



## Geomorphological Assessment Using Geoinformatics Applications of the Sloping System of Al-Ashaali Drainage Basin at Iraqi Southern Desert

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### ABSTRACT

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The research deals with the study of the slope systems of the Ashaali drainage basin in the southern Iraqi desert, using the geoinformatics' technique, digital elevation models (DEM), satellite images of the Landsat ETM<sup>+</sup>8, in addition to the topographic, geological, and hydrological maps. The slope systems of the study area are studied through 4 topographic sectors (longitudinal and transverse) that represent the stages of geomorphological development of the drainage basin following Davis erosion cycle, as well as by knowing the regression categories according to the young classification, the direction of the slopes, the sloping parts and the types of slopes (straight, convex, concave). The results show an increase in the area of the slope category 5-10, which reached 25.499%, as well as an increase in the percentage of the direction of the southwestern slopes, which has the highest percentage of 16.277%. As for the sloping parts, the maturity area recorded the highest percentage, estimated at 251 slope parts. In addition, the results show that there is variation in the types of slopes, and the central basin area (maturity stage) of the geomorphological cycle representing all types.

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# التقييم الجيومورفولوجي باستخدام تطبيقات الجيوماتكس للنظام الانحداري لحوض تصريف الأشعلى في صحراء العراق الجنوبية

بشار فؤاد معروف

جامعة بابل – مركز بابل للدراسات الحضارية والتاريخية

## الملخص

تناول البحث دراسة أنظمة المنحدرات لحوض تصريف الأشعلى أحد أحواض الوُديان الجافة في صحراء العراق الجنوبية باستخدام تقنية (الجيوماتكس) ونموذج الارتفاع الرقمي (DEM) وصور القمر الصناعي الأمريكي لاندسات ETM+8 ، كما تم استخدام الخرائط الطبوغرافية للمقياسين 100000/1 و 250000/1، والخرائط الجيولوجية للمقياسين 1000000/1 و 250000/1، وخرائط التربة والخرائط الهيدرولوجية. وقد تمت دراسة أنظمة المنحدرات لمنطقة الدراسة من خلال 4 قطاعات طبوغرافية (طولية وعرضية) تمثل مراحل التطور الجيومورفولوجي لحوض التصريف النهري وفقاً لدورة ديفيس للتعرية، وكذلك من خلال معرفة فئات الانحدار وفقاً لتصنيف بونغ (اتجاه المنحدرات والأجزاء المنحدرة وأنواع المنحدرات - مستقيمة، محدبة، مقعرة). وأظهرت النتائج زيادة مساحة المنحدر فئة 5-10 بلغت 25.499٪، وكذلك زيادة في نسبة اتجاه المنحدرات الجنوبية الغربية حيث بلغت 16.277٪ وهي النسبة الأعلى. أما بالنسبة للأجزاء المنحدرة فقد سجلت منطقة النضج أعلى نسبة تقدر بنحو 251 جزء منحدر. إضافة إلى ذلك، أظهرت النتائج أن هناك تبايناً في أنواع المنحدرات، وتمثل منطقة وسط الحوض (مرحلة النضج) للدورة الجيومورفولوجية جميع الأنواع.

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## Introduction

The slope is one of the most important elements in any geomorphological system, as the diversity in the forms of the earth's surface is related to its different heights and slopes (Montgomery, 2001), and the slope is the result of all the prevailing ancient and current environmental changes determined by achieving a dynamic equilibrium when geomorphological processes follow an expected pattern that tends to have repetition and stability (Sharp, 1982). The slopes of the study area are a natural response to a group of factors (topography, geological structure, climate, water flow, and natural vegetation), with the effect of each of them varying according to the severity or weakness of this factor.

To study the slopes of the area under investigation, Young's classification (Young, 1975) is relied upon, by dividing a single cross-section into several regression units which include the regression segments, the regression elements that make up each cross-section, knowing the lengths of the cross-section, the regression parts, the degree of decline and the degree of strength in order to classify them into straight, convex, concave and flat slopes based on the shape obtained from the slope section.

The problem statement of this paper is the spatial relationship between the characteristics of the slopes and the geomorphological factors responsible for their formation, which includes (geological structure, climate, runoff water, natural vegetation), how much of each of these factors affects, as well as the mechanisms for the action of these factors and the expected results of the forms of these slopes.

The paper aims to identify the slope types and their dispersal patterns of Al-Ashaali drainage basin in the southern Iraq desert by studying a range of terrain sections of the basin while studying the conditions of environmental interaction of the geomorphological factors that led to the formation of the regression system of the basin.

The study of slopes is of practical importance in the management of development projects. The surface slope is also taken into account when carrying out construction and engineering projects, such as road, tunnel, and bridge constructions, water or oil pipelines, or sewage systems construction, all of them are directly or indirectly related to the slope (Fookes et al., 2007).

### **Methodology**

The data of the DEM digital elevation model with resolution 30 m and the Landsat ETM + 8 satellite data for 2019 are used in this study. Topographic maps of 1/100000 and 1/250000 scales, and geological maps of the 1/1000000 and 1/250000 scales, soil and hydrological maps of the Iraqi Geological Survey have been adopted in the completion of this research. The high-quality data of these sources have been handled through geoinformatics' technique by digitizing these data through building regression models, measuring and determining their degrees and types according to Young's classification (1975). Also analyzing the spatial relationships between regressions and geomorphological factors responsible for their formation. This is done by the analytical approach based on tracking the phenomenon under study, understanding its stages of development, and interpreting the conditions of environmental interaction between form, factor, and process, with a view to building. Then interpreting and analyzing models at high levels, using mathematical and statistical methods based on classified digital and descriptive data.

The study area was covered by four terrain cross-sections from south to north and west to east. Each category contains several slope units. Related to the units, their components, parts have been studied based on their lengths, slopes, and magnitudes, as well as being classified into straight, bounded, sloped, and flat slopes. This is done by analyzing and interpreting the graphs created based on SRTM DEM with spatial resolution 30 m using Arc GIS V.10.8. Interpolate line has been used to derive high-resolution data for vertical separation measurements and then all the above-mentioned slope elements are measured with their morphometric properties and the geomorphological phase of the basin, as well as the geomorphological processes that contributed to the formation of their slopes, where known.

### **Study Area**

Al-Ashaali drainage basin is located in the eastern part of the Iraqi southern desert within the administrative boundary of the Al-Muthanna Governorate. It is bordered from the north, northwest, and west by Abu Hadair drainage basin, and from south by Al-Kasir drainage basin, and from east by Al-Sulaibate depression near Dhi Qar Governorate. It lies between longitudes (45°10'49.2"E – 45°41'31.3"E) and latitudes (30°26'27.1"N – 30°58'29.6"N) (Fig. 1). Al-Ashaali drainage basin is one of the dry valleys of southern Iraq in the lower valleys and Salman desert, with an area of 1128.889 km<sup>2</sup>, and the total length of the basin reached 73.245 km (Table 1), starting from its upper sources near the Rujailat Abu Hadair area and ending at its mouth in Al-Sulaibate depression. Its elevation ranges between 10m and 180m above sea level (a.s.l.) (Fig. 2). The basin flows from southwest towards northeast (Fig. 3) and is characterized by drought at present, where the water does not flow into it except after rainfall in the form of irregular torrents in an amount that formed its geomorphological characteristics and the shapes of its slopes.

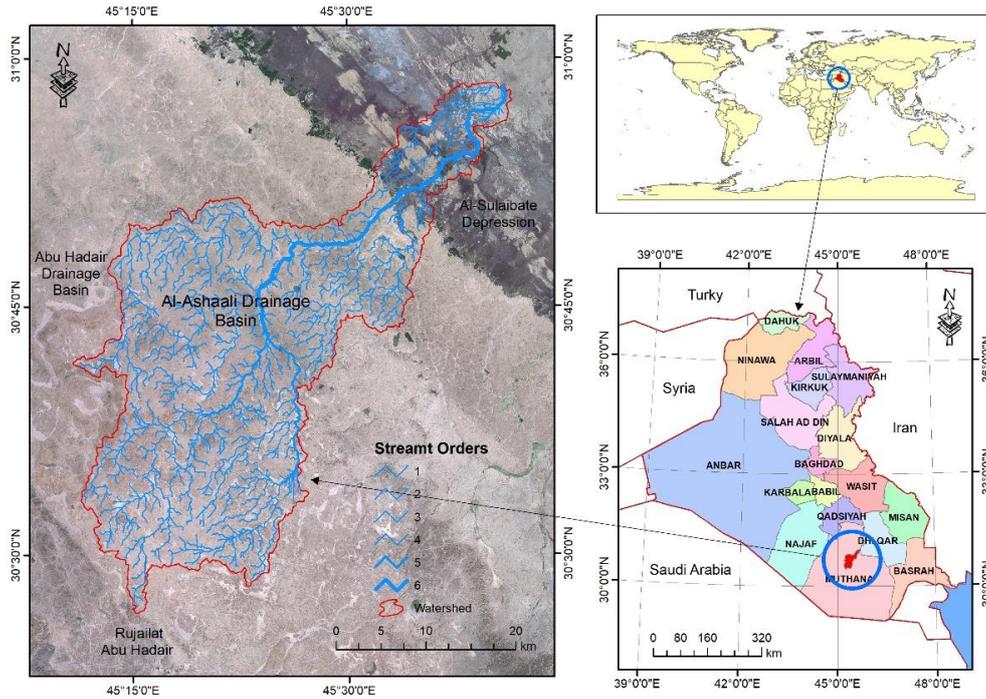


Fig. 1. The location of the Al-Ashaali drainage basin in the Iraqi southern desert.

Table 1. The area, perimeter, and length of Al-Ashaali drainage basin and its secondary drainage basins.

The Name of Basin	Area (km <sup>2</sup> )	Perimeter (km)	Length (km)
Main Al-Ashaali drainage basin	1128.889	255.234	73.245
Al-Ashaali secondary drainage basin 1	670.013	202.030	53.696
Al-Ashaali secondary drainage basin 2	273.914	108.950	34.036
Al-Ashaali secondary drainage basin 3	184.918	95.733	28.719

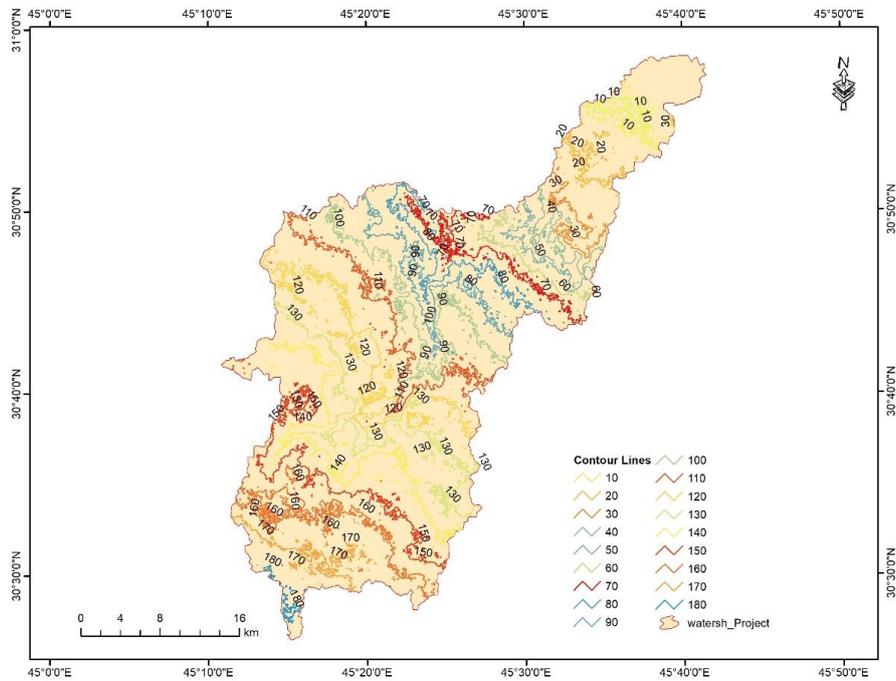
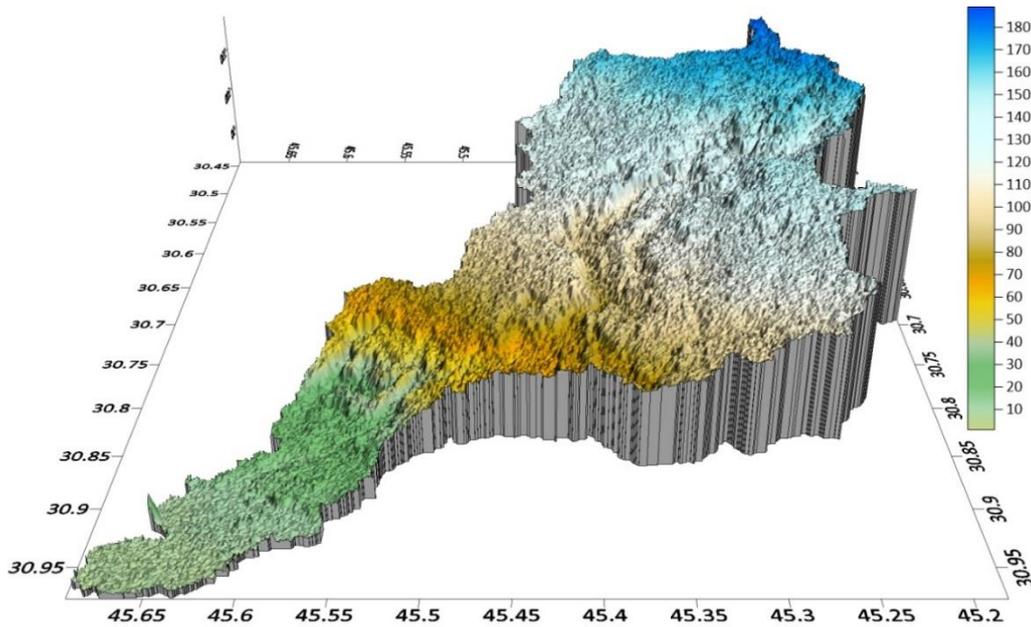
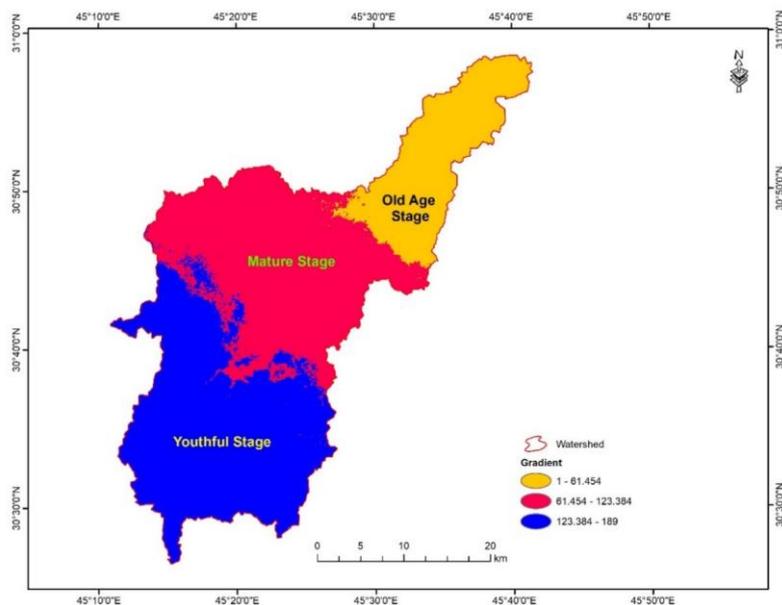


Fig. 2. Lines of equal heights (contour lines) for Al-Ashaali drainage basin.



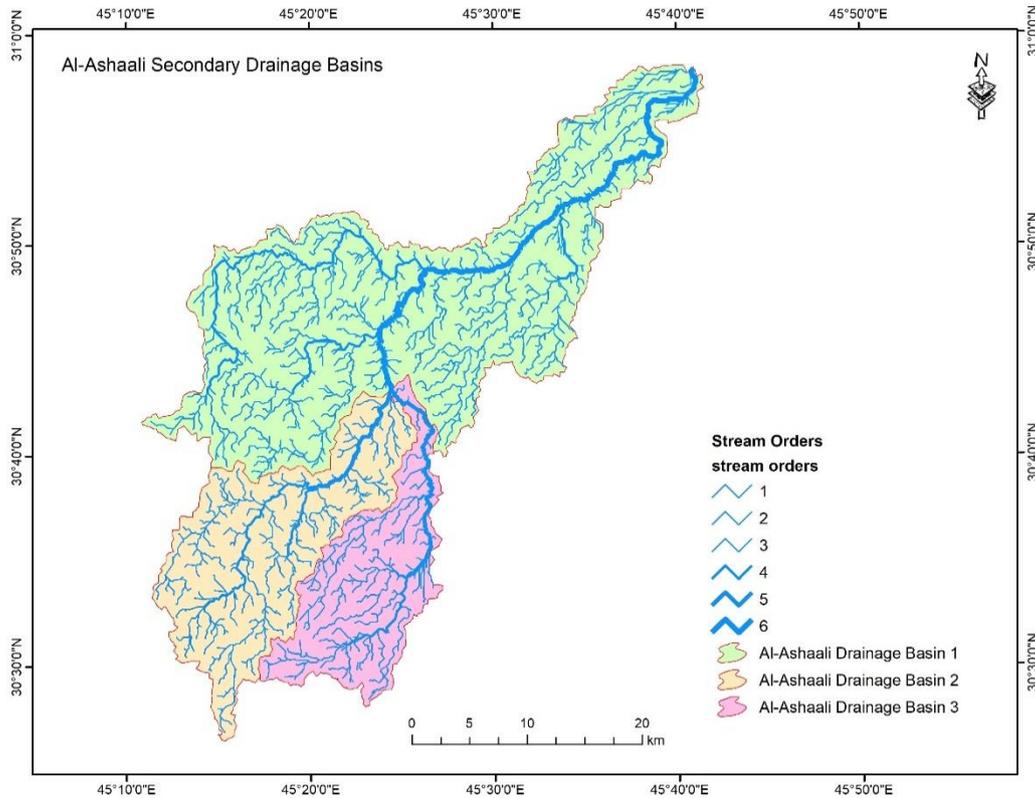
**Fig. 3. Topographical model for Al-Ashaali drainage basin.**

Geomorphologically, Al-Ashaali drainage basin is characterized by relatively low-rise hilly character and its gradual slope from southwest to northeast, and the general slope rate about (2.466 m per 1 km). It is noted that the severity of the basin terrain increases in its upper parts, which represent the upstream region that is confined between the contour lines 130-180 m a.s.l.. This region represents the youth stage according to the stages of the Davis cycle regarding the stages of development of the river basins, where many terrain features such as plateaus, hills, rift edges, and other terrain features spread. The central region of the basin, which represents the maturity stage of the Davidian geomorphological cycle, is confined between the contour lines 60-130 m a.s.l., it is represented by all the known landforms in the southern Iraqi desert, which is less steep and forearm than the first region, it continues to gradually decrease its level until it reaches the mouth area, which represents the old age stage of the geomorphological cycle, and it is confined between the contour lines 10-60 m a.s.l. (Fig. 4).



**Fig. 4. Division of Al-Ashaali drainage basin areas according to the Davis cycle.**

The drainage basin of the study area was divided into three secondary basins and some characteristics of these secondary basins are shown in (Table 1 and Fig 5).

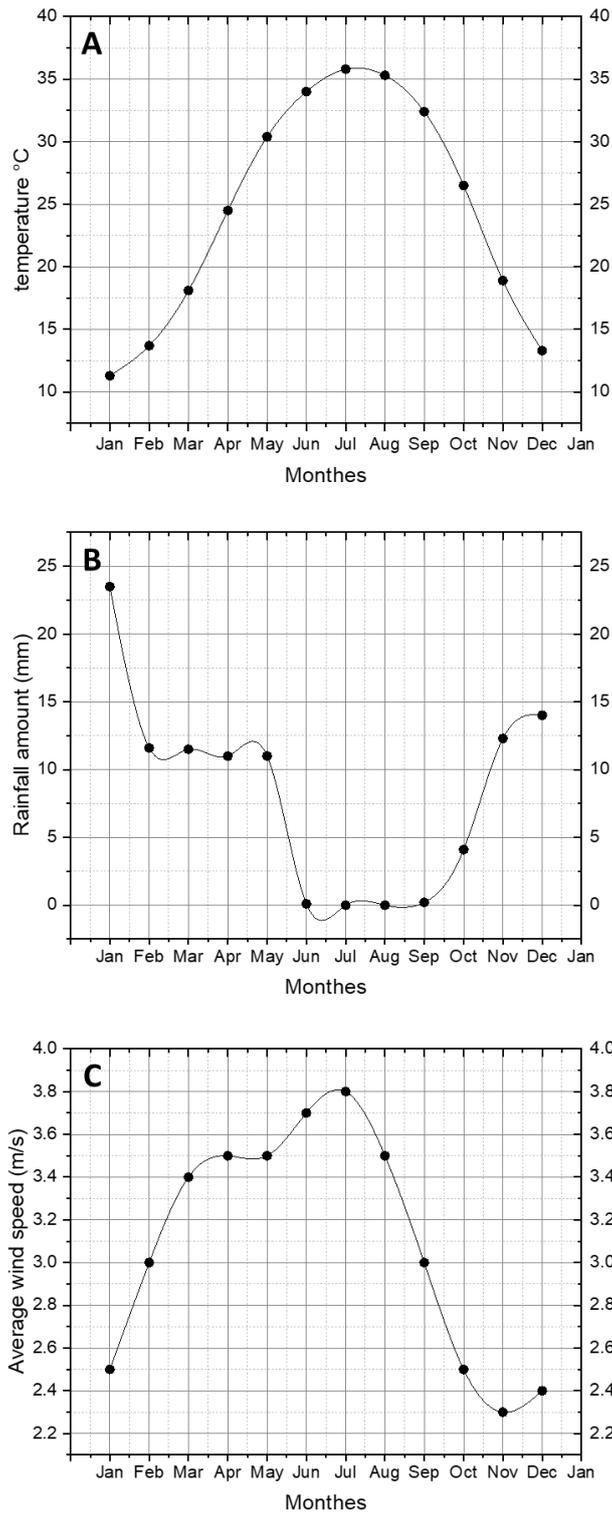


**Fig. 5. The Secondary basins with their orders for the Al-Ashaali drainage basin.**

Climatically, Al-Ashaali drainage basin is classified to be of a dry climate. The data in Figure (6A) indicate that temperatures begin to rise from March, reaching (18.8) °C, and reaching their highest levels in July (35.8 °C), and temperatures continue to rise in August to reach (35.3) °C. The opposite occurs during the cold season of the year, which starts from late November to mid-April when the temperature reaches (18) °C and this case distances Iraq from the tropical climate according to the Köppen classification (MaarooF et al., 2021).

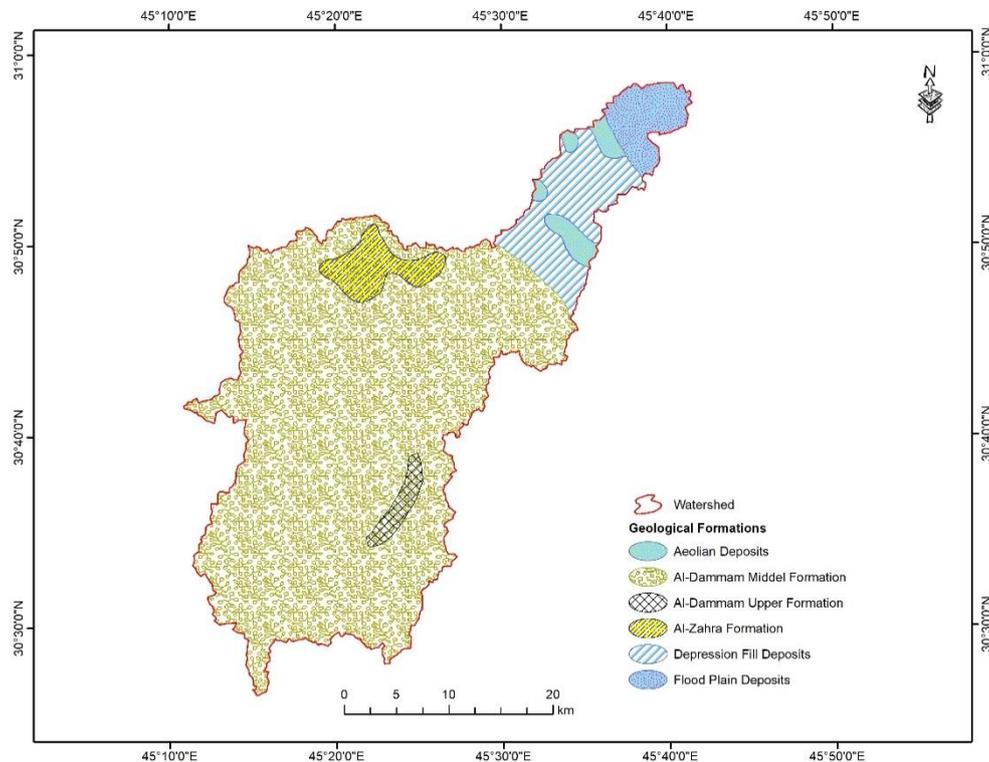
The study area is characterized by seasonal rainfall, where rain falls at relatively distant periods in the form of showers that quickly turn into torrents. The precipitation starts from October to May, and its annual total is 99.3 mm, the rainfall in the study area is characterized by its annual and monthly fluctuation (Şarlak and Mahmood Agha, 2018) (Figure 6B).

The north and northwest winds are the prevailing winds in the study area, and they do not differ any way from the winds blowing over the central regions of Iraq, especially those located in the sedimentary plain area as the same winds mentioned above prevail over them, and its gusts are closely related to the distribution of atmospheric pressure days outside the region's boundaries. The annual average wind speed in the study area is (3.6) m/s, and the wind speed increases in the summer months, reaching in (June, July, August) (3.7), (3.8), and (3.5) m/s respectively. The average wind speed decreases in the winter months (October, December, and January) to reach (2.5), (2,3), and (2.5) m/s respectively (Agha and Şarlak, 2016) (Figure 6C).



**Fig. 6. Averages (temperatures, precipitation, wind speed) for the study area according to the data of the Al-Samawah Climatic Station, for the period (1973 – 2017).**

Geologically, the exposed rock formations in the study area are controlled by their deposition environments, where some of them were deposited under continental conditions resulting from marine decline, while others were deposited under marine conditions resulting from marine progress (Hatem et al., 2015). The study area contains many stratigraphic units appeared as outcrops, ranging in age from upper Eocene to Holocene. Those formations are shown in Figure (7). The two cases of marine subsidence and submersion are due to the land movements that the region was subjected to during its geological history causing changes in sea level and climatic. Several geological formations appear in the study area, including Dammam Formation, which is exposed in the northern part of the basin and is covered with a variable thickness of sand plate deposits (Sissakian and Fouad, 2015). The formation of Al-Ghar, which unfolds in the central and western parts of the basin, is partially covered by aerobic sediments. The formation of Al-Zahra is revealed in the southern parts, where it consists of sandy mudstone and limestone sandstone (Jassim and Goff, 2006).



**Fig. 7: Geological formations of Al-Ashaali drainage basin.**

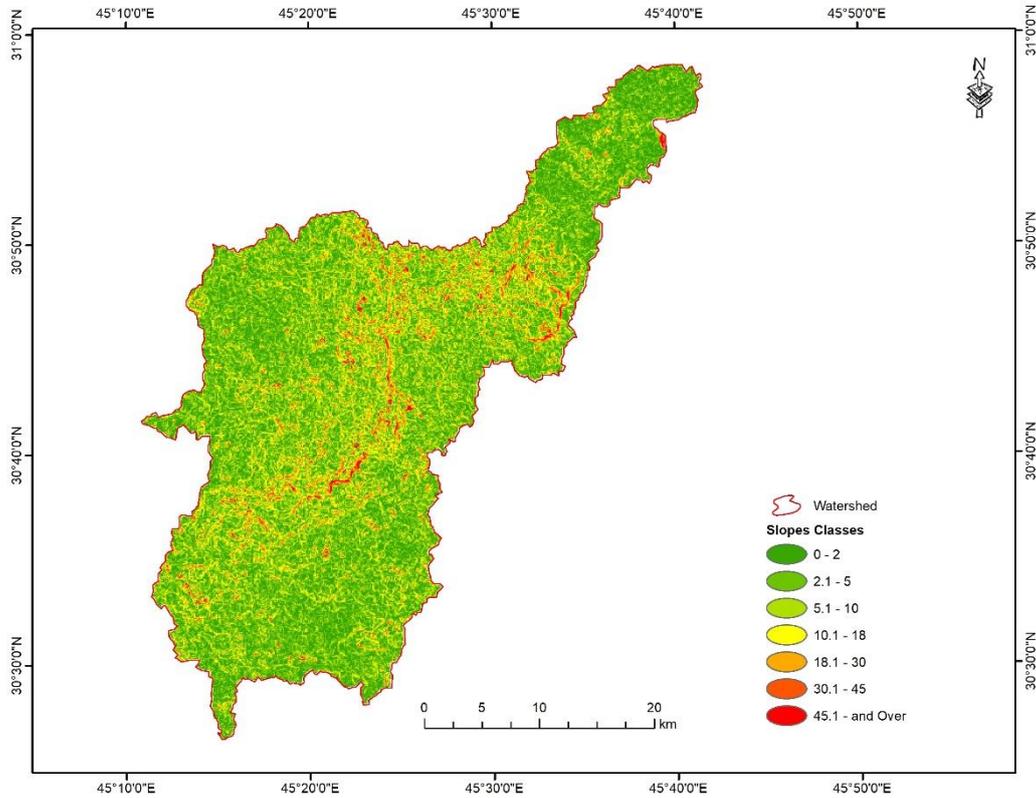
## Results

### 1. Categories of Slope:

According to Young's slope classification (Korup and Schlunegger, 2007), Al-Ashaali drainage basin was divided into seven regression categories ranging from 0 degrees to more than 45 degrees. Each category has its regression characteristics in line with the geomorphological phase of the basin in all its parts. There is a clear spatial variation in the geographical distribution of the slope categories in the basin, whereas the slope category 5-10 has covered an area of 287.859 km<sup>2</sup> by 25.499% as a highest rate of decline recorded in the basin (Table 2 and Figure 8), the gradient category 45 + has covered an area of 11.465 km<sup>2</sup>, with a percentage of 1.015, which is the lowest.

**Table 2. According to Young's classification, area and percentage of regressive groups in the study area.**

Type of Slop	Slop Angle (degrees)	Area (km2)	Percentage (%)
Semi-flat lands	0 – 2	281.725	24.955
Simple slope lands	2 – 5	148.606	13.163
Light sloping land	5 – 10	287.859	25.499
Moderate terrain	10 – 18	97.576	8.643
Steep terrain	18 – 30	208.952	18.509
Very steep terrain	30 – 45	24.685	2.186
Cliffs	45 +	11.465	1.015



**Fig. 8. Slopes classes for the Al-Ashaali drainage basin.**

**2. The direction of slope:**

The study area is characterized by its gradual decline from southwest towards northeast representing its general decline. The region also has localized regressions that have their main trends at north, east, south, and west, as well as secondary trends. There is a clear discrepancy in the areas and percentages of the basin's slope directions. The area of the slopes towards southwest reached 183.752 km<sup>2</sup> with a percentage of 16.277% as a highest percentage, while the area of the northern slopes reached 75.396 km<sup>2</sup>, with a percentage of 6.678%, which is the lowest percentage recorded in the basin (Table 3 and Figure 9).

**Table 3. Area and percentage of slope direction in the study area.**

The direction of the slope	Area (km2)	Percentage (%)
Flatlands	110.323	9.772
North	75.396	6.678
North East	118.196	10.470
East	96.814	8.576
South East	108.539	9.614
South	179.001	15.856
Southwest	183.752	16.277
West	93.520	8.284
Northwest	143.998	12.755

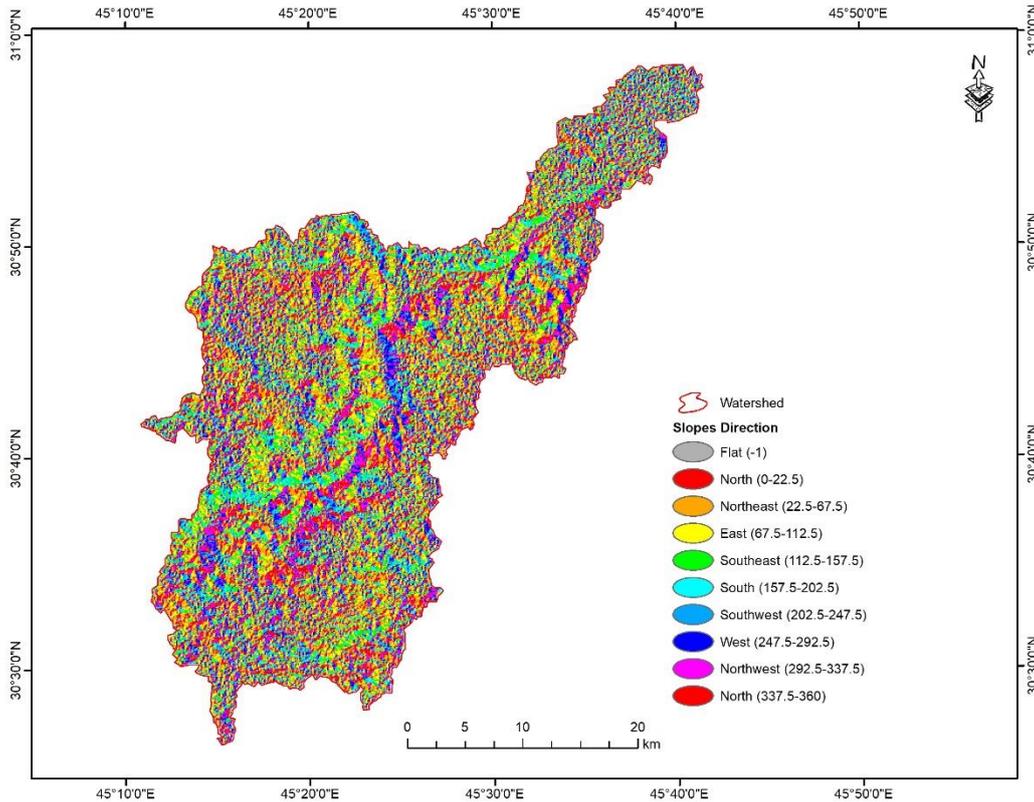


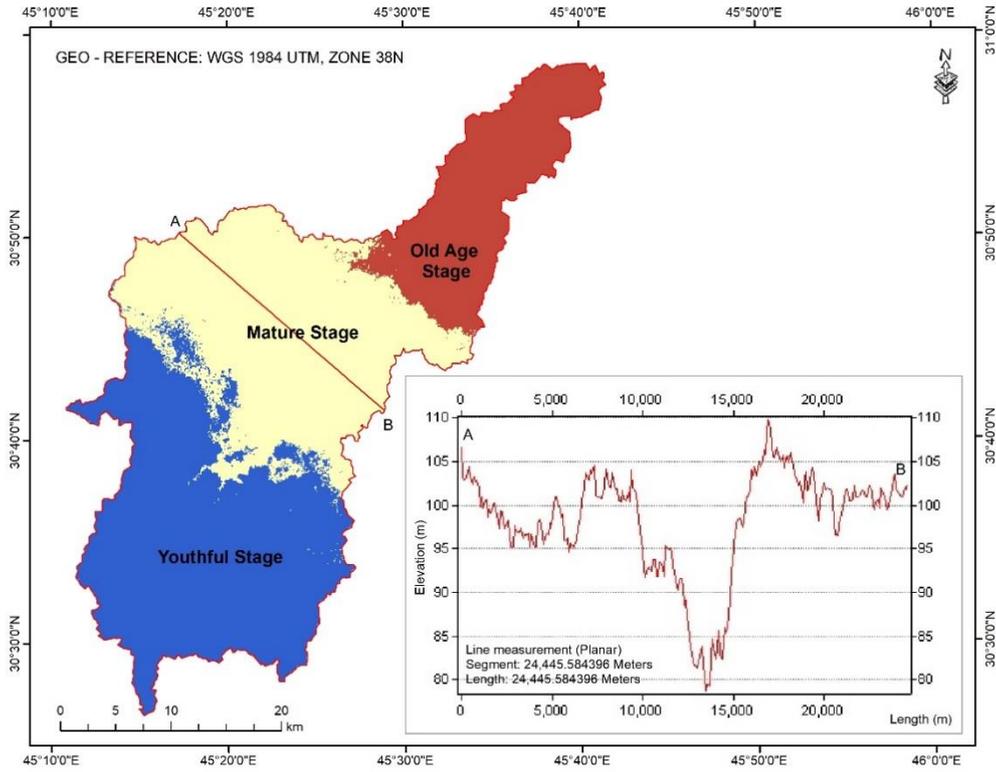
Fig. 9. Slopes direction for the Al-Ashaali drainage basin.

### 3. The slope parts:

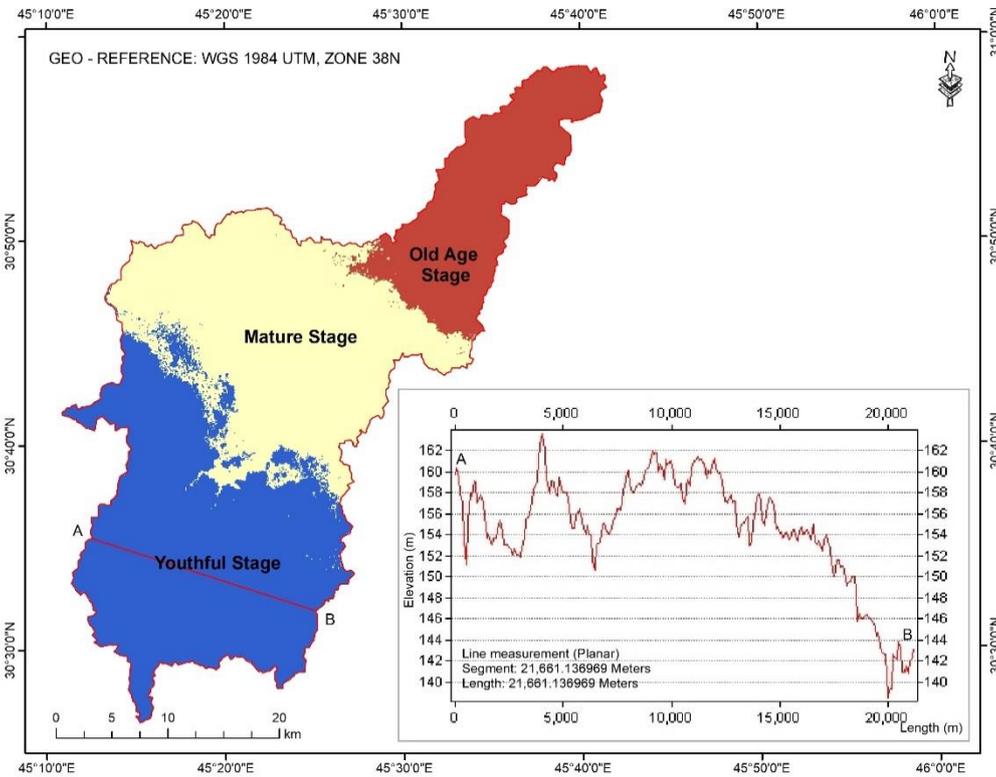
The slope part is the section at which the slope angle is constant, and when it is studied, it appears to have a regularity at the total length of the terrain sector as well as the standard properties of the regression elements and units (Mariani and Zerboni, 2020). There is a clear variation in the numbers and averages of the regression parts. The number of slope parts in the by-sector of the mid-basin region (maturity area) is 251 (Table 4 and Figure 10), which is the highest value recorded at the cross-section level. The second place is the terrain section of the basin's source area (Figure 11), the number of regression segments in this section was 251. The third place comes the basin estuary area in the Al-Sulaibate depression (Figures 12 and 13), which has the lowest number of regression segments at the basin level, at 79, and for the longitudinal section, which extends from the upper source area south of the basin to the downstream area (Figure 14) The number of regression segments was 766, corresponding to the length of 66.371 km.

Table 4. The regression parts of the transverse and longitudinal sections in the study area.

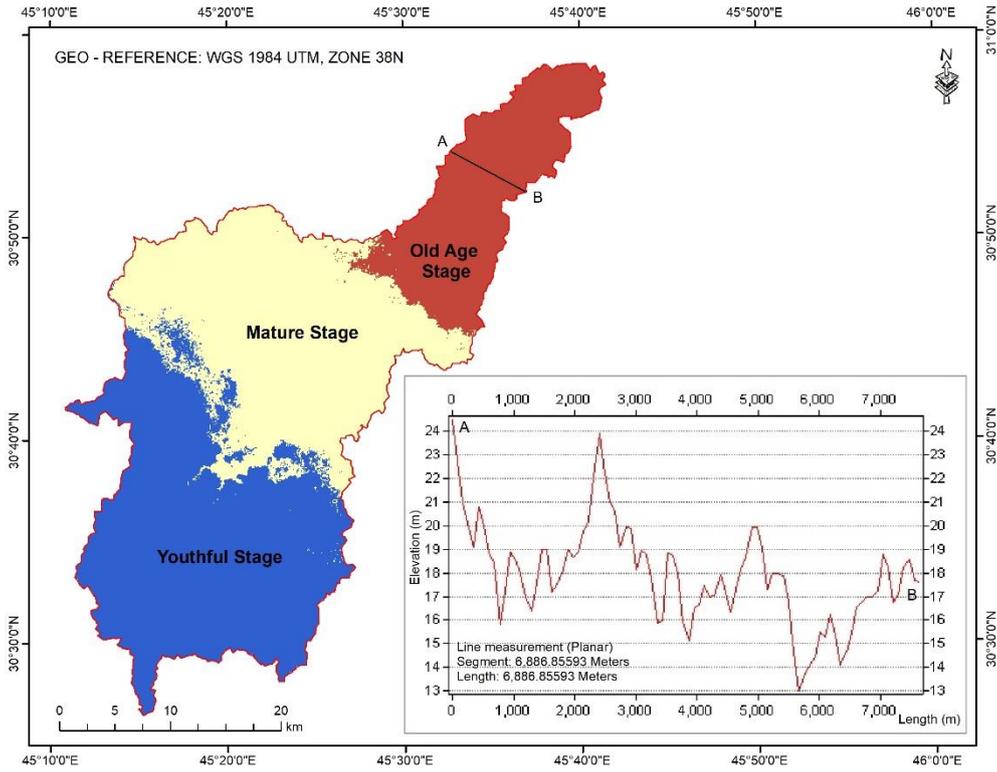
Terrain section	The length of the terrain cross-section (km)	Number of terrain cross-section
Sources of the basin	21.661	251
Middle of the basin	24.445	284
Mouth of basin	6.886	79
Longitudinal section	66.371	766



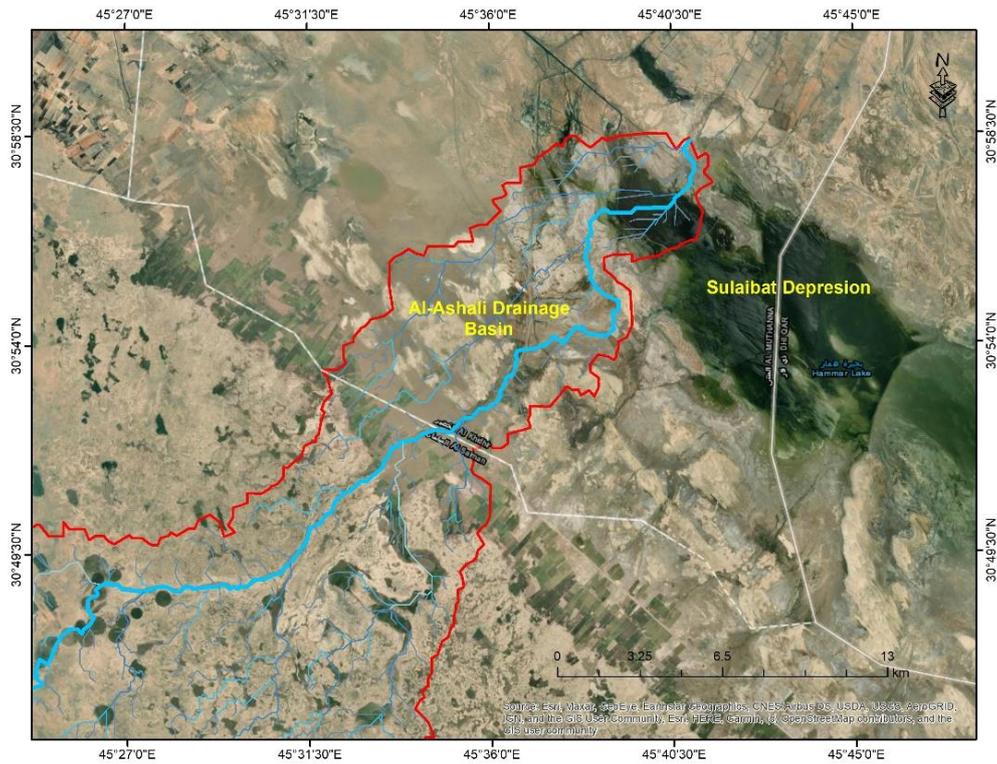
**Fig. 10. Topographical cross-section of the central region (maturity stage) at the study area.**



**Fig. 11. Topographic cross-section of the upper headwaters (youth stage) at the study area.**



**Fig. 12. Downstream topographical cross-section (old age stage) at the study area.**



**Fig. 13. The area of the mouth of the Al-Ashali drainage basin in the Al-Sulaibate depression.**

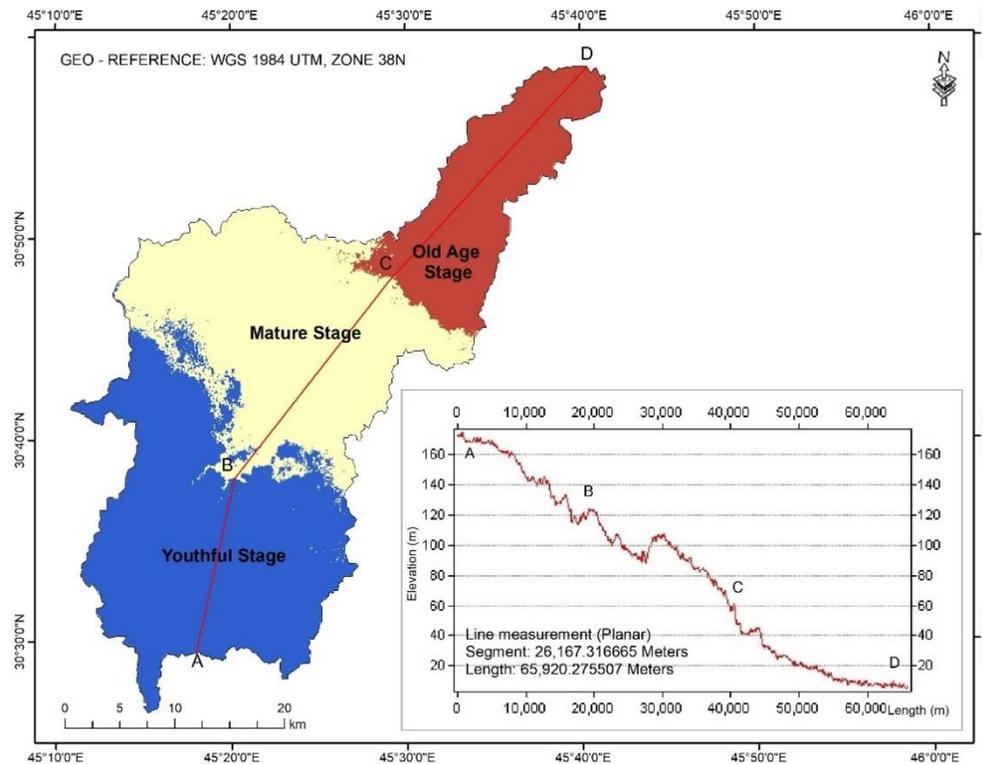


Fig. 14. Longitudinal topographic cross-section of the Al-Ashaali drainage basin.

#### 4. The slope types:

The types of slopes vary in the study area according to the nature of the slope elements, where the sloping element is that part of the slope section along which the curvature coefficient remains constant (Buccolini et al., 2012). The sloping element may consist of a single sloping part, as in the straight and planar components, or it may consist of several sloping parts, as in the convex and concave components (Clubb et al., 2017).

**a. Regular Slopes:** The sloping surface is flat and free from any elevation or depression in its parts, no matter how severe, medium, or slight the gradient is. Therefore, the contour lines are organized in distribution along those slopes (Hendrickx et al., 2020). This type appears clearly in the middle parts of the cross-section of the basin estuary region at the kilometeric location (2-6) (Figures 15 C and 16).

**b. Concave Slopes:** It is very steep at its top and moderate in its middle and end. Therefore, the contour lines are convergent at the top and divergent at the middle and bottom surfaces, and gradually, this type of slope appears in all topographic sections (longitudinal and transverse) (Wang et al., 2020). This type of slope appears in all topographic sections (longitudinal and transverse) and is very clear in the cross-section of the mid-basin region (maturity zone) (Figures 15 B and 16).

**c. Convex Slopes:** It is slow in gradient at its top and becomes more severe in the part under the top and gradually converges towards the bottom of the slope and to a greater extent at the bottom of the slope (Veilleux et al., 2020). It is noted that its presence is limited in the study area, except the areas located to the east of the cross-section of the middle of the basin (maturity area) (Figures 15 B and 16).

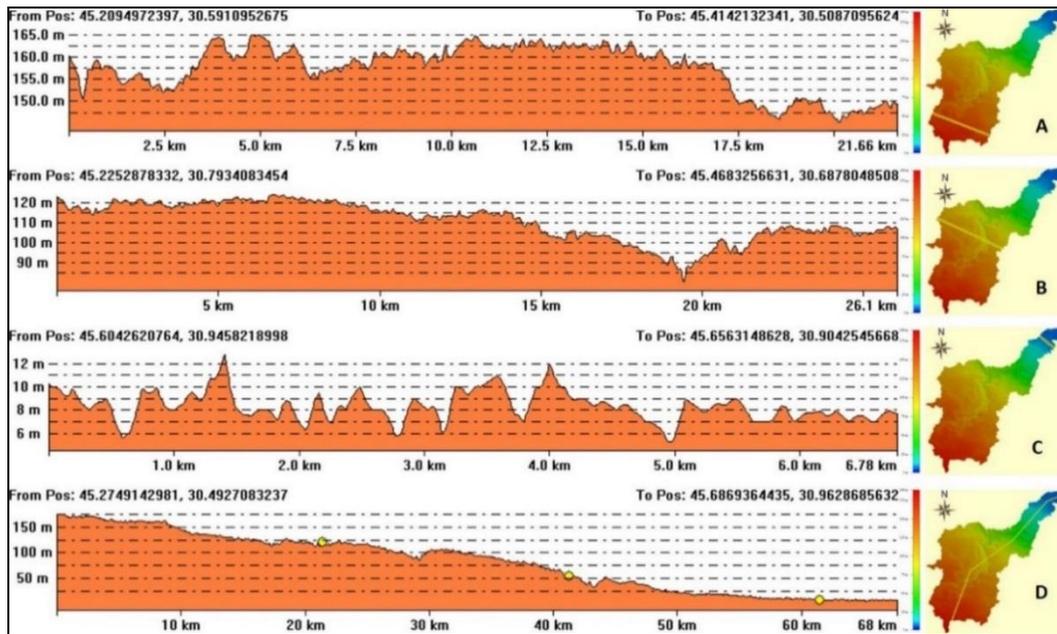


Fig. 15. The types of slopes of the Al-Ashaali drainage basin.

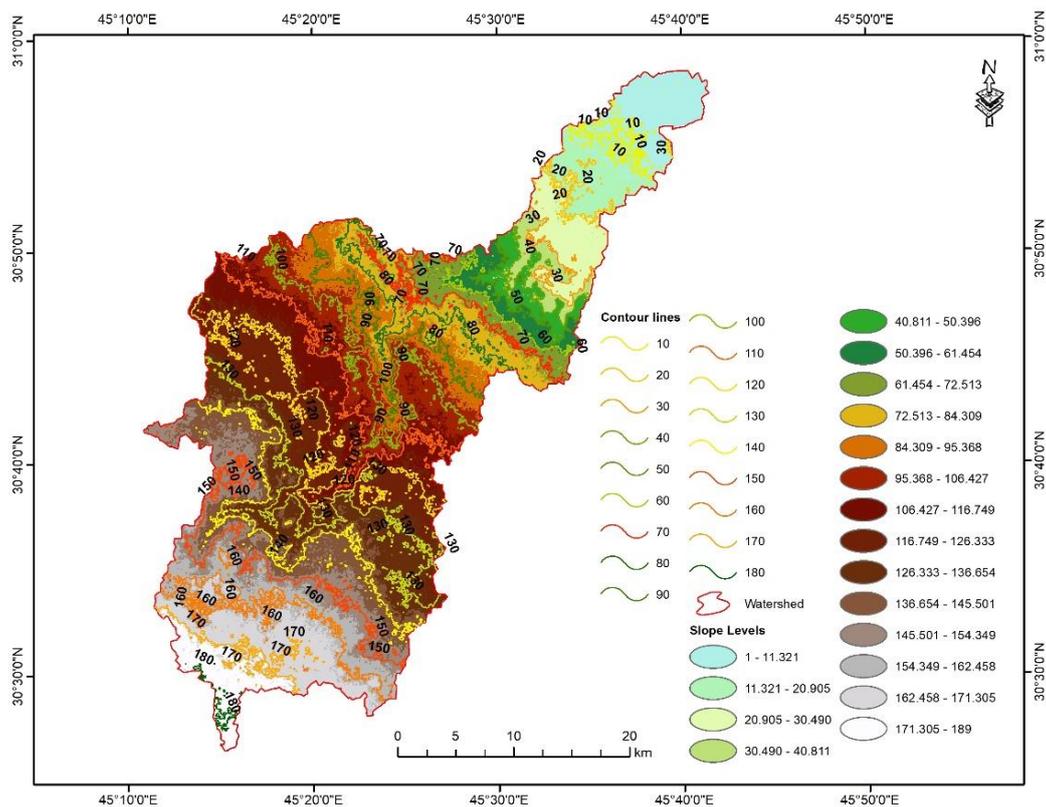


Fig. 16. Spatial overlay between the contour lines and the slope levels of the Al-Ashaali drainage basin.

### Discussion

The results show that there is variation in all the values of the regressive elements in the study area. The results indicate a variation in the area and percentage of the regressive categories. The reason is due to the characteristics of the natural factors affecting the formation of slopes, the most important is the climate with its main elements, especially rain and the torrential rains that occur during a rainstorm, and the degree of response of rocks to geomorphological processes (erosion and weathering) according to the nature of the

geological structure, the fragile rocks are more responsive to these processes, as the torrential waters carry out the erosion process according to the system of joints and cracks, as the flowing water, according to gravity, following the lowest point on the surface of the earth, and during its flow, it erodes the rocks on both sides of the cracks and joints and quickly expands and forms channels, the rest of the prominent rocks represent hard rocks that are resistant to erosion processes, and thus serve to form the sloping system of the drainage basin (Buccolini et al., 2012).

As for the directions of the slopes, the variation is also very clear (north, south, east, and west) and this corresponds to the general slope of the surface of the region, as well as its compatibility with the structure and the general direction of the water resources network, linear structures direct the paths of water resources, which in turn carry out the processes of erosion of rocks and the formation of the general direction of the slopes (Veilleux et al., 2020).

The data given in Table 5 and Figures (11-15) indicate that there is a variation in the number of sloping parts for all-terrain sectors (latitudinal and longitudinal), where we find that the number of sloping parts is high in the cross-section of the middle of the drainage basin (maturity stage), and the reason for this is due to the effectiveness of the water erosion processes that the area has been exposed to, and the resistance processes shown by limestone and dolomite rocks in some parts in front of the watercourses, and the presence of some weak rocks that are subjected to these processes and the formation of grooves that form the slopes and their parts. As for the downstream region, it has the least number of sloping parts, and the reason for this is that this region represents the aging phase of the geomorphological cycle, and the waterways of the basin have almost completed their work in reducing the surface of the region to the base level of erosion (Alvioli et al., 2020).

Also, the data in Figures 16 and 17 refer to the study area in which there are variations in the types of slopes between (straight, convex, and concave), as the natural characteristics of the area have an impact on this, the rock and mineral compositions vary in their response to the processes of erosion and weathering (chemical and physical), especially in light of the availability of climatic conditions that worked on the development of these processes, including differences in temperature ranges and the spatial and temporal variation of the amounts of rain precipitation. All of them lead to the presence of differential weathering in the detectors of linear structures dating back to different geological times (Zhao and Zhang, 2020). This results in the instability of the slopes and the superiority of the driving force of the Earth's gravitational movement over the resistive forces and the development of the movement of materials of different types on the ground slopes leading to the formation of different types of slopes (Graf, 2006).

## **Conclusion**

The different geological formations in the study area play an important role in shaping the slope systems, through the varying in the degree of response to different geomorphological processes (erosion and weathering), where there are weak rocks in front of these processes that lead to their fraction into fine fragments that are easy to transport by water or wind or the movement of materials by gravity, and hard rocks resistant to these processes remain to form slope systems in the region.

The ancient and current climates played an important role in shaping the slopes of the study area through its elements (temperature, rainfall, and wind), where this effect is through the development of hilly and sedimentary slopes in indirect ways by determining the quality and rates of erosion and weathering and the degree of rock resistance, as well as the effectiveness of the climate in determining the water discharge of rivers and the rates of

drainage and determining their role in rock erosion and slope formation, in addition to determining the wind activity and its influential role in eroding the surfaces of slopes and transferring very small sedimentary fragments.

There is a variation in the morphological characteristics of the regression categories of the basin, and each category is characterized by its regression indicators in line with the geomorphological stage that the basin is going through. The directions of the slopes vary in all directions (east, west, north, south) as well as secondary directions. The direction southwest recorded the highest rank, while the direction of the northern slopes came in the lowest rank, and there is a variation in the number of regression parts according to the terrain sectors and according to the geomorphological stage of each region. The maturity region contained the highest rank in the number of regression parts, while the downstream region ranked last in the number of regressive parts.

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