Gully erosion Sufficiency mapping at Robatturk Watershed (Iran) using an artificial neural network model

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Abstract
Spatial prediction of occurrence of gully erosion through the use of models that are based on the sufficiency of land to gully erosion and output them to the hazard mapping of gully erosion in the gully erosion hazard zone, most appropriate strategy for land management planning in watersheds prevent the occurrence of erosion. Therefore, in this research, the sensitivity of gully erosion in the Robatturk watershed Markazi province of Multilayer Perception neural network structure and the use of variables the selected suitable factors are: lithology, land use, distance from river, distance from road, soil texture, slope degree, slope aspect and altitude. The results of ANN represents the final structure 1-6-8 with 0.5 of learning and sigmoid activation function in the hidden layer for mapping is appropriate to the sensitivity of gully erosion in this area. The result of erosion hazard zone using artificial neural network using the 1-6-8 structure, learning about 0.5 and sigmoid activation function in the hidden layer shown that 70.35% very low, 3.10% in low-class, 1.05% percent in the medium risk category, 4.14% and 22.39% are classified as high risk is too much risk.

Keywords:
ANN, hazard zone, Landuse, Markazi Province

1 Introduction

Gully erosion in agricultural land has a special problem., It destroyed lands and damage them. When This event occure roads, environment and agriculture are damaged. (Burkard and Kostaschuk 1997; Nyssen et al. 2002; Valentin et al. 2005; Choi et al. 2008; Takken et al. 2008; Akgun and Turk 2011; Chaplot 2013; Zakerinejad and Maerker 2015). Gully erosion in west of Iran is one of the main causes of environmental damages. Gully erosion is scattered in the large parts of Markazi province. (Noormohammadi et al. 2013, 2014). Geographic and environmental factors that control critical circumstances for development of Gully include topography, lithology, rainfall, soil, and land use (Bryan and Jones 2000; Poesen et al. 2003; Martınez-Casasnovas et al. 2004; Capra et al. 2009; Gomez Gutierrez et al. 2009b; Cui et al. 2012; El Maaoui et al. 2012). Kirkby and Bracken (2009) confirmed that surface runoff is one of the main factors which help the event of gully erosion. The rate and amount of concentrated surface flow are also controlled by land use and geography attributes. (e.g., causal drainage area, slope sharpness, and slope curve) (Vandekerckhove et al. 2000; Valentin et al. 2005; Zucca et al. 2006; Dondofema 2007; Samani et al. 2009; Capra et al. 2009; Svoray and Markovitch 2009; Conoscenti et al. 2013). One way to classify and identify sensitive land degradation using artificial neural network., from the last two decades Artificial NeuralNetworks (ANNs) has emerged as a powerful computing system for highly complex and nonlinear systems. ANN belongsto the black box time series models and offers a relatively flexible and quick means of modeling. These models can treat the nonlinearity of system to some extent due to their paralle larchi tecture.Several studies on the use of neural networks in rainfall-runoff modeling (Sajikumar et al., 1999; El-Shafie et al., 2011), flood frequency analysis (Shu and Bum, 2004), predict the groundwater level (Shirmohammadi et al., 2013; Moosavi et al., 2013), land zoning landslide susceptibility (Nourani et al., 2014) and Dubai predict daily and monthly (Wang et al., 2009; Vafakhah, 2012) was conducted and this method as an efficient way superior to estimate hydrologic variables and soil erosion are different. The main objective of this study is as follow factors affecting the accuracy of gully erosion mapping using artificial neural network in the watersheds Robat Markarzi province.

2 Method and Material

2.1 Study area

The study area is located in the 35 kilometer of Delijan city, Iran, one of the sub basin Shoor river and between latitudes of 33 42- 35 45N and longitudes 50 46- 50 52 of (Fig. 1). It covers an area of about 2,500 km2, and its altitude ranges from 1807.39 to 2723.49 m above sea level. The study area

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is considered to have an arid and semiarid climate with a mean annual rainfall of 213.7 mm (WRCI 2013). It receives approximately 85 % of its annual rainfall from December to April. Peak stream flows are experienced between February and June (WRCI 2013).

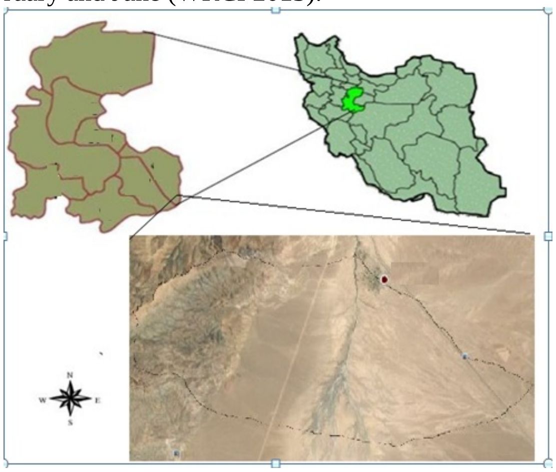


Figure 1. The approximate location of the studied watershed in Iran

2.2 Methodology

The methodological approach applied in the current study is a statistical bivariate analysis,as illustrated in Fig. 2. It consists of six main steps:
1. Gully erosion supply mapping
2. prepare of maps of gully erosion condition factors
3. significant analysis of gully condition factors
4. using frequency ratio and weights-of-evidence models
5. production of gully erosion susceptibility maps
6. confirmation of the gully erosion susceptibility maps.

These steps are explained and expanded in the following sections.

2.3 Gully erosion conditioning factors

As gully erosion process is controlled by both erosivity of runoff waters and the erodibility of soil cover, several geo-environmental attributes should be considered (Agnesi et al. 2011). It is essential to determine the gully erosion conditioning factors in order to perform gully susceptibility mapping (Conoscenti et al. 2008; De Vente et al. 2009). Therefore, in the first stage, gully erosion related to spatial database should be prepared. Through the knowledge attained from the literature, availability of data and field surveys of the conditioning factors were chosen (Kuhnert et al. 2010; Conforti et al. 2010; Luca` et al. 2011; Ma¨rker et al. 2011; Svoray et al. 2012; Conoscenti et al. 2013, 2014; Zakerinejad and Maerker 2015). Hence, ten gully erosion conditioning factors were selected to prepare the GESM of the study area.

2.3.1 Lithology

The lithology factor is identified as an significant variable in the natural risk analysis (Pourghasemi and Kerle 2016). Litho logical properties are associated with the geomorphological features and assessment of a land (Dai et al. 2001; Zinck et al. 2001; Gorum et al. 2008; Zhu et al. 2014). Moreover, gully erosion is particularly dependent on the lithology properties of the material exposed or close to the earth surface (Casali et al. 1999; Stotle et al. 2003; Agnesi et al. 2011; Conforti et al. 2010; El Maaoui et al. 2012; Golestani et al. 2014). The lithology layer was condocted by digitizing the geological map (Geological Survey Department of Iran, Robatsheet at 1:100,000 scale) (GSDI 1997). The lithology map was prepared from an available 1:100,000-scale geological map (Fig. 2).

2.3.2 Land use Factor

Land-use management has a significant influence on the geomorphological slope stability and gully occurrence (Anabalagan 1992; Zucca et al. 2006; Agnesi et al. 2011; Conoscenti et al. 2013, 2014; Zakerinejad and Maerker 2015). usually unproductive land and lightly vegetated areas are more susceptible to erosion than forests where vegetation cover strongly reduces the erosive action of surface runoff (Dai et al. 2001; C¸ evik and Topal 2003; Go´mezGutie´rrez et al. 2009a). In other terms, a negative correlation exists among erosion rate and vegetation density (Snelder and Bryan 1995; Hughes et al. 2001; Chaplot et al. 2005b). The land-use map was obtained from Iranian Department of Water Resource Management (IDWRM 2012). Main land-use types have been identified in the study area were agriculture, range and urban classes (Fig. 2). In particular, more than 83.88 % of the study area present rangeland land-use type in which is included the large part of the gullies . Consequently, agriculture and urban areas are covered by 11.9, 4.22% of the study area, respectively.

2.3.3 Distance from rivers Factor

In the majority cases, gullies are connected to the drainage/stream system, facilitating the migration of the material eroded from upland areas (Conoscenti et al. 2014). In order to discover the influence of drainage network, the factor of distance from rivers was measured (Choi et al. 2008; Conoscenti et al. 2014; Dube et al. 2014; Zakerinejad and Maerker 2015). Hence, the distance calculation process in ArcGIS 10.2 was exercised to derive the distance from rivers and classify it into four categories based on quantity classification scheme (Fig. 2).

2.3.4 Soil texture factor

The material properties of the surface soil play an significant task in soil infiltration, runoff rate, soil confrontation to erosion, and gully occurrence (Bryan and Jones 2000; BouKheir et al. 2007, 2008; Geissen et al. 2007; Magliulo 2012; Torri et al. 2012; Deng et al. 2015). Above all, soil texture influences hypodermic/subsurface flow and piping occurrence (tunnel erosion), which can lead to forming gullies when the roofs of pipes collapse (Bull and Kirkby 1997; Bryan and Jones 2000; Valentin et al. 2005; Pulice et al. 2012). Therefore, soil texture was selected to assess gully erosion susceptibility (Wells et al. 2009; Agnesi et al. 2011; Conoscenti et al. 2013). A soil texture map was digitized from soil characteristics map obtained from Iranian Department of Agriculture. Two soil types were in the study areas, namely Entisols and Ardisols. (Fig. 2).

2.3.5 Slope degree factor

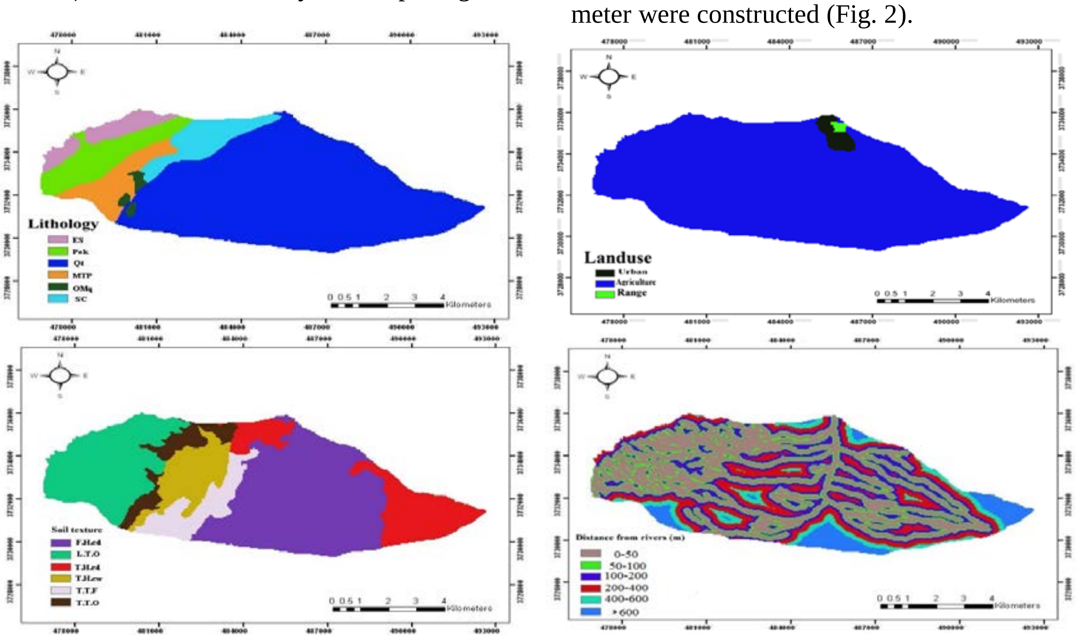
The kind of slope areas are highly potential areas for surface flow accumulation and consequent exposure to gully initiation (Dramis and Gentili 1977; Valentin et al. 2005; Agnesiet al. 2011; Rahmati et al. 2015b; GhorbaniNejad et al. 2016). In the case of gully erosion, gullies in the catchment are mainly located on gentle slopes as confirmed by other researches (Flu¨gel et al. 2003; Chaplot et al. 2005a; Kakembo et al. 2009; Le Roux and Summer 2012). In the current study, the slope degree was derived from the DEM and was divided into five classes (Fig. 2).

2.3.6 Slope aspect Factor

Slope aspect is also considered a vital factor in natural risk analysis and susceptibility mapping (Maharaj 1993; Baeza and Corominas 2001; Pourghasemi et al. 2013b; Umaret al. 2014). The slope aspect can indirectly influence erosion processes because it controls duration of sunlight exposition, evapotranspiration, moisture retention, vegetation cover type, and vegetation distribution on slopes (Dai et al. 2001; Sidle and Ochiai 2006; Agnesiet al. 2011; Wang et al. 2011; Jaafari et al. 2014). Moreover, it can indirectly express (proxy role) the influence of the structural setting (Conoscenti et al. 2013). The slope aspect map was constructed automatically in ArcGIS 10.2 software, using the DEM with a grid cell size of 20 * 20 m, and is classified into nine categories (Fig. 2).

2.3.7 Altitude factor

The topographic attributes (such as altitude and slope angle) mainly control gully erosion process and, thus, determine the spatial distribution of gullies (Conoscenti et al. 2014;Hongchun et al. 2014; Go´mez-Gutie´rrez et al. 2015). In addition, altitude plays important roles in vegetation cover type and precipitation properties. Hence, altitude map of the study area was obtained from the DEM, and three classes (<2500, 2500-2600 and 2600> meter were constructed (Fig. 2).



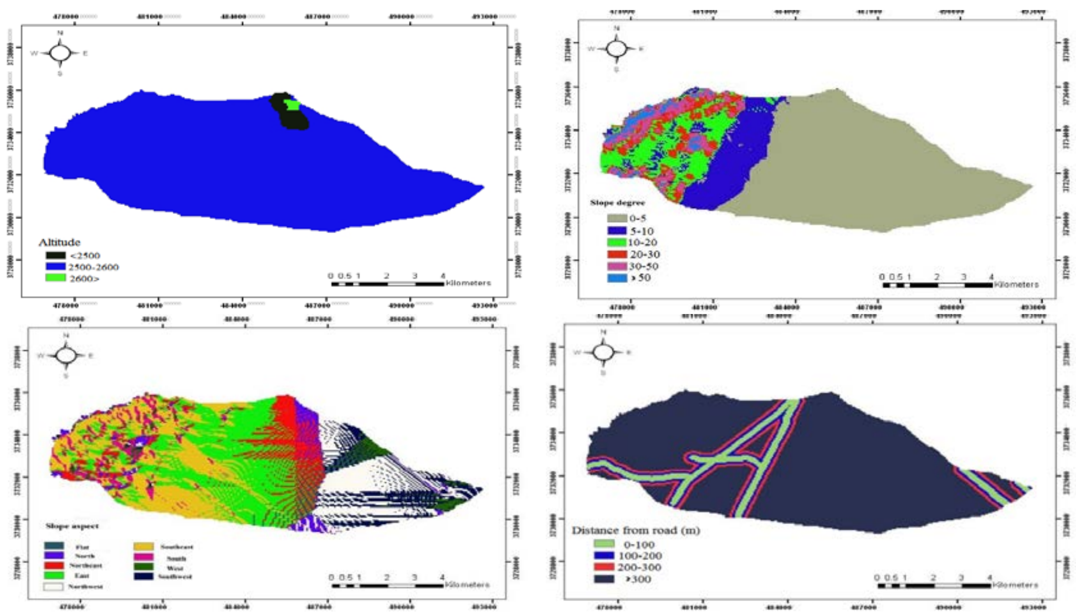


Fig. 2. Gully conditioning factors

2.4 Artificial Neural Networks (ANNs)

ANNs are inspired from biological nervous system, though much of the biological detail is neglected. ANNs are massively parallel systems composed of many processing elements. The network consists of layers of parallel processing elements, called neurons, with each layer being fully connected to the proceeding layer by interconnection weights. Randomly assigned initial weight values are progressively corrected during a training process that compares calculated outputs to known outputs and the errors are back-propagated to determine the appropriate weight adjustments necessary to minimize the errors (Kisi, 2005). The detailed theoretical information about ANN can be found in Haykin (1998). In the present study, the ANN was trained using conjugate gradient algorithm which is more powerful and faster than the standard gradient descent algorithm (Kisi, 2007). A difficult task with ANN involves choosing the hidden nodes' number. Here, the ANN with one hidden layer was used and the hidden nodes' number was determined using trial and error. Different activation functions (logarithm sigmoid, tangent sigmoid, linear) were tried for the hidden and output nodes.

2.5 Analysis of the results

At each step of model development, Root Mean Square Error (RMSE) statistical evaluation criteria were used to assess the model performance:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{n}\left(O_i - P_i\right)^2}$$

Where O_i and P_i denote the observed and modeled values respectively.

2.6 Zoning gully erosion

After determining the basic structure of the neural network and providing the information needed for training the neural network, also, to achieve an acceptable error, the network is ready to analyse areas that previously have not had to do. In order to determine the best artificial neural network according to the root mean square error, the entire area, including the network was available to 26805 pixels. The network output is obtained from between one and zero. This period was divided into 5 groups with different 0.2. The result of this classification, identification of five areas with low to very high risks.

3 Results and discussion

3.1 The factors influencing the occurrence of gully erosion

Correlation between factors influencing the occurrence of gully erosion in the study area is presented in Tables 1 to 8.

Table 1. The values of the relationship between the slope and gully erosion occurred

frequency ratio	Percentage of gullies	No. of gullies	Percentage of no gullies	No. of no gullies	No. of pixels in domain	Class
1/58	100	332	63.18	16727	17059	0-5

0	0	0	14.47	3830	3830	5-10
0	0	0	10 .30	2726	2726	10-20
0	0	0	5/65	1496	1496	20-30
0	0	0	4/80	1271	1271	30-50
0	0	0	1/60	423	423	<50

According to the most sensitive slopes of Table 1 in 5-0 percent of the gully floor and on the floor of 10-5, 15-10, 20-15, 20-30 and 30-50 were not observed.

Table 2. The values of the relationship between land use and gully erosion occurred

frequency ratio	Percentage of gullies	No. of gullies	Percentage of no gullies	No. of no gullies	No. of pixels in domain	Class
29.40	37/05	123	1.52	402	525	agricultural
0.62	61/45	204	98.16	25987	26191	range
4.75	1/50	5	0.32	84	89	residential

As can be seen in Table 2, agricultural lands, residential and range in amounts lots 29.4, 4.75 and 0.62 had the greatest impact on the occurrence of gully erosion.

Table 3. The values of the relationship between altitude and gully erosion occurred

frequency ratio	Percentage of gullies	No. of gullies	Percentage of no gullies	No. of no gullies	No. of pixels in domain	Class
1.01	100	332	98.83	26163	26495	>2500
0	0	0	0.68	179	179	2500-2600
0	0	0	0.49	131	131	<2600

According to table 3 most gully erosion has occurred at an altitude of less than 2,500 at an altitude of 2500-2600 and 2600-up occurred ditch.

Table 4. The values of the relationship between distance from rivers and gully erosion occurred

frequency ratio	Percentage of gullies	No. of gullies	Percentage of no gullies	No. of no gullies	No. of pixels in domain	Class (m)
2.29	18.93	272	35.73	9460	9732	0-50
0.90	12.65	42	14.01	3710	3752	50-100
0.28	5.42	18	18.99	5028	5046	100-200
0	0	0	17.15	4542	4541	200-400
0	0	0	6/82	1806	1806	400-600
0	0	0	7/28	1928	1928	<600

As can be seen in table 4, are 50-0 meters from the river view is the highest number of ditches and gullies have fallen away from the channel number. And at a distance of 400-200, 600-400 and more than 600 meters of drainage ditch can't be seen.

Table 5. The values of the relationship between distance from road and gully erosion occurred

frequency ratio	Percentage of gullies	No. of gullies	Percentage of no gullies	No. of no gullies	No. of pixels in domain	Class (m)
0	0	0	7.78	2061	2061	0-100
0	0	0	5.85	1549	1549	100-200
0	0	0	5.65	1495	1495	200-300
1.24	100	332	80.72	21378	21700	<300

As seen in table 5, at a distance greater than 300 meters from the road observed the largest number of gullies and within walking distance to the road ditch was found.

Table 6. The values of the relationship between slope aspect and gully erosion occurred

frequency ratio	Percentage of gullies	No. of gullies	Percentage of no gullies	No. of no gullies	No. of pixels in domain	Class
1.74	3.31	11	1.90	504	515	Flat
0/78	3.31	11	4.25	1124	1135	North
5.49	62/05	206	11.29	2990	3196	Northeast
1.04	28.31	94	27.16	7189	7283	East
0	0	0	23.37	6186	6186	Southeast
0	0	0	4.38	1160	1160	South
0	0	0	3.12	825	825	Southwest
0.14	1.20	4	8.79	2326	2330	West
0.11	1.81	6	15.75	4169	4175	Northwest

According to table 6 ditch in the Northeast has the highest incidence in the southeast, south and southwest of gully erosion has been observed.

Table 7. The values of the relationship between geology land gully erosion occurred

frequency ratio	Percentage of gullies	No. of gullies	Percentage of no gullies	No. of no gullies	No. of pixels in domain	Formation
0	0	0	5	1325	1325	Es
0	0	0	9.67	2561	2561	Pek
1.42	99.40	330	69.82	18485	18815	Qt
0	0	0	6.95	1840	1840	Mtp
0	0	0	1.11	295	295	Omq
0.08	0.60	2	7.43	1967	1969	Sc

According to table 7 most gully erosion in the geological units of the quaternary alluvial terraces and in the geological units Es, Pek, Mtp and Omq occurred gully.

Table 8. The values of the relationship between soil and gully erosion occurred

frequency ratio	Percentage of gullies	No. of gullies	Percentage of no gullies	No. of no gullies	No. of pixels in domain	Soil type
2	80.42	267	40.10	10615	10882	F.H.cd
0	0	0	21.81	5773	5773	L.T.o
1.31	19.52	65	14.89	3943	4008	T.H.cd
0	0	0	9.47	2506	2506	T.H.cw
0	0	0	7.92	2097	2097	T.T.F
0	0	0	5.81	1539	1539	T.T.o

According to table 8 soil units FHcd and THcd most of gully erosion in the soil ranks ye Sol 2 and 1.31 respectively with relative frequency and soil type units LTo, THcw, TTF and there was a ditch TTo.

3.2 Determine the optimal structure of artificial neural network

To select the optimal structure of artificial neural networks of neurons in the middle layer of 3 to 20 and 0.1 to 0.5 of learning was changed and root mean square error was calculated at each stage. The structure that has the smallest error was chosen as the optimal structure that results can be seen in table 9.

Table 9. Results of iterations to select the optimal network structure

LR=0.5		LR=0.4		LR=0.3		LR=0.2		LR=0.1		Number of neurons
RMSE	R2	RMSE	R2	RMSE	R2	RMSE	R2	RMSE	R2	
0.0358	0.9946	0.0413	0.9932	0.0371	0.9945	0.0380	0.9942	/06560	0.983	7

According to the table showed that learning about 0.5 and 7 neurons in the middle layer of artificial neural network to a minimum error and provide the best answer.

3.3 Gully erosion hazard zoning maps of the study area

Figure 12 zoning maps using artificial neural networks are values obtained results. The results of gully erosion hazard zoning 70.35 percent very low, 3.01% in the low-class1.05 per cent in risk class on average, 4.14 percent and 22.39 percent are classified as high risk is too much risk.

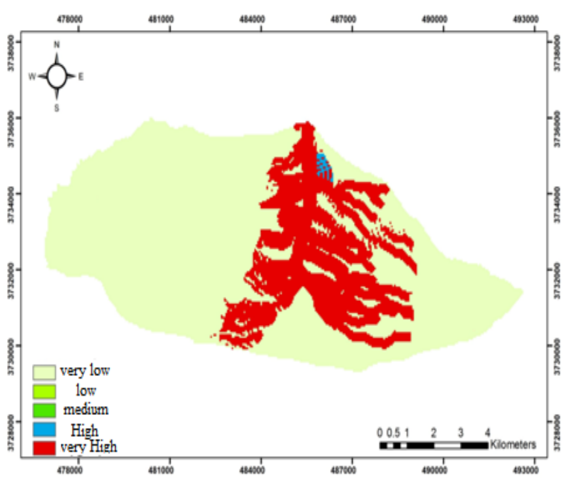


Figure 3 gully erosion hazard zoning map with a ratio of 0.5 and 7 neurons in the hidden layer learning

4. Conclusion

Due to hazardous characteristics of gullies erosion, several researchers and natural resources managers throughout the world have focused on assessing gully erosion susceptibility hazards and determining their spatial pattern for a given area. The results of ANN represents the final structure 1-6-8 with 0.5 of learning and sigmoid activation function in the hidden layer for mapping is appropriate to the sensitivity of gully erosion in this area. The result of erosion hazard zoning using artificial neural network using the 1-6-8 structure, learning about 0.5 and sigmoid activation function in the hidden layer shown that 70.35% very low, 3.10% in low-class, 1.05% per cent in the medium risk category, 4.14% and 22.39% are classified as high risk is too much risk. The results of ANN zoning gully erosion, which is about 26.53% of the area exposed with very high sensitivity and high class marked. The areas of focus in the central part of the basin.

In summary, the findings of the present research proved that GIS-based FR and ANN could be successfully applied to the gully susceptibility mapping, particularly in developing and low income countries. In fact, the above-mentioned models require data usually available for large areas (such as regional-scale resolution) or achievable without high cost- and time-consuming methods; accordingly, these models are capable of being easily reproduced and employed in other regions with the aim of gully erosion susceptibility mapping. Hence, the information provided by these gully susceptibility maps can help planners and natural resources managers reduce losses caused by focusing on ‘‘hotspot’’ areas of gully erosion.

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