J. Basic. Appl. Sci. Res., 3(3)765-773, 2013
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ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Application of GIS and Remote sensing Techniques in Assessment of Natural Hazards in the Central Zab Basin, Northwest of Iran

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ABSTRACT

This research was based on a complete understanding of the central Zab basin (particularly in the neighboring Sardasht county in west Azerbaijan in northwest of Iran) and identify bottlenecks and instability, natural environmental hazards are identified and appropriate strategies should be presented in order to confront and control them. This study demonstrates the synergistic use of medium resolution of SPOT-5 Satellite, for prepare of landslide-inventory map and Landsat ETM+ satellite for prepare of Land use map. After making of TIN and DEM data from the limit of study area from topography maps, aerial photos and satellite images, and have been used GIS techniques and analysis of relevant factors. Methods In this study, based on field studies, library, quantitative and morphometric study was to prepare maps and GIS techniques and analysis of relevant factors have been used. The results indicate a dominance of geomorphologic natural hazards and human hazards. As a result, using the logical and scientific approaches can greatly reduce the morphodynamics factors and make balance between Morphogenesis and pedogenic phenomena and can be achieved stable environment with crisis management.

KEY WORDS: GIS and RS techniques, morphometric, environmental hazards, central Zab basin.

INTRODUCTION

Since hazard is the incidence of inconsistency in nature and human life which leads to disrupt the public order; recognition and planning to control or eliminate hazards are quintessential [1]. Therefore, through an effective management, we must, first, identify the factors affecting the instability, morphodynamic intensification and disrupting its balance by complete recognition of the environment; meanwhile, scientific solutions must be applied to reduce the intensity of the morphodynamic factors. It should be noted that the total extent of Zab is vast and such span reduces the possibility of accurate scrutiny [2]. Therefore, in this paper, we tried to control hazards and crises resulting from factors through focusing the investigations on the central part of Zab near Sardasht, Iran, with identifying instability through offering suggestions and solutions more accurately.

Moshanir a consultant engineer conducted a study (1998) called as Zab Hydroelectric Model, was considered as the latest research (regarding the long statistic duration) in hydrological field has the higher level of authenticity estimations. Its hydrometric statistics can be beneficial and utilized in the computation parameters of the higher region of the research section in Zab basin [3].

In the book entitlesd "physical geography of Mokeryan Kurdistan", by Khezri, 2000.one chapter is dedicated to the hydro morphology of Zab river basin, which the targeted zone of study is situated in the central part of it. In this book additional to the recitation of some points regarding the quantitative hydro morphology subject matters of the basin, some parts about water erosion and foot movements has also been outlined, and it is the most codified source which has provided ample information in the form of charts, tables, and diagrams, which has explained the hydro morphological matters in depth [4].

In this study, to identify the critical areas of natural environmental hazards in which slope hazards and instabilities are considered as the most important and dominant risky phenomena, firstly, the relationship between each of the instability factors with mass processes has been examined and the role of each factor has separately been determined and instable region has been identified. After recognizing the region mass movements and their distribution, we studied the status of river hydromorphology to identify the critical points of region and hazards and damages resulting from them. Finally, given that the region is located in the dynamic zone of Sanandaj- Sirjan, Iran and the main Zagros fault, the region potentiality has been studied in terms of seismicity.

CASE STUDY REGION

Politically, Zab basin includes the cities of Piranshahr and Sardasht in the West Azerbaijan, Iran and a part of Bane in Kurdistan. The scope of the current study is a part of the mountain and foothills in the southwest of

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West Azerbaijan province, Iran. In the study area, Zab river that is located between North latitude (36 degrees, 8 minutes and 25 seconds) to (36 degrees, 26 minutes and 27 seconds) and East longitude (45 degrees, 21 minutes and 21 seconds) to (45 degrees, 40 minutes and 44 seconds). In terms of political divisions, it belongs to Sardasht, and involves eastern and western slopes of Zab valley from Sardasht to Myrabad with the shape of a guitar [5]. Its maximum east-west spread is 30km and its maximum north-south elongation is 33.25km. The lowest- and highest elevation of the studied region is 995m and 2404m, respectively. It includes one city, three towns and more than 80 villages and has place a population of over 70 thousand people. Of the total area of catchment areas in Iran (with 460,000 hectares), only, 520 square kilometers are located in the scope of this study (Fig 1).

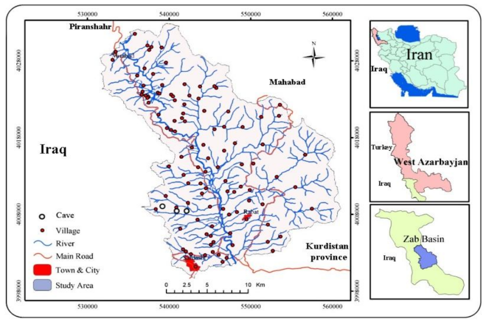

Fig 1: Geographical position of central Zab basin in district, province and country

MATERIAL AND METHODS

In order to determine the causes of natural environmental hazards including hazards, mass instability and hydromotphology hazards in the study area, the following steps have been taken:

First of all, a digital elevation model (DEM) of the study area was generated from a triangulated irregular network (TIN) model that was derived from digitized contours of four 1:50,000 scale topographical maps with a contour interval of 25 m. The slope, slope aspect parameters were obtained from the generated DEM, it has been overlapped with the layer of hazards and mass instability. The critical point was the selection of appropriate pixel size for positional accuracy and precision of susceptibility levels in the resultant map. The positional accuracy needed for 1:50000 scale maps must be 150 m. For this reason, a pixel size of 50 m was selected for our DEM. The DEM was then used to describe geomorphological and geological processes in the landscape (Fig 2).

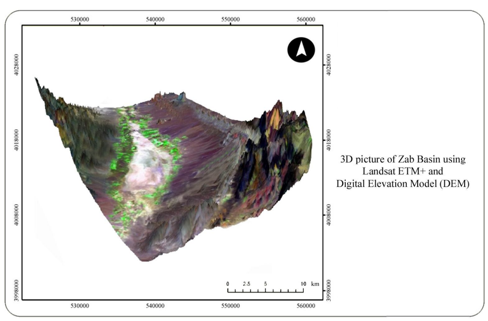

Fig 2: 3D image picture of central Zab Basin, extracted using Landsat ETM $^{+}$ satellite photos

Fault lines were derived from 1:100000 scale geology maps and the aerial orthogonal distance of all pixels to fault lines calculated. A similar process was carried out for road lines, and drainage networks. In addition, the kilometer square density of drainage networks, road and fault lines were also used to demonstrate the importance of the features in the whole study area. To maintain the 1 square km search distance, a 564 m search radius with a 100 m offset was used [6].

Another dataset used was land cover, which was interpreted from Landsat ETM^{+} image on the 21 April 2009. It was calibrated using field observations. Because of significant cloud coverage, results of the classification were edited and simplified by manual digitization. The interpreted images were then digitally processed to further modify the boundaries by supervision classification with ERDAS (Earth Resource Data Analysis System) software. The accuracy of the land cover interpretation was checked by in the field work [7]. landslide-inventory map of the study area was identified by SPOT 5 satellite on the 25 May 2008 Extensive field studies were used to check the size and shape of landslides, to identify the type of movements and the materials involved, and to determine the state of activity (active, dormant, etc.) of the landslides (Fig 3).

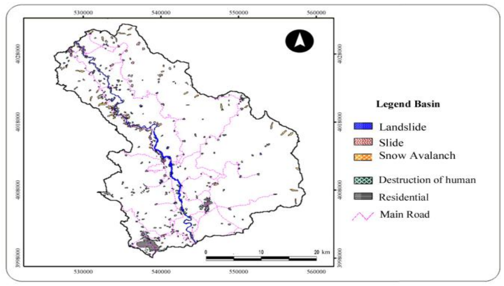

Fig 3: Landslide Inventory map of central Zab Basin

To examine the role of tectonic, mass movements' layer taken by GPS has been overlapped on the map of faults boundaries. In studying the role of rock strength, firstly, rock strength has been classified on the basis of the common methods in preparing strength maps with respect to geological sections and field reviews and also with referring to reputable sources and reference, then the lithology strength map has been prepared and overlapped with mass movement layer. In studying the role of altitudinal levels in the incidence of instabilities, firstly, the digital topographic map in GIS environment was prepared based on the topographic map and the situation of the altitude was determined then, the layer of hazards and mass instabilities have been overlapped on the digital map by overlapping in the mentioned environment.

In examining the effect of the status of shallow waters in creating instabilities, firstly, digital hydrographic map was provided based on the topographical map then, euro-hydrography map was extracted. Then, in order to understand the relationships between various mass processes in GIS the buffer (boundary) of all waterways was specified and the related map was drawn and finally, the layer of mass processes was overlapped on the map of river boundary.

In expressing human role in disrupting the balance of area, first, the applied map lands was prepared in GIS and then, mass movements layer was overlapped on it. Boundary roads map was also provided in GIS and mass movement's layer was overlapped on it so that the expansion of above movements can be specified in road boundaries. To identify hydro-morphologic status, the area was divided into several sub-areas. Due to the hydro-morphologic similarity of some units and providing the possibility of doing more detailed research, among the total of all sub-areas, the features of 18 hydro-morphologic units have been studied.

RESULTS AND DISCUSSION

Effective factors in creating the natural environmental hazards of the area (hazards and mass instabilities):

Issues and factors involved in creating environmental hazards and particularly hazards and mass instabilities have been studied bellow:

A) The role of land material and ecological structure in hazards and mass instabilities

The layer was extracted from 1:100000 maps of the Iranian Geology Organization. It was quantified and then appended to the model since it proved to be statistically significant. It is important to note that the study area lacks lithographical consistence and uniformity, and lithological sequence and disruptions are clearly visible between different strata, which evidently suggest the role of dynamic tectonic forces. Most of slide events in the study area occurred in loose formations including fine-grained sediments in particular in alluvial terraces. Stones, homogenous phylite formations, marble, lime, green Andesite, dolomite and sandstone have the widest distribution in the region (Fig 4).

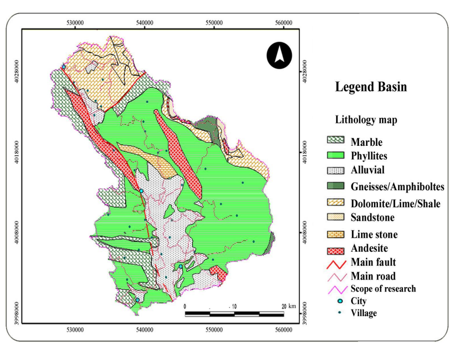

Fig 4: Lithology map of cntral zab basin

B) The effect of tectonics and building land in the morphology of the slopes

In the studies, the role of tectonics has been proved on the collection of landslides [8]. Therefore, given the transition of one of the most important faults of the West of Iran (Main Zagros thrust fault) known as the South fault of piranshahr in various sources, emphasizing on this factor in the research area is necessary [9]. One of the studying methods of tectonic role in mass processes is the preparation of faults distribution map with their hazard boundary. According to the results obtained in the study area, standing the slopes in the boundary of faults causes more stimulation. The most movements of rock fall is near to major Piranshahr fault in the central part of the area and most slope movements are in 1000m boundary of the main faults. Therefore, one of the most important factors in the occurrence of mass movements (especially stone falling) is the factor of distance with the fault lines (Fig 5).

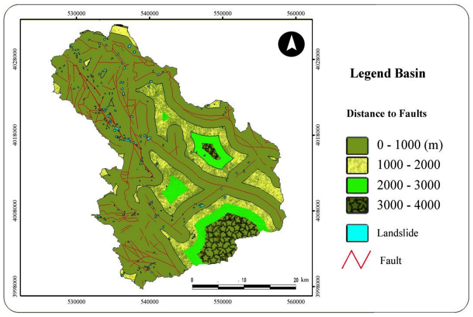

Fig 5: Expansion of the hazards and mass instabilities in the fault boundaries in central Zab basin

C) Examining the stones resistance in mass processes and instabilities

According to the conducted studies, despite the resistance of andesite, most of the rock falls and snowy corridors are seen in this stone which seems that the effect of tectonic factors have faded the role and effect of lithology in the central part of the area in creating mass movements. Slips and non-stone mass movements are seen more on the alluvial materials and uniform phyllite that show the dominance of the lithology role in this relationship and marble and crystalline limestone are of resistant rocks and have the least amount of mass movements.

D) The role of climate factors in the incidence of hazards and mass instabilities

Glaciations and temperature fluctuations are a part of climatic elements affecting the morphology of the area. Based on climate data (Sardasht synoptic and Brysoveh climatology station), the mountainous area and expanding heights provide harsh and stimulated mass movements climatic conditions (Fig 6). High rainfall average has changed the area to a rainy cell of the country [10].

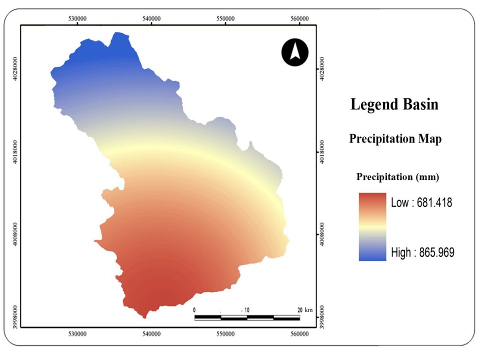

Fig. 6: Precipitation map of central Zab basin

E) The role of slopes form in the creation of hazards and mass instabilities

Given the results obtained from the maps, the concave slopes of the area have the most aptitude in falling activities while the convex slopes show the minimal scattering of mass processes. However, the scattering of mass processes is generally evident on various forms.

F) Studying the role of altitudinal levels in the incidence of instability

Based on information obtained from the ground- map and studies, high altitudinal levels had most physical destruction and chemical destruction and erosion is expanded at low altitudinal levels especially in the southern part of the area. Maximum mass movements have been placed in the altitudinal levels of 1100 to 1500m. However, mass processes are generally visible as scattered in the most altitudinal levels of mass processes.

G) The role- and direction of slope in the occurrence of hazards and mass instabilities

According to the obtained results, rocky falls are consistent with high level slopes, but non-stone mass movements have often been replaced in low slope levels. The direction of the slope plays an important role in mass processes due to the relationship which has with the velocity of absorption and loss of moisture [11]. Due to getting low radiation of sun, slopes with north direction are wetter than slopes with south direction. Accordingly, given the direction of instabilities, unstable slopes are located in the western mountains (Fig 7).

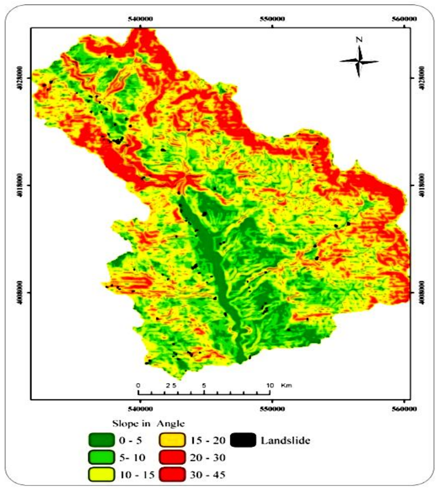

Fig 7: The expansion of hazards and mass instabilities in slope levels of central Zab basin

H) Studying the effect of surface water status in the creation of hazards and mass instabilities

Hydrographic network is considered as the important morphogenic factor in the occurrence of mass processes in this mountainous area. The highest rainfall is in the spring, and also the greatest mass movements are especially in this season. According to the obtained results, maximum mass movements of rocky fall is seen in the boundary of the main river (Zab) in the central part from the Gerzhal throat to Myrabad in north and non-rock mass movements are also seen in the boundary of sub-waterways and in their vicinity. There is the maximum of non-rocky mass movements in the 1000m boundary of Zab River in the downstream of Gerzhal throat to area output in south.

I) studying the role of land use in the incidence of instability

Changes in ground surface have the potential to affect slope failure, given the presence of other relevant factors. The lack of appropriate coverage such as vegetation is influential in increased frequency of landslides. In addition, loading the slope, and in particular digging the base of slope and undercutting and injecting water into it are effective elements in landslide occurrence [12]. Land use map was interpreted from Landsat ETM^{+} image on the 21 April 2009, it was calibrated using field observations.

Seven main land cover types were considered, namely second class pasture, first class pasture, settled, natural forest, and mane made forest, dry farm land and barren land. Based on validation from field observations, the land cover map has accuracy of the order of the Landsat image spatial resolution (~30 m) (Fig 8). After geo-referencing the resultant image, a combination of bands 1, 4 and 7 was used to make complex color pictures, and operational information layer created by the method of Categorization of Utmost Probability [12].

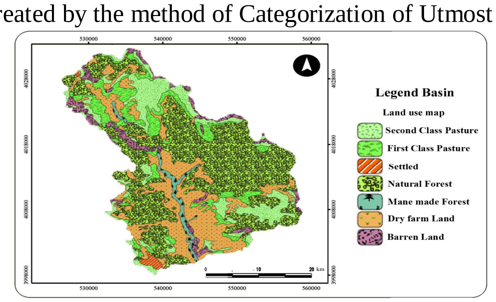

Fig 8: Land use map of central Zab basin

G) The seismic hazard role in the region:

Earthquake leaves a major and particular geomorphological effect on the surface of the Earth such as: Creating faults with vertical or horizontal shift, creating gaps of different sizes, stimulating and intensifying the movement of material on slopes (especially the rock fall and landslides and avalanches), blocking and redirection of water channels etc. [13]. Using Iran Seismic Risk Analysis done by Norouzi and Ahmadi, the seismotectonic of West Azerbaijan (uromieh) in which Zab is located, in a period of 50 years, the possibility of occurring an earthquake with a magnitude of 6 Richter is 98% and an earthquake with a magnitude of 7 and 7.5 is 42% and 18%, respectively; and the acceleration caused by the earthquake for a period of 100 years for 7 degrees Richter is 0.661og. Also in the code 2800, which is provided by the Building and Housing Research Center, Zab district is located in relatively high risk areas. Given the relationship between the maximum horizontal acceleration and the strength of the earthquake by Terrifonac and the relationship between the intensity of earthquakes and shallow distance of the earthquakes, it can be said that Piranshahr fault (main fault of Zab in East Bane) with seismic creating of 7.2 Richter can cause severe acceleration [4].

K) The human role in disrupting the area balance

The erosion taking place by humans through cultivated plants instead of natural plants and unethical methods in the use of ground is called anthropic. The new anthropic morphogenic system was introduced as a major geomorphology factor and broadly means the destruction and loss of dismissed material specifically soil [14, 15]. The results obtained from overlapping show the more expansion of rock mass movements on the bare areas and without dense vegetation. Also, the mass movements of non-rock materials in the areas where forest has been applied changed and homebred agricultural land or vinery and grasslands are consistent. The more scattering of mass movements near to the communicational ways shows the destructive role of human in the occurrence of instabilities and disrupting the ecological balance. Most mass non-rock movements are seen in 200m boundary of the main road of Sardasht- Piranshahr and Sardasht- Rabet. Also, most of the mass rock movements belong to 100m boundary of Vavan- Kachal abad on the road to Piranshahr. The classification map of mass instabilities of following natural hazards extracted from overlapping the layers of information and factor maps (Fig 9). The mass movement and instabilities are obvious against natural hazards in exposing the high risk of study area.

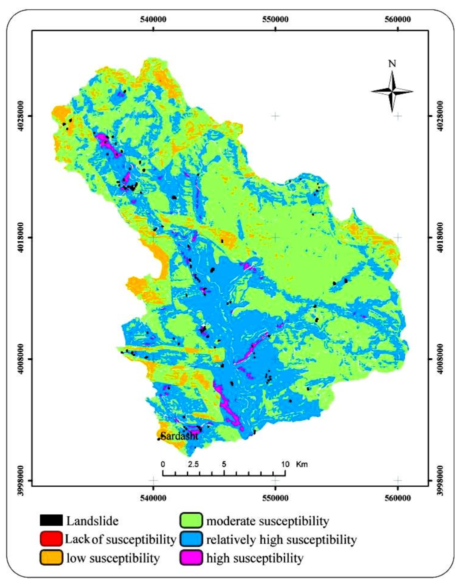

Fig 9: landslide zoning map of central Zab basin

Studying the features of hydro-morphologic units in the creation of natural hazards:

A) Determining the area of hydro-morphologic units and their role in the rates of water discharge and sedimentation

The whole studying area has 520.084 square kilometers extent which its 30.45% is located in the west and its 69.55% located in the east of the main river. Whatever the size of the catchment of waterways (such as minerals Guez = 67) is greater, the rate of flow and volume of alluvial cones material will be higher. According to area, the rate of flow and volume of runoff in the western part is lower than that in the eastern part and consequently the amounts of erosive material of the western part is more than the erosive material of the eastern part (Fig 10).

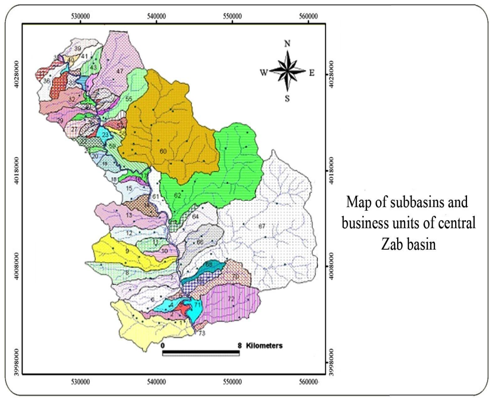

Fig 10: hydromorphology map of central Zab basin

B) Studying the status of hydromorphologic unit slopes and their role in sedimentation and erosion hazards

Slope is worthy to consider more than any other features in this area because the water flow speed, its erosive power and the amount of carried materials are related to slope. Based on the slope map, the maximum slope rate is related to the middle part of the area, ridges and eastern and western heights. Thus, the erosive river power and its speed is more in this area and conversely, south hydromorphologic units especially around the main river have fewer slopes. Therefore, in this area, the erosive river power and its speed are low and the action of placing material is at its highest level.

C) Extracting river frontages and the risk of flooding

In examining river frontages, considering laws related to water is essential. Digital elevation model of the area has been changed into grid and the boundary of main Zab river and waterways have been done. In buffering (boundary) the main river of Zab with an average buffer of 25m, 3.648 square kilometers is exposed to the flood risk or risks resulting from river deviation [6]. The risk boundary of rivers and following sub-scope waterways lead to Zab River with an average buffer of 15m include the area of 16.34 square kilometers (Fig 11).

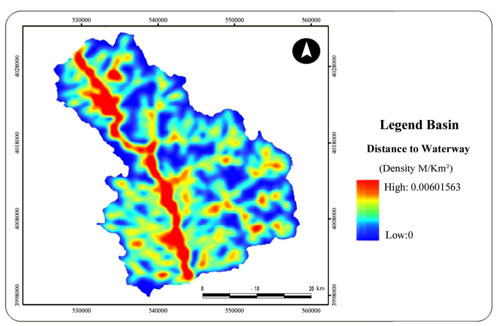

Fig 11: waterway map of central Zab basin

D) Studying the status of the runoffs in hydromorphologic units and water erosion hazards

Given the lack of hydrometric stations on the rout of the rivers in the hydromorphologic unit of the area, the necessity of using inductive methods to estimate the amount of runoff is essential. In the applied heuristic method, the equation $h = CP$ is true where h is the height of the runoff, P is precipitation and C is the runoff coefficient. The above-mentioned coefficient is obtained using soil type and average slope of the Hydromorphology unit. Connie Guez , Vergyl , Shekhil and the Shiveh Jou units had the highest runoff belonging to the widest part of the area. Guez and Vergyl Hydromorphology units that are located in the South East and the dominant lithology is uniform and non-resistant phyllite has been more affected by water erosion, but Shiveh Jou and Shekhil units in the North East region has an area of less than 2 units above as a resistant lithology is limestone and andesite despite the volume of runoff have strength and narrow valleys are narrow.

E) Evaluation of the maximum flood as hazard in Hydro- morphology units

Due to the lack of hydrometric stations in the logic or reasoning method, to estimate the flood in metric system, the equation $Q = 0.275\ CIA$ has been used. According to the calculations, the maximum flood of mineral units Guez with 81.06 cubic meters per second in a two-year period returns have been calculated while the latter field is also the largest Hydro- morphologic unit. The minimum rate of flow for the maximum flood is related to Hydro-morphology unit of upper Grzhal with 3.66 cubic meters per second for a period of 2 years return period.

CONCLUSIONS

River flooding, earthquakes and slope motions are the most hazards in Iran. The studied area has also all of these hazards; therefore, it can be more representative of the general problem of natural hazards in our country. Given the evidence, this conclusion is obtained that the existence of water and rain and snow fall in the studied area with an average annual rainfall of over 900 mm have been effective in stimulating the slope movements. Water causes an increase in the mass weight of the materials and increases its force down the slope. Therefore, we observe a mass movement of materials in late winter and early spring (especially on the western slopes).

Indiscriminate human activities lead in turn to disrupting ecological balance and enhancing hazards and slope instability. In the area, construction and widening the communication can be considered as a very important factor in mass instabilities. In regard with the distribution of slope movements, their frequent incidence in rural areas or communication roadsides indicates the importance and role of the human activities in disrupting the balance of the relatively stable geomorphic environments.The eastern part of Nelas town and the villages of the lower Gerjal and much of the arable land in the lower Grzhal are in the boundaries of the river or diversion of the river are at risk of flooding. It is therefore critical and should be subjected to careful planning (Fig 12).

In areas such as Kani Guez in which the area is too much and consequently, the volume of flow and sediments are more, measures must be taken to control flood and sediment. Given all the particular geomorphological effects resulting from earthquake in the area and also investigations conducted by different people, it can be said that seismicity of the region is likely, therefore, it is necessary that the risk maps be prepared and due actions and plans be done for each area .

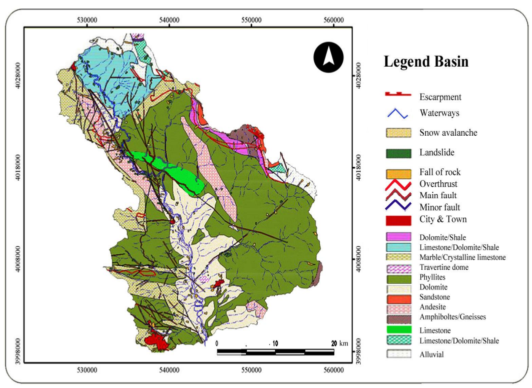

Fig 12: Hydrologic and geomorphologic maps of natural hazards in central Zab basin

ACKNOWLEDGMENT

We are thankful to the Department of Remote sensing in Universiti Teknologi Malaysia and Department of Physical Geography in University of Kurdistan and UTM International Doctorial Fellowship (IDF) for providing the facilities for this investigation.

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