is transported in suspension, termed the suspended sediment load (Owens et al., 2005). The fine fraction incorporates both the organic (e.g. plankton and detritus) and mineral particles (e.g. sand and silt) of diameters > 0.45 μm and < 2000 μm. Particles within this range account for the majority of material eroded from the landscape and transported by rivers and streams (Meade et al., 1990). On the other Soil reflectance increased with soil moisture after a critical level (Weidong et al., 2002). The Organic matter in soil is constituted of chemically distinct and naturally stable molecules (Lehmann and Kleber, 2015).

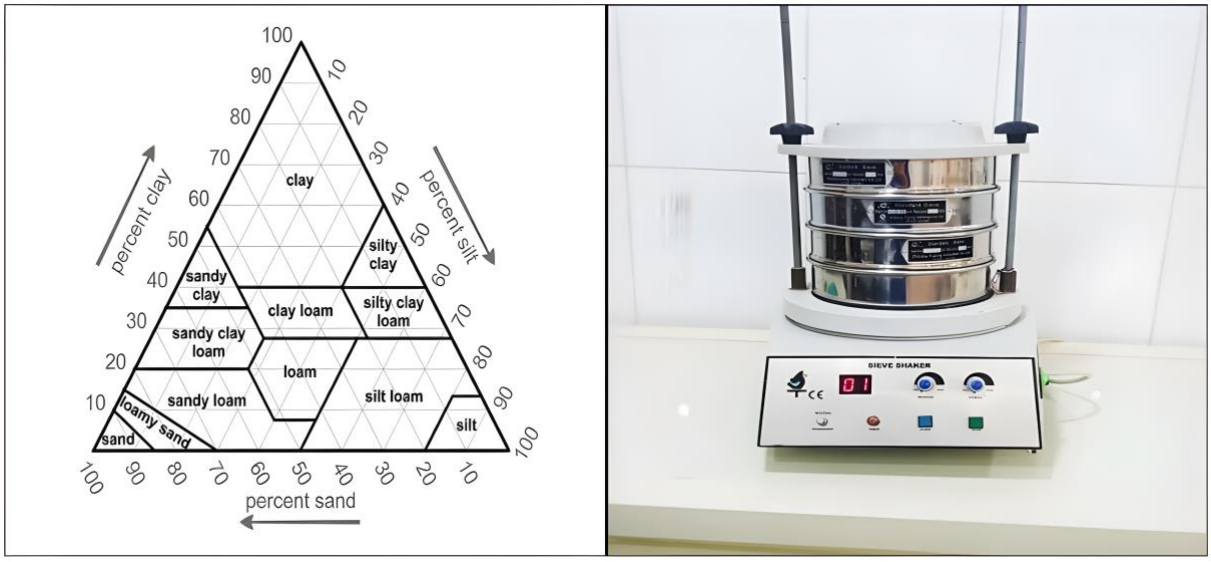


Fig.4. Type of soil with the standard triangular of soil textural (US Department of Agriculture soil textural triangle, 2022)

6.4 .Water Turbidity Samples

Samples were collected from the river at three depths-surface, middle, and bed –using a sealed container to avoid material leakage. This procedure was done to determine the content of turbidity in the water and its impact on reflectivity. Representative samples were collected from three locations adjacent to the river banks and the central section of the river. Subsequently, the samples were examined to determine the water turbidity proportion at the measurement time. This procedure was done twice on January 11, 2023, and April 24, 2024.

6.5. Satellite Series Images

To follow up on the changes that occurred to the river within different periods, which indicate the river's activity (growth of meandering, lateral shifting, and sinuosity factor) Digital satellite photos of the Sentinel-2 (Fig.7) and Landsat satellites 1,5 (Fig.5 and Fig.6) were matched Using the ArcGis 10.8 software, the coordinates between this series of images are matched to detect any change that occurs in the river during the recording periods. Some changes can be distinguished with the naked eye. As for the smaller ones in size and area, a program was adopted to subtract the reflections of the images from each other, and differences will be noted in the reflectivity of any change in values. As for the areas not subject to changes, there will be dark areas in the images resulting from the subtraction process. These operations took place in two periods before and after the construction of the Tharthar Channel in 1978, and it is possible that it greatly affected the stability of the river. Another way to detect the rivers stability is by calculating the sinuosity factor.

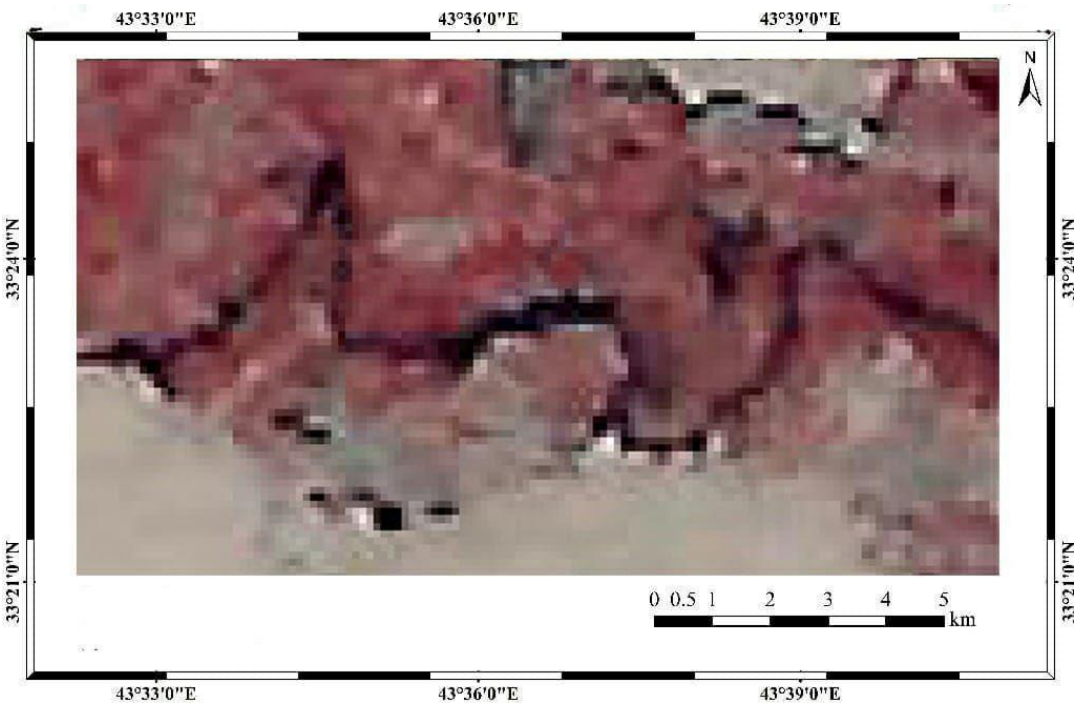


Fig.5. Area at 21/11/1972 Landsat 1

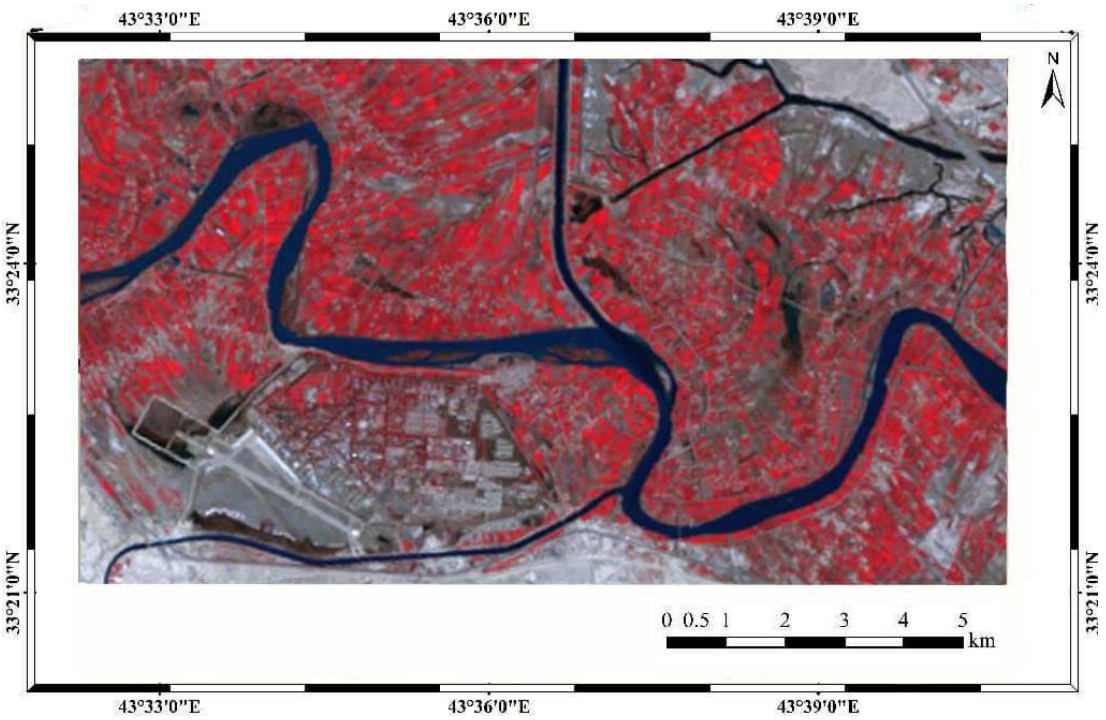


Fig.6. Area at 23/3/1994 Landsat 5

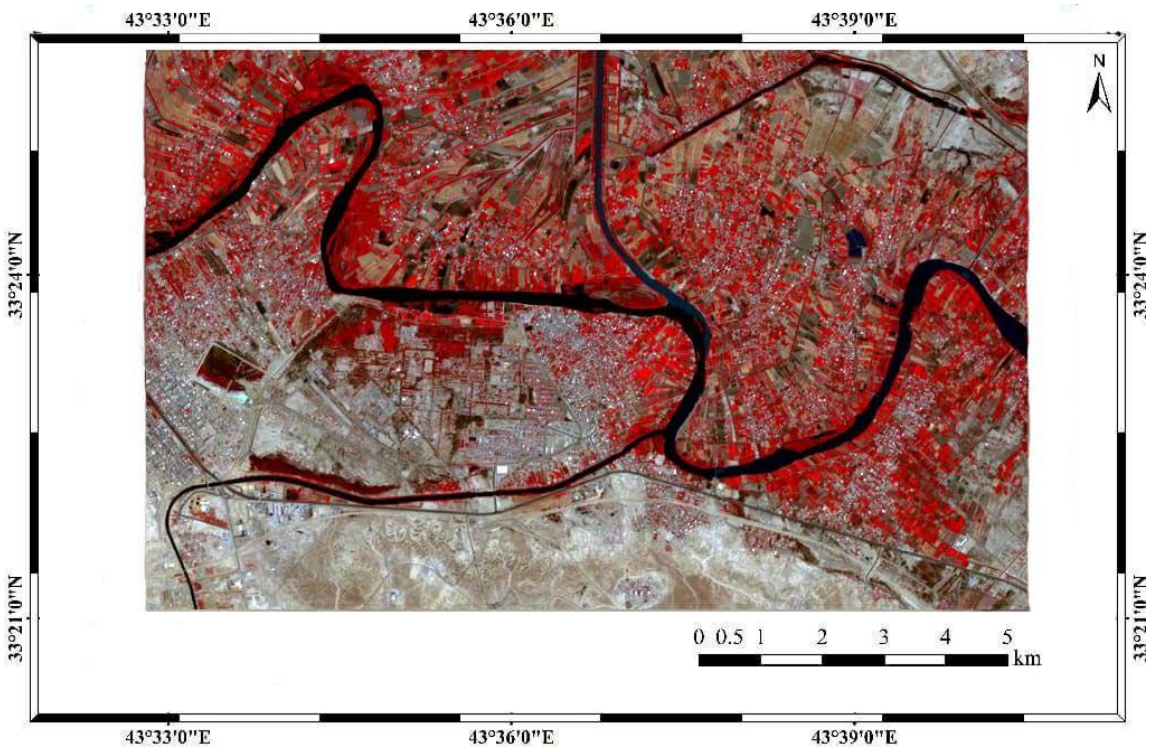


Fig.7. Area at 19/6/2024 Sentinel -2

7. Results and Discussions

To obtain a clear idea about the region's condition and the natural relationships that affect spectral reflectivity and its significance instability, a connection needs to be made between all of the field and laboratory work results. This is because these relationships have an interrelated effect.

7.1. Spectral Measurements

Field reflectivity measurements were carried out for two profiles across the river and in two different places before and after the meeting point between the Euphrates River and the Tharthar Channel. For each profile, the measurement was (left bank-river-right bank).

Profile before meeting point P1: The results showed a clear difference between the shape and amounts of the reflectivity measurement curves for both sections, as well as differences due to the dates of the measurements (Fig.8).

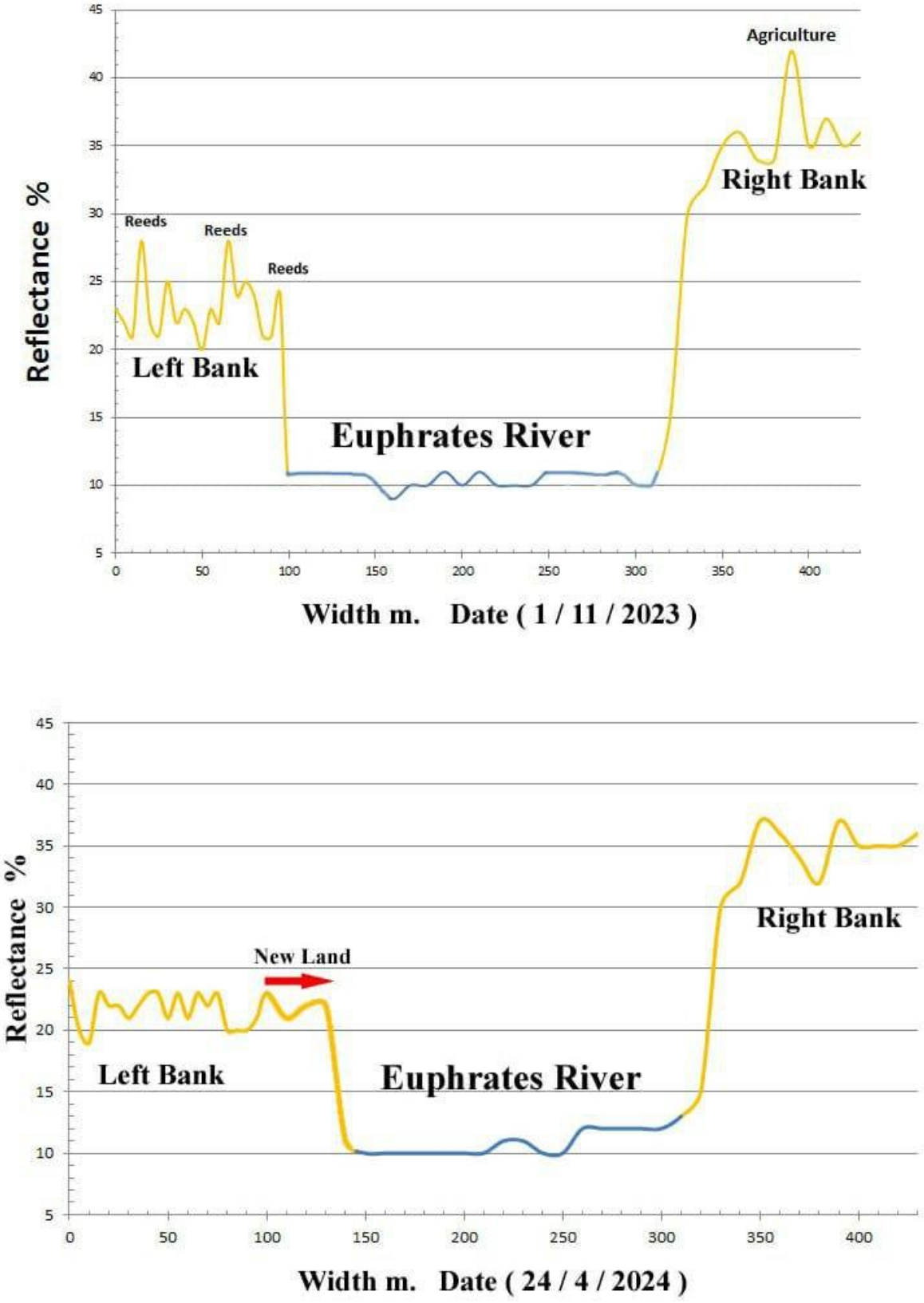


Fig.8. Reflectance profile for cross-section P1

In the first profile, measurements were made on 1/11/2023, during a period of drought and the beginning of the rainy season, and also a low discharge of the river. The Left bank showed a clear difference in the value of the reflections, with an average ranging between 22-25%. Some higher peaks were due to the presence of many plants (Reeds). The water depth was very shallow due to it covering an island almost attached to the bank. This caused reduced reflectivity values.

As the body of the river itself, the reflectivity ranged around 10 % up and down; due to the amount of turbidity of the water current that passes through it, the sediments carried increased the reflectivity peak at the points measured there. but generally, it was homogeneous.

Measurements of the right bank were different due to the side that is being eroded by the river current, and there are no recent deposits observed there; the soil was dry and soft, and this is the reason for the increase in the reflectivity average reach 35- 40% since this bank was It is not threatened by severe erosion, farmers have used it as fertile pasture areas, and it is noted that there are some reflective peaks due to agricultural fields. Human impacts in the river system's upstream section may increase the size and frequency of floods (Panhalkar and Jarag, 2017), directly or indirectly resulting in the river's course change. Repeating the same measurements for the same section, but on April 24 (wet season), this is the rainy season. There will be an increase in the quantity and speed of the river current, possibly carrying larger amounts of suspended sediments. In general, the soil of the banks is more humid and, therefore, less reflective. The fast-flowing rivers are prone to silting up, allowing sand and suspended matter to deposit in their slower, wider depths, exerting resistance and driving the river to move laterally (Wakode et al., 2013; Rai et al., 2018). All these River bed topographic profiles directly affect water and bank reflectance, especially since many changes happen within a period of 2 measurements. Maximum depth increases by about 1.5 m. because of increasing discharge (rainy season), and the river width decreases because a new bank island appears and acts as a new land (soil). Regarding water reflectivity, it shows more suspended sediments at the right bank location.

Profile after meeting point P2: This profile was chosen to be after the meeting point between the main Euphrates River and the Tharthar channel to determine the effect of this channel on the river by using reflectance measurements. The same procedure for profile 1 is repeated at 100 m with 5 m distance reflectance measurements for each bank left and right and 10 m distance in the river water body.

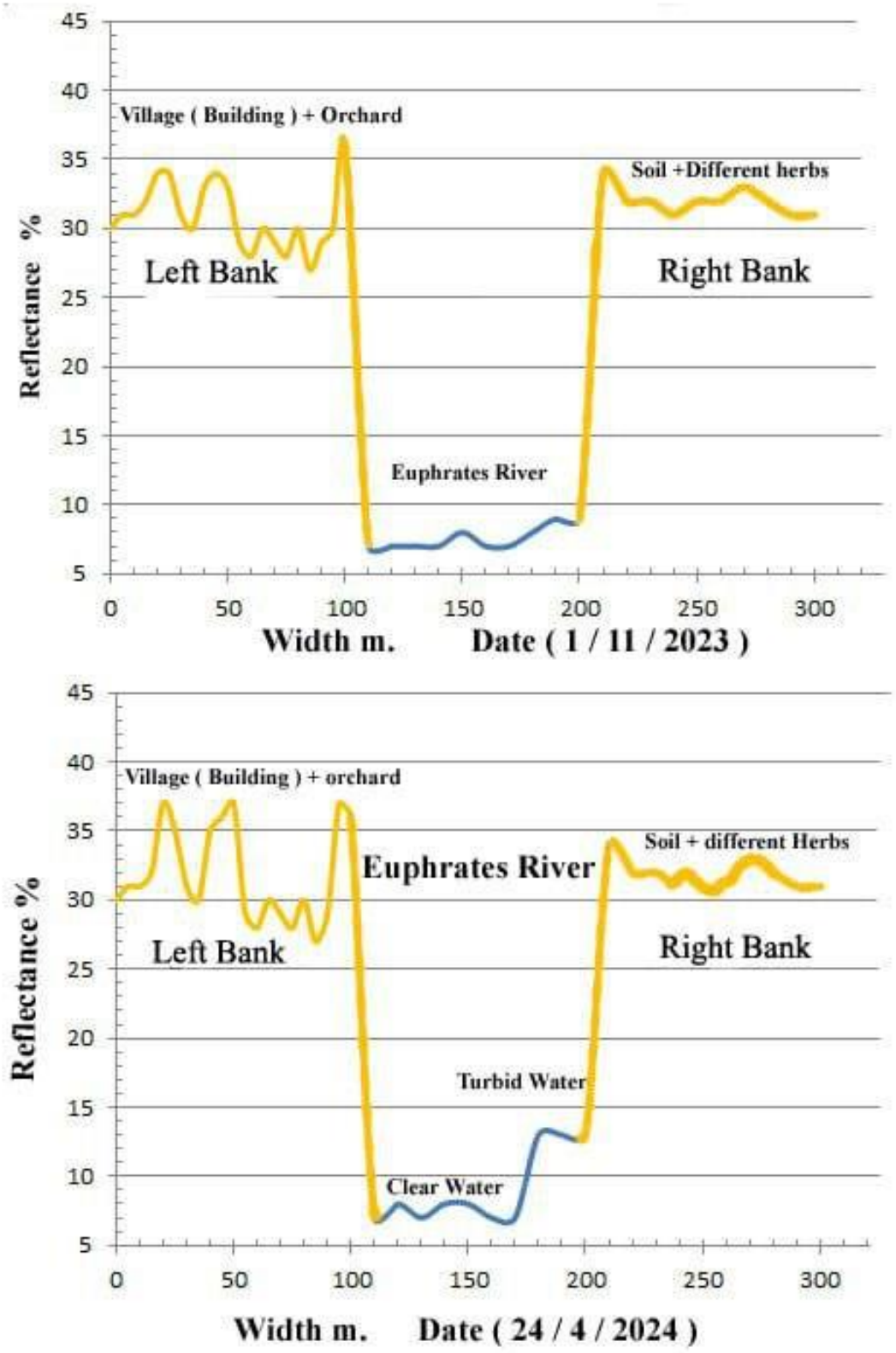


Fig.9. Reflectance profile for cross-section P2

A set of measurements done on 1/11/2023 left the bank there was a difference in the reflectance up and down and because of a farmers and fishermen village small houses and stores of crops and other people activities on the bank so became very high reflectivity up to 30-35% ripple with reflected 27-30% is considered agricultural crops (plant), it has been found that built-up areas have an increase in reflectance from green band to red band (Xu et al., 2017). The water reflectance of the Euphrates River is somewhat homogenous due to low discharge and a small amount of water turbidity and suspended material carried there except for the close right bank, which revealed a more significant amount of suspended silt. The right bank is ordinary soil utilized by man, with cultivation represented by various crops and plants. It is considered more homogenous than the left bank because it contains soil and plants, not building. Organic matter is the most essential soil component and a key indicator of soil fertility and reflectance spectrum. Although it accounts for 10% or less of overall soil composition, its value cannot be overstated. Organic matter is essential for agricultural production, soil preservation, plant growth and soil quality and health. As a result, we must ensure that such estimates are efficient and accurate when assessing soil organic matter levels (Xie and Xiao, 2018).

By repeating the same measurements for the same section, on April 24, 2024 (wet season), the rainy season, there is a difference in reflectance on the left bank. In the Same village (buildings), The reflectivity of crops differed due to the harvest season by 35-40%. The main difference in Euphrates River water is due to increasing discharge (flood season) from the Tharthar channel and high quantities of suspended sediment caused by turbid water. The reflection near the right bank is up to 6-14%. The bank in right bank reflectance is still similar to the previous measurements on 2023/11/1 by 31-33%.

7.2 River Depth

Direct measurements for river depth from a boat showed some changes in the shape and depth of the river bed, which is related to profile P1 (Fig.10).

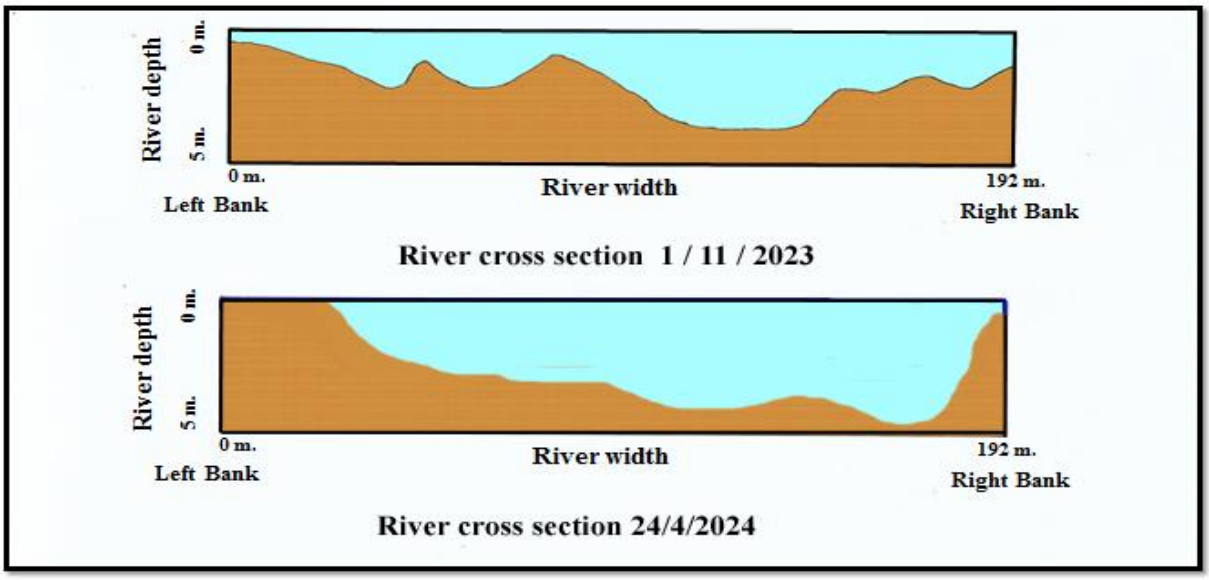


Fig.10. River depth cross-section for P1

Results mention both shape and depth changed within the period of measurements which in general bed changed to more depth (-1.5 m) and smoother at the second set of measurements that because of more discharge and faster water current (flood season), in remote sensing reading for reflectance, more deep water have less amount of reflectance so that must be in consider when interpreting water body reflectance which is due to depth or turbid water, the second profile P2 (Fig.11).

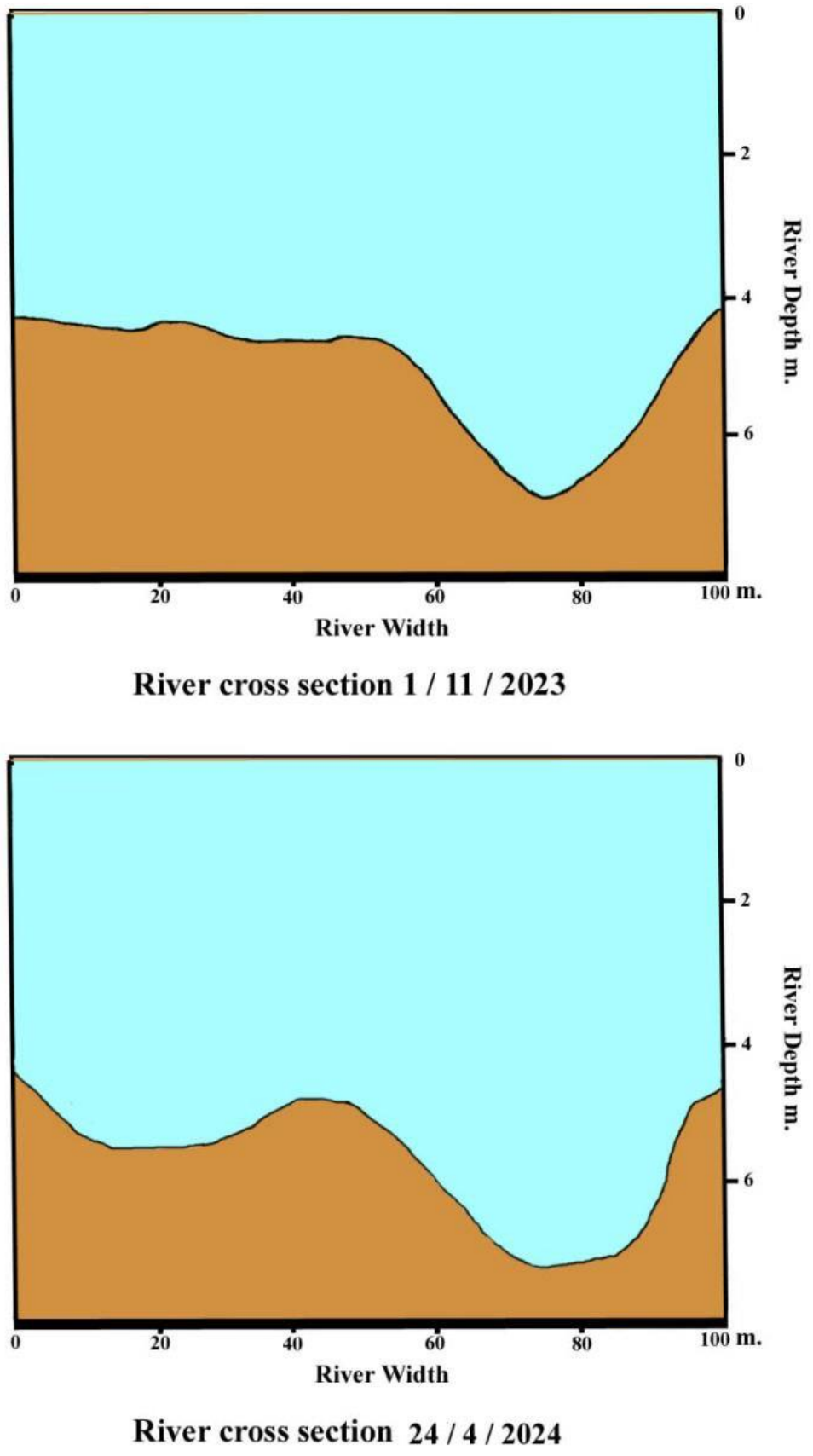


Fig.11. River depth cross-section for P2

Depth measurements still showed one depth hole near the right bank (because large quantities of water come from the Tharthar channel), with a new digging place still 3m from the left bank. So after the meeting point between the Euphrates and the channel, not such a huge change will occur, but more depth will occur near the right bank.

7.3 Samples of Banks Soil

The results and classification of soil samples according to USDA standards triangular showed that most samples were classified within (Sandy Loam) and some samples within (Sandy Clay Loam). This classification corresponds to the fact that the Euphrates River in the study region is in a mature stage and is characterized by coarse to medium sand deposits, These sizes decrease as the river enters the old stage toward the south. Soil characteristics change with certain stimuli, which change their reflectivity and therefore lose their characteristic properties (Abbas and Al-Jarrah, 2023). In terms of reflectivity, there is a similarity in the sizes of the sediments, so their reflectivity will be very close, except for some of the samples. The main factor that will change the reflectivity of sediments is the amount of compaction if they are old sediments (areas of bank erosion with a higher reflectance value), and if they are loose without sufficient compaction for areas of deposition (modern islands) or the extension of the bank itself will record a lower reflectance value (Figs.8 and 9).

7.4 Water Turbidity Samples

The river water samples were analyzed in the Nephelometric Turbidity Units (NTU) procedure; results showed that the turbidity percentage for the first period ranged between24 and58 and differed according to the location of the banks or depth, but in general, it was within the natural turbidity levels of the river. As for the second period, the turbidity percentage was between 42 and 88 This is due to the flood season and transporting of sediments in larger quantities. These ratios explained why the river's surface showed different reflectivity in both periods and that the results were not very homogeneous clea, pure river water without carried sediments will have very low reflectance (less than 10%) when the river shows more reflectivity. This is an indication of the increased turbidity of the water.

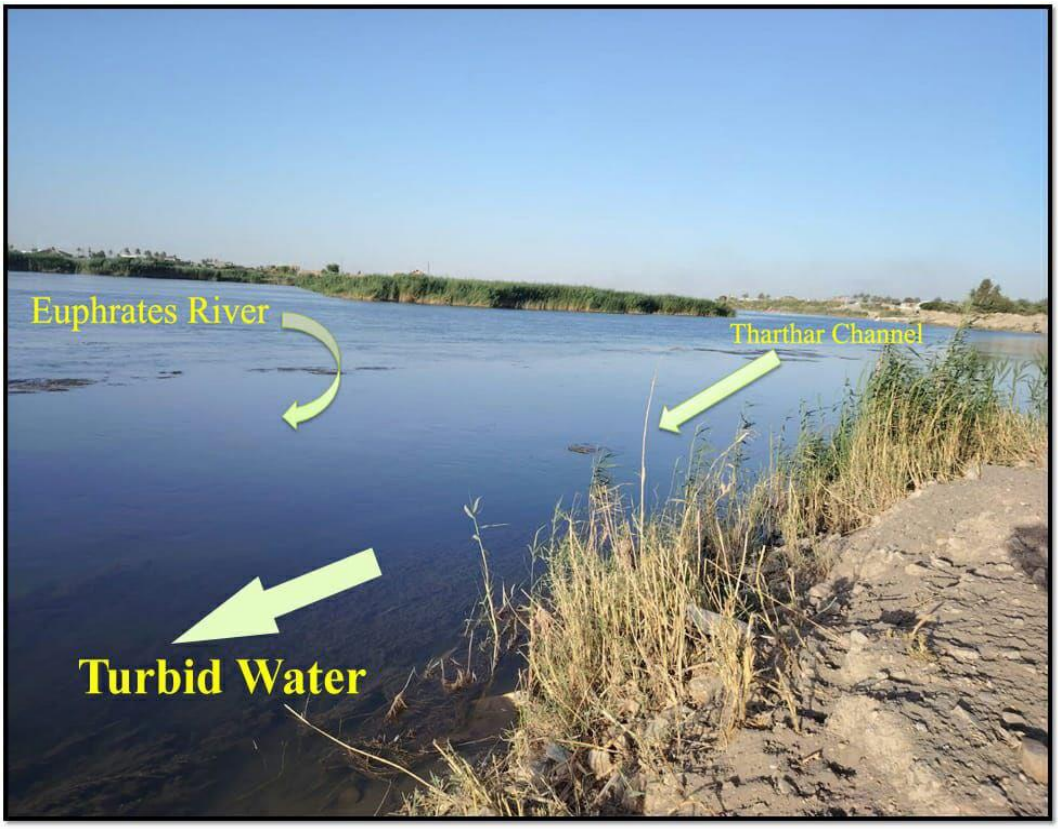


Fig.12. Types of water at meeting point.

7.5. Satellite Series Images

Digital satellite images are based on the amount of spectral reflectivity the ground reflects in the imaging area. These values remain constant under certain influences and change depending on the type of factor. Time is one of the most important reasons for changing reflectivity values, as shown by a series of satellite images recorded before and after the establishment of the Al-Tharthar channel. (It is considered one of the most important factors for the instability of the river) Reflective subtraction operations were performed between these images to obtain the changed area and the directions of the river's shifting. The subtraction was done by matching the coordinates of the areas with each other to ensure the reflectivity resulting from the same phenomenon or object, whenever to subtraction value is considerable, it will indicate a more significant change with a lighter reflective value, and vice versa. Sinuosity is calculated within 52 years for both river courses before and after the Euphrates and Tharthar channel meeting points (Table 1).

Table 1. Sinuosity for the Euphrates River before and after the establishment of the Tharthar channel

1972 (Tharthar channel established 1976) Abdullah and Al-Ansari (2021)		**2024**	
Sinuosity before meeting point	Sinuosity after meeting point	Sinuosity before meeting point	Sinuosity after meeting point
1.36	2.07	1.44	2.21

Interpreting the image obtained by subtracting reflective digital images for various dates, revealed specific information about the areas affected by the river's activity over 52 years, the possible directions of the river shift, and the additional areas and river islands that appeared, which were identified as yellow in the Fig.13.

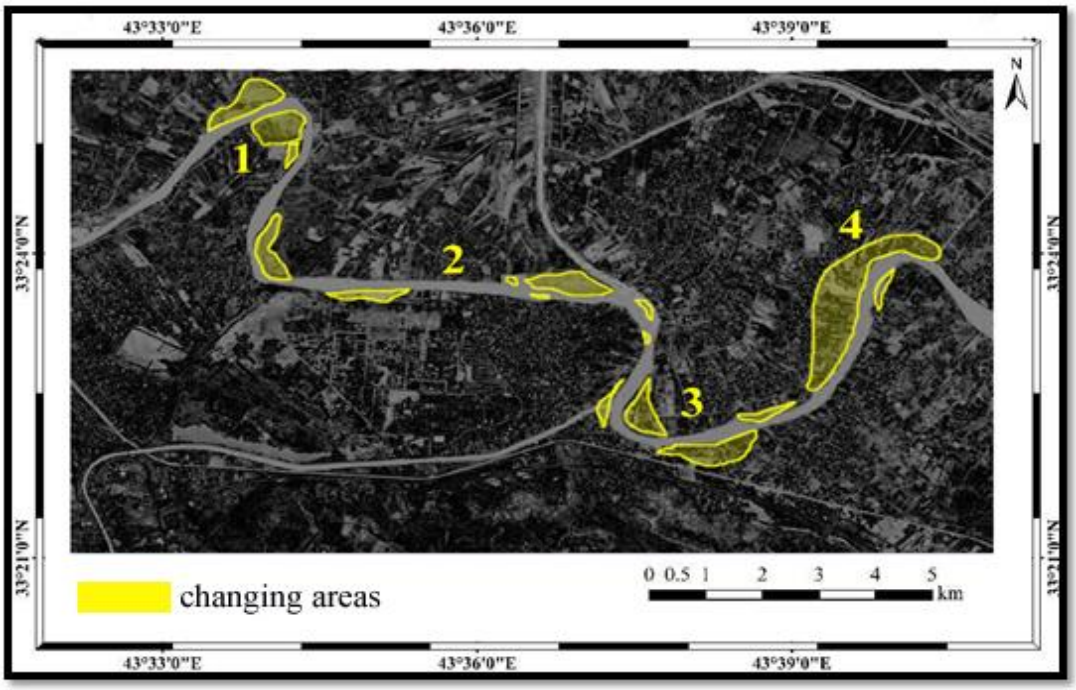


Fig.13. Areas of changes for Euphrates river

8. Conclusions

- The main results of spectral reflectivity measurements for two river profiles extending from (left bank - water body - right bank) showed areas that had already changed or maybe affected later by the difference in reflectivity between the right and left banks. Results mention that the direction of the river shifts and changes from water areas to dry sediment areas on one side of the river and the opposite happens on the opposite side. Thus it became easy to determine the rivers' movement and the shallow water areas that the naked eye cannot distinguish.
- The Tharthar Channel had a clear impact on the Euphrates River, due to the amounts of water and sediment added to the river that will change the stability of the river then start to shift, meander, and Deepen the bed to return to a state of stability again. An example is the increase in river sinuosity calculated from the satellite image after constructing the channel to the Euphrates, The Sinuosity ratio is greater than the sinuosity ratio of the area before it.
- The Euphrates River still has some activities and powers to change its course even in the past and current low river discharges and the continuous drought seasons for decades.
- The results of sorting and analyzing the sediments of the banks showed that the soil samples of the banks were different between the two banks, As the river erodes the bank it has more cohesive sediments because it is the oldest bank, and therefore its reflection will be higher than the relatively recent bank, Its sediments will be rougher and its reflection will be less than the first type. This is clear from the reflectivity diagrams of the river profiles, and it has become possible to distinguish the kind of banks through their reflectivity.
- Turbidity measurements of water samples gave a difference depending on the location of the sample and its proximity or distance from the banks or the middle of the river course. The water

current coming from the Tharthar Channel had higher turbidity than the original Euphrates River, Water samples due to the speed of this current and the type of area through which it passes.

- Matching serial satellite images over the years and comparing them with each other revealed to us the areas towards which the river has shifted (this is a major threat). Som shift distances reached 900-1000 m qa in the less affected areas to 100-200 m This is a way to identify the threatened and less stable areas.

References

Abbas, E. H., Al-Jarrah, O. B., 2023. The relationship between organic matter and soil reflectance at Ramadi, Iraq. Iraqi Geological Journal, 12-17.

Abdul-Jabbar, A. A., 2013. Tectonic Study of Al-Thirthar, Al-Habbaniya, and Al-Razzazah Depressions, West of Tigris River, Iraq. Unpublished Ph. D. Dissertation, University of Baghdad, Iraq.

Abdullah, M., Al-Ansari, N., 2021. Irrigation projects in Iraq. Journal of Earth Sciences and Geotechnical Engineering, 11(2), 35-160.

Al-Ansari, N., Adamo, N., Sissakian, V., 2019. Hydrological characteristics of the Tigris and Euphrates Rivers. Journal of Earth Sciences and Geotechnical Engineering, 9(4), 1-26.

Al-Ansari, N., Adamo, N., Sissakian, V., Knutsson, S., Laue, J., 2018. Water resources of the Euphrates River catchment. Journal of Earth Sciences and Geotechnical Engineering, 8(3), 1-20.

Brookes, A., 1994. River channel change. In P. Calow and GE Petts, The Rivers Handbook: Hydrological and Ecological Principles, 55–75.

Jaafar, E. N., Daliman, S., 2022. Analysis of river channel change using remote sensing images at Kelantan River Basin. In Institute of Physics Publishing (IOP) Conference Series: Earth and Environmental Science, 1102(1), 012082. IOP Publishing.

Lehmann, J., Kleber, M., 2015. The contentious nature of soil organic matter. Nature, 528 (7580), 60–68.

Leopold, L.B., 1994. A View of the River. Harvard University Press.

Meade, T. W., Dyer, S., Browne, W., Townsend, J., Frank, A. O., 1990. Low back pain of mechanical origin: randomised comparison of chiropractic and hospital outpatient treatment. British Medical Journal, 300 (6737), 1431-1437.

Owens, P. N., Batalla, R. J., Collins, A. J., Gomez, B., Hicks, D. M., Horowitz, A. J., 2005. Fine-grained sediment in river systems: Environmental significance and management issues. River Research an Applications, 21(7), 693-717.

Panhalkar, S.S., Jarag, A. P., 2017. Flood risk assessment of Panchganga River (Kolhapur district, Maharashtra) using GIS-based multicriteria decision. Current Science, 112 (4).

Rai, P. K., Chandel, R. S., Mishra, V. N., Singh, P., 2018. Hydrological inferences through morphometric analysis of lower Kosi river basin of India for water resource management based on remote sensing data. Applied Water Science, 8, 1-16.

Syahreza, S., MatJafri, M. Z., Lim, H. S., Mustapha, M. R., 2012. Water quality assessment in Kelantan delta using remote sensing technique. In Electro-optical remote sensing, photonic technologies, and applications VI, Society of Photo-Optical Instrumentation Engineers, 8542, 286-292.

Wakode, H. B., Dutta, D., Desai, V. R., Baier, K., Azzam, R., 2013. Morphometric analysis of the upper catchment of Kosi River using GIS techniques. Arabian Journal of Geosciences, 6, 395-408.

Weidong, L., Baret, F., Xingfa, G., Qingxi, T., Lanfen, Z., Bing, Z., 2002. Relating soil surface moisture to reflectance. Remote Sensing of Environment, 81(2–3), 238–246.

Xie, R., Xiao, H., 2018. Application of remote sensing in the estimation of soil organic matter content. Chemical Engineering Transactions, 66, 469–474

Xu, R., Hu, Y., Gao, H., Pan, Z., 2017. Derivation of fractional urban signals in better capturing urbanization process. Environmental Earth Sciences, 76, 1-11.

Zhou, Y., Tang, Q., 2022. Meandering Characteristics of the Yimin River in Hulun Buir Grassland, Inner Mongolia, China. Remote Sensing, 14(11), 2696.