Hydrological Analysis of the Dwerige Alluvial fan, Maysan Governorate. Southern Iraq, using GIS technique and remote sensing

Lect. Dr. Suaad Albhadili
Asst. Lect. Dr. Ali Khaled Al-Ali
Asst. Lect. Duha Saleh Karem
Department of Geology / College of Science / University of Basrah

Abstract

In order to create a digital geographic information database for the basin, the study intends to use Geographic Information System (GIS) technology to uncover the hydrological traits of the Dwerige alluvial fan, including spatial, morphological, and topographic features as well as drainage network characteristics and patterns. The hydrological features of the Dwerige alluvial fan were determined by the research using Arc Map in ArcGIS v.10.8 and Digital Elevation Model (DEM) data. A river network map was produced using a quantitative methodology that concentrated on valley analysis within the study area. According to the research, the Dwerige alluvial fan has five basins and watersheds and four stream orders, with a predominate flow direction of northeast to southwest.

1. Introduction

Because fans have special hydrological consequences relating to water runoff qualities, water channel and valley hydrology, erosion, and deposition processes, examining and defining fans is an important part of hydrological study. Comprehending the complex interactions between various elements and geological occurrences in watersheds has been a long-standing endeavor, initially directed by theories developed by Horton in 1945 and subsequently improved upon by (Strahler in 1957). This field has benefited greatly from the introduction of a mathematical method for analyzing watersheds, which involves tributary numbers and lengths. In order to better understand watershed areas in dry regions, recent studies have switched toward using cutting-edge technologies, particularly geographic information systems and remote sensing (Sartell, 2012). This technology integration is essential for many different disciplines, such as soil studies, agricultural investment, and water resources. These instruments provide useful information for calculating the hydrological properties of the water network that supplies the fan. The convention for naming fans is to give the fan the names of the rivers that helped form it. The Dowairij River, for example, is the source of the name of the Dowairij fan. This illustrates the continuous applicability of historical concepts along with the incorporation of contemporary technologies in the thorough examination of fans and the hydrological characteristics that are related to them.

Understanding the distribution, mobility, and properties of water in various states—such as precipitation, surface runoff, and groundwater flow—was accomplished through this analysis. A systematic study that involves examining and interpreting various hydrological phenomena in a certain area or watershed is known as hydrological analysis. A watershed or drainage basin is an area where all water converges to a common outflow, and its boundaries must be identified and marked. This process is known as "watershed delineation." The fan's digital elevation model (DEM) and the numbers of basins and tributaries were determined in this study (AL-Jboory et al., 2021). Additionally, the DEM from the USGS Earth Explorer was used to determine the quantity of water reservoirs in the area. A number of processes were implemented, starting with the integration.

There has been little study done on the geological, hydrological, and geomorphological characteristics of the Dowairij fan. A few studies offer a comprehensive summary, and the research area has served as the focus of these investigations. Among these studies, Rashid (2001) is particularly noteworthy because it examines the geomorphology and sedimentation of Hawr Al Jazeera and its surroundings, focusing on the hydrological characteristics of the nearby wetlands. In a separate study, the chemical characteristics of a subset of well fluids in the northeastern Maysan Governorate which includes the northern Dowairij fan—were investigated (Sartell, 2012). This study highlighted the spatial, morphological, and hierarchical elements of the main basin while focusing on the morphometric properties of the Dowairij River basin's lower parts. The primary goal of the study is to examine the hydrological features of the Dowairij fan, which entails figuring out the fan's elevation, comprehending the direction of water flow, and locating the spots where water tends to collect. The study also seeks to determine how many basins and watersheds are included in the Dowairij watershed.

2. Location of study area

Dowairij Fan is a geographical area that is located near the border between Iraq and Iran in the southeast of the country. Its entire area, 1608.74 square kilometers, is contained within the boundaries of the Iraqi Maysan Governorate. Lake Ress and Sanaf border it to the north; the Hamrin Highlands to the east; Lake Hawiza to the south; and the Al-Musharrah River and Ghazilah Drain to the west. The latitudinal range of (31.04056 to 32.01041) north and the longitudinal range of (47.01815 to 47.05139) east are where Dowairij Fan is situated. The headwaters of the Dowairij Fan are located south of the sources of the Tigris River, and the basin as a whole lies in Iranian territory.

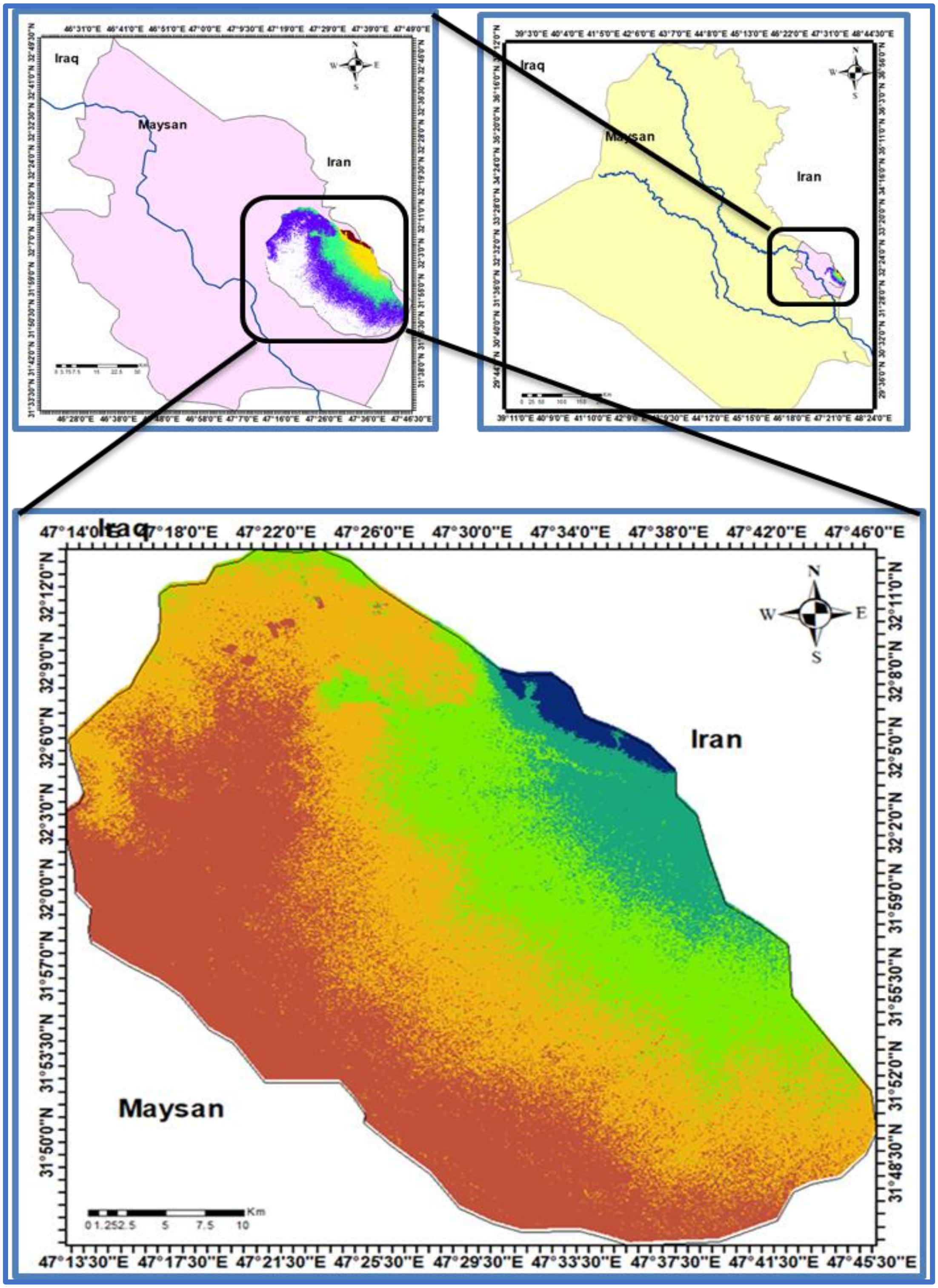

Figure 1: location map of study area

3. General description of study area

- **Geological and Tectonically description on the study area**

The study is centered on the southeast portion of a depositional plain that is located inside the Arabian Shield's unstable platform, as defined by (Buddy and Jassim, 1987). The region is located in the Tigris Secondary Zone due to its lithological features, per (Jassim and Goff, 2006). As a result, the alluvial fan is located on the depositional plain at a lower elevation at the foothills of unstable mountains. The Arabian Plate sub ducted beneath the Iranian Plate during the Miocene–Pliocene epoch, which represents the final stages of the Alpine orogeny, giving rise to this terrain. East of Amara City, on the eastern portion of the Mesopotamia Plain, next to the Low Folded Zone, is where the notable geomorphic unit known as the Dwerige fan originated. The fan covers. Massive, unsorted gravel beds with sand in the near section and a mud matrix (sand, silty clay) in the far part are what define the fan. (Domas and Yacoub, 1983) reported that the exposed thickness of the alluvial fan ranged from 5 to 6 meters. One characteristic that sets them apart is the abrupt decrease in grain size downstream, which starts at the apex and proceeds in different directions to the distal margins (Figure, 2), who states that internally formed dendritic channels inside earlier deposits erode developed surfaces and transport debris to depositional areas downslope.

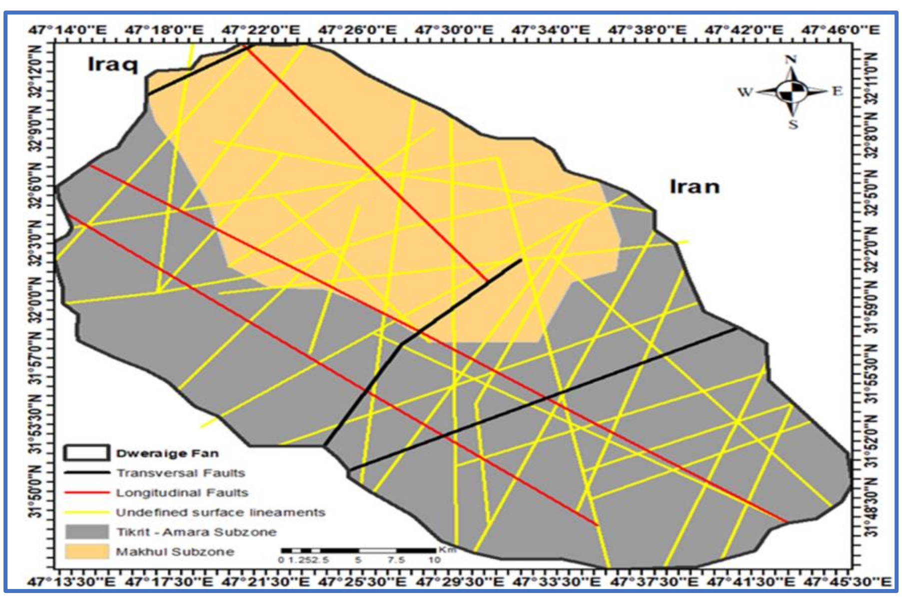

Figure 2: Tectonic map of Dwerige Alluvial fan

In the northern parts of the river basin, the alluvial fan exhibits Middle Eocene deposits, among other different geological formations. There are Pliocene-era formations visible as one moves south. Furthermore, geological formations that originate from the Bai Hassan and Mukdadiyah formations are exposed in regions near the border between Iraq and Iran, including Sheikh Fares, Abu Ghraib, and Al-Shuhaniyah (Figure, 3).

1. **Mukdadiyah formations**: The depositional environment of this geological formation is comparable to that of the Bai Hassan Formation, having originated in a riverine setting. It is made up of gravel, conglomeratic sandstone, shale, siltstone, sandstone, and sandy mudstone layers. According to Jasim and Goff (2006), this formation is located in the southwest of the alluvial fan along the border between Iraq and Iran. It is particularly noticeable in the Sheikh Fares region.
2. **Bai Hassan**: This formation is made up of sandstone and shale rocks that were formed in a freshwater river environment. It can be distinguished from the Mukdadiyah Formation by thin strata. Along the western and southern edges of the alluvial fan along the border between Iran and Iraq, this geological formation is exposed longitudinally. Moreover, it may be seen in the Sheikh Fares region close to the fan's neck as well as the surrounding territories; it is also visible in the Bazrkan hills to the fan's north (Sabah, 2011).
3. **Flood Plain Sediments**: These bands of sedimentary formations are found along some riverbanks, and they are vulnerable to being submerged by river flows, especially during floods. There is further sedimentation, which adds to the current deposits. Particularly in the lower part of the river's basin, these structures stretch across both banks of the Dowairij River. They are made up of layers that can be several meters thick in certain places, made up of sand, gravel, and greenish clay (Jassim and Goff, 2006).

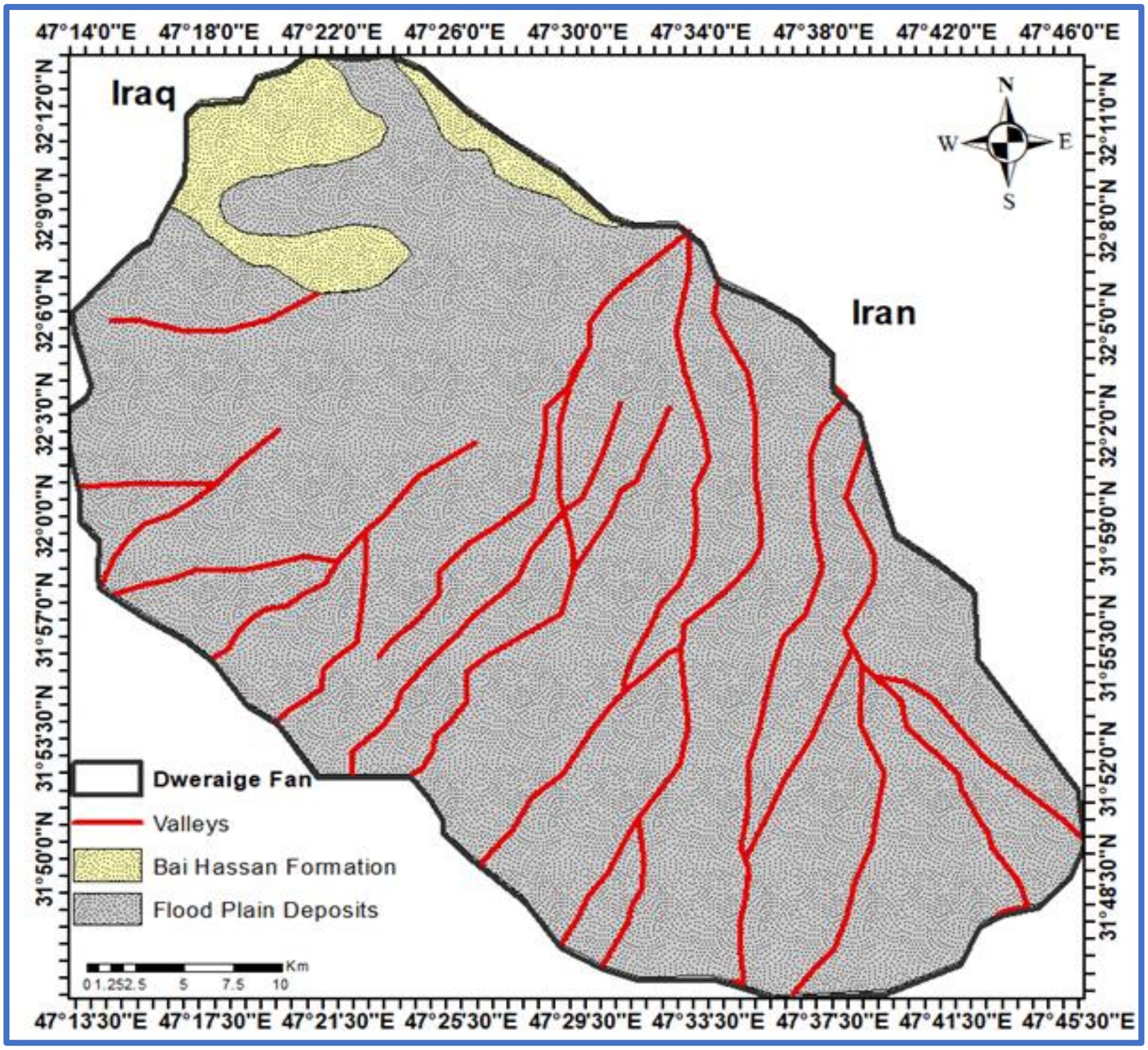

Figure 3: geological map of Dwerige Alluvial fan.

4. Material and methods

A hydrological analysis methodically looks into the water movement patterns in a particular research area, such the Dowairij fan. This procedure entails necessary actions to identify the features of watersheds and categorize stream networks. The main focus lies in determining the principal drainage basins and classifying streams into different orders, providing an understanding of the hydrological dynamics in the area. The study gathers and processes data for hydrological studies using GIS and remote sensing techniques. Specifically, ASTER GDEM data and detailed spatial information from Landsat OLI 8 are integrated. While GIS serves as a framework for organizing, analyzing, and displaying spatial data, remote sensing entails gathering data from a distance, frequently by satellite or aerial images. For data processing and analysis, the study uses software tools including ArcGIS version 10.4.1 and ERDAS IMAGINE version 14. ArcGIS's Hydrology toolkit is particularly useful for retrieving data about geometric properties and stream orders. The study uses the UTM coordinate system with the WGS-1984 datum in zone 38S to ensure accuracy in georeferencing and spatial analysis. The summary of the hydrological analysis is shown graphically in (Figure, 4) .

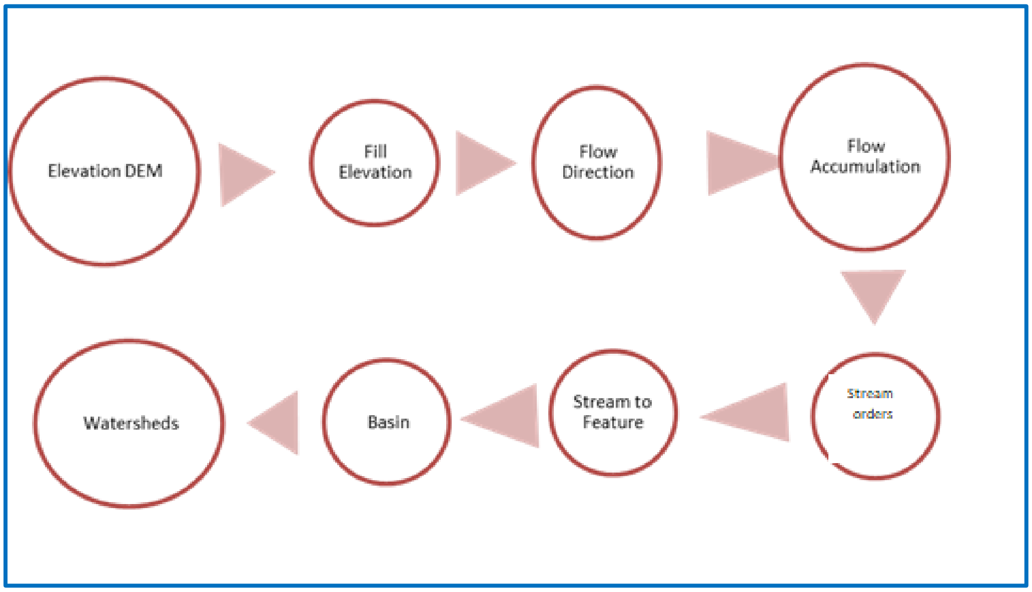

Figure 4: steps of Hydrological analysis

5. Result and discussion

This method comprises categorizing the smaller watersheds inside the fan, classifying the stream order, establishing the borders of the main basin, and detailing the drainage system. Assessing elevation, figuring out fill elevation, determining flow direction, analyzing flow accumulation, categorizing stream orders, mapping stream characteristics, locating basins, and drawing watershed boundaries are the first phases in the process. The direction of flow in each cell is determined by taking the steepest drop, which is usually in the direction of the southwest from the northeast. Using a raster dataset containing elevation data, digital elevation models (DEMs) are widely used to represent the topography or surface of a site (Silvestro et al., 2012). Using digital elevation models is another way to depict landscape in a geographic information system. The steps in the method are to obtain the DEM from USGS Earth Explorer, mosaic raster data into a single raster using Arc Toolbox, then project the raster and use the raster calculator. The elevation data for the designated area is provided as the ultimate result of these procedures (Figure, 5).

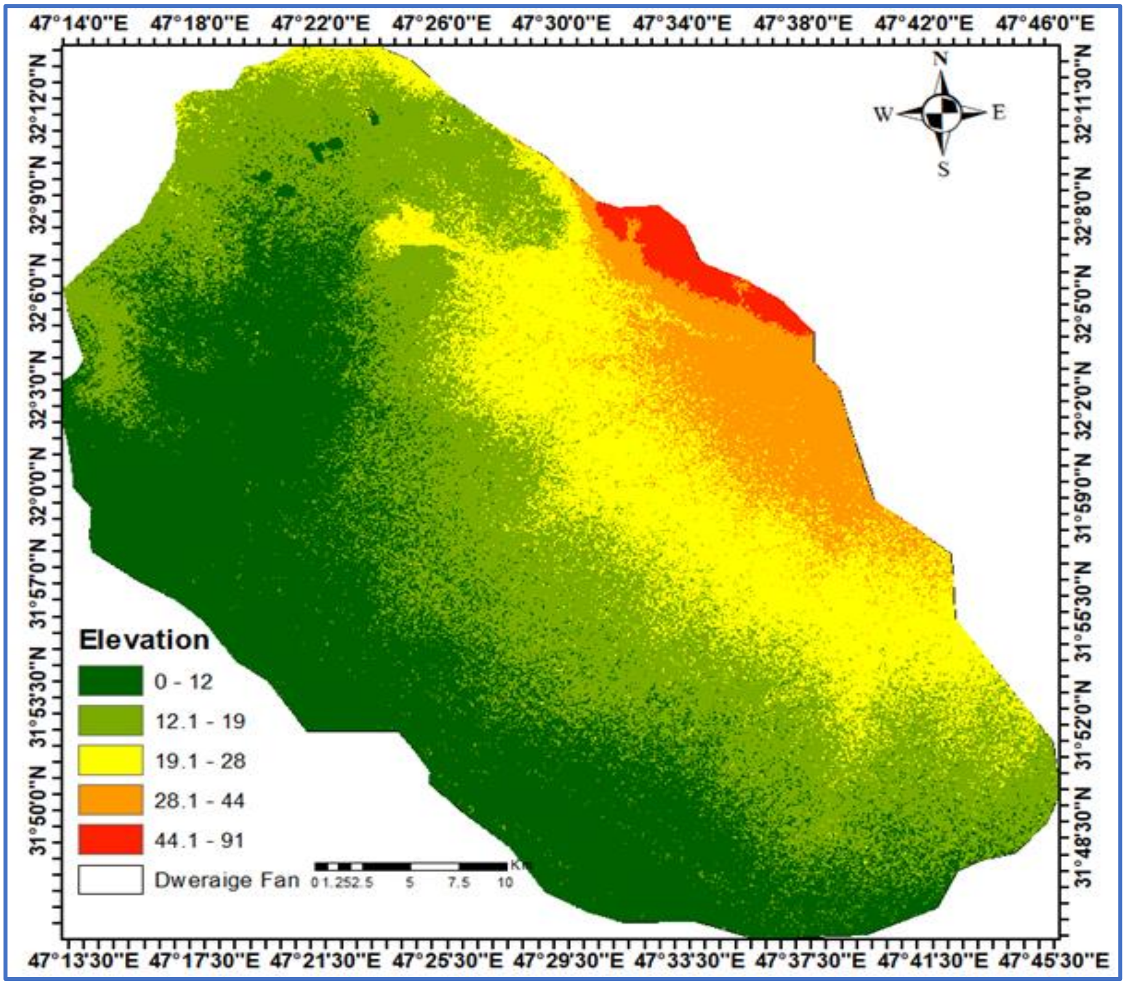

Figure 5: Elevation map of Dwerige Alluvial fan

Where there are gaps or voids in the elevation data, pixels are created using the Elevation Fill function. To locate and fill in topographic depressions, this tool combines elements of multiple other tools, including Focal Flow, Flow Direction, Sink, Watershed, and Zonal Fill (Meijerink et al., 2014). Until every depression inside the designated z limit is adequately filled, the iterative process is carried out repeatedly. The fill elevation is determined by the Fill Elevation tool (Figure, 6) of the Arc Toolbox, a spatial analyst tool specifically located inside the Hydrology section.

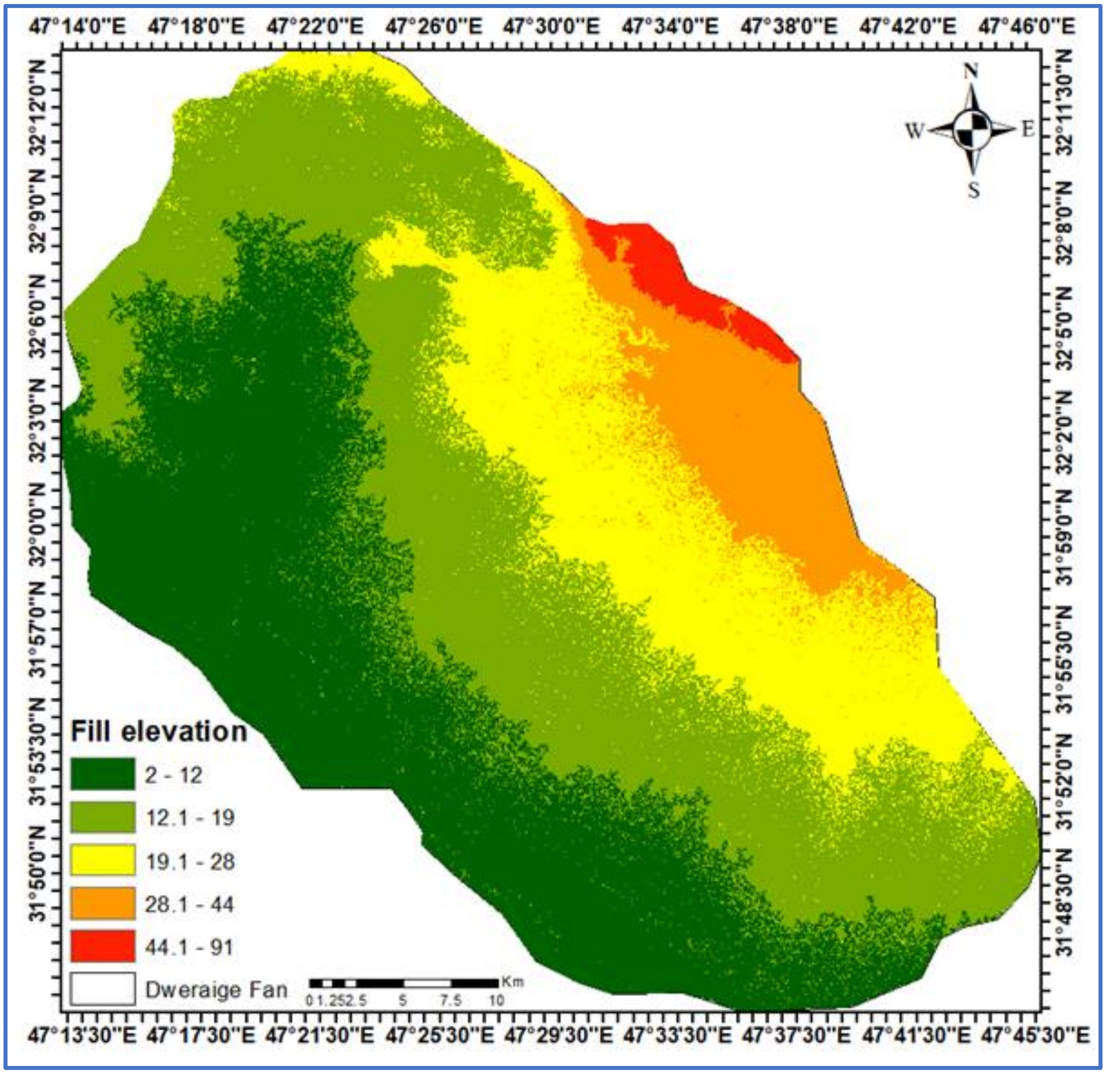

Figure 6: Fill Elevation map of Dwerige Alluvial fan

Determining the flow direction from each raster cell is an essential step in obtaining hydrologic parameters from a surface (Meijerink et al., 1994). The Flow Direction tool (Gorte & Koolhoven, 1990) is used to do this. It takes a surface as input and outputs a raster that shows the direction of flow departing each cell. The method of figuring out flow direction is carried out by using the Flow Direction tool in the Hydrology part of the Arc Toolbox, a spatial analyst tool. The flow direction that was consistently observed in the research area was from the northeast to the southwest (Figure 7).

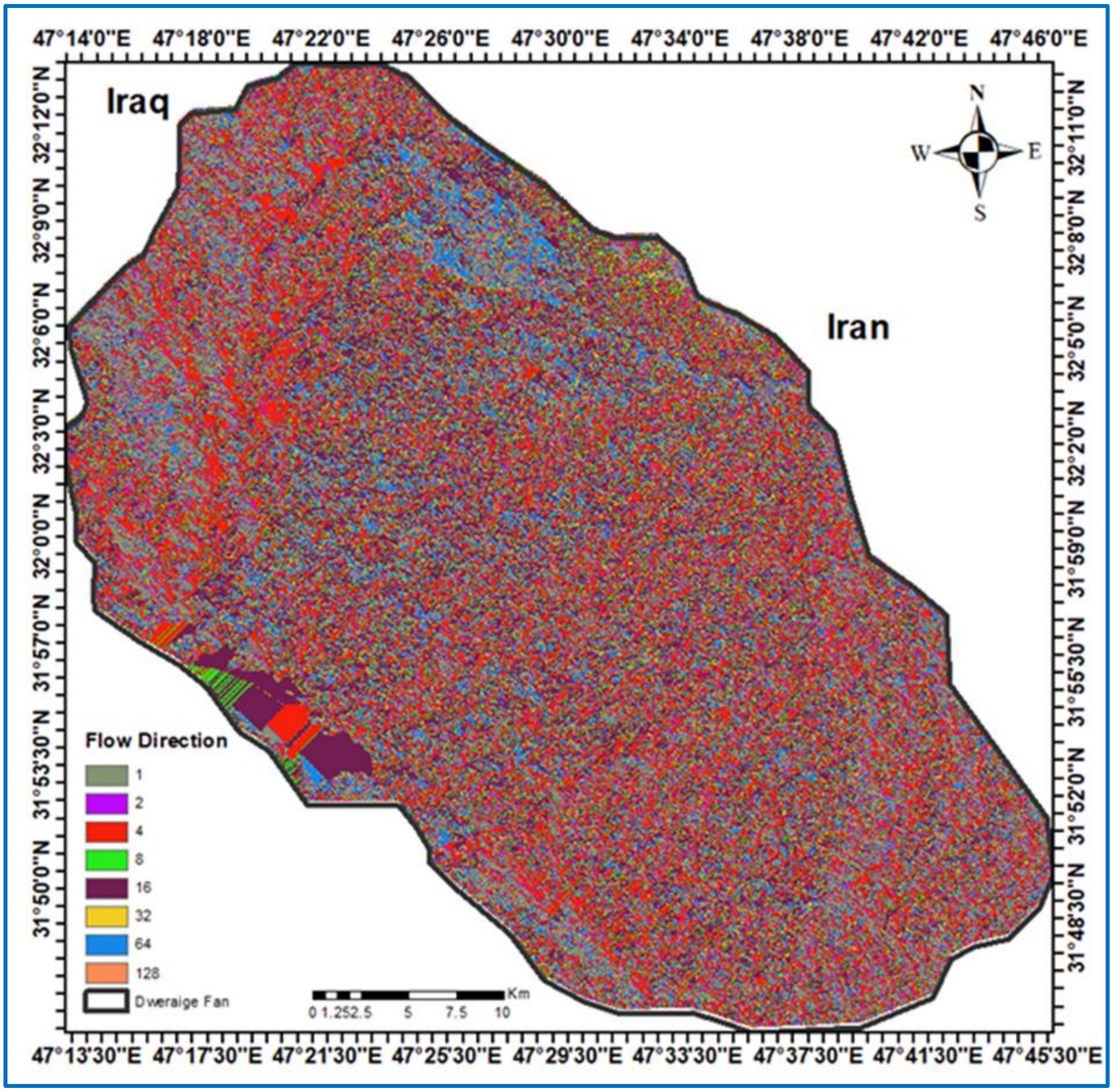

Figure 7: Flow direction map of Dwerige Alluvial fan

A flow accumulation function is described by O'Callaghan & Mark (1984) as an operator that computes a resultant matrix given a drainage direction matrix and a weight matrix. Every element in this matrix represents the total of all the weights of the other components in the matrix that drain to that particular element. Procedures for aggregating flows from individual elements or pixels in a digital elevation model have been described by a number of writers. The approach taken in this instance is derived from (Donker's, 1992). This tool can be found under Hydrology, Flow Accumulation, and Spatial Analyst Tools in the Arc Toolbox. Finding the most concentrated area where water flow accumulates most significantly is the goal of using this technique. The data indicates that the majority of this shows locations where a significant quantity of collected flow converges, offering important information on the water movement and drainage patterns in the landscape (Figure, 8).

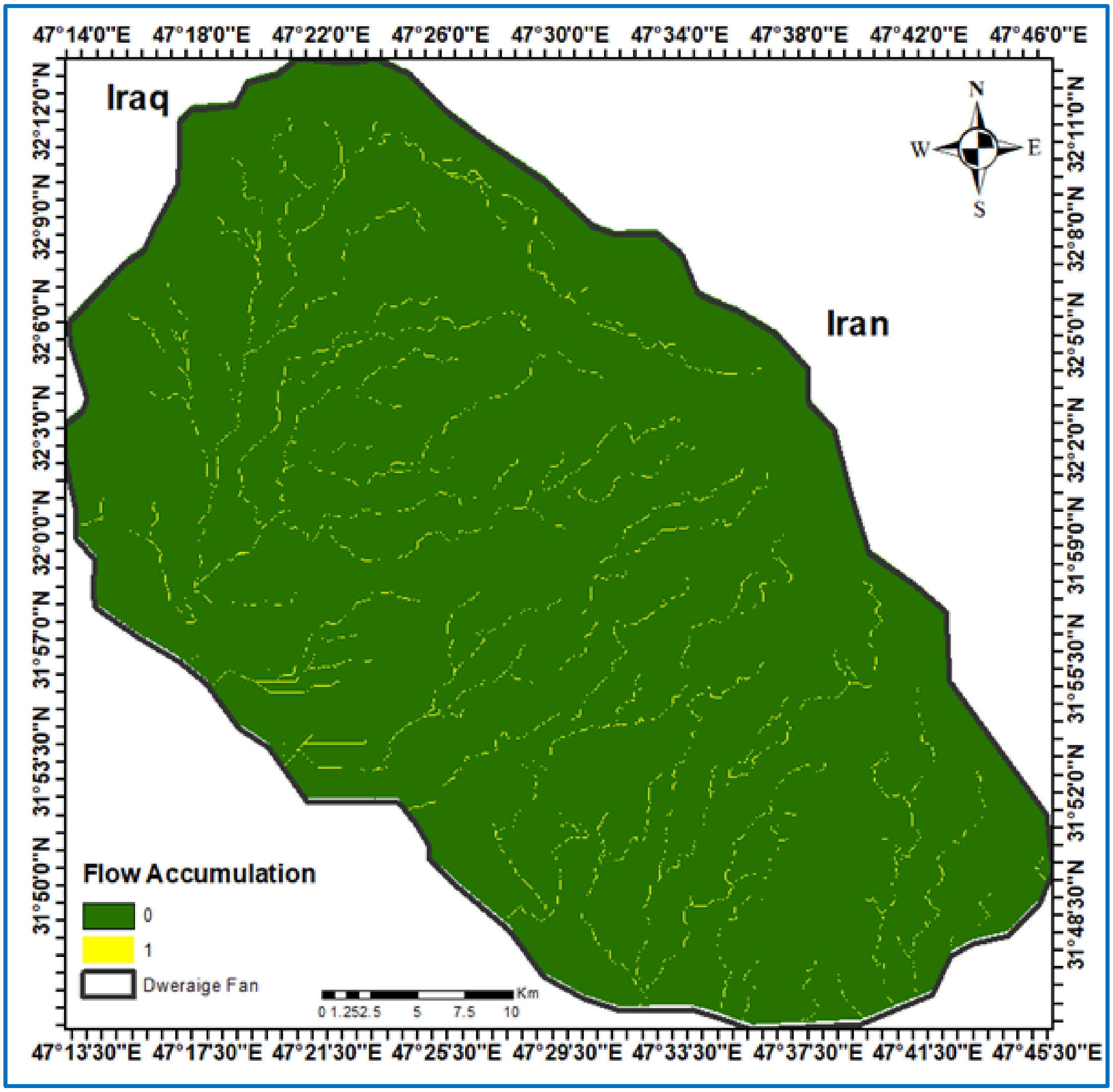

Figure 8: Flow direction map of Dwerige Alluvial fan

Stream order makes it easier to categorize streams according to where they are in the network by offering a methodical way to arrange and comprehend the hierarchical structure of a river network (Strahler, 1952). In order to analyze drainage systems and comprehend water flow within a watershed, higher-order streams usually originate from the confluence of two or more lower-order streams. This establishes a hierarchical structure. The greater slope between the fan's head and base is thought to be responsible for the region's profusion of varied stream orders. Furthermore, the distribution of stream orders within the basin is greatly influenced by a number of variables pertaining to the landforms, altitudes, and structural conditions of the studied area (Silvestro et al., 2012). This drainage system's diverse range of stream orders is mostly due to geomorphic factors, including nearby geological formations, uniform lithology, little relief change, and easily eroded sediments (Figure 9). First-order streams in the research area are found to have the maximum density, and the number of streams decreases progressively with increasing order. In the Dowairij fan, for instance, four stream orders are found.

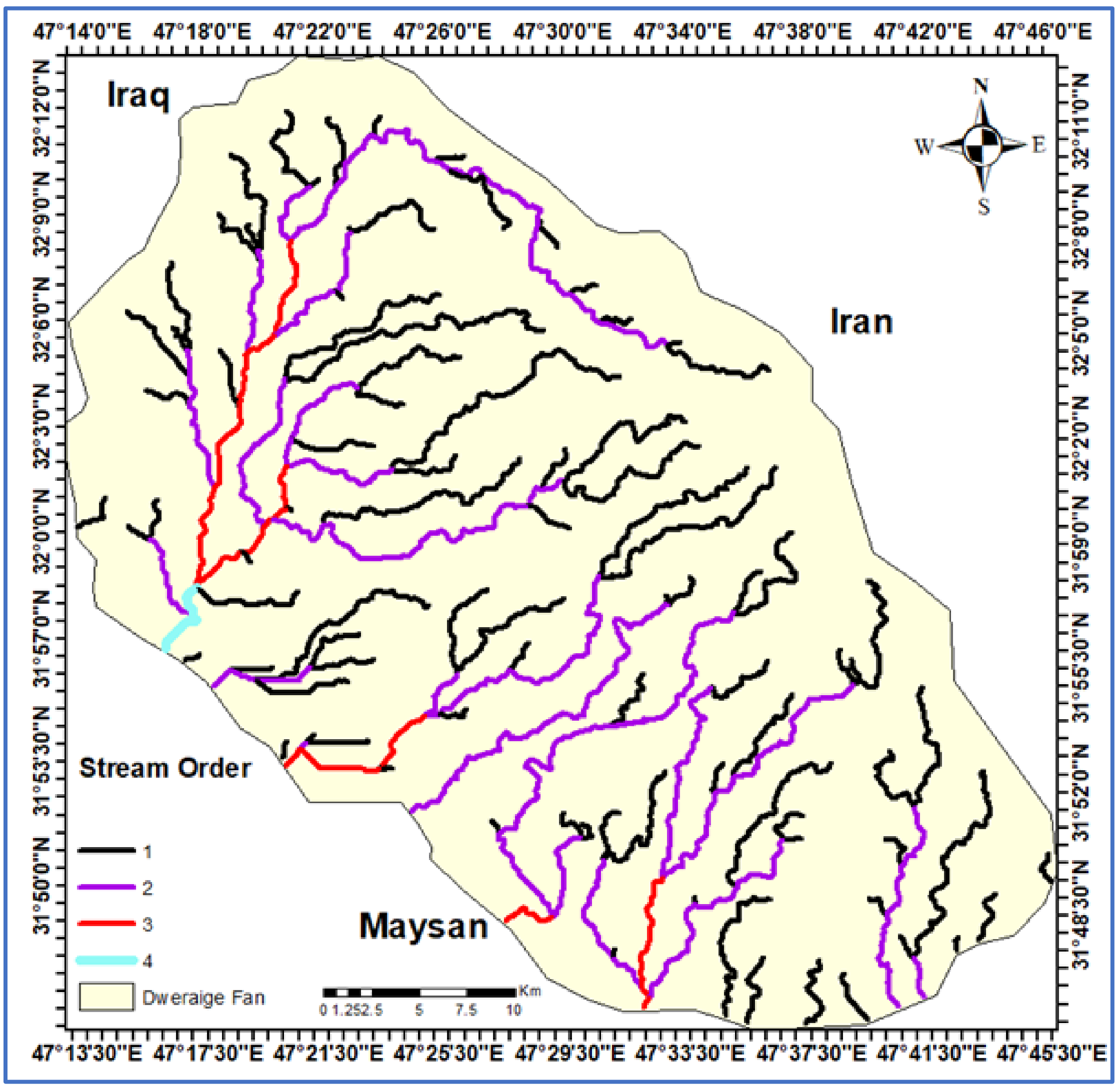

Figure 9: Stream order map of Dwerige Alluvial fan

Al-Jboory et al. (2021) state that Basin provides a comprehensive framework that combines modeling tools with environmental spatial and tabular data through a Geographic Information System (GIS) interface. Basin delineation is accomplished via the Arc Toolbox, specifically via the Spatial Analyst Tools, Hydrology, and Basin sections. Five basins are found in the study region, according to the assessment (Figure, 10).

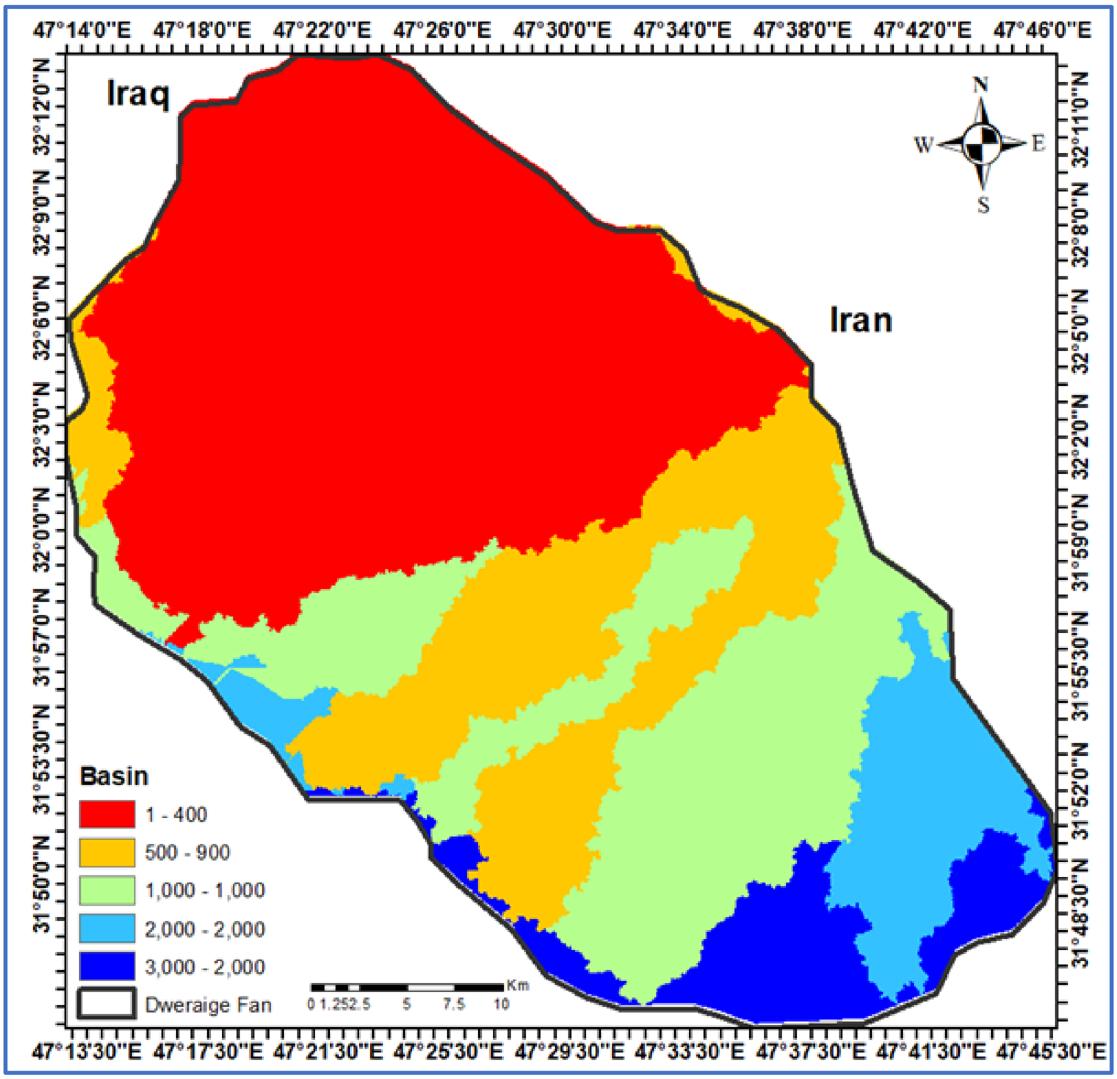

Figure 10: Basin map of Dwerige Alluvial fan

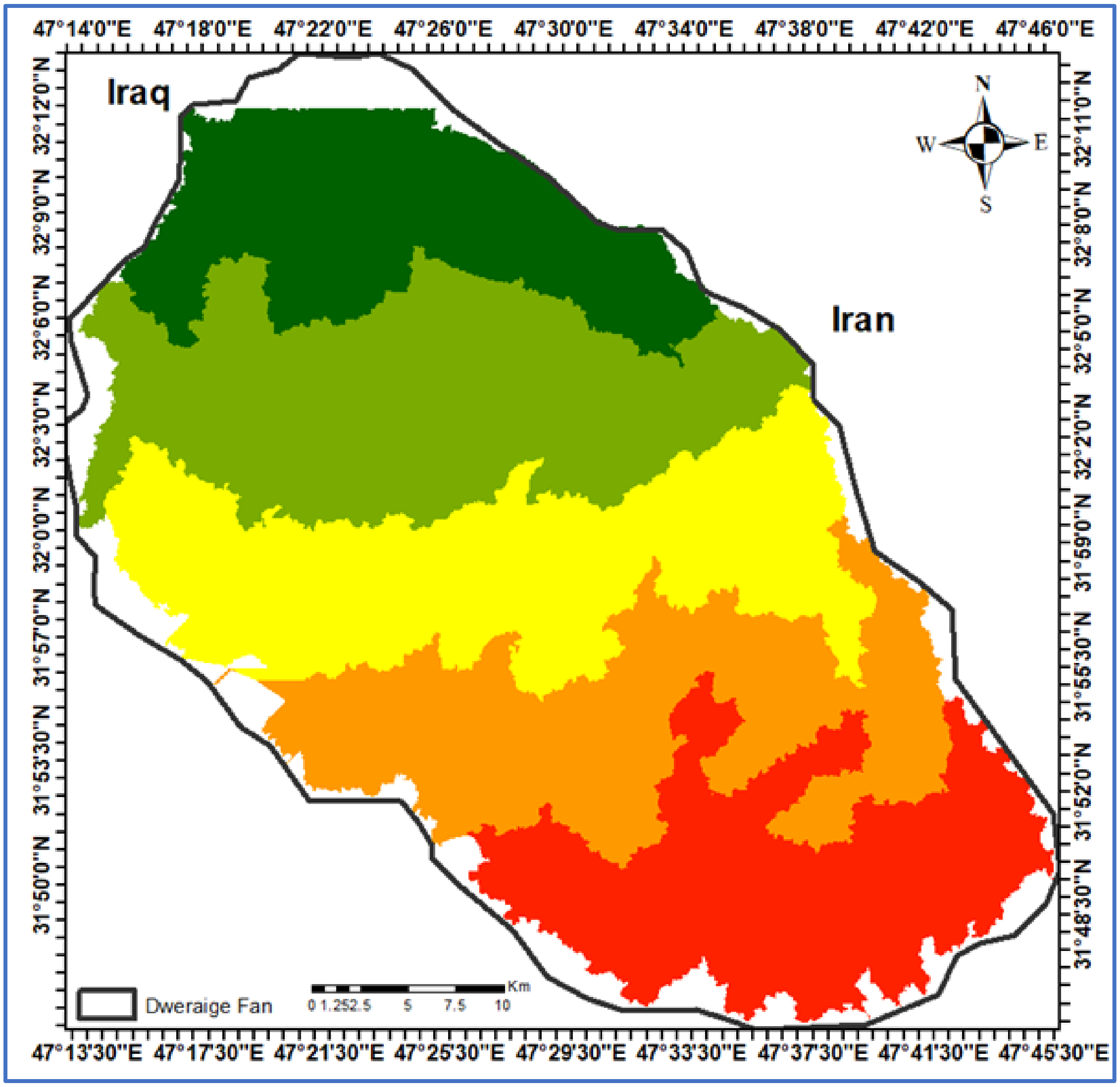

Figure 11: Watersheds map of Dwerige Alluvial fan

A watershed is an elevated area that creates concentrated drainage by guiding water flow to a common outlet. It may consist of smaller divisions referred to as sub basins and be a subset of a larger watershed (Al-Jboory et al., 2021). Moreover, the Arc Toolbox can be used to demarcate watersheds; specifically, look under Spatial Analyst Tools, Hydrology, and Watersheds. Five watersheds are included in the study region, according to the analysis (Figure, 11).

6. Conclusion.

1. The hydrological analysis focuses on examining the water circulation patterns within a specific study area, such as the Dowairij fan. This process involves key steps, including the delineation of watershed characteristics and the classification of stream networks. To conduct this analysis, a Digital Elevation Model (DEM) from the USGS Earth Explorer is utilized, along with the integration of detailed spatial data derived from Landsat OLI 8 and ASTER GDEM. These data sources collectively enable a comprehensive hydrological assessment of the Dowairij fan.
2. The analysis reveals that the elevation of the Dowairij fan ranges from 0 to 91 meters above sea level, reflecting a pronounced slope from higher to lower areas. The water flow direction is identified as moving from northeast to southwest. Notably, within the study area, first-order streams exhibit the highest density, while the number of streams progressively declines with increasing stream order. For instance, the Dowairij fan comprises five basins and five watersheds.

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