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Cartographic modelling of the waterways network of the basin of Wali Kafan valley in Sulaymaniyah Governorate using GIS

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ABSTRACT: The important role of GIS as an advanced means of dealing with data in various scientific fields, notably hydrological studies, has emerged as it provides accurate automated methods in analysing spatial data and linking them to descriptive data. This helps us study the morphometric characteristics of the water drainage network using a sophisticated mechanism and building a database with morphometric variables based on advanced data sources. These sources are represented by Satellite Images and Digital Elevation Models (DEM). Spatial information system programs offer scientific methods that are based on measurement, analysis and interpretation. This, in turn, helps to predict the future of basins and to provide proposals and solutions that support future development plans. Morphometric properties are quantitative geomorphological properties in their general sense. These are analytical methods dealing with earth surface phenomena based mainly on data from contour maps, aerial images, satellite images, field studies such as DEM digital altitude data. The process of analysing morphometric characteristics in creating a spatial database for Wali Kafan valley and drawing the water drainage network for the basin as a natural morphometric phenomenon has a relationship in determining the use of land through the process of water harvesting and utilization during the drought period. It is also connected with the establishment of a submersible dam in the course of the valley and how to conserve and benefit from water as well as treatment of sediment transported in the stream of the valley and its effect on the submersible dam in the valley of Wali Kafan. This is in addition to its relationship to the study of drainage levels during the period of rain storms draining during the wet season.

Keywords (morphometric measurements, hydrological measurements, slope, satellite images, geomorphology, geographic information systems)

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1. **Introduction**

Climatic characteristics usually play an important role in the process of calculating the water budget of the river drainage basins. However, the specificity of the research in estimating the peak drainage and the volume of runoff after rainstorms makes the amounts of rain falling on the studied basins during the hours of the rain storm a priority especially in this research. The climatic elements despite its importance, can be made into the secondary effect on the water losses processes during the period of drainage of torrents in the valley of Wali Kafan. Particularly, the evaporation processes can not be calculated in a real way during the upper drainage period of the valley. Therefore, the characteristics of the basin and the factors affecting the processes of surface runoff were analysed. The degrees of torrential rain are usually related to the rain that causes it, taking into account the leakage and storage capacity of the drainage basins. It is also difficult to estimate the intensity and duration of the distribution of rain along the basin due to the absence of measurements in the area. However, the drainage rate is calculated through the period of the occurrence of floods in the basin of the valley course, i.e. the surface water in the basin. This means the water running in the area and falling on its surface, or the water that drains into it from the neighbouring areas. In the research area, the focus is on the group of streams and valleys coming from the highlands, which are the basis of life for many residents, although their relative importance is minimal in terms of the amount of water they supply. The feeder streams in Wali Kafan valley, which is one of the important surface water resources in the research area. This water originates from the highlands inside Iraq from a group of highlands in the Sulaymaniyah Governorate, which are (Jabal Korek, Jabal Zinka Turka, Jabal Shah Ma Hind and Peak Kalaka) in the region. The area of the basin is (95,029) Km², the basin circumference (63.846 km), the length of the basin (25,424 km), and the average width of the basin (7.030 km) (Al-Abdan, 2004, p. 130). As for the morphometric analyses that were adopted in this research, they are represented in the fourth level Toolbox- Spatial Analyst – Hydrology) based on accurate data with a high spatial clarity represented in (the satellite image, and the digital elevation model DEM), which helps us in drawing the water drainage network in an accurate and clear manner. This is reflected in the results of the morphometric analysis, thereby saving effort and time. The morphometric characteristics reflect the natural conditions accompanying the water basins and affect them directly such as the geological structure, climate and vegetation cover as any change in these factors leads to a clear change in the morphometric properties.

The morphometric studies and the results that can be reached are employed in studying the hydrology of the river, determining the amount of water discharge and predicting it, as well as determining the characteristics of the river's flood. The reason for this is that the shape, size and internal composition of the river basin are characteristics that all control the determination of the characteristics of the flow of the valley. As the general shape of the tributaries of the river and its different orders within the basin is a result of the relationship between the characteristics of the rocks of the region and their structural forms on the one hand, and the conditions of the old and current climate on the other. They reflect the characteristics of the rocks in terms of the degree of permeability, hardness, general slope of the surface and areas of rock weakness. The effect of all these characteristics is evident in modifying the general appearance of the valley drainage shape and determining the activity of the orders in the basin (Dawood, 1947, pp. 35-36).

Therefore, the structure of the research runs as follows:

1.1 Research problem

Are the water imports of the Wali Kafan valley Basin a result of environmental interactions that control the volume of water resources during torrential periods? or are they the product of the influence of natural factors that control the amount of water losses represented by the process of leakage, drainage or human use, and the amount of water harvested during the peak period of drainage for the valley?

1.2 Research hypothesis

It is represented by a set of answers of the problem assessed in this study.

a) The natural factors of the area affected the quantities of drainage and the utilization of water harvesting in the Wali Kafan valley stream, especially since the area is one of the most fertile agricultural lands in the area. This can be seen in the high slope rate, which contributes to the speed of drainage at the height of the torrential waters.
b) The construction of dams in the valley stream or on the edges of the heights to benefit from the rain and torrential waters during the rainy season, as well as to benefit from the spring water that spreads in the region and is approved by agriculture.
c) There are no measures to determine the quantities of high discharge, as well as the region's lack of devices and equipment to predict the occurrence of floods, especially during the rainy season.

1.3 The limits of the research

The research area represents the geographical location and the astronomical location. The region is located in the northern part of the Sulaymaniyah Governorate within the Dokan district and extends into the territory of Iraq. Astronomically, it is located between latitudes (36.25 – 36.12) north and longitudes (45.10 – 44.55) east. Figure (1) shows the location of the study area.

1.4 Research tools

The research tools can be outlined as follows:

- Geological map of the study area at 1:50000 scale for the area
- Topographic map of the area on a scale of 1:50000 for the area
- Satellite Images of LANDSAT.8 and KwikBear
- 12m DEM digital elevation data.
- Toolbox-Spatial Analyst – Hydrology

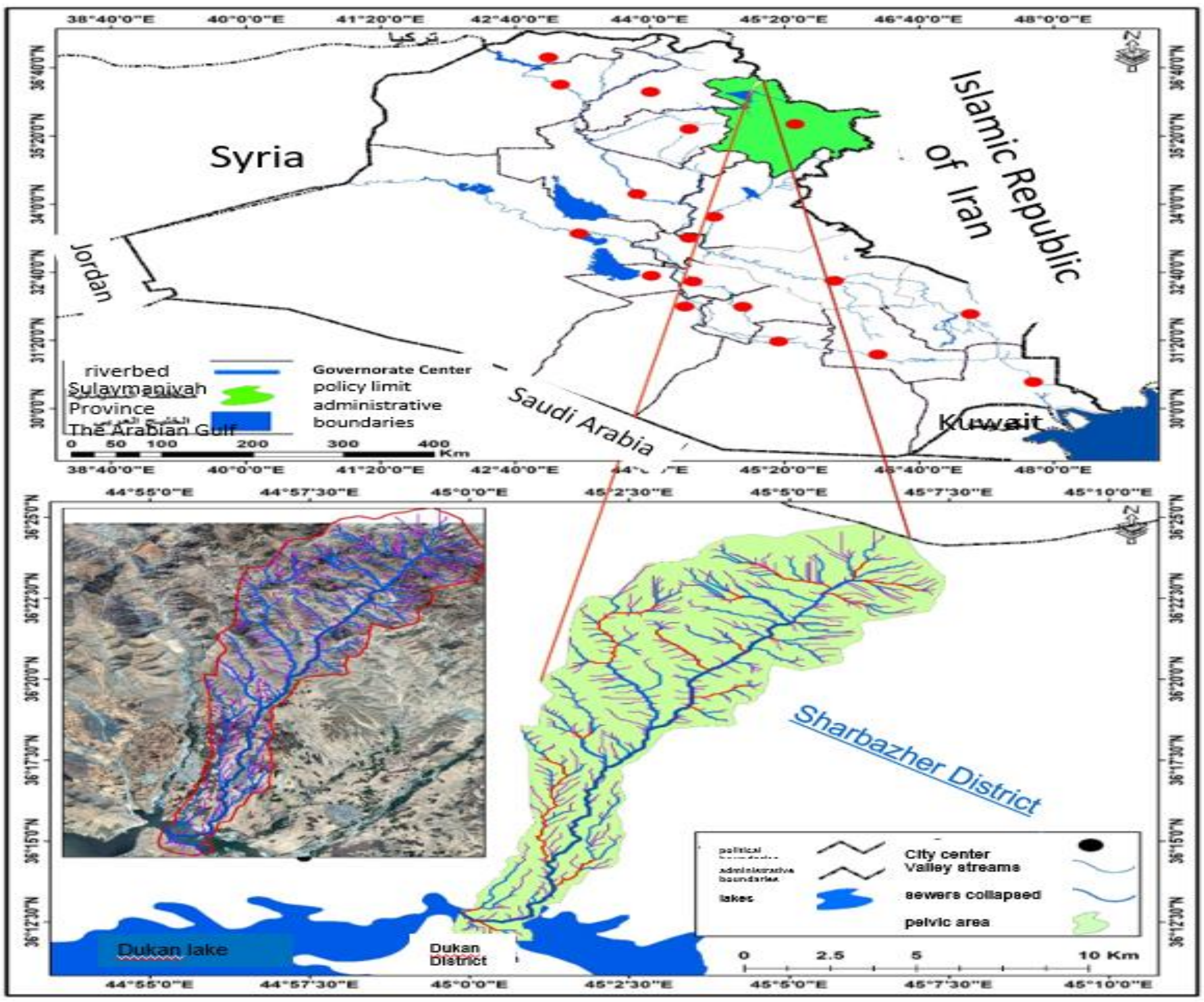
1.5 Objectives of the research

The research aims can be outlined as follows:

- Determining the purpose and benefit of harvesting the water of Wali Kafan valley.
- Establishing dams and reservoirs to keep water inside the stream in the area for a longer period to recharge groundwater, springs and springs.

After clarifying the research problem, research hypothesis, tools, importance and location of the research area, it is necessary to study the characteristics or morphometric analysis of the basin of Wali Kafan valley in order to draw and build roads through which water can be harvested and benefited from throughout the year. The morphometric characteristics can be shown below.

Map (1): the location of the study area



Source: Prepared by the researchers using the ARC MAP10.3 geographic information system program and Landsat image 2013. Dokan dashboard map: 50000:1 scale

2. the morphometric analysis of the Wali Kafan valley basin

Morphometric analysis is used as a quantitative method in geomorphometric studies and it means the process of digital analysis of the phenomena of the Earth's surface based on data obtained from topographic maps, aerial photographs, satellite images and field studies. The importance of studying the morphometric analysis of drainage basins is the backbone in the geomorphological study of drainage basins. The similarity of the basins in their dimensions and morphometric characteristics indicates a

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similarity in their geological and climatic characteristics, their genesis, the factors of formation and their development. This sheds light on the geomorphology of the basins of the region.

The morphometric analysis of the drainage network basin was carried out by analysing satellite images in the drawing of drainage networks with topographic maps (scale 1/100,000) and the use of Erdas imagine 8.4 in the analysis of satellite images, the creation of the DEM digital height model. It also involved the use of Arc map10.8 in the preparation of drainage network maps, stream order mapping and the use of the excel program in extracting the results of morphometric equations after conducting calculations with Arc map10.8.

2.1 Morphometric characteristics of the basin

The Drainage Basin is defined as the area the running water of which is fed in the event that a certain watercourse is available. This is so that its surface water flows from all the surrounding high directions towards the main stream that does not require its development into a permanent river. Rather, it may remain in the form of a temporary or seasonal watercourse according to the hydrological conditions prevailing in the drainage basin (Al-Salihi & Al-Ghuriri, 2004, p. 127).

a) Spatial variables: the study of the area and dimensions of the drainage basin includes studying the total area of the drainage basin and its dimensions. These include length, width and circumference, which indicates the volumetric characteristics of this basin and the calculation of many morphometric characteristics associated with the formal characteristics of the drainage basin and the basin network in the region.
b) Basin area: The study of the area of the drainage basin indicates its close relationship with the water network system, as if all morphological factors are similar, the drainage volume and its peak are mainly due to the area of the drainage basin. The total area of the Wali Kafan valley Basin is (95,029 km2). The large area of the drainage basin is due primarily to the influence of the geological structure lines and the natural characteristics of the rocks. It is also due the time period that the drainage basin crossed from its geomorphological cycle. See Table (1). See map (2).

Table (1): Area and dimensions of the drainage basin in Wali Kafan valley

Basin	perimeter/km	length /m	Area/km2	Width/km2
Wadi Wali Kafan	63.846	25,424	95.029	7.030

Source: Using the Arc map 10.8 program to extract the results and DEM data.

c) Basin length variable: The study of the length of the drainage basin is important in identifying the general shape of the basin, as well as in measuring some morphometric variables peculiar to the shape of the basin and studying its terrain characteristics. Table (1) shows that the length of Valley of Kafan Basin, reached (25,424 km).

d) Width of the drainage basin: The width of the drainage basin was calculated by direct measurement of the widest parts of the basin from satellite images with a comparison with the maximum length of the drainage basin. From Table (1), the width of the Wali Kafan valley Basin was 7,030 km. The variation in the width of the drainage basin is ascribed to the difference in the type of rocks and their natural characteristics, in addition to the effect of the structure, especially the faults in the region (Al-Harboud, 2000, p. 50).

e) Basin perimeter variable: The drainage basin circumference is the length of the water dividing line between the drainage basins. It is used in calculating many morphometric variables related to the morphological and topographical characteristics of the drainage basin. It is clear from Table (1) that the perimeter of the Valley of Kafan Valley ranges 63,846 km. This difference reflects the severity of the zigzag lines of the water division of the basin and the asymmetry in the shape of the basin. The length of the perimeter of the drainage basins was measured from satellite images using Arc. Map 10.3 program.

2.2 The morphological characteristics of the drainage basin

The morphological characteristics of the drainage basin are compared with the geometric shapes. The drainage basins that are different in size can be similar in geometry. This is reflected in the similarity in their other geomorphometric characteristics, because such similarity must result from the same geomorphometric factors and processes. The morphology of the drainage basins is affected by three main factors: the natural characteristics of the rocks, the geological structure and climatic characteristics. Among the most important morphometric parameters include:

A) Elongation Ratio: The elongation ratio is the ratio between the diameter of the circle equal to the area of the basin to the maximum length of the basin. This coefficient illustrates the extent of similarity between the form of drainage and rectangular shape. It also indicates the value of the coefficients on the presence of an inverse relationship between the value of the elongation ratio and the shape of the basin. The more the value decreased and approached zero, the more the basin tends to elongate and vice versa. The elongation value was (0.432), which indicates that the basin tends to elongate. Table (2) The morphological characteristics of Wali Kafan valley.

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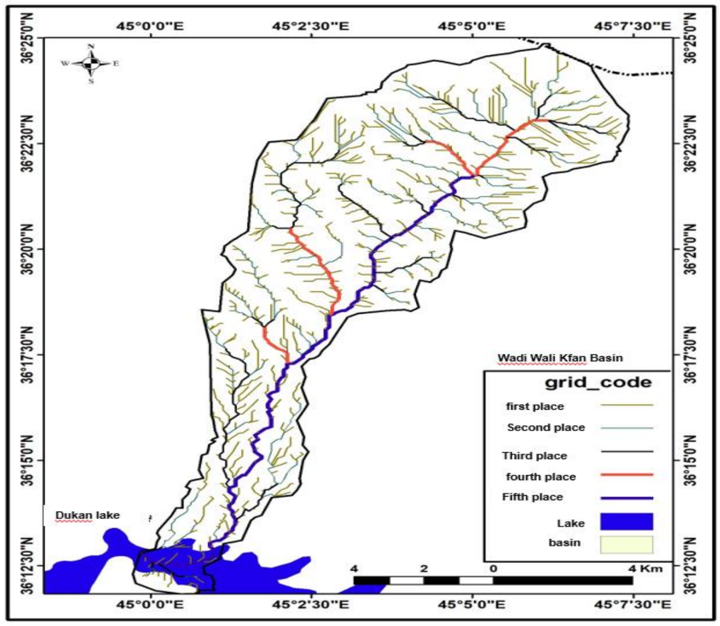
Map (2): of the waterways network of the study basin.



Source: Prepared by the two researchers based on the DEM digital elevation data and the topographic map of the Dokan Plate at a scale of 100,000:1

Table (2) The morphological characteristics of the drainage basins of Wali Kafan valley

Basin Name	Form Factor	Circulation ratio	elongation ratio	Lemniscates Factor	T
Kalal Badra	**1.833**	**0.292**	**0.432**	**0.147**	1

Source: Using Arc map 10.3 to extract the results.

B) Circulation Ratio: The circulation ratio indicates the ratio between the area of the basin to the area of the circle having the same circumference as the basin. The circulation ratio is the morphological inverse of the elongation ratio, as it means the similarity of the shape of the drainage basin with the circular shape. It shows the geomorphological significance of the circulation ratio, because there is a direct relationship between the value of the circulation ratio and the shape of the basin. The circulation ratio for Wali Kafan valley was (0.292). From the result, we infer that the rate of circulation is low, which indicates its distance from the circular shape, the irregularity of the water division lines surrounding this basin, and the severity of its sinuosity.

C) Basin Form factor: The form factor indicates the relationship between each of the area and the length of the drainage basin. This indicates the extent of consistency between the parts of the drainage basin and the regularity of their general shape. The high values indicate the consistency between the parts of the drainage basin and its closeness to the square shape. The low values indicate the inconsistency between the parts of the drainage basin, where the wideness of the drainage compensation at the sources and narrowness at the estuary. Thus, the shape of the drainage basin approaches the triangular shape. The calculation is done as follows: f=A\L2 .... A= area of drainage basin km2 L2= length of drainage basin km. The shape parameter of Wali Kafan valley was recorded (1.833). This indicates the widening of the basin at the upper source and its narrowness at the estuary.

D) Lemniscates Factor: This factor indicates the relationship between the square of the length of the drainage basin to four times the area of the basin. The pear shape because most of the symmetrically shaped drainage basins tend to have a pear shape, not a completely circular shape. The high values of the lemniscate factor indicate the increase in the elongation of the drainage basin and the predominance of the vertical corrosion processes more than the lateral corrosion. The lower values indicate an increase in the dent in the shape of the basin, which indicates an increase in the lengths and numbers of streams in the lower orders with the predominance of vertical and lateral corrosion processes. This is calculated as follows: 4A \ K=L2 .... K = Lemiscate factor L = length of drainage basin A = area of drainage basin km2 The valley of Wali Basin was recorded as (0.147). From the result, we conclude that the Wali Kafan valley basin recorded a higher value. This was reflected in the increase in the elongation of the drainage basin and the predominance of vertical corrosion processes more than lateral corrosion (Salama, 1980, p. 99).

2.3 Topographical characteristics of the drainage basin.

The study of the topographical characteristics of the drainage basin is based on the severity, terrain and ruggedness of the drainage basin. This depends on the activity of erosion processes and the impact of geological features in the region. It also indicates the geomorphological stage reached by the drainage basin.

a) Relief Ratio: This ratio is an important parameter in measuring the severity of the elevation of the drain basin, because it indirectly shows the degree of slope of the surface of the basin. The values of the elevation coefficient are directly proportional to the level of the elevation; the higher the value of the relief ratio, the greater the severity of the elevation surface of the drainage basin. It also indicates the early geomorphological phase that the drainage basin passes through and vice versa. The values of the relief ratio are inversely proportional to the area of the drainage basin and then to the amount of drainage. See Table (3).

Table (3) Topographic characteristics of Wali Kafan drainage basin.

Valley name	Relative terrain	Relief ratio	Ruggedness
Wali Kafan	0.677	2496	80

Source: Prepared by the two researchers using the Arc map 10.3 program to extract the results.

The drainage basin recorded a relief ratio of (2496) m. We can note that the relief ratio is high, which indicates the severity of the elevation of the surface.

b) Relative relief: Relative relief indicates the relationship between the terrain extent, i.e. the difference between the highest and lowest heights within the drainage basin and the surroundings of the drainage basin. The relative terrain coefficient indicates that there is an inverse correlation between the value of the relative terrain and the degree of resistance of rocks to erosion factors in the case of constant climatic conditions. See Table (3). Wali Kafan valley Record (0.677). This is due to its small area and high terrain. The calculation is done as follows: - Rr = H\P*100 .... Rr = Relative relief H = difference between the highest and lowest point inside the drain km P = length of the perimeter of the basin m
c) Ruggedness Number: The degree of ruggedness summarizes the relationship between the topography of the drainage basin and the density of drainage. This indicates the degree of surface interruption by the waterways, and sheds light on the erosive geomorphological stage that the drainage basins go through. The ruggedness degree coefficient values are directly proportional to the elevation of the basin and the density of the drainage. This indicates an increase in the ruggedness, the severity of the slopes and their length. The height of both the degree of ruggedness and the density of the drainage is related to the increase in the volume of surface water in the drainage basin. See Table (3). The degree of ruggedness was recorded for the Wali Kafan valley drainage was (80). From the analysis of the result for the Wali Kafan basin, the highest severity was recorded for the degree of ruggedness. This indicates the recentness of its corrosive cycle. The calculation is done as follows: Rn = H*D .... RN = degree of ruggedness H = relief D = density of drainage (km/km2).
d) Hypsometric integration: The Hypsometric integration parameter indicates the geomorphological stage reached by the drainage basin. It determines the time period that it crossed from its geomorphological cycle. It is calculated through the relationship between the topography of the drainage basin and the area of the drainage basin. The high values of the Hypsometric integration parameter indicate an increase in the area of the drainage basin at the expense of a decrease in its terrain range. This indicates the chronological age of this basin, as it shows the direct relationship between the values of Hypsometric integration and the time period that the drainage basin takes from its geomorphological cycle and vice versa.

2.4 Morphometric analysis of the network of the Wali Kafan valley Basin

The drainage network indicates the general shape in which a group of rivers appears in a region. It is the final outcome of the relationship between the type of rock and its structural system on the one hand, and the prevailing climatic conditions on the other. In addition, it is due to the nature of the original slope of the earth's surface and the effect of rifting movements and tectonic lifting movements on modifying the general appearance of the shape of the water drainage. Also, it is down to the degree of geomorphological development of the drainage basin (Morisawa, 1962).

2.4.1 The formal characteristics of the drainage basin networks

The study of the formal characteristics of the drainage basins covered in this study explains the morphometric variables related to the formal characteristics of the valley drainage networks, and the density of drainage.

A) Stream Orders: These are a reflection of the change in the characteristics of the valley course and the reflection of the surface on it. The Wali Kafan valley Basin recorded five grades, and the water soils totalled (366) orders. With a total length of (304.28) km. See Table (4).

Table (4): Orders of the waterways and their lengths for the basin of Wali Kafan valley.

Rank	Numbers of grades	height m	length km
1	250	169107.5	169.11
2	88	70236.54	70.13
3	23	31414.66	31.41
4	4	11359.4	11.36
5	1	22270.4	22.27
Total	366	304278.5	304.28

Source: Prepared by the authors using DEM.

B) Stream numbers: The numbers of streams for each valley represent the downstream phase that each valley passes through during its morphological cycle. To study the formal characteristics of the valley basin, the length of the streams, and their preparation, Table (5) shows that Wali Kafan valley consists of five grades that recorded different bifurcation ratios. The bifurcation rate for the first and second order reached (2.84) while the bifurcation rate for the third order amounted to (3.83). The fourth order amounted to (5.75), and the fifth order amounted to (4.00). The sum of the orders reached (16.42). See Map (2) of the river network of Wali Kafan valley.

Table (5) bifurcation ratios for the lengths of the waterways and their lengths for Lodi and Kafan.

Basin of Wali Kafan Valley	Waterway Rank	The sum of the lengths of the waterways for each grade	Number of waterways for each grade	Percentage for each grade	Branching ratio = number of waterways in one grade / number of waterways in the next grade	Percentage of lengths for each grade (%)
	1	169.11	250	45		56
	2	70.13	88	38	2.84	23

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	3	31.4	23	15	3.83	10
	4	11.36	4	1	5.75	4
	5	22.27	1	0	4.00	7
	Total	304.28	366	100	16.42	100

Source: The researchers based on DEM digital elevation data with an accuracy of 15m

C) Bifurcation Ratio: The bifurcation ratio indicates the ratio between the number of river courses in one order to the number of river courses in the next order. The branching ratio controls the volume of discharge through the direct relationship between the branching ratio and each of the discharge and time. This means that the higher the branching ratio, the higher the time for water to reach the estuary, and vice versa. The total branching ratio of Wali Kafan was (16.42). From the data values, we infer that the branching ratio is high. This indicates the velocity of water reaching the estuary.

D) Stream length: The length of the stream affects the volume of drainage and the shape of the basin, as the increase in the length of the stream works to reduce the speed of the stream, especially in the case of widening stream. This leads to a decrease in the amount of sediment transferred to the flood fans and then its area decreases. The opposite occurs in the case of lack of lengths of streams as the velocity of the current increases and the amount of sediment transferred to the flood fans increases then increases its area in relation to the drainage basin (Al-Babwati, 2000, p. 142). The total lengths of the grades of Wali Kafan valley was (304.28 km). By analysing the results, it was found that Wali Kafan valley, compared to the area, recorded a high rate in length. This was reflected in the amount of sediments, as the amount of sediments transferred to Lake Dokan increases.

E) Drainage density: Drainage density indicates the natural elements that control the river system in terms of the type of rock, its geological composition, the extent of the rugged surface, and the density of vegetation cover. It also sheds light on the extent to which the drainage basin is exposed to corrosion and intermittent operations due to waterways because of its close relationship to the amount of rain falling on the basin, evaporation rates and the energy of leakage into the soil as well as the extent of surface resistance to erosion processes (Salama, 1980, p. 99). Drainage density includes:

- Drainage Density: The density of the drainage basin indicates what an area of one km2 of the lengths of the streams inside the basin occupies in km. Or it is the ratio between the total lengths of watercourses in a given area unit. The density of the discharge is closely related to the volume of the discharge by virtue of its relation to the lengths of the streams and the area of the drainage basin. It is also an indicator of the extent to which the area is interrupted and exposed to water erosion, due to the relationship between surface run-off, soil seepage, precipitation and evaporation. See Table (6). The density of the discharge in Wali Kafan valley reached (3,20). We infer that Wali Kafan valley recorded a high rate in the density of drainage as evidenced in the extent of the intersection of the valley basin and its exposure to water erosion processes.

- Streams Frequency: The frequency of stream indicates the ratio between the number of stream that exist in a particular basin, regardless of their length, to the total area of the drainage basin. The frequency of stream is another expression of the intensity of drainage. It also expresses the degree of texture of the drainage network and the extent of the intensity of the basin's intersection with the waterways. The high values of the stream frequency parameter indicate the presence of a large number of tributaries. This increases the possibility of water gathering in the form of surface runoff. Low values indicate the presence of a small number of tributaries, which reduces the chance of surface run-off and increases the chance of vertical seepage to feed groundwater reservoirs (*). See table (6). The stream frequency in the valley of Wali Kafan was (0.039). We note that the valley recorded a low rate of recurring watercourses, which indicates a decrease in the number of tributaries and this leads to the lack of the possibility of water gathering in the form of surface runoff.
- Stream maintenance rate: The stream maintenance rate indicates the algebraic inversion of the drainage density of the basins. It refers to the ratio between the average square unit km 2 needed to feed the longitudinal unit of network ducts km. The high values of the parameter indicate the widening of the drainage basin area at the expense of the ducts of their networks of limited length. Hence the density of the discharge decreases and vice versa (*). See Table (6) and the survival rate of the stream was reached, where the recurrence rate for Wali Kafan valley (0.312). This percentage is high, which reflects the small number of waterways and the small area.

Table (6): The density of the drainage and some morphometric parameters of Wali Kafan valley.

Name of Valley	Stream Frequency duct km	Drainage density	Sewage Maintenance rate km2/km
Wali Kafan	0.039	3.20	0.312

Source: Prepared by the researchers based on the measurement results using the Arc MAP 10.3 . program.

3. Hydrological Analysis of Wali Kafan valley

It is important to study the formation of the landscape and the environmental balance of the basin in terms of its geological structure. This includes the types and characteristics of rocks and their response to water erosion processes, as well as the study of the situation (morphoclimatic) using satellite images and building a statistical analytical model. This forms the basis of hydrological studies and these studies are usually large in size (Tyner, 2014, p. 11). Based on this is the study of the geological situation and structural distortions to which the rocky layers are exposed as a result of the pressure and tensile forces emanating from the movement of tectonic plates. These lead to the earth-building movements of mountains and directly and indirectly affect the movements Localization (tectonic activation) and

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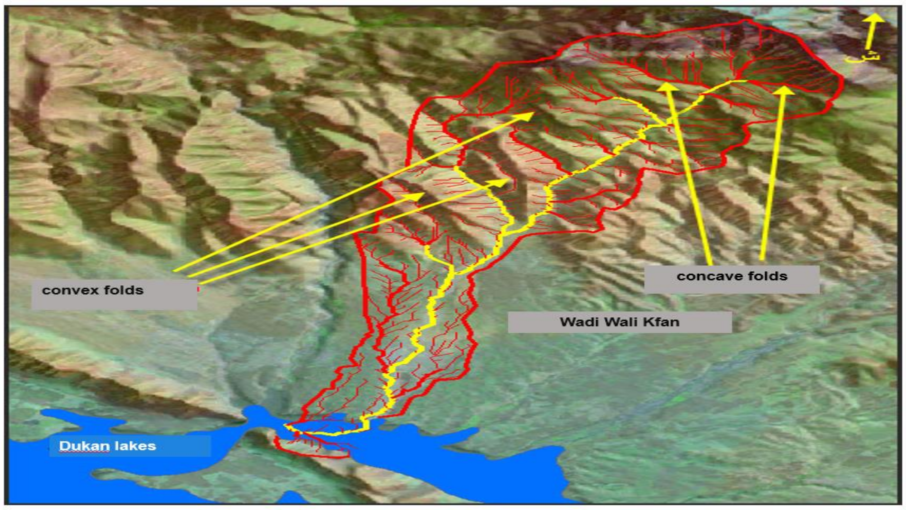
change in the base level. The text, tables, and even graphs do not contain the spatial component and do not allow readers to see distribution patterns, because of their inability to show spatial relationships. Maps are used as analytical and interpretive tools, as some geographical patterns cannot be recognized until they are presented in the form of a map (Al-Naqqash, 1985, p. 149). Among these variables are:

1) Structural deformations: This concept means the change in the position of the rock layers, such as folding, cracking, cracks and joints (Billings, 1984, p. 240). These distortions in the region resulted from the collision of the Arab and Iranian and Turkish plates, which was called the alpine movement. It generated a compression movement on the basin that led to the formation of convex and concave folds with the presence of many cracks spread in the basin and a clear change in the layers of the region, as well as a kinetic imbalance that was reflected in the high dentition of the area. This exposed it, in varying degrees, to factors of weathering and erosion and that the tectonics of the basin area fall within the range of the low folds affected by the alpine movements in particular. The following are the most important structural abnormalities in the basin region (Shendi *et al.* 1997).
2) Topographical features analysis: This is one of the components of geographic information systems. It is also the basis on which it depends to infer the properties related to the topography of valleys and extrapolation of information about their topography and the process of hydrologic simulation of rainwater runoff. In doing so, a set of analytical methods are used and applied to digital data to calculate the values of elevation, inclinations and surface features such as the boundaries of water basins and the drainage network (Al-Khabouli et al., 2018 , p. 341). Arc Hydro tools are used to determine some morphometric characteristics, determine the directions of water drainage, and determine the directions of surface water collection. They are also used to determine the water flow line within the drainage basin, as well as the points of connection of the basins with each other and the drainage points for each of the secondary basins and the point of water exit. This is done through a series of steps in the Arc environment GIS, which includes the study of topographic systems and units, which express the hydrological characteristics of the area, the shape resulting from the variation of land units, and the construction of digital maps to analyse the slopes and the direction of the slope. See Figure (1).
3) Variable analysis and classification of elevation: The study area is limited to between (484-2980) m above sea level. The north-eastern regions are located at the highest altitude, which represents the main division line and is a convex fold higher than the adjacent lands. The regions located at the lowest point are the western regions and represent the mouth of the stream. We can divide the region on the basis of height, according to the relationship with the subject of the study, into five main regions, taking the height and the land shape as the basis for its division, and as in Map (4), which are: -
    a) High Hills System: This system is an extension of the eastern mountainous heights of Iraq. This system is confined between the contour lines (1839 - 2980) m above sea level in the northern regions, and as in Map (4), the contour lines come close in these areas, which are the upstream areas of the water basin because of their severe erosion.

b) Elevated areas system: This system is limited to the Contour Lines (1216-1839) m above sea level. In the northeast of the basin, the area of high hills appears in the form of intermittent lands (Badland) interspersed with some major deep valleys.

Figure (1): Convex and concave folds of the region.

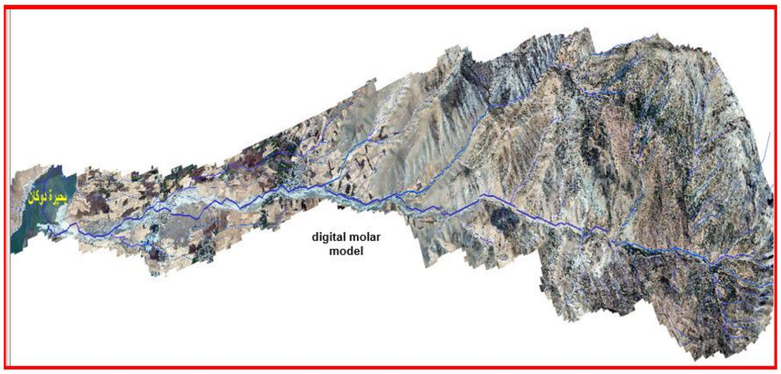


Source: Prepared by the two researchers based on the Digital Elevation Model (DEM) and (I.T.C) classification, using ARC MAP 10.6.1.

c) Low Hills System: It is represented by some of the convex folds in the basin area that are confined between the Contour Lines (808-1216) m above sea level. From observation of satellite images, it became clear that the folds are forest areas in most of their parts. Therefore, it was very difficult to determine their axis as it is cut off by the main streams forming the valley basin (Abu El-Enien, 2003).

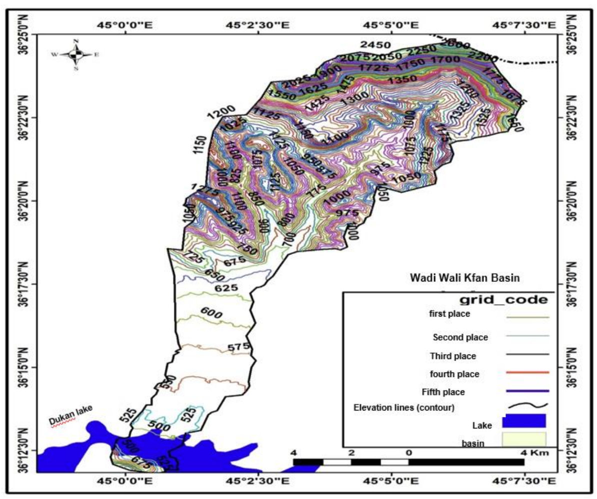
d) The Assembling Plain System: It is considered one of the lowest areas of the basin, as this system is confined between the Contour Lines (484-808) m above sea level. Therefore, it is exposed to the dangers of flooding in wet years. This section is considered one of the richest study areas in terms of agricultural production and the spread of population areas, and the availability of very fertile soils. See figure (2). and Map (3).

Figure (2): A three-dimensional model of the basin



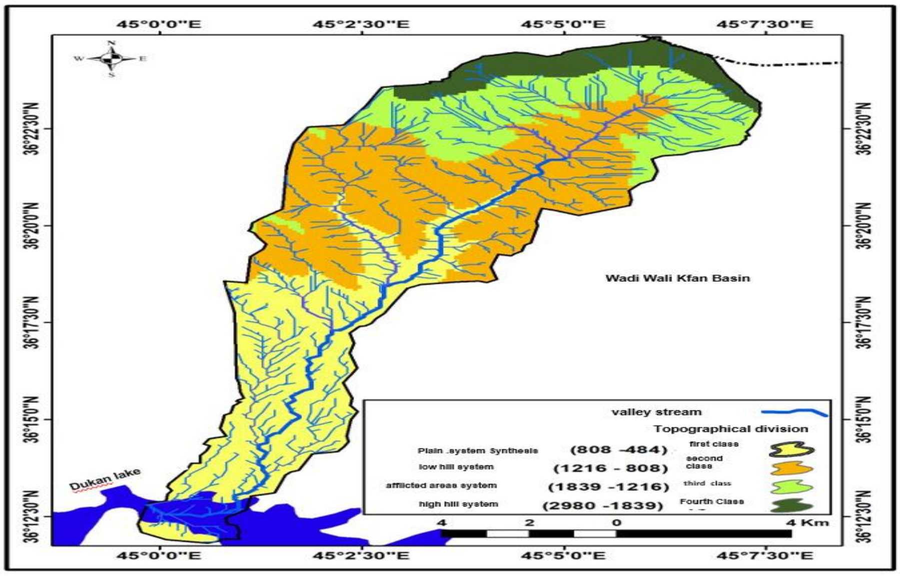
Source: Prepared by the two researchers based on the digital elevation data, the topographic map of the Dokan plate, the satellite image Landsat 8, and the ARC Scene program.

Map (3): elevation lines for the basin area



Source: Prepared by the researchers based on the digital elevation data and the topographic map of the Dokan plate and the satellite imagery of Landsat 8

Map (4) Topographical division of the basin area



Source: Prepared by the researchers based on the digital elevation data and the topographic map of the Dokan plate and the satellite imagery of Landsat 8.

3.1 Slope Analysis

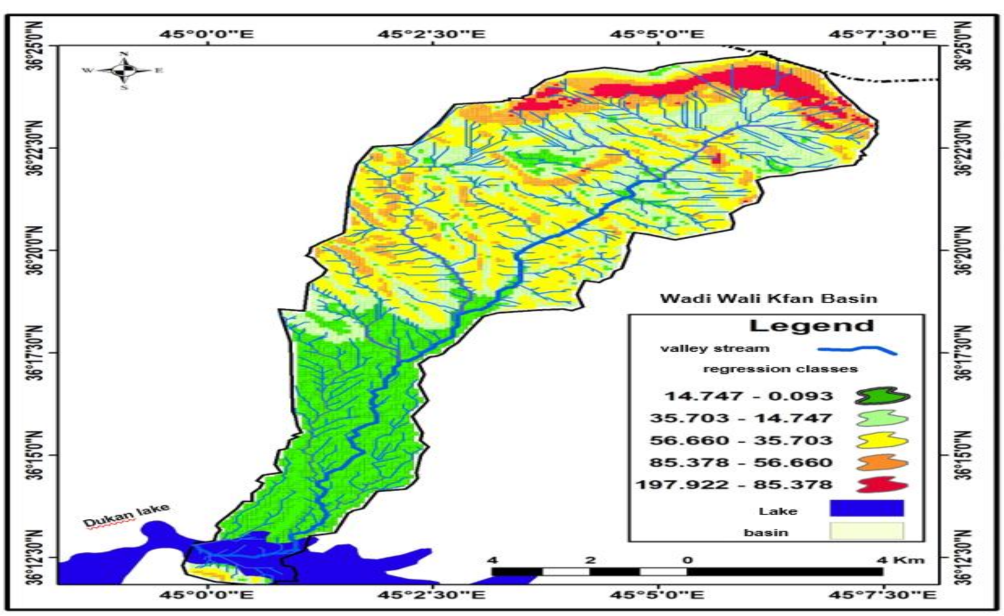
A high slope indicates a fast flow of water, while a low slope indicates inactivity of water movement and its ability to carry only small sediments. The current is less steep in valleys with a meandering tendency. The gradient characteristics are among the main factors that determine the activity of a watercourse and its ability to exert stress, transport and sedimentation. The increase in the degree of gradient is followed by an increase in the velocity of the flow and the amount of water discharge, due to the lack of leakage. This increases the ability of the watercourse to carry out salty operations and increase the sedimentary load. Increasing the slope also causes landslides (Al-Mohsen, 1996, p. 185). The slope map helps to clarify and highlight the hydrological variable, and to identify the features of the type and severity of hydrological processes, through which it is possible to assess the evolution of the movement of slopes. This has attracted the attention of many specialists given the important changes it causes on the surface of the earth, especially the relationship of water to slope. As it is reflected on the lithosphere and life and related aspects of application in human life. The map of gradient intensity and directions for the basin area was designed based on the digital elevation model (DEM), with a discriminatory accuracy of 12.5 m, which was designed through the spatial analysis tools included in the toolbox within the environment of the ARC GIS program. The shapes of the land surface in the basin area vary between flat land plains with little slope to high hills and undulating lands. In order to determine the characteristics of the slopes prevailing in the basin area and to distinguish their land appearance, the (ITC) classification was adopted for this purpose, which produced five classification levels. The classification starts from (0.093 – 14,747) % and ends with the category (85,378_ 197,922) %, as in Map (5) and Table (7).

Table (7): Slope ratios and their area according to the classification of (I.T.C).

	the colour	Description ITC	Description by(ITC)	regression class %
1		Flat or almost flat	**Flat or close to extroversion**	14.747% – 0.093
2		gently sloping	**gentle incline**	35.703% – 14,747
3		Sloping	**slope**	56,660 % – 35,703
4		Moderately steep	**moderate intensity**	85,378 % – 56,660
5		Steep	**very severe**	197.922 % – 85,378

Source: Prepared by the researchers based on Map (5).

Map (5) Characteristics of Basin Slope Analysis



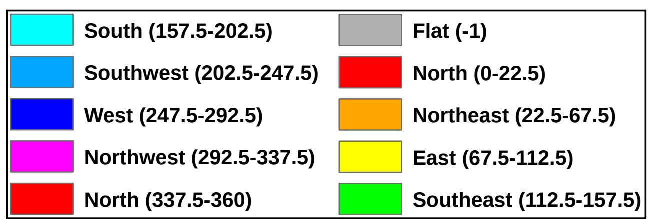
Source: Based on Digital Elevation Model (DEM) and (I.T.C) classification, using ARC MAP10.6.1

3.2 Aspect Slope Trend Analysis:

It is derived from a point surface that specifies the downward direction of the maximum rate of change of value from each cell to its neighbours. Direction is expressed in positive degrees (-1 - 360), and is measured clockwise from north to south. Map (6) and Figure (3) show that all directions prevail in the basin due to the diversity of terrain. However, the most obvious direction is the western, which represents the highest percentage of the gradient direction ratios, which amounted to (13.2 percent), followed by the east direction (12 ,92)%, then the southern by (12.70)%. These three directions represent the high percentages among the slope directions. These ratios gave a general picture, which is that the direction of the slope is generally western. This leads to an increase in the drainage basins here.

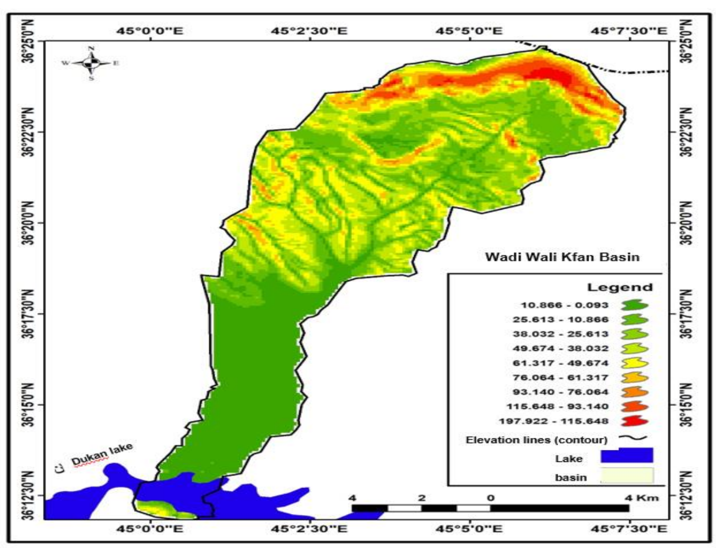
Several facts have been proven through the slope map derived in the GIS environment and the digital elevation model. The second feature is the impact of these directions on the amount of rain falling, as they are facing the fall of rain showers associated with Mediterranean depressions. This increases the effectiveness of water discharge, as the north and north-east are more harmful than the southern and south-western sides, as well as the impact of the downward direction on soil moisture. The soil of the northern slopes facing the sun is dry compared to the slopes in the shade, which has a direct impact on the growth and distribution of the natural plant (Mahmoud, 2014, p. 107).

Figure (3): The direction of the slopes of the basin area in degrees.



Source: Prepared by the two authors based on DEM.

Map (6): the direction of the slopes of the basin area in degrees



Source: Prepared by the two authors based on DEM.

3.3 Land cover modelling

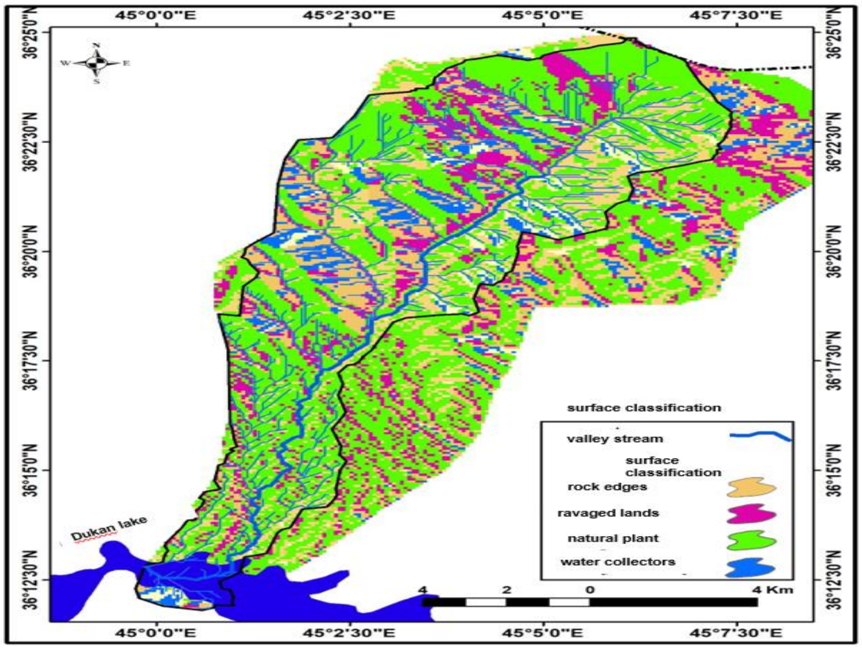
Countries strive to organize the use of their various resources through many special projects, which are related to the study of land cover patterns, and aim to survey them using all available means, whether land or aerial surveys, or relying on remote sensing data (Guertin, et al. 2010). Then, they prepare maps that vary by measuring them depending on the nature of the area studied and monitor the continuous development on the earth's surface with a particular coordinate system storing them in the computer and linking them to the metadata associated with these phenomena. This is done through analysing the database and demonstrating the relationship between these phenomena. It is also done by researching the employment of the geographic information system in entering (Capture) and storing (Data storage) the paper information that was collected and processed (Data Processing), and (Data Analysis), and its management (Data Management), and the output of spatial information. Then, these are linked to the descriptive information (The Attribute) and are extracted in the form of maps and their relationship to the hydrological characteristics of the basin through the analysis and classification of satellite images. This is performed in order to identify cover patterns and search for their role in classifying land cover patterns and the relationship of these patterns in the course of hydrological processes and the ecological balance of the basin. Satellite images for 2020 were relied upon to detect earth cover patterns and their relationship to hydrological properties to be one of the hydrological map layers of the basin area, where the Likelihood Maximum Probability classification approach was used on basin data, using the probability coefficient to classify unknown pixels. This can be obtained by calculating the probability of pixels belonging to each category of earth cover patterns and treated and classified using modern techniques (Garde & Raju, 2000, p. 32). As shown in Map (7) and Table (8).

Table (8): classification of the surface of the basin area.

	Area / km2	Items	Ratio %
1	40.149	natural plant	42.25
2	25.05	rims	26.36
3	20.13	Elevated lands	21.18
4	9.7	waters	10.21
5	95.029	Group	100

Source: Prepared by the researchers based on Map (7)

Map (7): Classification of the surface of the basin area.



Source: Based on Digital Elevation Model (DEM), Landsat Image 2020, I.T.C classification, using ARC MAP10.6.1.

4. Conclusions and Suggestions

4.1 Conclusions

- There is lack of reservoirs in the region to store water during periods of floods in the region.
- The slope factor has a significant impact on the lack of reservoirs in the area, as well as the lack of dams in the valley's stream.
- The morphometric measurements showed the discrepancy in the measurements decreases the width of the basin compared to the area covered by the Basin of Wali Kafan valley.
- There are no monitoring stations for water resources in the valley.
- The density of the river network in the course of the valley compared to the area of the basin of Wali Kafan valley.
- The water of the valley, that is, the high discharge that occurs during the cold season during the period when the use of water in the area is scarce. This leads to the discharge of water to the Dokan reservoir without benefiting from it during the farming season in the region.
- The factor of height plays a major role in drawing the river network and its reflection on the surface of the earth and the water drainage in the area.
- The vegetation cover in the region has a great impact on the quantities of discharge and its reflection on the rate of erosion of all kinds in the basin.

4.2 Suggestions

- Paying attention to the region through the development of the region and investment in the industrial, tourism and agricultural aspects.
- Paying attention to agriculture and orchards, and expanding the area of areas planted with orchards, by planting some trees that can bear the low percentage of water in the area.
- Establishment of monitoring stations for torrential water and the real drainage of Wali Kafan valley.
- Benefiting from surface water and turning it into sources of groundwater in the region and benefiting from groundwater during the hot season.
- Relying on modern techniques for harvesting water in the basin of Wali Kafan valley and constructing submersible dams to raise water levels.

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