Larhyss Journal, ISSN 1112-3680, n°48, Dec 2021, pp. 189-210

NON-REVENUE WATER (NRW) AND 3D HIERARCHICAL MODEL FOR LANDSLIDE

HARIRI ASLI H.[1*], HOZOURI A.[2]

[1] Civil Engineering Department, Faculty of Engineering, University of Guilan, Rasht, Khalij Fars highway, 5th kilometer of Ghazvin road, Postal Code: 4199613776, Rasht, Iran,
[2] Islamic Azad University, Rasht Branch, Rasht, Iran,

(*) *hossein_hariri@msc.guilan.ac.ir*

Research Article – Available at http://larhyss.net/ojs/index.php/larhyss/index
Received November 5, 2021, Received in revised form December 6, 2021, Accepted December 9, 2021

ABSTRACT

The landslide is triggered by a specific event such as a heavy rainfall, an earthquake, a slope cut to build a road, and many others. The landslide can cause Non-revenue water (NRW) in water reservoirs, water transmission pipelines and water distribution network. In present work, based on the analytical methods for landslide phenomenon, the water facility accidents and water loss were investigated for the highland city named Masal in the north of Iran. The Geospatial Information System (GIS) as a conceptualized framework provides the ability to capture and analyses spatial and geographic data in present work. The ArcGIS software analyzed the geospatial data. The Analytic Hierarchy Process (AHP) as an analysis algorithm was applied for finding the percentage of landslides based on the GIS. As a final result, the slopes of 10 to 30 degrees accounted for the highest percentage of landslides. These slopes were assumed as hazard and important cases for the water facilities disaster.

Keywords: Landslide, water facility accidents, Analytic Hierarchy Process, Geography Information System, Non Revenue Water.

INTRODUCTION

According to the global water stress, identifying areas prone to landslides through hazard zoning is one of the necessary items for measureing in disaster management. It is important in managing accidents and Non-revenue water (NRW) of water facilities. The NRW is the difference between water production and water consumption. The NRW is lost in water treatment plants, water reservoirs, water transmission pipelines and water distribution network before it reaches the customer. Losses can be real or physical losses (through leakage in water system) or apparent losses (through water measuring or metering facilities) (Hariri Asli K., et al., 2012). In order to investigate the effects of various factors such as environmental and human factors in landslide phenomenon at Masal region in the north of Iran, the present work used Analytic Hierarchy Process (AHP) as an analysis algorithm (Raghuvanshi, 2019).

Analytic Hierarchy Process (AHP) analysis contour lines which are the lines drawn on a topographic map to indicate ground elevation or depression. A contour interval is the vertical distance or difference in elevation between contour lines. Index contours are bold or thicker lines that appear at every fifth contour line. Mostly mountainous topography, high tectonic and seismic activities, various geological and climatic conditions and human stimuli such as road construction, especially in mountainous and sloping axes, create conditions for a wide range of landslides (Mengistu, et al., 2019).

In the series analysis method depending on the extent of landslides in each of the classes, various parameters such as slope, slope direction, height, distance from the fault, distance from the waterway, precipitation, distance from the road, lithology and land use have been studied and in layers. Separately, the weight of each parameter is determined by comparing pairs of factors in the form of numerical matrices and then in three groups of very high, medium and low landslide risk zoning map is prepared (Wu , 2015).

The force of gravity and the resulting gravity always cause a downward force and loose the unstable materials move down. The slopes to achieve stability based on the factors such as the geometric shape of the slope, type of material, type of movement and speed. The motion of materials creates a variety of amplitude motions. There are various definitions of landslides in different sources, some of which are briefly mentioned below:

The term landslide is all massive movements on slopes, including falls (Rock Falls), overturns (Topples) and Deloris flows. A landslide is a landslide in the direction of a slope or the fall of a rock mass or a mixture of rock and soil. It occurs at the lower level of the unit, under the influence of the dominance of destructive, motivating or aggressive forces over resistant forces on sloping surfaces (Meten, et al., 2015).

- The massive descent of loose and detached materials on the slopes, where some water is also present, is landslide or mass displacement of materials.
- Landslide is the movement of large masses of rock and soil and the collapse of weathering products.
- The movement of the mass of earth constituents from a slope downwards is called landslide or slope instability.
- Many gravitational processes of materials are called slides. Slip occurs when the adhesives move together along a well-defined surface. Sometimes the surface is a seam surface, a fault surface, or a layering surface that is approximately parallel to the slope.

In present work, by contour lines, the slope and direction of the slope were studied. After examining the maps of 1:25000 of Guilan Natural Resources Department, first the curves of the main and sub-values were examined separately and for each curve, in the database of that map, the exact altitude number was assigned. The Elevation (Figure 1) for main curves with distance 50 meters and sub-curves with a distance of 10 meters were built. This distance was the real value of the map that was not recorded in its database. After entering these numbers, the elevation value of each curve was obtained and processed in ARC-GIS software. Finally, after creating a geo-database with the help of benchmarks, the main map of the TIN elevation model was created. Then, from the TIN elevation model, slope and slope direction for raster models were designed and constructed. The histogram for each of them was obtained in separate diagrams.

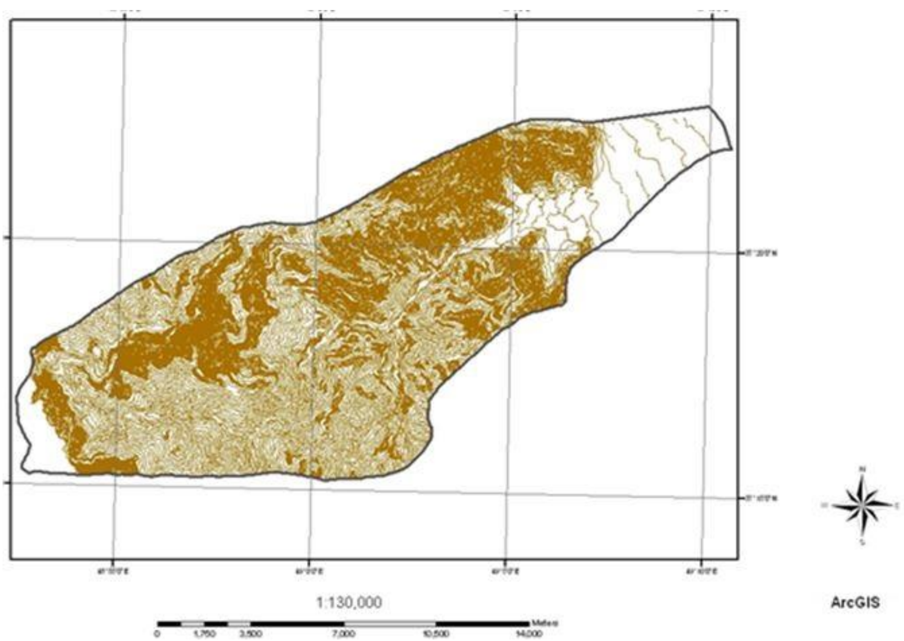

Figure 1: Counter curves in Masal district

METHODS

Landslide, as its meaning implies, means landslides, but is landslides possible everywhere?

Certainly not, and moving or landslides require a ground force or gravity on a sloping surface (Razifard, et al., 2012).

This driving force can be natural factors such as rainfall, river flow, faults, tectonic activities, melting ice or human factors such as road construction, unprincipled deforestation, etc. (Mandaglio, et al., 2016).

Cause of movement and landslide

The following two main factors are effective in the occurrence of landslide:

External causes

These forces increase the shear stresses. These stresses increase along the potential rupture level until a slip occurs.

External causes affecting instability

- Changing the slope geometry due to leaching, erosion, trench construction, artificial drilling to change the slope height, slope length and gradient.
- Unloading, erosion, cutting, special drilling.
- Loading, increasing materials, increasing height, etc.
- Shocks and vibrations (socks and vibration) and especially earthquakes.
- Drop in water level due to falling water in the lake or reservoir.
- Water regime change (rainfall, weight gain, pore pressure).

Internal causes

This force leads to a reduction in the shear strength of the material.

In addition to these two factors, a group of intermediate factors can also exist, which is a combination of both external and internal causes (Mahmood, et al., 2005).

Internal causes affecting instability

- Internal rupture in conditions of stability
- Weathering (freezing, ice opening, drying, reduced adhesion, loss of cement).
- Erosion due to seepage.
- Mass movements are several forms of mass movement and related phenomena.

Rock slide

The Rock slide occurs when pieces of a rock layer are pulled out of place and sloping toward the slope. This phenomenon is very rapid and destructive and usually occurs when the rock layers are tilted or have seams and fractures along the slope. When the part of the lower rocks of the slope is displaced, the upper rocks lose their support and slide down the slope. This phenomenon often occurs when rain and water from melting snow slide the soft floors beneath hard rock layers so that no more frictional force can hold them in place (Van and Haarhoff , 2007). The Rock slide occurs mostly in spring due to increased rainfall and melting of ice and snow. Another factor in the formation of this phenomenon is the movement due to the gravity on the slopes (Figure 2).

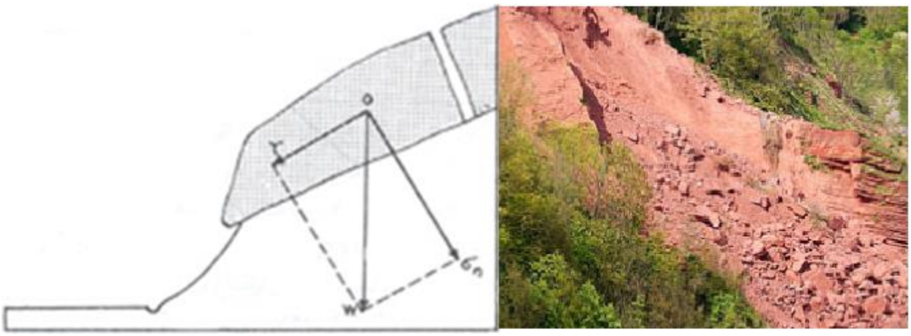

Figure 2: Rock slide phenomenon (www.ngdir.ir)

Slump Rotational slip

The Slipping of rocks or soft materials along a curved surface is called slump. Slip materials usually move very fast and do not move very far. This form of gravitational movement of materials occurs frequently, especially where the adhesive material is very thick, such as clay. The fracture surface below the slip piece is basically spoon-shaped and concave upwards or outwards. After moving, a crescent-shaped precipice forms on its forehead (Figure 3) and the upper surface of the slippery piece tilts backwards. This phenomenon occurs when the load of the slope is heavy and puts a lot of stress on the substrate. This type of slump where weak and rich clay materials are placed under strong and durable rock layers such as sandstone. Then occurs the water infiltration from the upper layers and reduces the strength of the lower clay and causes the slope to fall (Zecchin, et al., 2005).

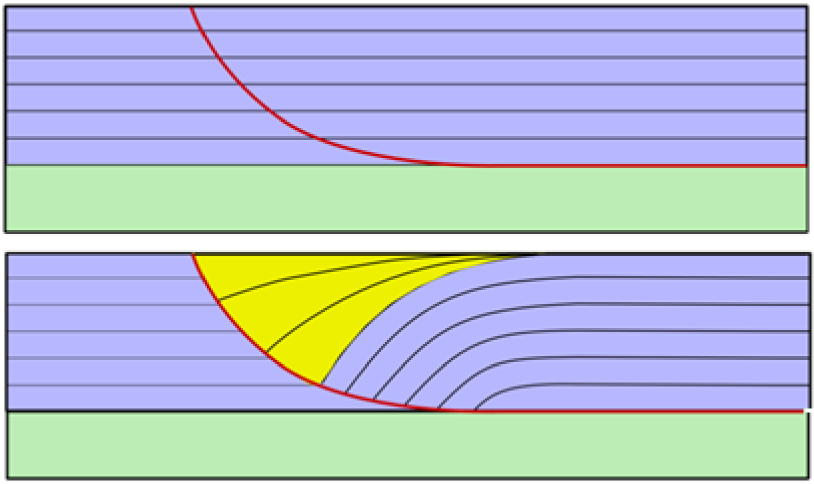

Figure 3: Slipping of rocks or soft materials, https://en.wikipedia.org/wiki/Fault_(geology)

Such slips can generally be analyzed with sufficient accuracy, assuming the surface is circular, spherical, or spiral.

Mudflow

The Mudflow is a relatively fast type of gravitational movement of materials and a stream of particles of gravel with a large amount of water. The mud flows are specific to semi-arid mountainous areas and flow along ravines and valleys due to their abundant water and abundant fine particles, although rainfall is low in semi-arid areas (Mondal ,2016). But it is mostly heavy and severe. During heavy showers and rapid melting of mountain snow, sudden floods occur. In this condition, because the vegetation cover is low to maintain surface materials, a large amount of soil and regulite is washed away and enters the river canals. This creates a lingual flow that is a mixture of mud, soil, rock, and water (Figure 4).

Figure 4: Mudflow or gravitational movement of gravel with a large amount of water (www.ngdir.ir)

Its concentration and consistency vary from a thick cement mortar to a soup-like mixture that has a concentration close to that of muddy water. Therefore, the amount of flow depends not only on the slope, but also on the amount of water. In addition, large and intense flow beds are able to move boulders, trees and even houses easily.

Earth flows

Unlike mud streams, soil streams are common in wetlands. When water saturates the clay-rich regoliths of steep slopes, the material on the slopes begins to move, and after a short distance, scars and wounds on the slope. They leave depending on the slope and the uniformity of the composition of the material. The velocity of soil flows varies from a few millimeters per hour to several meters per minute in effect to the soil streams are quite thick. Therefore, they move more slowly than mud flows because they are seen in the slopes of the hills (Walski , 2000).

Creep

Creep is a gravitational movement of materials that is done in connection with the gradual movement of soil and regulite on the hills. The primary cause of creep is the expansion and contraction of surface materials as a result of freezing and thawing or moisture and drying. Freezing or moisture raises the soil perpendicular to the slope of the slope, and ice melting or drying causes them to return to a lower level. When the earth loses its stickiness due to saturated water and soil particles, they are pulled downwards due to gravity. This condition occurs in shallow soils and debris and is mostly seasonal (Yeung, 2001).

Creep often occurs on all steep slopes (including rocky slopes). The rate of creep varies throughout the year. These movements are often limited to the surface layers. Although with the advent of rupture, the rate of motion also increases.

Soil (solifluction)

Earth icy blue phenomena, which are movements caused by the softening of icy slopes. At high latitudes in spring and summer the ice melts a few meters above the regulite while the ground beneath them is in permanent frost. Because the water flow by the melting of the upper parts has no place to go. These water-saturated materials flow slowly down the sloping hills, even with very low slopes. In this way, the pressure from the weight of the upper layers is reduced and the lower rocks are expanded. The expanded rocks are again affected by ash or ice water (Zêzere ,2004).

The types of mass movements in natural slopes have divided into four general categories and several subcategories as follows (Table 1). The data were derived by some landslide phenomena studies separately and outside the landslide area.

Table 1: Classification of types of mass movements

Category	Sub Category
Drops	—
Rotational landslides	Shallow rotational landslides Composite rotational slips Consecutive rotational slips
Transition slips	Block slips Board slips Composite transfer slips
Flows	Flowing soil soil liquifaction Debris floods floods slips Sole fluxion

Slope

The slope (1) or in other words, the angle that two points make with the horizon (Figure 5), is measured in degrees, percentages or gradients (Lee, 2017):

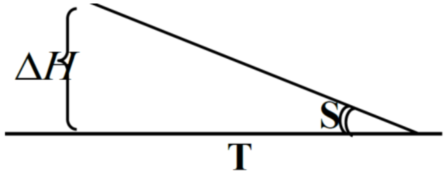

Figure 5: The slope or gradient of a line

$$S = \frac{\Delta H}{T}$$

H - Height difference between two points.

T - Distance between two points.

S- Slope.

The heavy energy resulting from the surface difference per unit length determines the degree of instability of the environment.

Domain direction

The location of the slope or hill does not have a direct effect on the occurrence of landslides, but can indirectly affect the weather or climatic factors in the area. The slopes of the same degree but with different degrees in an area usually do not face the same landslide risk. The climatic factors can be different in two directions of the range. The position of the slope compared to receiving solar energy and the amount of heat due to sunlight on the slopes facing the sun, has more heat per unit area than the sloping hills but behind the sun. The sunny slopes are warmer and evaporation is higher and water storage in the soil is low. As a result of less plant growth, in addition, in sunny slopes, intense sunlight by decomposing humus organic matter eliminates humus and as a result, soil adhesion is lost and is prone to weathering and erosion. The direction of the slope and the position of the slope in the direction of the prevailing wind affect the amount of rain. The amount of rain that falls on two equal levels with the same slope but in different directions are different. The slope located in the direction of the prevailing wind can be Get more rain. As a result, the factors related to the direction of the slope mentioned in the previous discussions can indirectly affect the occurrence of landslides regard to the direction of the slope in soil erosion (Zainalabideen and Helal ,2016).

Height

The two factors of slope and height are important factors for controlling the instability of a slope. In two similar slopes with a constant slope value, the slope that is higher has more potential for instability (Memariyan, et al., 2006).

By increasing altitude, the amount of loading on the slope and consequently with increasing the weight of the mass due to the height of the slope, the probability of mass movements on higher slopes is higher than on the similar slopes but with lower height. The change in the height of the slope is due to excavation, trench construction, artificial drilling or sub-washing in the change of slope geometry and as a result, the possibility of landslides.

In each slope, there are shear stresses due to the weight of the mass, which increase with increasing slope and height, and the unit weight of the volume of slope constituents. A slope with a higher altitude receives more rainfall than a slope with a lower elevation (Marek, et al., 2007).

Research tools

This study informed by the analytical method based on topographic maps with a scale of 1:25000 and 1:50000 and geology maps with a scale of 1:100000. The study also was included by extraction of components, various natural and human factors. It informed along with field visits, photography, by using Global Positioning System (GPS), the Hierarchical Analysis Method (AHP), ARCGIS and Autocad software. After extracting natural and human factors, the determination of landslides by summarizing and classifying of the topographic and geological maps, altitude layers, slopes, direction of slopes, distance from waterway, forest areas, farms and gardens, communication roads, faults and faults lithology, residential areas. Finally, the Hierarchical Analysis Method (AHP) and pairwise comparison of factors and components were selected as the best method of landslide zoning. This research was carried out after collecting library and field information and transferring information to processed databases and weighting various natural and human factors. Then, by combining data and information using ArcGIS software and extracting raster and vector models and extracting three-dimensional models such as DAM and TIN models, the zoning was done in the region. The slip-prone areas were identified and the points were divided into six categories: very sensitive, sensitive, medium, low sensitivity, very low sensitivity and no risk cases based on the slip sensitivity. The following steps were performed to provide preliminary information and landslide analysis:

The first stage

At first, the digitized topographic maps of 1:25000 of the Natural Resources Department were prepared for Guilan province. In this step, first the maps are digitized with reverse Mercator image system and UTM coordinates.

They were put together and provided a single map in DWG format. Then the areas outside the Masal city were removed. The required layers were reconstructed and corrected. The curves of the separate volumes were connected to each other and the elevation figure of each line was entered in its database. After making data corrections, it was entered into GIS though ARCGIS software. A non-topological data format is used in ESRI products which is called Shapefile. A shapefile was created for each layer of Masal city.

The second stage

At this stage, the geological maps of Masal district with a scale of 1:100000 of the Geological Survey were first SCAN and converted to photo format (TIFE). After that, the images of the maps were digitized with the geo-referencing command in ARCGIS software and placed in the main location of the project area. The tectonic and fault layers were removed from these maps and stored as separate layers. The distance from faults, roads and waterways were determined. These factors were linear. In order to determine their area, they were first measured from the distance option in Spatial Analyst up to a distance of 200 meters. These factors were prepared in different raster classes. Then, with the reclassify command, they were defined in 6 classes, and through the convert command, they were converted from raster to vector mode in separate polygons. Finally, with the geo-database command, the amount of polygon area in the defined classes was measured through the Arc Catalog.

Third stage

In the third stage, after performing the previous steps, all operations were performed in GIS software. First of all, the topographic map of the Masal district was created with the Create Tin from features command for the 3D Analyst menu and by using the Elevation database. Thus a hypsometric field was constructed. In the second step, by this map and based on the Spatial Analyst menu and the slope and Aspect options, the slope and direction of the slopes were designed and the numerical value of each of them was defined in separate diagrams. Then, after determining the location of 9 meteorological and rainfall stations around the project area by executing interpolate to Raster command from the Spatial Analyst menu, a map of the area and the temperature of the region were drawn.

Fourth stage

In the fourth stage, the landslides were identified by topographic maps. Then by the main and sub-level curves of maps were prepared a separate layer. The boundaries of landslides and the area of each of them were determined by using the geo-database command in Arc-Catalog. Finally, 91 landslides were identified and mapped.

Step Five

In the five stage, by using GIS software, landslides were investigated and statistically analyzed. By combining and overlapping the layers and the amount of impact of each factor on the landslide, the landslides defined separately. Therefore, the amount of landslide slope and the slope direction which the landslide occurred was defined. The altitude range of landslide is the distance between the faults and the landslide. Then the foundation of landslide in rock, the distance from the waterway, the distance from the road, the land use of the landslide were determined.

Calculation of effectiveness for the studied factors

In order to determine the weight of each of the nine factors needs to define a matrix with the size of 9×9×9. A matrix is a rectangular array of quantities arranged in rows and columns that are often used as an aid in expressing and solving a system of algebraic equations. The data value and percentage of each class in relevant matrix elements were compared one by one. In this matrix, which is a level one matrix, the intensity of each factor due to landslides are in the range of 1 to 9 and are related to the relative weight of each of them.

Research hypothesis

In this work, first of all, the main causes of hills instability are identified by case studies of special fractures. The prediction of rupture at natural slopes of hills, often in geological, geomorphological, and hydrological conditions, is similar to the prevailing conditions in past ruptures. Therefore, it is possible for us to estimate how the slope of hills will be ruptured. Thus the frequency of occurrence, the development, and the consequences that may occur in the future can be predicted. The Geospatial Information System (GIS) as a conceptualized framework provides the ability to capture and analyze spatial and geographic data and the consequences that may occur in the future (Hariri Asli, et al., 2020). The goal should always be to develop an understanding of the processes involved in landslides.

Why do landslides occur?

When and where did it happen?

What is the mechanism of slippage?

In this regard, several questions and hypotheses can come to mind, here according to the type of research, some of them will be as follows:

- Question 1: What is the cause of landslides in the region?
- Hypothesis 1: It seems natural factors.
- Question 2: Which factor has the most impact on range movements?
- Hypothesis 2: Apparently "morphological and geological factor.
- Question 3: Can humans have a significant effect on the intensification of landslides?
- Hypothesis 3: Due to human manipulation in nature, man can be effective.
- Question 4: Are landslides in this region directly related to its specific environmental conditions?
- Hypothesis 4: Due to the rainy climate and current rivers and location on multiple faults, it seems that it can be directly related to environmental factors.

RESULTS AND DISCUSSION

In terms of topography, Masal city at Masal district is divided into three parts: plain, mountain, and mountain. The height variations of this city are in the range of 100 to 2300 meters. The height in the northern sight is higher than in the southern sight. The maximum height in the south sight is equal to 1500 meters. The heights in the northern region are up to 2300 meters. The average height of the Masal city is up to 1200 meters. The heights of the largest areas of this city are in the range of 600 to 800 meters. The TIN model of the elevation figure of this city classifies the hypsometric situation in 10 elevation groups and turns it into a raster model transformed from the TIN model showing the elevation distances in the range of 0 to 2000 meters which are located in separated colors. A three-dimensional model shows the altitude situation in this area. Due to the geographical location, Masal city has different heights and accordingly has gentle to very steep slopes in the high and mountainous area. The amount of the topographic variation is in the range of 0 to 80 degrees. The slope in the range of 20 to 40 degrees has the highest frequency, which covers more than 17% of the total area. The present slope map is in degrees and is divided into 10 classes. The lowest slope is in the range of 70 to 80 degrees, which is less than 1% of the total area. The 2% of slope of this area is more than 80 degrees. According to the 9 mentioned factors, the amount of landslide risk in different areas of Masal district was defined in ARC-GIS software in three classes (Figure 6-9).

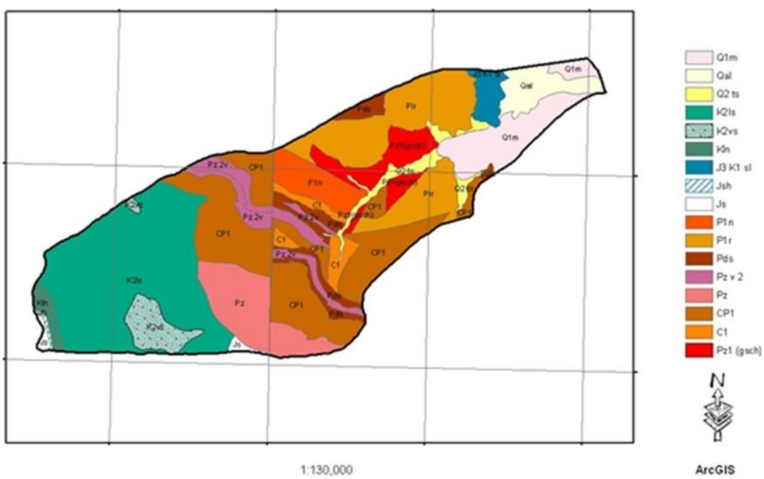

Figure 6: State of rural development of Masal district

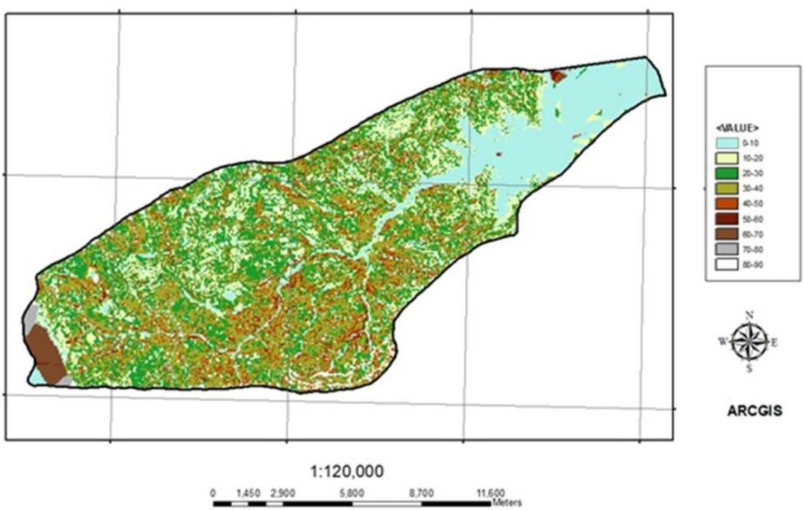

Figure 7: Raster model height in meter - Masal district

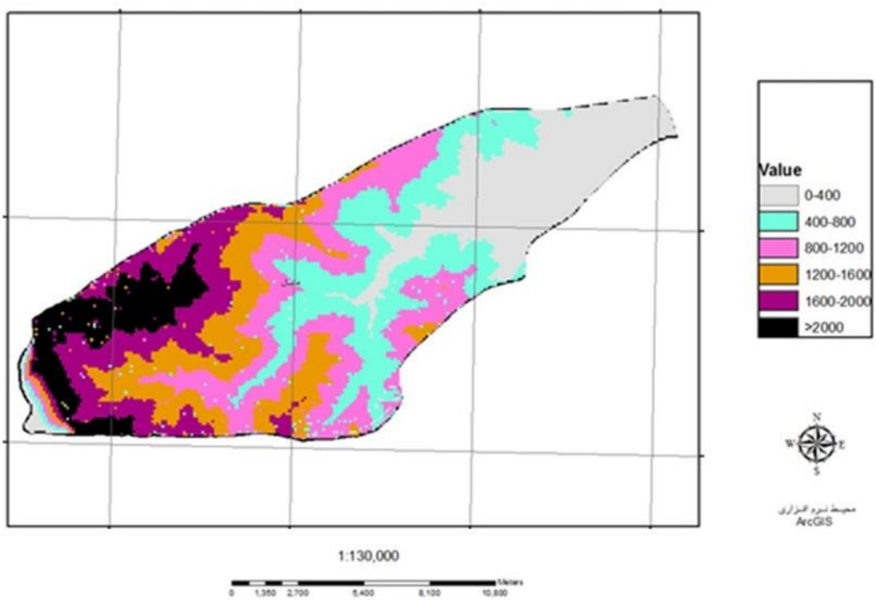

Figure 8: Raster model height in meter - Masal district

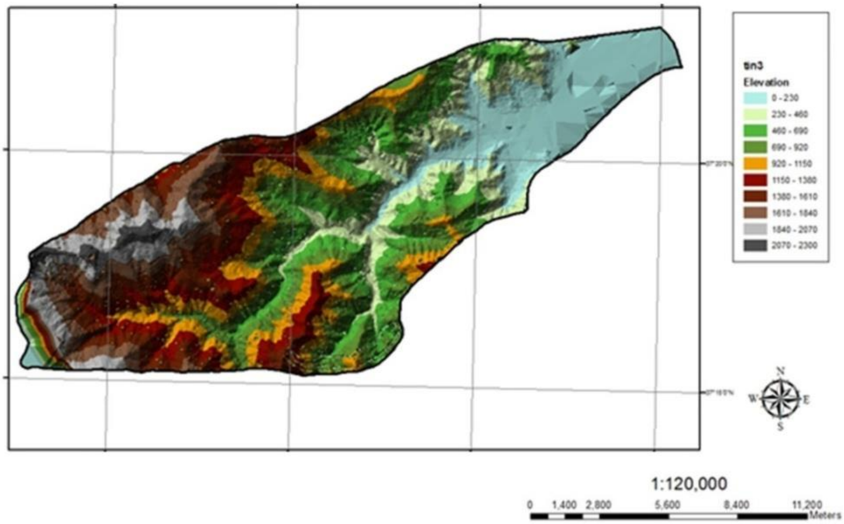

Figure 9: Elevation model (TIN) height in meter - Masal district

By calculating the data value rate of 9 factors in Masal rural area (Table 1) by the data value method, first of all, the weight of each class of effective factors should be brought to it (Digitized topographic maps of 1.25000 by the Department of Natural Resources).

Table 2: Max. and Min. landslides for 9 factors at Masal district

	Summary of the status of the 9 factors	
agents	the least effective agent	The most effective agent
Lithology	Pz	P^1r
Distance from the fault	160-200 meters	0-40 meters
distance from waterway	80-160 meters	0-40 meters
Distance to the road	80-160 meters	0-40 meters
altitude	> 2000 meters	40-100 meters
Slope	0-10 degrees	10-20 degrees
direction	west	southeast
Use of bare	pasture lands	lands
precipitation	950-1010 mm	950-1010 mm

The following equation is used to calculate the data value rate (2):

$$W_{inf} = [(A/B)/(C/D)] \tag{2}$$

W_{inf} - Effective rate factors for each class.

A - Landslide area occurred in each class (ha).

B - Area of each class (hectares).

C - Total area of landslides in the study area (hectares).

D - Total area of the study area (hectares).

Classes of landslide risk related to different factors

In order to classification of landslide risk, by using equations 3-4, the percentage of landslides risk and the level of occupancy were obtained. The landslide risks for different classes were scored in the range of 0 to100. The numerical value for the classes that has the highest percentage of occupancy was 100. Thus relative to the first class and proportional to it the numerical values are given to each of the following classes (3). For example, if 59.3% of the landslide occupancy occurred on a slope in the range of 10 to 20 degrees, this range of the slope has the highest percentage of landslide events. The effect of this category is matched to 0 to 100 (maximum ash). The effective values of other categories were calculated in terms of percentage and its weight was determined.

$$S = \left(\frac{S^{-2}}{S^{-1}}\right) \times 100 \tag{3}$$

S- slope

For example, if the landslide has a value of 30.7% on a slope of 20 to 30 degrees, then the amount of weight or its effect on the scale is 0 to 100 times. Then the effect of other factors for measuring the nine factors will be obtained. This operation can be obtained by equation 4. After scoring 9 factors in the matrix table and pairwise comparison and calculating the relative weight of these factors, the values of scores related to different classes can be multiplied by the relative weight coefficients of the level one matrix and obtained the desired overall factor M (4) for the model:

$$M = a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5 + a_6x_6 + a_7x_7 + a_8x_8 + a_9x_9 \tag{4}$$

M - The sensitivity factor

α - The relative weight of the surface matrix of level one.

X -Weight of data value of elements.

X1- Slope.

X2- Lithology.

X3- Land use.

X4- Distance from the fault.

X5- Distance from the waterway.

X6- Distance from the road.

X7- Slope direction.

X8- Altitude.

X9- Precipitation.

The value of M is written and calculated for each class separately. The magnitude of the M changes is in the range of 0 to 100. The smaller values of it can be described as a landslide-safe area, and for high values, the area will be at high-risk or ultra-high relative to the landslide risk. In order to separate the M values into different classes (Figure 10-11), the sensitivity can be divided as follows (Table 3):

$0 \leq M \leq 20$ safe area

$20 \leq M \leq 30$ area with very low risk

$30 \leq M \leq 45$ low risk area

$45 \leq M \leq 60$ Medium risk area

$60 \leq M \leq 75$ High risk area

$75 \leq M \leq 100$ area with very high risk

Table 3: Frequency of landslides related to height classes- Masal district

Frequency of landslides		
(%)	**nos**	**height**
36	33	100-400
24	11	400-800
18	16	800-1200
14	13	1200-1600
6	5	1600-2000
2	2	above 2000

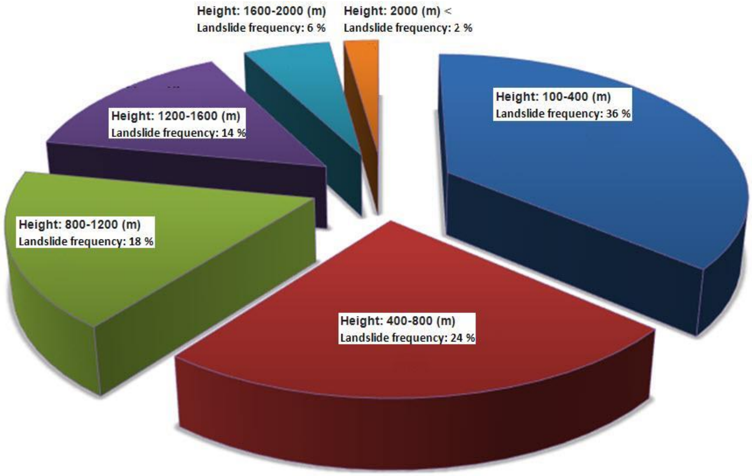

Figure 10: Frequency of landslides at different slopes for height classes-Masal district

Table 4: Frequency of landslides in slope classes - Masal district

Frequency of landslides		
(%)	nos	**Slope (Degree)**
8	7	0-10
45	41	10-20
37	34	20-30
10	9	30-40

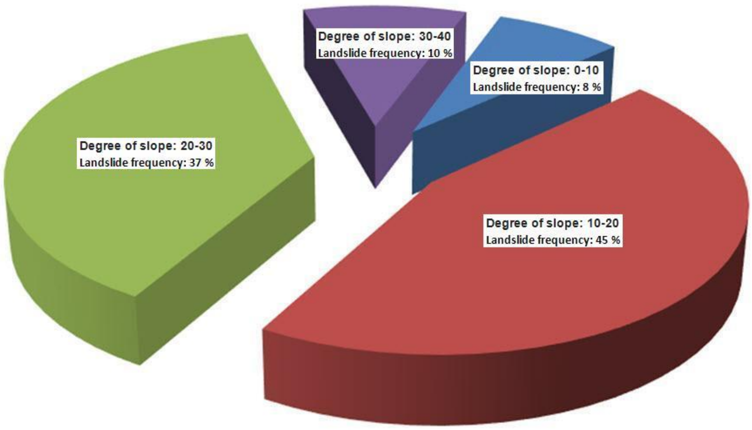

Figure 11: Frequency of landslides for different slopes - Masal district

Comparison of present work results with other expert's research

In the present work, based on descriptive and analytical methods for the landslide phenomenon, the water facility accidents and water loss were investigated. In this regard, topographic maps with a scale of 1: 25000 and 1:50000 and geological maps with a scale of 1:100000 were used. The Global Positioning System (GPS) and ArcGIS software as geospatial research tools and Analytic Hierarchy Process (AHP) as an analysis algorithm were applied for this work. The data were analyzed in Arc-GIS software linked to Analytic Hierarchy Process (AHP) method. by ArcGIS software and extracting raster and vector models and preparing three-dimensional models such as DAM and TIN models, zoning was done in the Masal district.

Another group of experts (Mondal, 2016) used a computational model of the Analytical Hierarchy Process to assess the spatial distribution of slope instability in the Shivkhola Watershed of Darjiling, Himalaya (Figure 12).

Remote Sensing and GIS tools have been incorporated to prepare the various thematic maps processed in that study and estimate the accuracy level of each landslide susceptibility map. The Erdas Imagine 9.0, ArcMap, PCI Geomatica, and MATLAB Software fulfilled the basic objectives. Results revealed that Analytical Hierarchy Process and the 1-D slope stability model are fully accepted approaches in landslide assessment and prediction.

The work of Sujit Mondal identifies such susceptible zones where the stability is expressed as a function of a number of factors. The site-specific management of slope is necessary and that can save the region from potential destruction and the proper execution of the suggestion made may save the resources and ultimately the society and thus it will find social relevance. The factor-based approach considered 0.25 sq km. grid and corresponding landslide triggering factors where the areal extension was too large and it was not possible to assess landslide inducing parameters. The spatial zonation of landslide susceptibility did not take into account the pixel domain.

The work of Sujit Mondal concluded the same results as the present work.

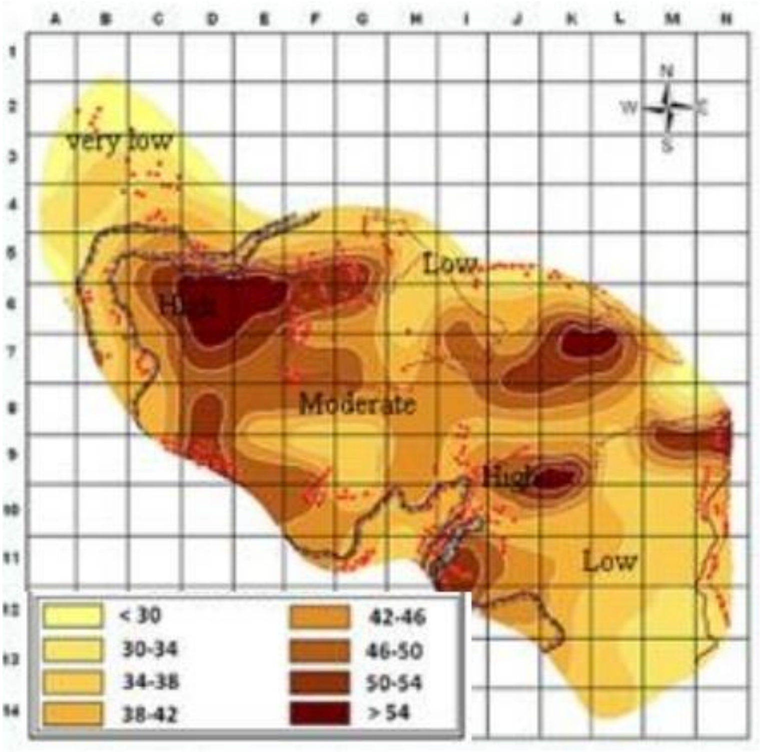

Figure 12: Landslide susceptibility map (Mondal, 2016)

CONCLUSION

This work, investigated the factors related to each other in the occurrence with landslides phenomena for Masal district in the north of Iran. As a result, the occurrence of landslides in the southeastern slopes has the highest percentage and most of the faults in this area are in the same direction. Although the high rainfall in the Masal district at Guilan province are 1000 mm per year. This matter attracts the attention of most researchers, but statistics show that the impact of rainfall and its relationship with landslides is not a primary factor. It can be considered as a secondary factor in connection with other mentioned factors, especially in changing land uses and its foundation. As a final result of this work, not only in the hierarchical analysis method but also in comparing the frequency of investigated factors, the slopes of 10 to 30 degrees had the highest percentage of landslides risk, which is the most important factor in the water disaster management for water facilities includes water reservoirs, water transmission pipelines and water distribution networks at Masal district. On the other hand, the increasing of accident for water system due to landslide can cause increasing the possibility of water leakage and Non-Revenue Water (NRW), energy losses and economic costs.

ACKNOWLEDGMENT

The authors thank to all specialists for their valuable observations and advice, and the referees for recommendations that improved the quality of this paper.

REFERENCES

MEMARIYAN H., SAYARPOUR M. (2006). The role of slope slope parameter in the occurrence of error in landslide risk zoning, Journal of the Faculty of Engineering, Vol. 40, Issues 1, pp. 1-4.

HARIRI ASLI K., HAGHI A. K., HARIRI ASLI H., SABERMAASH ESHGHI E. (2012). Water Hammer Modelling and Simulation by GIS, Modelling and Simulation in Engineering, Hindawi Publishing Corporation, Article ID 704163, 4 pages doi:10.1155/2012/704163, ISSN: 16875605, 16875591, Pub., Vol. 1, Issues 3, pp. 1-4. USA, http://www.hindawi.com/journals/mse/aip/704163/

HARIRI ASLI H., ARABANI M., GOLPOUR Y. (2020). Reclaimed asphalt pavement (RAP) based on a geospatial information system (GIS), Slovak Journal of Civil Engineering, Vol. 28, Issue 2, pp.36-42, DOI: 10.2478/sjce-2020-0013, Slovak University of Technology in Bratislava, Slovak, https://sciendo.com/article/10.2478/sjce-2020-0013

LEE H.H. (2017). Finite element simulations with ANSYS workbench 17, SDC Publications, p. 51, ISBN 978-1-63057-088-0.

MAHMOOD F., PIMBLETT J.G., GRACE N.O., GRAYMAN W.M. (2005). Evaluation of water mixing characteristics in distribution system storage tanks, J.AWWA, Vol. 79, Issues 3, pp74–88.

MAREK M., STOESSER T., ROBERTS P. J. W., WEITBRECHT V., JIRKA G. H. (2007). “CFD modeling of turbulent jet mixing in a water storage tank,”XXXII IAHR Congress, July 1/6, Venice, Italy.

MANDAGLIO M.C., MORACI N., ROSONE M., AIRÒFARULLA C. (2016). Experimental study of a naturally weathered stiff clay. Can Geotech J., Vol. 53, Issues 12, pp. 2047–2057.

MENGISTU F., SURYABHAGAVAN K.V., RAGHUVANSHI T.K., LEWI E. (2019). Landslide Hazard zonation and slope instability assessment using optical and InSAR data: a case study from Gidole town and its surrounding areas, southern Ethiopia. Remote Sensing of Land, Vol. 3, Issues 1, pp. 1–14.

METEN M., BHANDARY N.P., YATABE R. (2015). Application of GIS-based fuzzy logic and rock engineering system (RES) approaches for landslide susceptibility mapping in Selelkula area of the lower Jema River gorge, Central Ethiopia. Environ Earth Sci, Vol. 74, Issues 4, pp. 3395–3416.

MONDAL S. (2016). European Journal of Geography, Association of European Geographers. Vol. 7, Issues 2, pp.21-47.

RAGHUVANSHI T.K. (2019). Governing factors influence on rock slope stability – Statistical analysis for plane mode of failure. J King Saud Univ - Sci, Vol. 31, Issues 4, pp. 1254–1263. https://doi.org/10.1016/j.jksus.2019.01.002

RAZIFARD M., SHOAEI G., ZARE M. (2018). Application of fuzzy logic in the preparation of hazard maps of landslides triggered by the twin Ahar-Varzeghan earthquakes. (2012). Bull Eng Geol Environ, Vol. 78, Issues 1, pp. 223–245.

VAN ZYL J. E., HAARHOFF J. (2007). Reliability Analysis of Municipal Storage Reservoirs Using Stochastic Analysis, Journal of the South African Institution of Civil Engineering, Vol. 49, Issues 3, pp. 27–32.

WALSKI T. M. (2000). Hydraulic Design of Water Distribution Storage Tanks, In Water Distribution Systems Handbook, Chapter 10, ed. L. W. Mays, Mc Graw-Hill, New York, USA.

WU L.Z., HUANG R.Q., XU Q., ZHANG L.M., LI H.L. (2015) Analysis of physical testing of rainfall-induced soil slope failures. Environ Earth Sci, Vol. 73, Issues 12, pp. 8519–8533.

YEUNG H. (2001). Modeling of service reservoirs, Journal of Hydroinformatics, Vol.3, Issues 3, pp. 165–172.

ZAINALABIDEEN K, HELAL M. (2016). Determination of the safe orientation and dip of a rock slope in an open pit mine in Syria using kinematic analysis. Al-Nahrain Univ College Eng J, Vol., 91, Issues 1, pp. 33–45.

ZECCHIN A.C., MAIER H.R., SIMPSON A.R., LEONARD M., NIXON J.B. (2005). Parametric study for an ant algorithm applied to water distribution system optimization, IEEE Transitions on Evolutionary Computation, Vol. 9, Issues 2, pp.175-191.

ZÊZERE J.L. (2004). Integration of spatial and temporal data for the definition of different landslide hazard scenarios in the area north of Lisbon (Portugal), Natural Hazards and Earth System Science, Vol. 4, Issues 1, pp. 133–46.