GIS-BASED GEOMORPHOLOGICAL ANALYSIS OF DEWANA BASIN, SULAIMANIYAH, KURDISTAN, IRAQ

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ABSTRACT

An integrated remote sensing data and Geographic Information Systems (GIS) were applied in geomorphological study of Dewana drainage basin, Sulaimaniyah Governorate, northeastern Iraq. The basin is considered as a good example of small scale drainage basins of a mountainous terrain with variable geomorphological processes and landscapes. Major basin divides are recognized by the homoclinal ridge of Baranan Mountain to the northeast and Sagerma Mountain to the southwest.

Satellite images as well as Digital Elevation Model with topographic, geologic, and structural maps were used in addition to field investigations to perform a geomorphological analysis, classification, and mapping.

Arc GIS 9.3 was used to digitize, measure and draw the spatial data of this analyses. General geomorphic mapping and classification of the basin's landforms using genetic origin; as a base for the grouping show that it includes five major groups or units. These units are: Structural origin, Denudational origin, Structural-Denudational origin, Fluvial origin, and Anthropogenic origin. Each of these five units includes related different subunits which were mapped on a 1: 150, 000 scale map to show special distribution and relation between the different landforms. Discussion of the five units and their subunits were made in term of their relation to geology, topography, drainage network as well as originating geomorphic process. The fluvial process is the most effective one, which generates most of the recent and pronounced landform groups such as: dry valley deposits, flood plain, valley fills, river terraces, alluvial fans, galleys, badlands. Other important processes are mass wasting activities.

التحليل الجيومورفولوجي لحوض ديوانه المائي باستخدام نظام المعلومات الجغرافية محافظة السليمانيه، كوردستان، شمال شرق العراق

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المستخلص

يتناول البحث دراسة مورفومترية تفصيلية لحوض ديوانة المائي اللذي يقع ضمن المنطقه الجبلية الى الجنوب الغربي من مدينة السليمانية في كوردستانن الى الشمال الشرقي من العراق وذلك باستخدام معطيات التحسس النائي ونظام المعلومات الجغرافية، إضافة الى تحليل الخرائط الطبوغراقية والجيولوجية واستخدام المرئيات الفضائية وصور الارتفاعات الرقمية المتباينة معززه بالدراسة والزيارات الميدانية. الحوض يعتبر نموذج للأحواض المائية الجبلية صغيرة الإتساع ومتنوعة الخصائص والعمليات الجيومورفولوجيه. تم تصنيف الحوض ورسم الخريطة الجيومورفولوجية التفصيلية وفقا لنظام التصنيف الجيومورفولوجي الدولي بعد مراجعة كافة العوامل والمكونات الطبيعية

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للبيئة الجيومورفولوجية للحوض وبالتركيز على نشاءة الأشكال الأرضية كأساس للتصنيف. الخريطة والتصنيف وضح ان الحوض يضم خمسة وحدات جيومرفولوجيية أساسية إضافة الى عدد من الوحدات الثانوية. الوحدات الرئيسية هي: وحدة الأشكال تركيبية الأصل، وحدة الأشكال تعروية الأصل، وحدة الأشكال التركيبية - التعروية وحدة الأشكال نهرية الأصل ووحدة الأشكال الناتجة عن نشاطات الإنسان. تمت مناقشة هذه الوحدات والأشكال الجيومورفولوجية ووصفها بالتفصيل مدعوما بالملاحظات والصور الحقلية والقياسات الميدانية للمنطقة. كما تم ربط هذه الأشكال ونشأتها بالعمليات الجيومورفولوجية السائدة في منطقة الحوض والتي تقع على رأسها عمليات التعرية والترسيب النهري مثل رواسب الوديان الجافه، السهل الفيضي، المصاطب النهرية، المضايق والأراضي الرديئه.

INTRODUCTION

Dewana Basin, as a part of Sulaimaniyah area lacks detailed geomorphological studies that include geomorphological mapping and evaluation. As the area faces rapid development and growth, similar kind of studies become important and necessary to establish a comprehensive background for any environmental, agricultural and even urban development planning.

The current study aims at conducting a preliminary geomorphological evaluation and analysis of Dewana Basin in an attempt to establish a physical environmental data base for future projects or development in the area. The geomorphological analysis is conducted through: field studies of landforms and their relation to different geologic features, classification and grouping of landforms of the study area according to their genetic origin and basin geomorphological mapping using remote sensing data.

Geographic Information System (GIS) is used together with remote sensing data, to contribute to the analysis and representation of the information required for geomorphological analysis of Dewana Basin. In addition, the impact of important geomorphological processes on environment had been examined to image future picture of environmental problems such as: water resources development, soil erosion and flood hazards, slope stability and mass wasting assessment, and agricultural land use and irrigation applications for the basin.

Dewana Basin is located in Sulaimaniyah Governorate, northeast Iraq. The basin area is located between 45° 14' 00" E and 45° 43' 00" E, 35° 03' 00" N and 35° 26' 00" N, with a total area of 606 Km^2. The Dewana perennial stream flows between Qara Dagh and Baranan mountains and drain into Diyala River. Most of the study area is characterized by mountain ranges stretching from southeast to northwest with general altitude ranging from 1878 m (a.s.l) at the highest point in Qala Gila Nawa peak to 360 m (a.s.l) at the confluence with Diyala River (Fig.1). Fig.2 shows the digital topography of Dewana Basin.

Fig.1: Location map of the study area

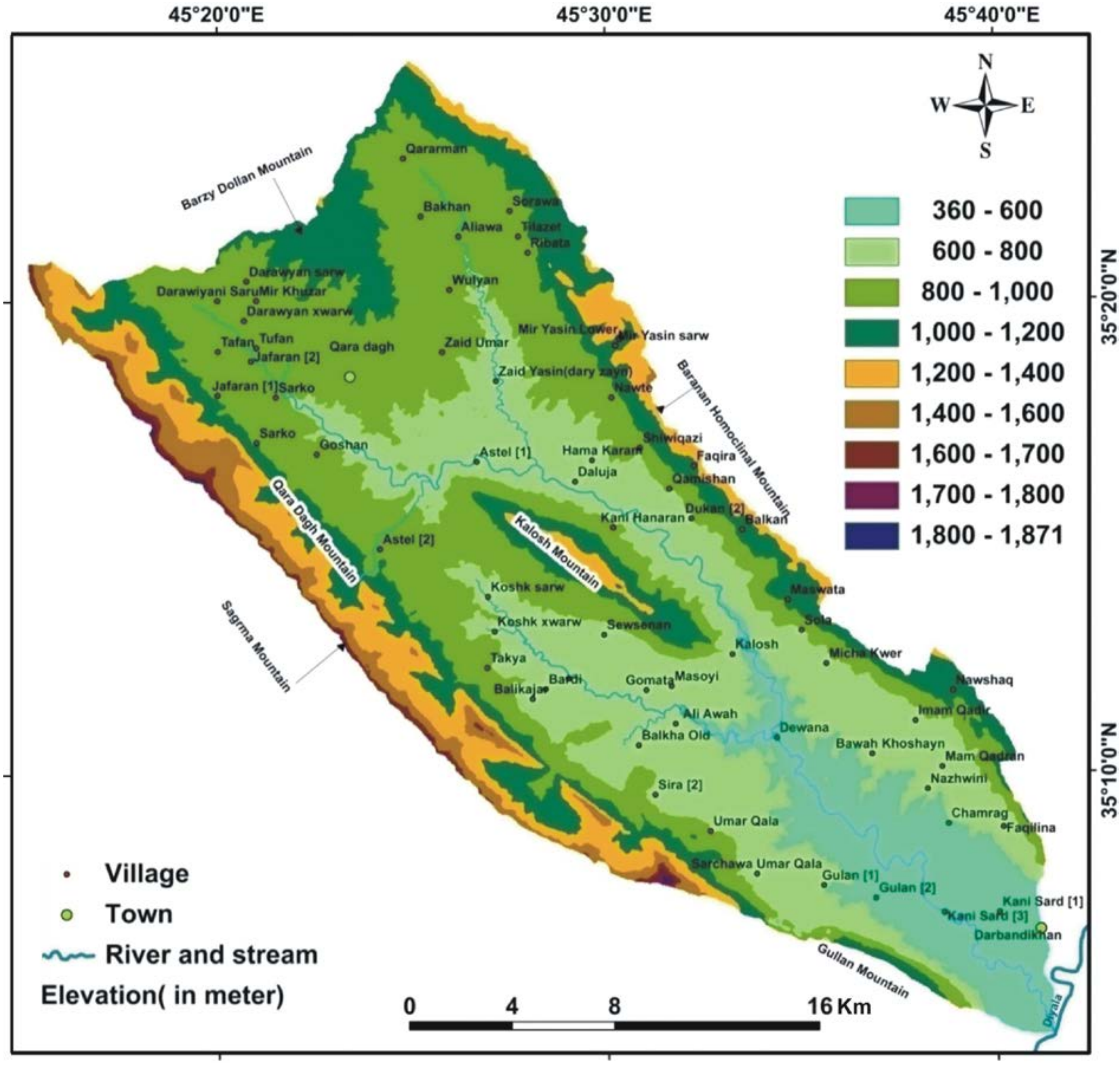

Fig.2: Digital elevation model of Dewana Basin

METHODOLOGY

Field observations were made along transverses selected across important segments of the study area. Field work was facilitated using topographic map of (1: 100 000), and geological map of (1: 250 000). Compass, and GPS are used to check significant localities. Field measurements and description of different landforms were conducted and field photos were taken to support description of different landforms.

Topographic maps of scale 1: 20 000 were scanned and georefrenced in Arc GIS 9.3 software with acceptable minimum RMS, projected all map to Universal Transverse Mercator Projection (UTM) coordinate system, with WGS-84 datum, zone 38N. Mosaic for 13 top sheets by ERDAS imagine 8.2 software are created. Drainage network was generated from Digital Elevation Model (DEM) by using the Arc-hydro tool within Arc GIS software.Band combination of Landsat TM image was created in ERDAS Imagine 8.2 software, for visual interpretation of landforms and geological units.

Geomorphological analysis and classifications into geomorphic units and sub-units is attempted as assigned by ITC (International Institute for Geo-Information Science and Earth Observation) and IGU (International Geographical Union) classification system. Medium scale geomorphological map of scale 1: 150 000 was constructed to cover basic units of the Dewana basin.

THE DEWANA BASIN

Dewana Basin includes the Dewana perennial stream and its main tributaries passing along the elongated basin (Fig.1). Its boundaries are surrounded by several mountains and homoclinal ridges, which separate it from the surrounding basins. The Baranan Range is located to the NE of the basin that separates Dewana Basin from Tanjero Basin and Sagrma Mountain with Gullan Mountain separateing it from Awa Spy basin. To the north, it is separated from Basara Basin by Barzy Dolan Mountain, and from the south all channels drain into Diyala river (Fig.3). Kolosh Mountain is located in the middle of the Dewana Basin. The maximum altitude of the basin is 1878 m, (a.s.l.); at Qala Gila Nawa peak, while the minimum altitude is 365 m, (a.s.l.) near Dewana stream before it reaches the Diyala River.

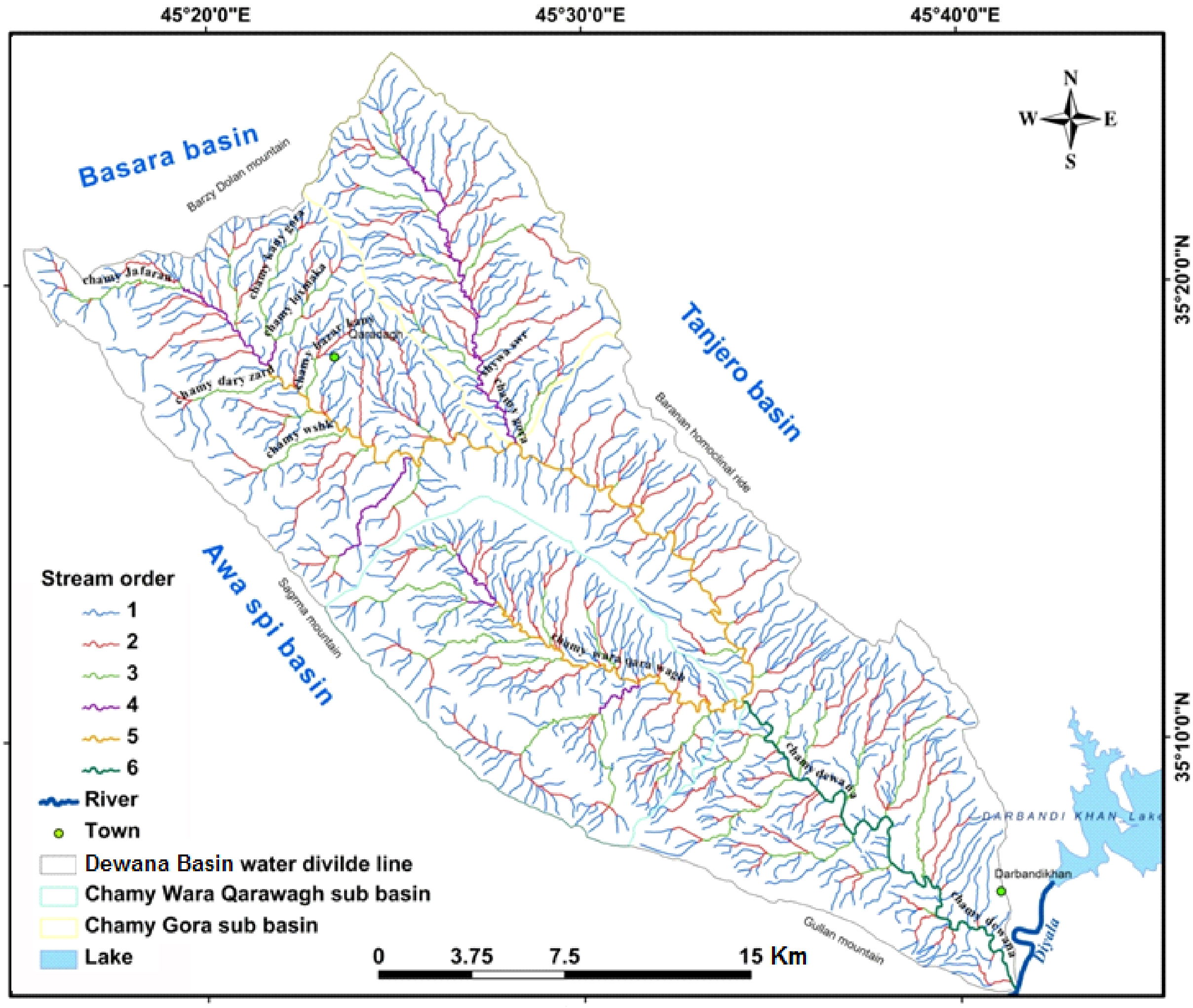

Fig.3: Dewana Basin drainage network and sub-basins
(Stream from digitized 1: 50 000 scale topographic map)

The basin area is made up of several carbonate and clastic deposits of Tertiary age. Since fractured carbonate rocks are dominant in the basin, a considerable amount of surface water recharges the aquifers. All the water courses of this basin flow eventually toward the Diyala River. Dewana stream flows through tens of villages and farms, which makes it an important source of water for agriculture and, encourages the planning of Dewana dam and reservoir downstream.

The Dewana Basin is delineated from surrounding basins based on location of water divide line by using 30 m grid DEM and vector stream network following (Dillabaugh, 2002; Lin *et al*., 2005; Korkalainen *et al*., 2007; Mendas, 2010; Graves, 2001 and Djokic, 2008) by using Arc hydro tool (Dartiguenave, 2007) and Spatial Analyst extension following Johnson (2009) in Arc GIS 9.3. This model is calibrated by using topographic maps of different scales.

Two major sub-basins were identified from Dewana Basin to show local variation in basin network. These two sub-basins were delineated depending on their branching major tributaries from the Dewana Stream and their different geomorphologic setting. It is divided by water divide line into Chamy Gora and Chamy Wara Qarawagh basins. The sub-basins are named according to the local names of streams. The areas of these basins are (99) and (131) Km^2 respectively (Fig.3).

GEOMORPHIC AND GEOLOGICAL SETTING

The Dewana Basin is located near the southwestern margin of the High Folded Zone of the Zagros Orogenic Belt of northern Iraq (Fig.1). The basin is locally represented by a topographic low expressing a syncline that extends between Sagerma anticline and Baranan homoclinal ridge. It is developed as a synclinal valley bounded by two anticlines and has a NW – SE trend. The syncline is generally symmetrical, with clear well shaped southeastern plunge.

Major structural trend follows the Zagros Folded Belt of NW – SE regional orientation. The geology of the basin is controlled by two major structural features. The first, known as Darbandikhan anticline, which bounds the basin on its northeastern side, diverges and splits into the Baranan homocline ridge by Baranan back thrust fault (Ibrahim, 2009). The strata at this ridge dips between (20 – 40)°. The second ridge; known as Sagerma anticline, bounds the basin from the southwest. The eastern flank, known as the Qara Dagh Mountain and the western flank as the Sagerma Mountain. The only disturbing structural feature within this syncline is represented by a local doubly plunging anticline known as the Kalos anticline. Its axis trends parallel to the major structural strike of the area. Its cap rock consists of hard resistant limestone of the Pila Spi Formation. Other important structural features are; Transverse fault system, which dissect the main ridges developing gorges of significant valleys.

The central area of the Dewana Basin is characterized by sub-horizontal clastic strata of the Injana Formation. However, Tertiary strata makes up the majority of exposed rocks of the basin (Fig.4). These strata represents (from old to young): Kolosh, Sinjar, Gercus, Pila Spi, Fatha, Injana, Mukdadiyah, and Bi Hassan formations. Below is a brief review of these units. The distribution of these strata is shown in the geologic map of Figure (4), and detailed description of their lithologies can be found in Ahmed (2012). The hard limestone of the Pila Spi and Sinjar Formations delineate the drainage basin's boundaries, and the soft clastic sediments of the Kolosh, Gercus, Fatha, Injana, Mukdadiyah, and Bai Hassan form the low land of the basin. Alternating limestone and sandstones with these clastics contribute to the detailed shaping of the basin's morphology.

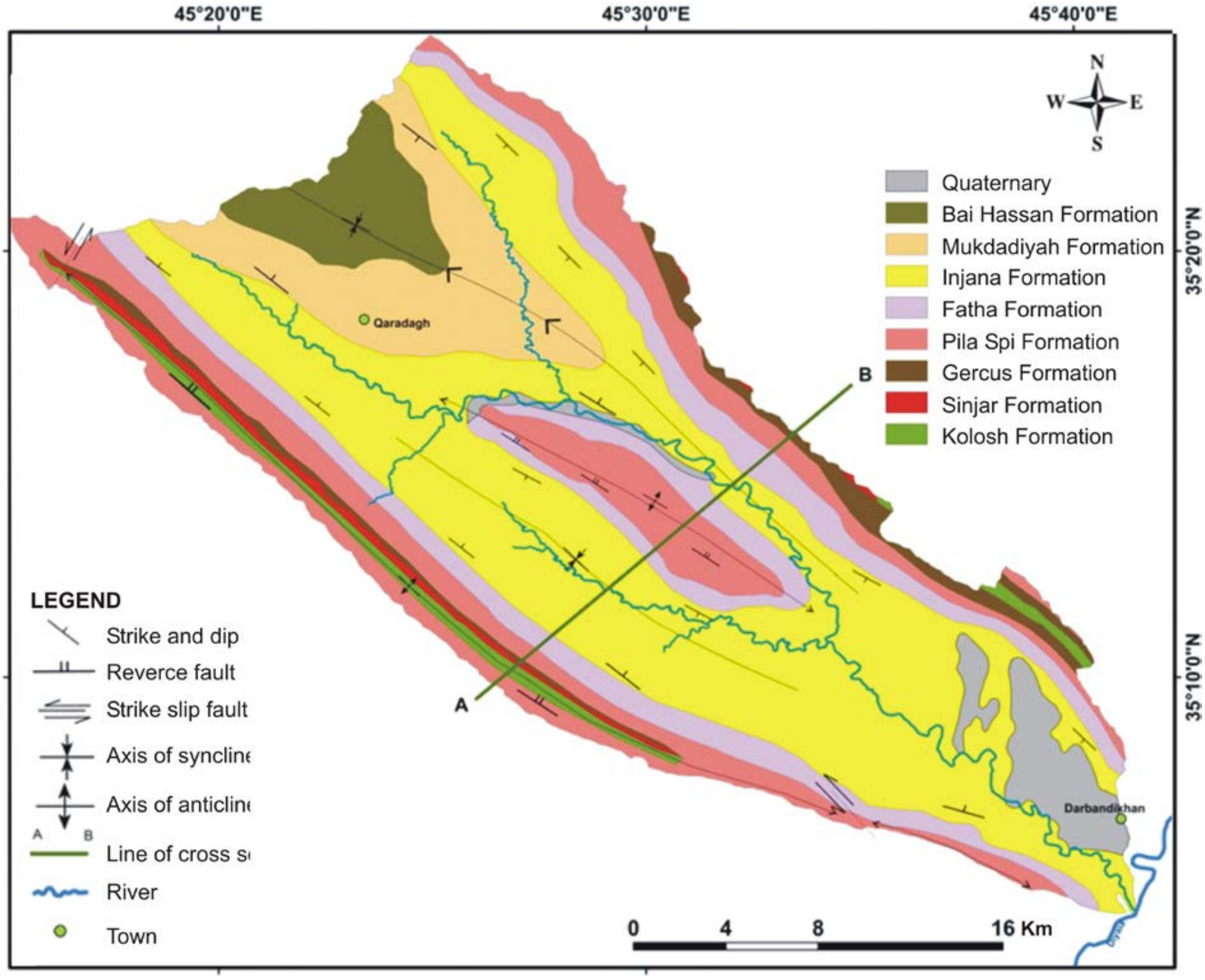

Fig.4: Geological map of Dewana Basin (modified after Ma'ala, 2008)

- **Soil Condition**

Soil cover over the rocks of the Dewana Basin is variable in thickness, composition and distribution. However, two basic groups were identified by Buringh (1960) and Hadad *et al*., (2009), which can be applied to the study area. These two classes are mapped in the study area and shown in figure (5):

— **Vertisols:** These soils are rich in clay minerals (exceeding 30%) down to 50 cm of depth. They consist of silty loam mixed with some gravels, grading into brown silty loam at 14 cm, with lime accumulation beginning at a depth of 30 cm. This soil has been named by Buringh as brown soil. This soil covers Qara dagh Syncline in the study area.

— **Aridisols:** These soils are of arid and semi-arid environments. Salinitization is important soil-forming processes acting in these soils, which lead to inhibition of root penetration (Hadad *et al*., 2009). It consists of rough, broken, stony and mountainous terrain and classified as rough broken and stony land. According to Buringh (1960), these types are distributed in ridges and foot slopes surrounding the Dewana Basin and over Kolosh Mountain (Fig.5).

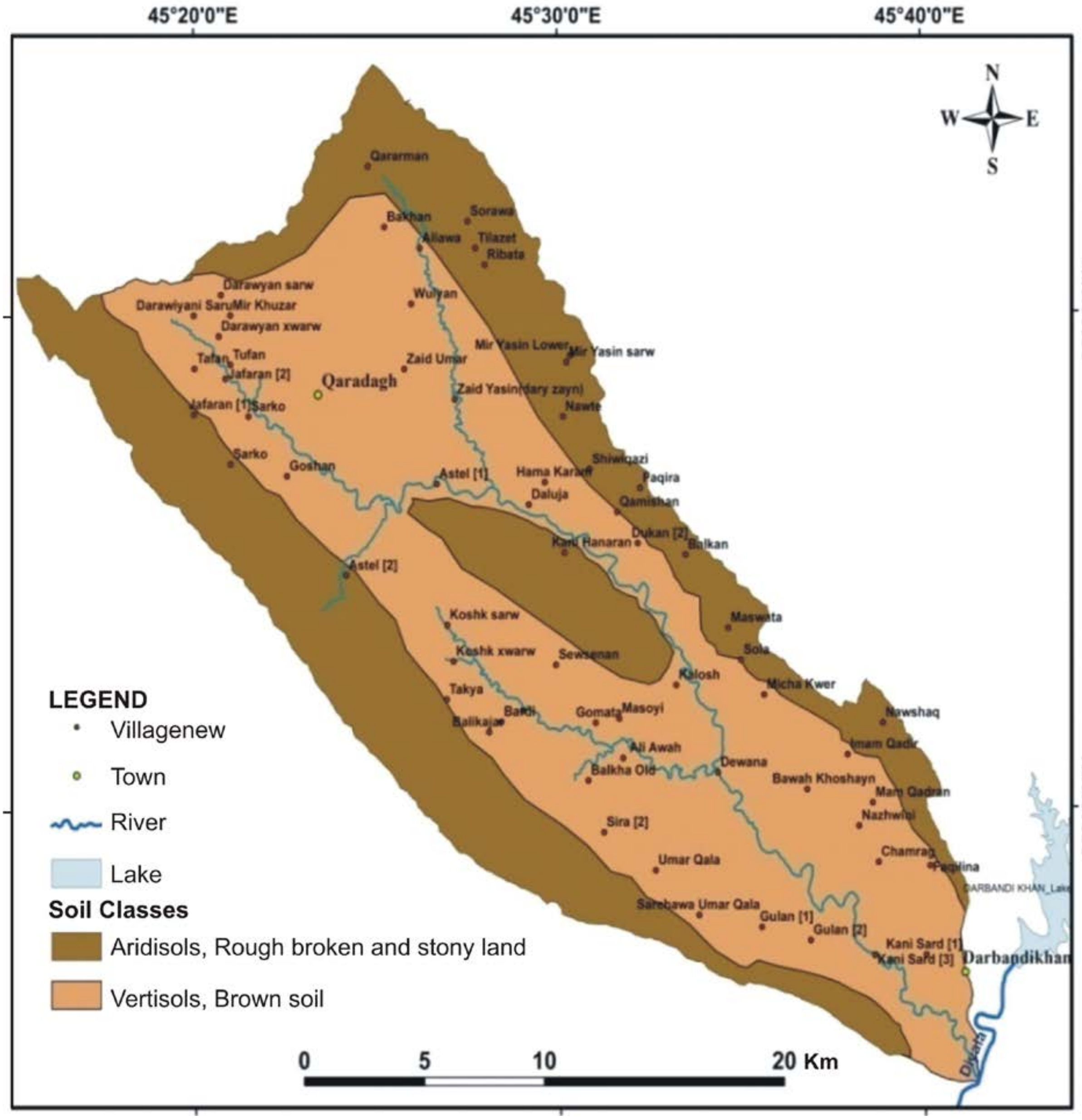

Fig.5: Distributions of soil classes in the study area
(compiled from Buring, 1960 and Hadad *et al*., 2009)

- **Water Resources**

Because the study area is mountainous, the relief and the trends of mountain ridges control the limit and quantity of precipitations, as it controls the direction of precipitation and flow direction. Also the slope direction determines the nature and direction of water flow. Permeable soil type (gravel, cracks and fractures) is widespread in the region, and thus reduces the surface runoff, and so does the natural vegetation or crops of the cultivated area, especially in dense vegetation cover. All these factors help in recharging ground water storage by additional source renewed annually. The exploitation human use of water resources in the region is a key factor in controlling the amount of water.

– **Surface Water:** Surface water can be classified into intermittent and ephemeral streams. These are related to the terms influent and effluent. The first are those in which the stream feeds the ground water as compared to effluent in which the stream receives water from it (Gordon *et al*., 2004). There is no clear relation between surface runoff and an ephemeral stream which is influenced by the climate, geology and vegetation in the studied area. It could be seen that the surface water is basically intermittent for some parts and others are perennial. Dewana Stream is considered as perennial stream (Fig.3).

Therefore, total surface water is represented by intermittent and perennial streams in which snow and rain represent source of recharge. Surface water is responsible for carving and shaping some landscapes. Most features are formed by water erosion or deposition, gully, rills, channels and karst are widely developed.

– **Ground Water:** The ground water represents the second water resource in addition to rain and snow form its main recharging sources.

Aquifers in the study area are of unconfined type, among which Sinjar Formation has the largest outcrop area for collecting water than Pila Spi, Fatha, Injana Formations and Quaternary deposits respectively in the susceptibility of water saving. Pila Spi and Sinjar Formations have fissured and karstic aquifers and intergranular aquifer of Muqdadya and Bai Hassan Formations (Lawa, 2003).

Different types of ground water are present, which contribute to the water resources of the basin including springs and wells. Many springs are of fractures and valley types. Around 44 springs exist in the area (based on 1: 20 000 topographic map survey), most of which are concentrated in the foot slopes of the main ridges around the basin. Astel spring is an important discharge point, which is located at the northwestern plunge of Kolosh anticline with high discharge, from the Pila Spi aquifer. Getting ground water using wells is common due to lack of rain and surface water at dry seasons. Wells are often dug in synclinal troughs, which help in collecting water draining from surrounding ridges.

GEOMORPHOLOGICAL CLASSIFICATION AND MAPPING

The Dewana Basin has been influenced by various processes which prevail in shaping the landform, like material removal, fluvial action (erosion and accumulation), structures (endogenic processes), etc. These processes have worked in the past and are still acting on soft and competent sedimentary rocks, which finally have developed the present landscapes.

The geomorphological setting of the Dewana Basin area seems to be resulted from a close interaction between tectonic activities and lithologic variations, in addition to the action of the climatic conditions, which led finally to the shaping of the regional landscape.

Geomorphic mapping and classification are applied in this study by using satellite images, aerial photographs, digital photography, 3D anaglyph and digital mapping methodologies, which provide high accuracy and spatial resolution, and enable to produce detailed geomorphological maps, both in print and digital format.

Basic geomorphic units in this study contain two fundamental features of classification, which are homogeneity (genetic or structural pattern) and indivisibility at the chosen scale, which is the approach followed by the IGU (International Geographical Union) and most European geomorphologists (Pavlopoulos *et al*., 2009).

The map produced is a basic geomorphological map type, which is produced by simple graphic transfer of data directly collected from field survey or image interpretation (Smith *et al*., 2011).

The geomorphologic map was drawn digitally instead of basic graphical map construction. The most recent refinement of geomorphological mapping is by using GIS platform which allows correlations with other spatial data (Griffiths and Abarahm, 2008; Hartvich and Vilímek, 2008; Galve *et al*., 2009; Gustavsson *et al*., 2008; Vozenílek, 2003 and Vicente *et al*., 2009).

In this study, the geomorphological mapping is carried out following ITC (International Institute for Geo-information Science and Earth Observation) scheme, and IGU (International Geographical Union) guide for medium-scale geomorphological mapping (Pavlopoulos *et al*., 2009).

The geomorphological map was drawn digitally by using Arc GIS 9.3 software which is verified in the field using mapping scale of (1: 150 000); which represents a medium scale according to (Demek and Embleton, 1978 in Verstappen, 1983), at which considerable generalization is required, using both color and symbols to convey information. Major morphogenetic units are colored according to Verstappen (1983). Purple color areas used for units of structural origin, brown is for unit of denudational origin and dark blue for units of fluvial origin. Minor forms are colored according to major units color but using different hues (Fig.6).

Because GIS software lacks suitable symbols for geomorphologic landforms and processes, it is difficult to adopt standard geomorphological symbols. As we know full standardization is only required in the case of the production of a map series at a national or international level (Smith *et al*., 2011); many new symbol sets have been created in GIS environment (Gustavsson *et al*., 2006 and Mihai *et al*., 2008). In order to carry out the geomorphological mapping in the Dewana Basin in GIS environment, it was necessary to interpret the available data, by locating geomorphic units and subunits and distinguishing each by tracing it as a polygons and lines. Each feature was assigned to a unique code and attribute, and was classified according to their origin (Fig.6).

Based on the origin and the genetic relations, the study area is classified into five basic geomorphic units which combine exogenic with endogenic processes. These units include: Unit of Structural Origin, Unit of Denudational Origin, Unit of Structural and Denudational Origin, Unit of Fluvial Origin, and Unit of Anthropogenic Origin. The following is a general review of the basic characters, association and distribution of each unit and their subunits and landforms.

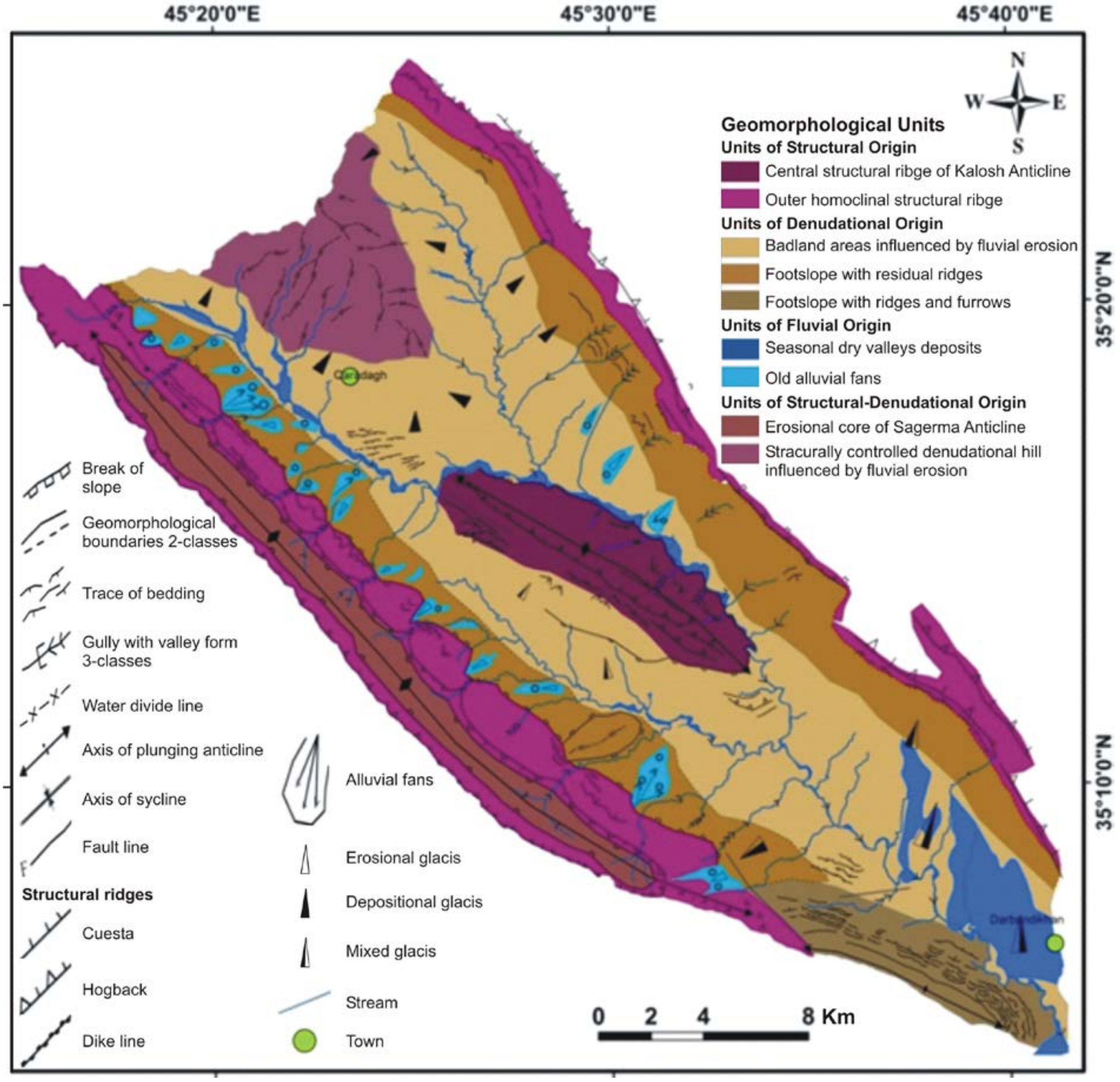

Fig.6: Geomorphological map of Dewana Basin

- **Units of Structural Origin**

These are structural landforms of regional extent. The origin and evolution of these landforms are related to the tectonic activities and deformations of strata and external factors. They are formed as results of folding, faulting, features resulted from interbedding of sedimentary rocks of different resistance to erosion and its situation (tilted or horizontal strata) in the study area. This group includes two major subunits:

– **Central Structural Ridge:** This unit is represented by most of the Kolosh Mountain carapace, which is located in the central part of the study area. It is characterized by a high altitude (1400 m, a.s.l) relative to the surroundings. The rocks of the Pila Spi Formation are more resistant to erosion than the surrounding rocks, such as Kolosh, Gercus, Fatha and Injana formations. It is basically formed of limestone and dolomitic limestone (Fig.4). The Kolosh Mountain represents an asymmetrical anticline, with steeper northestern limb (Fig.7). Both limbs are dissected by parallel valleys carving deep into the hard Pila Spi limestone and the flanking softer rocks of the Fatha and Injana formations.

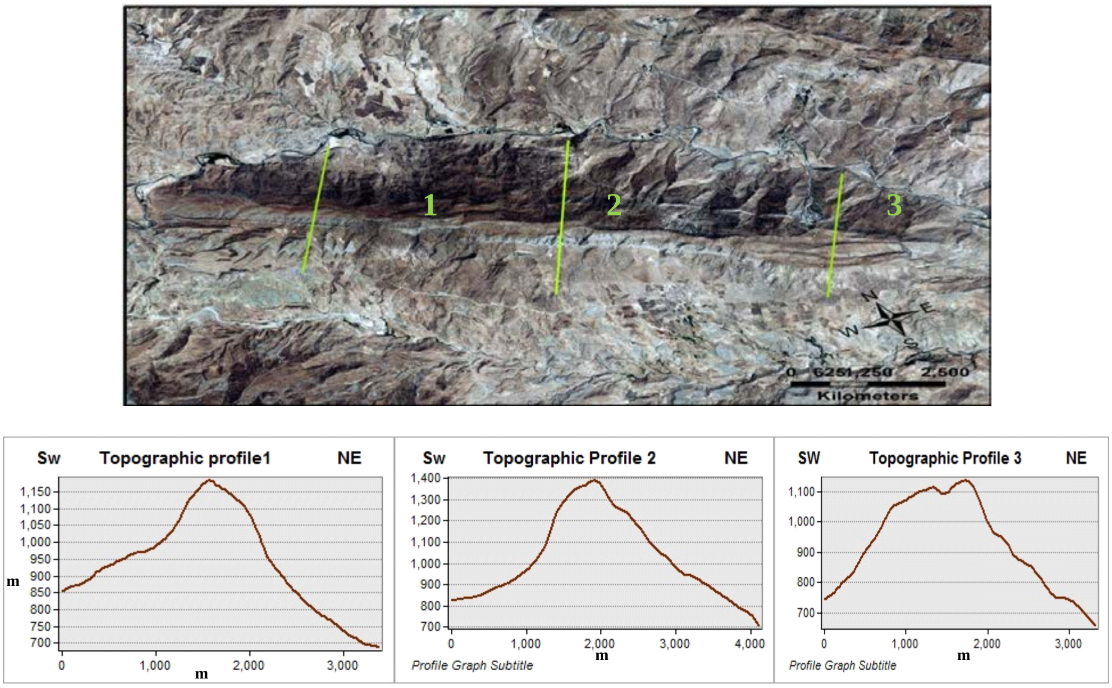

Fig.7: Satellite image showing regional form and topographic profiles of Kolosh anticline

― **Outer Homoclinal Ridges:** These are major structural ridges surrounding the study area from both sides of the basin. They are composed of the resistant dolostone and limestone of the Pila Spi Formation. The dip angle of these beds are relatively high and critical to the angle of repose of the rock slide of its slopes (Bloom, 1998). They form hogback in the southwestern side of the study area; the interfluves remnant of dissected hogback is called flatiron topography (Fig.8). The dissection occur along fault lines, where stream cutting steep-sided gorges that erode headward progressively, forming wind gaps. There is a rapid change in the dip amount at the toes of these ridges because of the erosion of incompetent rock of Fatha Formation along the lower parts of the slopes.

Fig.8: Flatiron on homoclinal ridge of the northeastern limb of Sagrma anticline

- **Units of Denudational Origin**

This group of landform is generated by active and continuous process of erosion on the original landscapes by repeated action of denudation by the geomorphic agents, such as water, wind, rainfall, temperature change. etc. (Roy *et al*., 2010). This group includes the following two landforms; Footslopes, Badlands.

– **Foot slopes:** Foot slopes are usually erosional, but may also be depositional. It is developed between mountain fronts and valley or basin's bottoms. They commonly form an extensive bedrock surface over which the weathering products from the retreating mountain fronts are transported to the basin (Zuidam and Zuidam, 1979). Erosional foot slopes have gently inclined erosional surface; they are carved in bedrock by weathering and erosion processes. They can be recognized by rapid slope changes of structural ridges of anticlines; they represent transitional stage between erosion and deposition and regression of the structural ridges. Foot slopes in the study area are divided in two subunits (Fig.16).

- **Foot Slope with Residual Ridges:** This sub-unit is developed on foot slopes of Qara Dagh Mountain and Baranan Ridge in the northwest and northeast of Dewana Basin, respectively, over Fatha and Injana formations. This form represents residual strike ridges left on foot slopes as a remnants of dissection and erosion.
- **Foot Slope with Ridges and Furrows:** This sub unit is developed in the foot slope of Gwllana's Mountain in southwestern Dewana Basin, over Fatha Formation. They form a shape of successive ridges and furrows, which are developed by different erosional process (Fig.9).

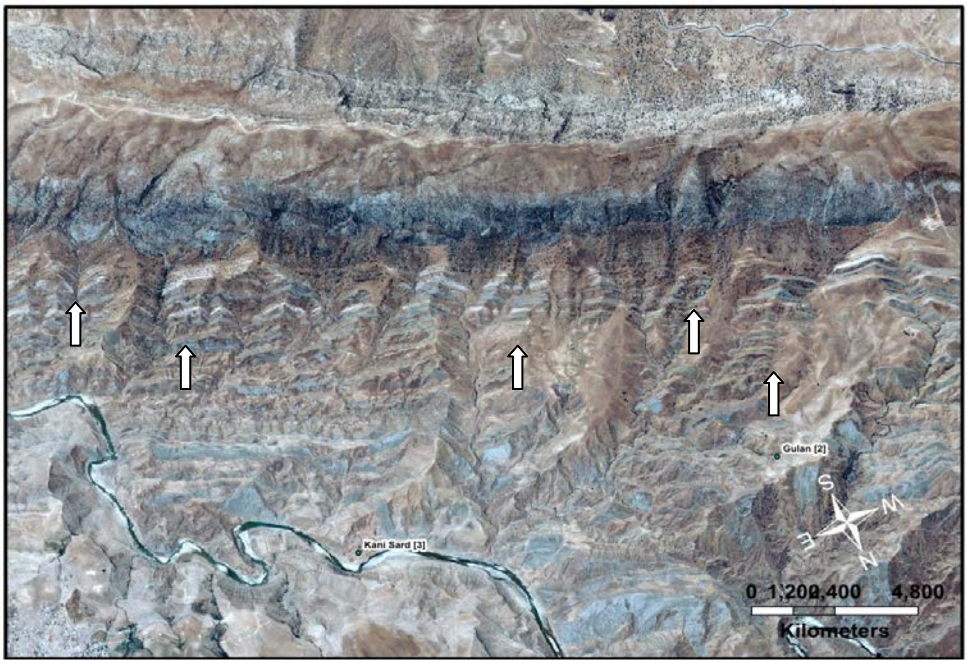

Fig.9: Satellite image shows ridges and furrows in Gullan mountain foot slope

─ **Badlands:** Badlands are deeply dissected erosional landscape formed commonly in soft rock terrain, not exclusively in semi-arid regions. Badlands usually have a high drainage density of rill and gully system, which are characterized by rugged topography, so they do not have significant land use or vegetation cover (Fig.10). Two prerequisites for badland development are important: erodible rock and high relief topography (Goudie, 2004).

Badland topography is well developed in the study area in most of the synclinal area of the upper and lower reaches of the basin. The rocks consist of sandstones alternating with soft claystones and siltstones. In addition, a series of strike ridges related to cuestas; which are formed by resistant sandstone that capped soft siltstone and claystone of Injana Formation. They are asymmetrical ridges with gentle dip slope (5° to 15°) and steep escarpments. Differential erosion of the exposed rocks help developing the badland terrain. It is developed over the outcrops of the Injana Formation exposed in the regional synclinal area.

Fig.10: Badland landscape in the study area

- **Units of Structural-Denudational Origin**

This group of landforms are formed by tectonic movements in addition to the active and continuous process of erosion by the repeated action of denudational processes. This unit includes two subunits: the erosional core of Sagerma anticline and the structurally controlled denudational hills influenced by fluvial erosional subunits.

─ **Erosional Core of Sagerma Anticline:** This unit is structurally controlled and represents an eroded landscape. It represents an early observation of topographic inversion where anticlinal axes become valley. The anticlinal axes have been breached by erosional processes in the zone of weakness and fractures. This unit occupies the core of Sagerma anticline in the northwestern part of the study area and is surrounded by ridges of the Pila Spi and Sinjar Formations (Fig.11), with core soft sediments of the Kolosh and Gercus formations which are easily eroded forming anticlinal valley. It is also developed with step-escarpment due to Sagerma Fault along fold axis (Stevanovic and Markovic, 2003), which facilitates the erosional process (Fig.12).

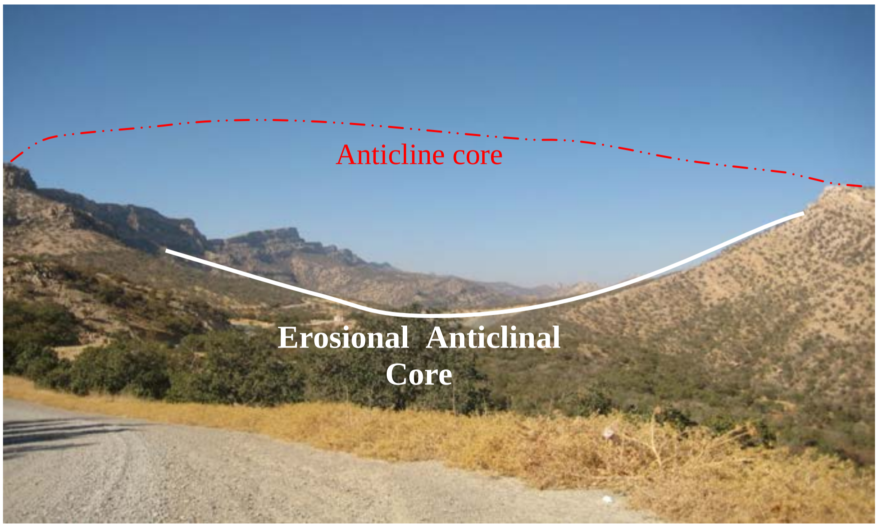

Fig.11: Erosional core of Sagerma anticline

Fig.12: Erosional ridge flanking the Sagerma anticlinal core

– **Structurally-controlled Denudational Hill Influenced by Fluvial Erosion:** It is a structurally controlled remnant hill located in the northeastern part of the synclinal trough of Dewana Basin. It is formed on Bai Hassan and Mukdadiyah formations. It covers an area around 82.2 Square Kilometers, and reaches 1196 m in elevation; it is called Barzy Dollan Mountain. The beds are near horizontal with small degree of dip angle. An active gully erosion prevails in the area due to active fluvial erosion (Fig.13). Structural-denudational terraces are formed on Mukdadiyah Formation because of differential erosion on the alternating soft and hard rocks leading to overhanging protrusion of hard rocks (Fig.14).

Fig.13: Gully erosion on Barzy Dolan Mountain, north of Dewana Basin

Fig.14: Structural benches in denudation hill area, Dewana Basin

- **Units of Fluvial Origin**

Fluvial landforms are generated by the direct action of major rivers or streams of the area and the processes associated with them (Roy *et al*, 2010). The fluvial units in the study area include two groups: Seasonal dry valley deposits, and old alluvial fans.

─ Seasonal Dry Valleys Deposits: This unit forms Dewana stream bed and its major tributaries, in addition to its surrounding flood plain. They are the most easily detectable landforms on satellite images. However, other associated small scale landforms and subunits are hard to be recognized from these images and are often identified from topographic maps and land survey. The other fluvial subunits and landforms include:

- **Flood Plain Sediments:** These are very locally developed along meanders or wide channel of the Dewana perennial stream. They are irregular small plains which are covered by water during flooding seasons. These plains are composed of poorly cemented sand, silt, clay and rarely gravels. The thickness is less than one meter. Two stages are recognized in the study area (Fig.15). The flood plain areas represent a fertile land for agricultural activities.

- **Channel deposits:** These are river sediments spreading in the study area within channels, consisting of mixed gravel, sand and rock fragment from neighboring mountains.

The gravels are composed of cobbles and pebbles, mainly of limestone, with rounded to well rounded, rarely sub rounded shapes. Grain size range from few millimeters up to (15 – 35) cm, the thickness ranges from (0.5 – 4.0) m. Morphologically, they form a string or a trails of elongated body, sometimes shows meanders or sinuous shape following valley bends. It often fills the river channel completely when the grain size is coarse, and partly when, mixed sediments are recognized (Fig.16).

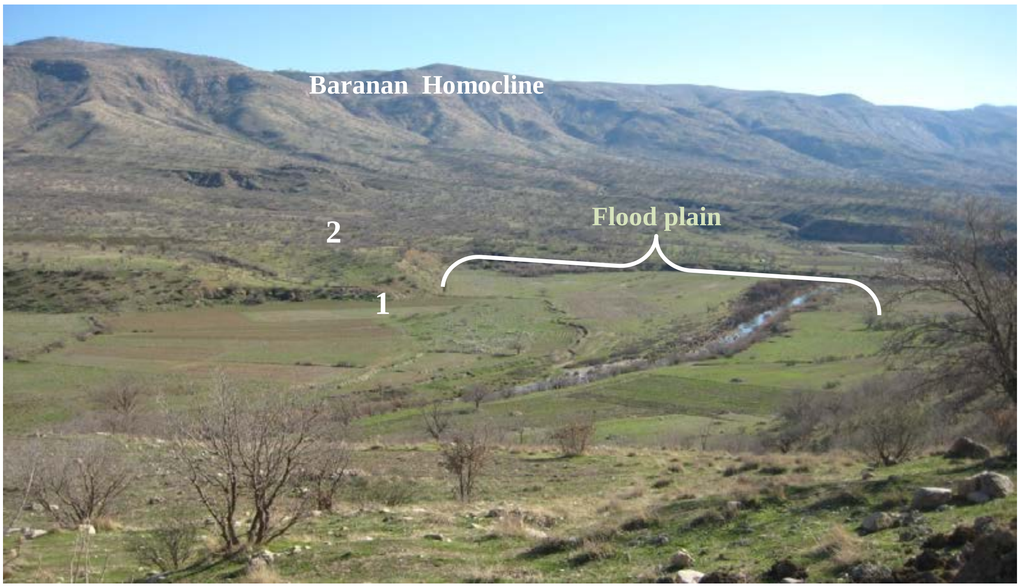

Fig.15: Flood plain near Tazade village between Baranan and Kolosh Mountains

Fig.16: Channel deposits at a local meander of the Dewana stream

– **River Terraces:** Are topographic surface which mark former valley floor levels or former flood plains (Thornbury, 1969). The terraces, like surfaces, are formed because of responses to fluctuations of geomorphic cycles, which are generated by repeated action of the local fluvial system (Bull, 2007). Cyclicity of fluvial system can be related to climatic changes and tectonic pulses. They are often developed in pairs and located within the river valley at relatively higher levels forming a terrace or a bench looking down the river channel. In the study area, two specific levels of river terraces are recognized near

Dewana village along the main channel. The major terraces of the area belong to Diyala river and are believed to represent (2 – 3) flooding stages (Armaghani, 1992). The lower one is about 2 m in thickness and about 4 m above stream bed (Fig.17). The upper level, on the other hand, reaches (2 – 3) m thick and is about 10 m above stream bed (Fig.18). The pebbles are mainly of limestone and some chert and sandstones, with subordinate amount of igneous and metamorphic rocks. Pebbles are rounded to well rounded, and ranging in size from few millimeters up to 20 cm. It is well cemented with sandy and calcareous materials. To the south of the right abutment of the proposed dam for Dewana, river terraces were also detected and described by Working Group (2009).

– **Old Alluvial Fans:** Alluvial fans are fan-shaped bodies that form where a stream flowing out from mountains debouches onto a nearby plain (Huggett, 2003). In the study area several locations with sediment accumulation were recognized at the foot of Qara Dagh Mountain having fan shapes. They have relatively small steep apex areas with gentler and wider distal areas. These fans are up to 10's of kilometers in dimensions and distributed individually as a residual land forms (old fans). Generally, the fans vary considerably in morphology and extent because of varying characteristics of catchment areas and different local base levels. Fans are composed of thick gravelly deposits. Some parts of the fan are removed due to younger erosion processes (Figs.19).

- **Units of Anthropogenic origin**

The land forms of this unit are formed due to different human activities, (Al-Daghastani, 2004). Some landforms are produced by direct human work, others are related anthropogenic activities. In the study area and despite its semiarid climate, human activities were spread over most of the Dewana Basin, especially in the central depressed area. Tens of villages are established along main stream course and major tributaries, which are connected by paved and peneplained road network. All causes a variation in the general surface morphology of the area. Major dam project is under construction downstream of the river near Darbandi Khan. It has and will modify the landscape of the area (Fig.20). Agricultural activities such as, terrace farming (Fig.21), channelization, irrigation channel construction, and farming ditches are considered to be important anthropogenic forms.

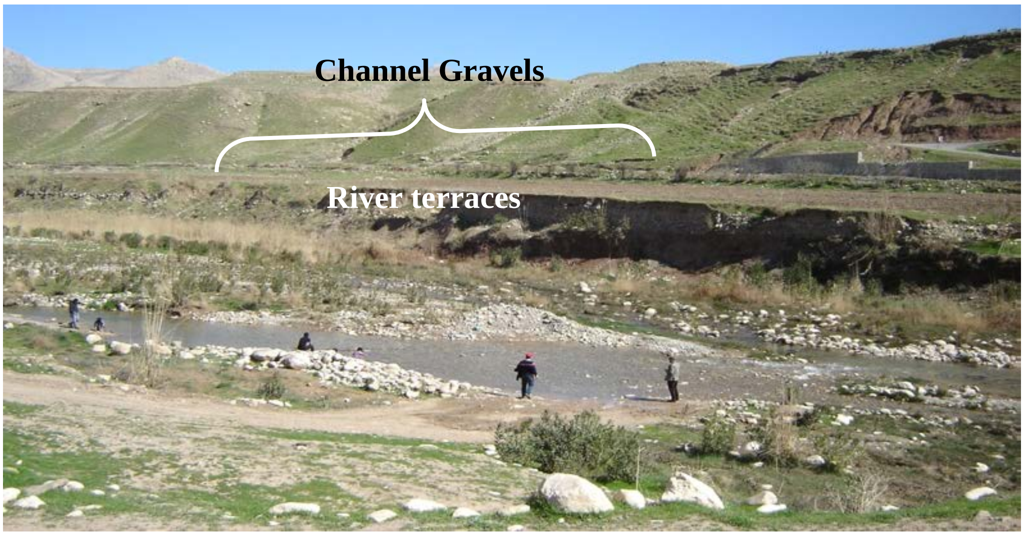

Fig.17: Lower river terrace of Dewana stream, near Dewana village

Fig.18: Gravely high level of river terrace covering red claystone of Injana Formation, near Dewana village

Fig.19: Satellite image of old alluvial fan near Balkha village southeast of Qara Dagh Mountain

Fig.20: Construction of a new dam project along Dewana downstream

Fig.21: Terrace farming, Dukan village, Dewana Basin

SUMMARY AND CONCLUSIONS

Geomorphologic investigations on Dewana Basin of Kurdistan Region, NE Iraq using different remote sensing data and field measurements and descriptions have assisted in the geomorphic classification and mapping of the basin area. Results were presented in a GIS environment. The basin regional geomorphic shaping is controlled by endogenic tectonic setting and the lithologic variation of the exposed rocks. Limestone units of the Sinjar and Pila Spi formations define the basin bounding ridges. The clastic sediment successions of the Fatha and Injana and to a certain extent the Mukdadiyah and Bai Hassan formations and its lithologic variations which are exposed over most of the basin area contribute to the pattern of the drainage network and the associated fluvial denudational-depositional landforms. Based on that, the landforms of the basin area are found to include five basic units. These are: unit of structural origin, unit of denudational origin, unit of structural and denudational origin, unit of fluvial origin, and unit of anthropogenic origin.

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