Priority assessment and zoning of natural and agricultural hazards in Guilan Province

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Abstract

This study has aimed to analyze and evaluate the natural and agricultural hazards of Guilan Province. Guilan Province, due to the presence of multiple life zones and the existence of permanent rivers, suitable lands and important wetlands, can produce a variety of crops and livestock productions, which gives this province a prominent statues and natural and agricultural hazards could result in loss of these privileges. The purpose of this study is to identify, assess and prioritize risks of natural disasters and activities of the agricultural sector in the Guilan Province. The required data and information, has been adopted with regard to the review of the library studies and professional meetings in two major sections of agriculture and natural hazards. The agricultural and the natural sectors each respectively have four and five sub-criteria. After indexing each sub-criterion, Entropy model was used to evaluate the sub-criteria, and TOPSIS model was used for prioritization. All maps were produced in GIS format and then converted to Raster data. Zoning of all data formed the risk zones at the provincial level based on five classes of very low, low, high, very high and critical. The final results showed that approximately 15.70% of Guilan Province is in critical level in terms of natural and agricultural hazards, while 14.57% had high level of risks, 26.49% had an average level of risks, and 22.64% had a very low level of risks. This paper showed an innovative and reliable method to integrate the decision-making procedures of the risks and for identification of the most important criteria using an integrated multi criteria method. The weights of the criteria are determined by Entropy-TOPSIS method. The results indicated that the amount of fertilizer used in agricultural sectors is the critical criteria to make a hazard risk. Next in rank are the earthquakes risk, production in agricultural section, flood and production in the garden sector. The results of percentage of risk in different classes at the province level emphasises the need for integrated planning in these two sectors.

Keywords: Priority assessment, Natural and Agricultural risks, Entropy and TOPSIS.

1- Introduction

The risk has been identified as the current or event that could potentially cause harm in the future (Royal Society, 1992). In fact there are extreme events that can be derived from a human or geophysical trend. Today, despite progress in various fields of science, technology, environmental hazards are critical and problematic in many countries. By the occurrence of environmental disasters, the development of countries affected by that disaster would be changed. But in some countries after the occurrence of environmental disasters, there is an opportunity to accelerate the restructuring process of development. In some countries, environmental hazards would cause halt in development programs and sometimes regression of those countries so that prioritizing risks scientifically with effective measures, in order to prevent and reduce risks would bring more fulfilment for planning of managing risk and crisis in different areas (Ron Store and Jyrki Kangas, 2001).

Guilan Province has the possibility of producing a variety of crops and livestock production, permanent rivers and important wetlands, having suitable lands, forest storages and plant cover with appropriate density that led to development of biological risks which eventually leads to the lack of valuable resources in the region. Moreover, some polluting industries within the residential zones and habitats, the existence of industry in fertile lands, water and soil pollution by pesticides and fertilizers, erosion and soil degradation, pollution and loss of available water resources and a long list of environmental problems. All of these problems that are due to lack of attention will become serious problems which cannot be solved easily. Therefore, the full identification of the risks and the problems that could be harmful will be one of the first steps in risk management. In today's world achieving a sustainable development does not include environmental protection principles, and in this method a new concept of economic growth is concerned. There should be a growth that brings the living facilities and justice for all people and all generations without degradation of the limited capacities and resources of the world. (Vincent *et al.,* 1993). With occurrence of any environmental accidents, the development process of damaged countries can be changed considerably. But in some countries after the occurrence of environmental disasters, there is an opportunity to accelerate the development restructuring process. In some countries, environmental hazards occurrence stops the developmental programs and sometimes it takes the countries back because all societies are threatened by environmental hazards. So the important condition in reducing the effects of environmental hazards is to reduce the risk of these disasters. Every year, environmental hazards impose extensive damages on developing countries. On the other hand recent decades, various factors such as population growth, urbanization, industrial development, misuse of natural and domain resources have made these damages more variable and also increased their consequences severity and magnitude.

According to what we have mentioned above, access to safety against the risks of natural environment is one of the essential needs of human society. Therefore, given the importance of the negative role of environmental hazards including natural and agricultural disasters in developing, evaluating and prioritizing these risks and then making plan for them has a particular importance. Prioritization of risks has a special importance and can help the planners to specialize and to optimize the resources and also to timely reduce or prevent the damages (Beer and Ziolkowski, 1996).

This paper, with a precise planning, tries to prevent probable risks and damages given the importance of the study area which has a large and very dense human population and with a detailed study on the identification, prioritization and also review of the danger zone of high risk in the province scale that seems essential by the GIS software. So the presentation of management solutions, long-term planning, environmental risks management, land use planning and sustainable development projects are so essential to be done in advance. Implementation of management solutions should be in such a way that the activities can be managed in the form of risk management and before the occurrence of human and financial losses and transformation of risk to disaster. So risk management should precede the crisis management which is planned at the time of disaster and the human and financial losses (Power *et al.,* 1998). After criteria identification by experts, using the multi criteria evaluation method, deciding the prioritization of them will be implemented. Multi-criteria decision-making methods

(MCDM) are a subfield of decision-making procedures which are the sub-branch of research in operations models (Puhker and Ramachandran, 2004). Multi-criteria decision is one of the problems in which the decision-maker seeks to find the optimal solution among the options ahead that are also based on qualitative and quantitative criteria that are sometimes in conflict with each other (Malczewski, 1999).

According to the type of risks indicators and the need to rank these indicators in this study the compensatory model TOPSIS was used. TOPSIS is one of the adaptive methods in which the value of answers depends on their closeness to the ideal positive answer and their distance from ideal negative answer (Huang and Yoon, 1981). Generally in the past decade, TOPSIS model was used in the high risk evaluations and prioritizations, out of hand problems, and evaluation and selection of areas (Jiang *et al.,* 2010). But due to the fact that TOPSIS does not have the weighting power so Shannon Entropy was used to evaluate the weight of the indicators. The procedure is carried out based on the decision matrix.

In this paper, the new method with the integration of Shannon Entropy and TOPSIS was used for weighting and ranking the risks and the weight of the indicators were used to prepare the final risk zone. With regard to the issues raised above, in terms of prioritization of environmental hazard the following questions are raised:

1. The most weight of environmental hazards priority is related to which one of the major hazards?
2. Do the indicators resulted from technical meetings facilitate the prioritization process?

There are some previous studies in this subject in Iran. Jozi *et al*. (2009) applied multi-criteria decision methods in the analysis of environmental hazards of Bushehr Hillah protected areas and the indicators have been weighted and prioritized using the Shannon Entropy. Kiani *et al*. (2012) have assessed and prioritized the hazards of the natural environment of Zabol City. The required data and information were extracted according to local experiences through questionnaires and they were determined based on the priorities of citizens and major strategies. TOPSIS technique was used to set priorities. Moeinifar *et al*. (2013) have studied the assessment and the establishment of educational spaces with the integrated model of Shannon Entropy and TOPSIS. Mahmoodzade *et al.* (2014) have studied flood hazard zoning within the city of Tabriz using AHP method. They have divided the zoning to the category of high risk, risk, medium risk or low risk in terms of flood prevention.

2- Methods and Materials

2.1- Geographical location of the study area

The current study is implemented in Guilan Province with the area of 14 thousand square Kilometers in the North of Iran between 36 34 to 38 27 north latitude and 48 53 to 50 43 east longitudes. Alborz Mountain range with an altitude of 3000 meters and is drawn like a wall in the west and south of Guilan and this area except the Manjil Valley has no any other road to Iranian plateau. Guilan Province is limited from the north to the Caspian Sea and Republic of Azerbaijan, from the west to Ardebil, from the south to Zanjan and Qazvin Province and from the east to Mazandaran. Alborz Mountains in the West and South of the province have caused the climate to be temperate and it has high humidity in the most parts. In fact Guilan is the wettest region of the country.

To assess the risks and hazards of natural resources and agricultural sector, using relevant scientific literatures and various expert opinions, library studies, the list of all various hazards were modified.

Figure 1 shows the location of Guilan Province as a study area.

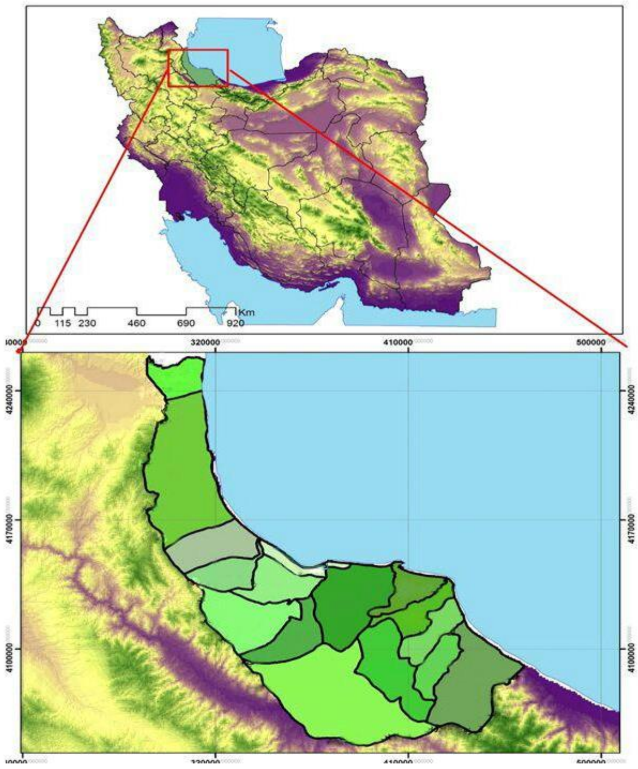

Figure 1) Location of Study Area

To assess the risks and hazards of natural resources and agricultural sector, using relevant scientific literatures and various expert opinions, library studies, the list of all various hazards were modified.

2.2- Lack of sustainability in the agricultural sector

Guilan Province due to its fertile soil and favorable climate and abundant resources of surface and underground waters is one of the potential areas to produce cultivation crops. This province with the production about two million and four hundred thousand tons of agricultural products provides equivalent to 8 to 10 percent of the country's food production. Despite the power and potential of agricultural production, this province is faced with various problems and bottlenecks in the optimal production of these products. In this study, low efficiency of agriculture, low potentiated lands for agriculture, excessive use of fertilizers and agricultural imbalance with slope in assessing the indicators of instability are involved in the agricultural sector.

2.3- Low efficiency of agriculture

Performance per hectare of agricultural products and performance per hectare of crop production has been indicated as sub criteria. The Table 1 shows sub-criteria were calculated by the value indicator of agricultural production of agricultural and garden lands.

Table 1- low efficiency of agricultural products based on different cities

Criteria	Rasht	Talesh	Bandar anzali	Amlash	Ashrafi Astane	Astara	Rezvanshahr	Masal	Langerud	Lahijan	Fuman	Sumesara	Shaft	Siahkal	Rudsar	Rudbar
Performance per hectare of agricultural products	407.34	679.46	902.64	575. 02	6629.99	1282.78	61.008	155.98	701.55	628.01	832.67	74.48	580.68	393.26	634.34	209.22
Performance per hectare of crop production	481.45	482.05	716.64	260.37	575.01	513.82	528.75	547.68	582.38	474.54	47.54	457.04	427.19	190.24	536.79	141.49

2.4- Low potentiated lands for agriculture

In Guilan province a part of irrigated and rain fed agricultural lands are deployed in areas with potential, the rest of the land in terms of soil type, slope, erosion of the amount of available water don't have the agricultural and ecological potentials but they are being used currently which decreases the production efficiency. To investigate this sub-criterion the ecological agricultural map of the province was overlaid with the current agricultural map so that the percentage of low agricultural areas for each city was achieved according to their segregation. To obtain the region's ecological potential in this study, firstly the region's inventory of resources were investigated, then considering the ecological resources of the region, it was tried to prepare the agricultural model throughout the province to be a model in accordance with the province conditions (specific model). This model can also be used as a model to use in other regions. Ecological model of agriculture in this study consists of seven floors. To prepare this model, firstly the applicable ecological model of agriculture (Makhdum et al., 2006) and combining it with other studies within and outside the country was used. In this study, to determine the final model, the expert's opinion specializing in various fields of agriculture have been used and they were totally familiar with the study area as well. At first, the ecological base model was put at the disposal of each expert and they were asked to identify the most important factors for each function and to determine the appropriate classes. After this phase, the model was adjusted and again it was available to the professionals. Other individuals have explained the reason for the modifications in the model for each expert. After the secondary modifications and changes, the final version was control with the individuals. In order to prepare the slope and orientation map the digital topographic maps 1/25000 was used. Firstly in GIS environment the slope area digital elevation model was extracted and then was classified based on Makhdum *et al*. (2006). Map of soil parameters used in this study are prepared from Agriculture Organization of Guilan Province. In order to prepare the water map, the data of water rate per hectare of the country water resources management, was used. The available information includes the amount of land water per hectare. Analysis process for the preparation of suitability ecological map of the study includes the composition of the sustainable and unsustainable ecological resource classes. Figure 2 shows agricultural suitability based on ecological criteria.

2.5- Excessive use of fertilizers

Agricultural operations lead to transmission and leaking of the used fertilizer from the agricultural lands. Soil texture, agricultural type of operation, factors of culture, nature, method of using and managing the fertilizer and irrigation methods are affecting fertilizer transmission into surface and underground water resources. As Figure 3 indicates, fertilizers after leaving agricultural land join the water resources; it leads to changes in the ecosystem and their quality. So too much use of chemical fertilizers can cause water and soil pollution. Therefore, it can be identified as a significant hazard and should be controlled.

2.6- Agricultural sectors in high slope area

Slope is one of the most important effective physiographic aspects for the farmers' utilization of the land in the area. The slope effects are studied both directly and indirectly. As Figure 4 indicates, the most obvious direct effect of the slope is preventing the cultivation and lack of access to the land. The indirect effect of slop is reflected in geology and climate changes; including the location of the water table, soil development, the heavy air movement and freezing protection. Studying the spatial distribution of agricultural lands according to slope levels show that in many areas due to high slopes the irrigated agriculture is not allowed, and these areas are under the rain fed cultivation. This process results in irreparable damage such as soil erosion, water loss, disruption of the ecological balance of the environment.

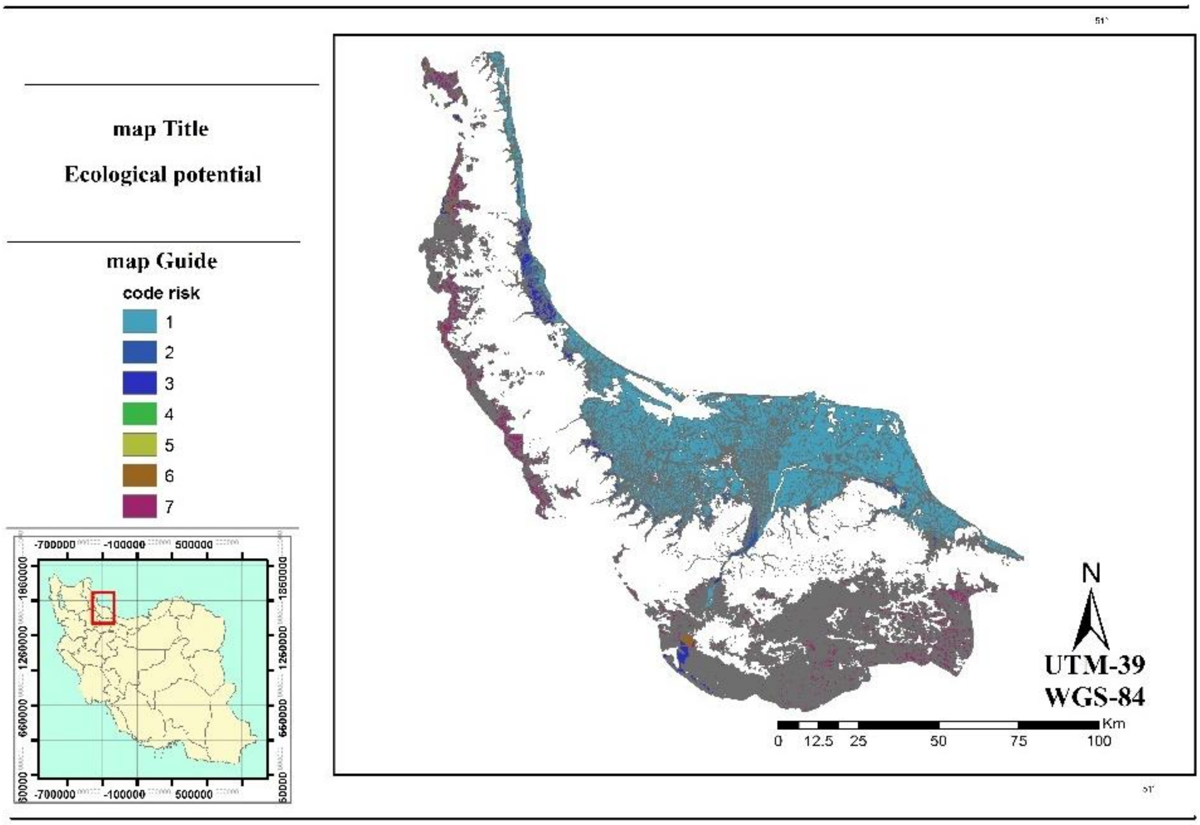

Figure 2) Agricultural suitability based on ecological criteria.

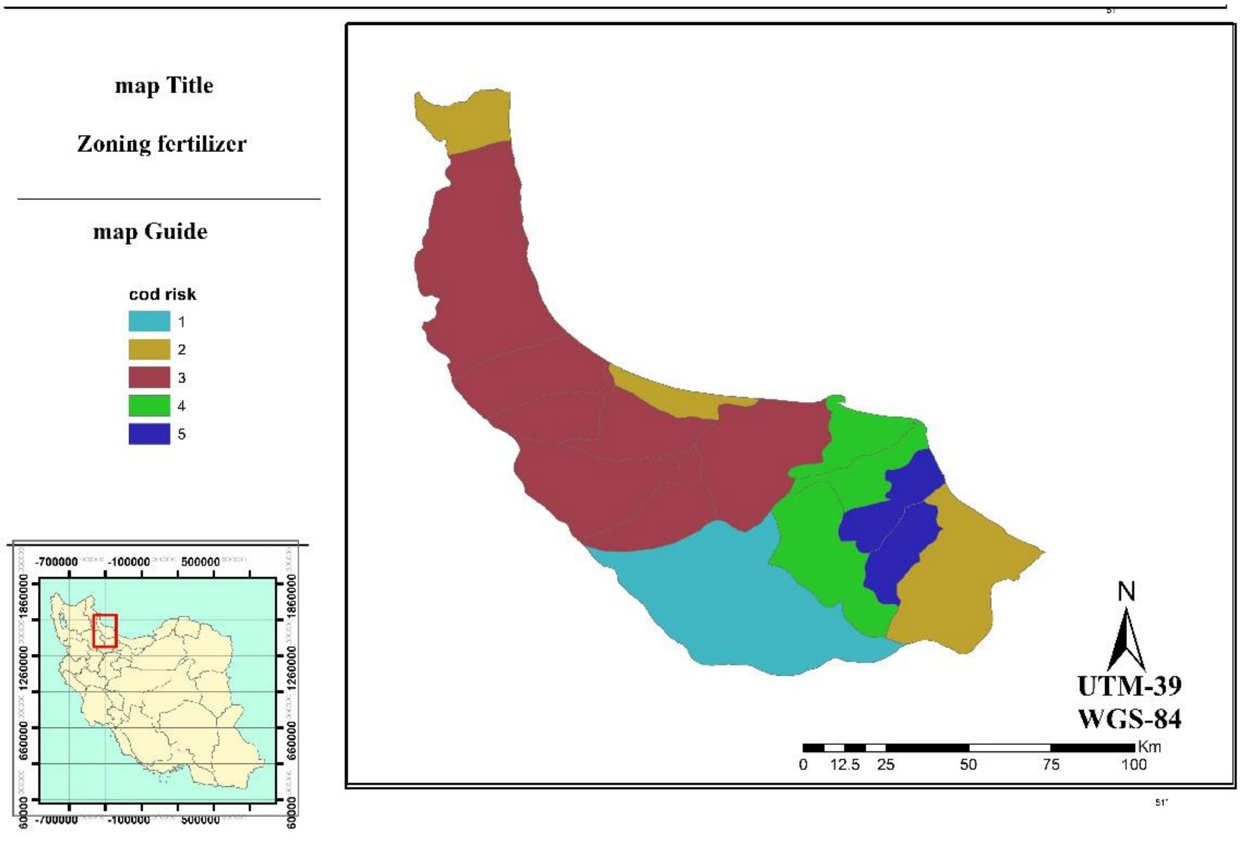

Figure 3) Chemical fertilizer consumption.

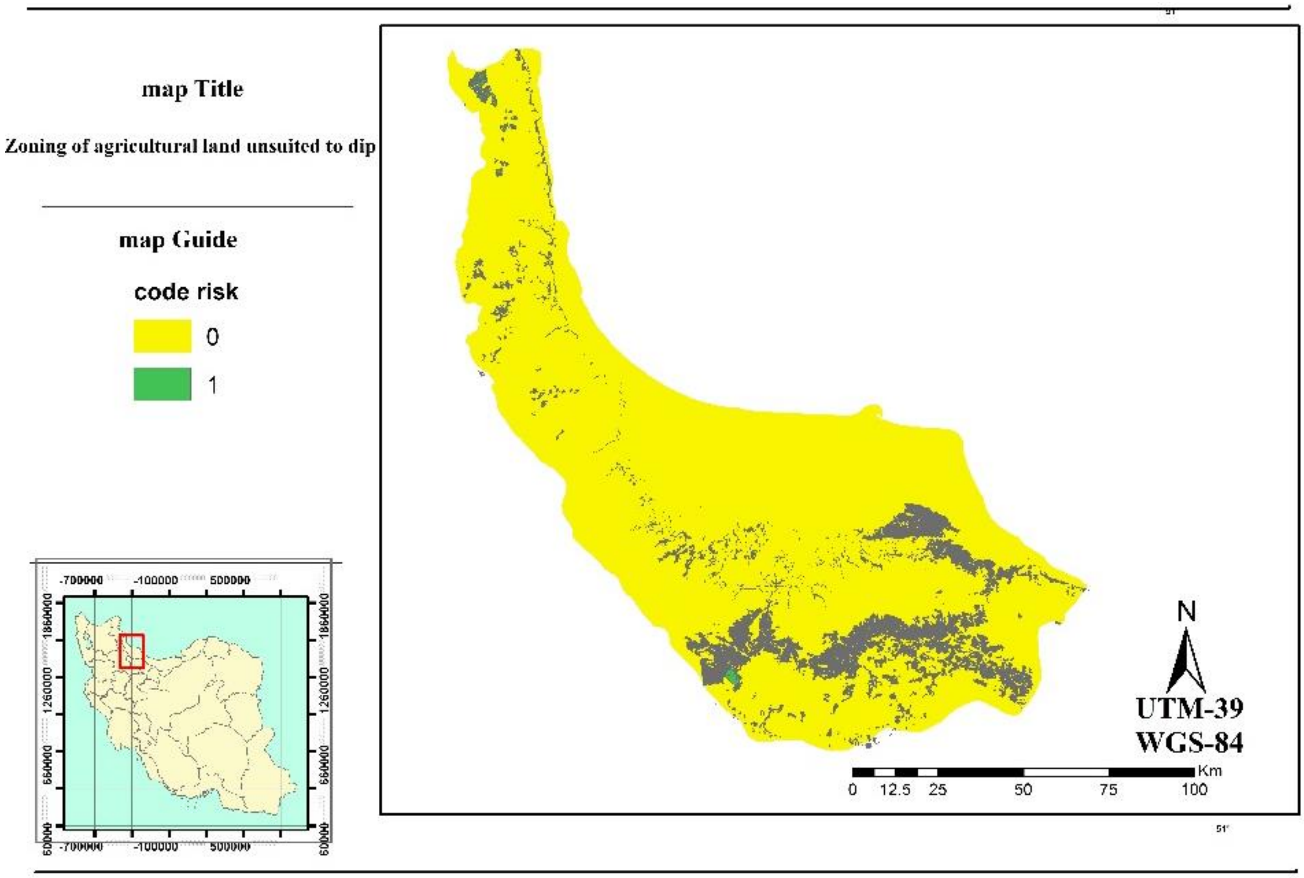

Figure 4) Agriculture development based on slope.

2.6- Natural sector problems

Any natural phenomenon that causes weakness and the destruction of economic, social, and physical abilities such as life and financial losses, destruction of infrastructure and economic resources are defined as natural disasters. Effects and damages caused by natural hazards majorly depend on settlement centers and human activities. Floods, Landslide, Earthquake, Drought, and Erosion were used to assess these sections.

2.7- Flood

One of the most devastating floods of Guilan occurred in July, 2012. After the flow of this flood, major life and financial losses have happened in this province. Intensity and duration of rainfall, spatial and temporal distribution of rainfall, condition of baseness and height, the plant cover, amount of soil infiltration, and evaporation rates are the criteria affecting flooding in the study area. The zoning map of flood with a return period of 25 years that was collected from the Ministry of Energy is the criteria for assessing the risk of flood occurrence or flood absorption. Figure 5 shows the risk-taking of flood in the cities of Guilan province.

2.8- Landslide

The movement of mass of the Earth's ingredients from a slope to downward is called landslides or mudslides. Landslide is one of the natural hazards that happen under the influence of intrinsic and stimuli factors (natural and sometimes artificial) and cause financial and life losses and damage to natural resources. Landslide risk in the most parts of the mountainous and forested mountains in altitudes above 200 meters is very important and unfortunately, a lot of constructions in recent years that have been implemented in the steep slopes are faced with this risk.

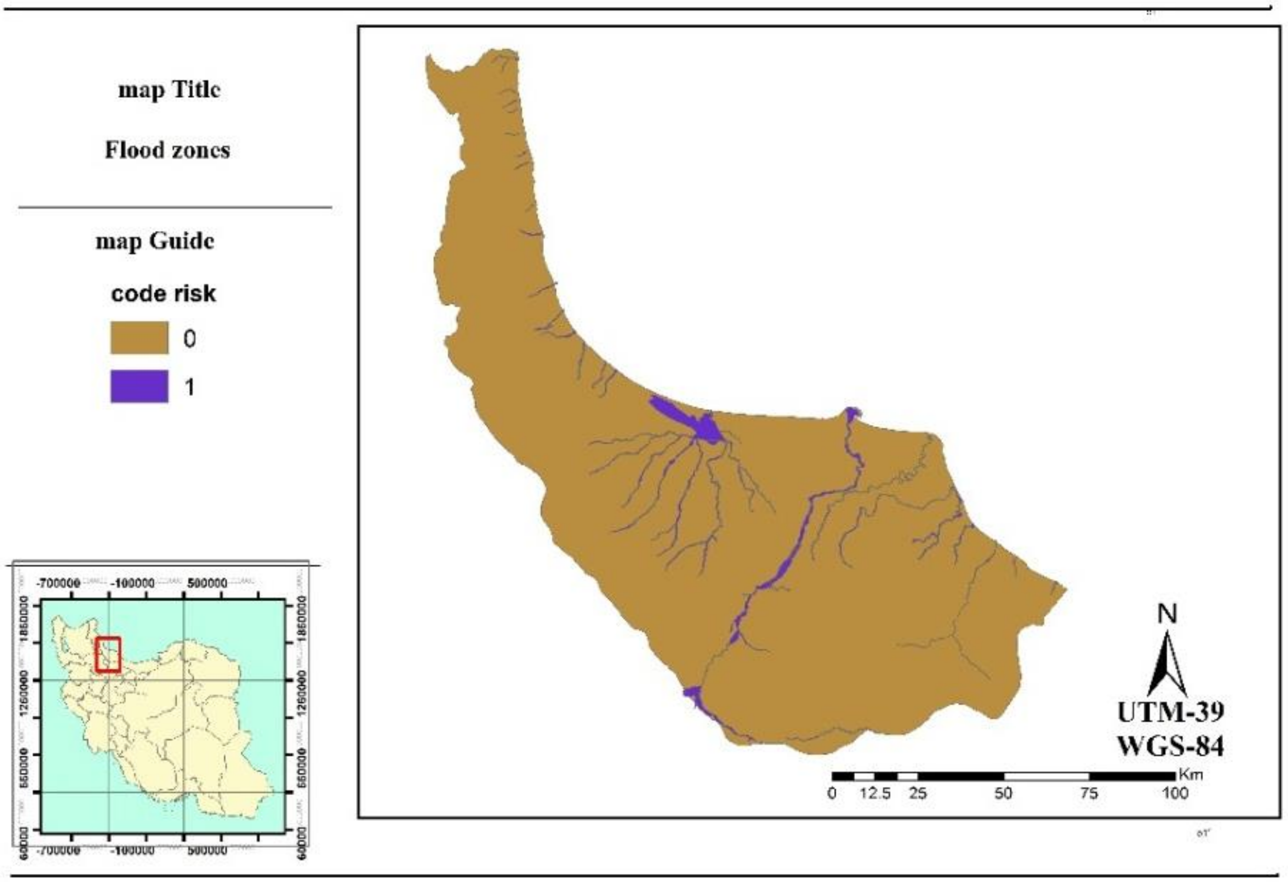

Figure 5) Risk of flood in Guilan Province.

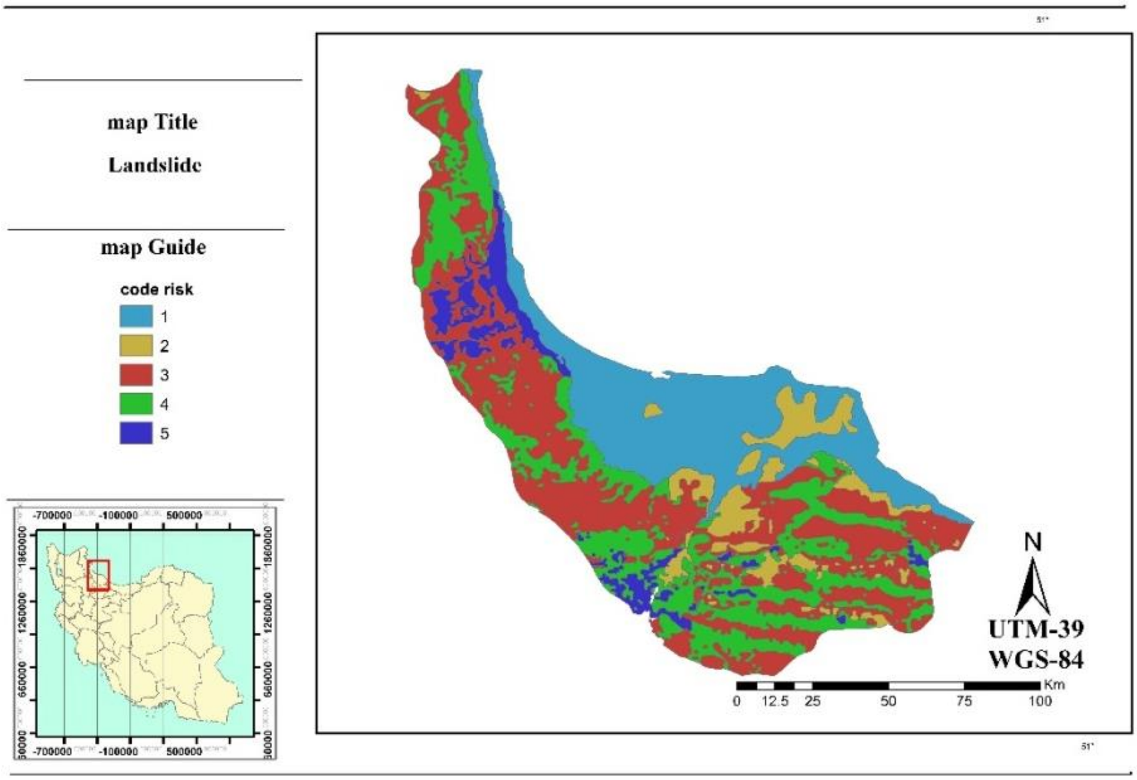

Figure 6) Landslide risk.

This issue has been recorded in Alborz mountain range and should be considered for any development. The highest number of landslides which is 82 times has happened in Rudbar city that includes total of about 37 percent of the province's total landslides. After

Rudbar, the cities of Talesh, Astara and Rudsar are the most hazardous cities in Guilan Province that are associated with landslides. Figure 6 shows landslide risk in the province.

2.9- Drought

Drought is one of the most important and perhaps the most influential natural hazards of Guilan Province. Drought concept is the water shortage compared to its normal amount. Drought imposes huge losses to the economical and agricultural sector. Drought has different effects on water resources and also crop, horticulture and livestock production. The other effects of drought on livestock sector is the decreased production of honey in the beekeeping units that in some years is on the average of 5 kg per year in each bee hive. For this sub-criterion the percentage of severe and very severe drought area is divided by the area of each city so that its numerical indicators will be obtained. Figure 7 shows Drought risk in the province.

2.10- Earthquakes

Guilan Province in the years 1991 to 2012 has witnessed 35 earthquakes. So the need to study and search for the practical solutions to prevent its harmful effects is proposed. To study these sub-criteria, the area intensity percentage of high risk and very high risk is divided by each city area. The research on the earthquake risk in the province based on the earthquake occurrence information in the province area and seismic centers show that there are three zones of high, medium, and low risks incidence of earthquakes. Central part of the province is the population and industry center of the province. In order to counter the adverse consequences of earthquakes, it seems that taking measures related to retrofitting buildings and human constructions and public education and outreach centers equipment and reinforcement of prerequisite for crisis management are essential in the province. Figure 8 shows earthquake risk in the province

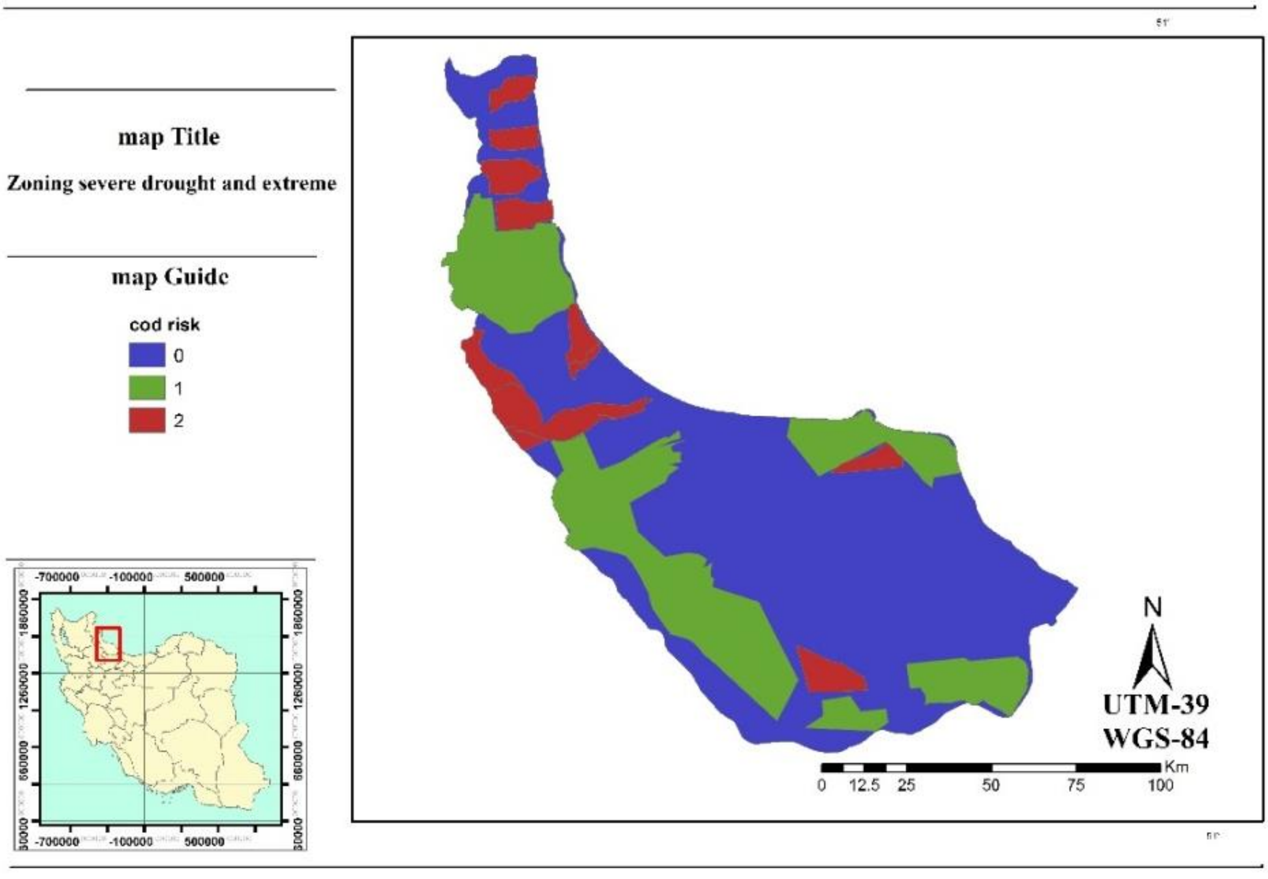

Figure 7) Drought risk in the Guilan Province

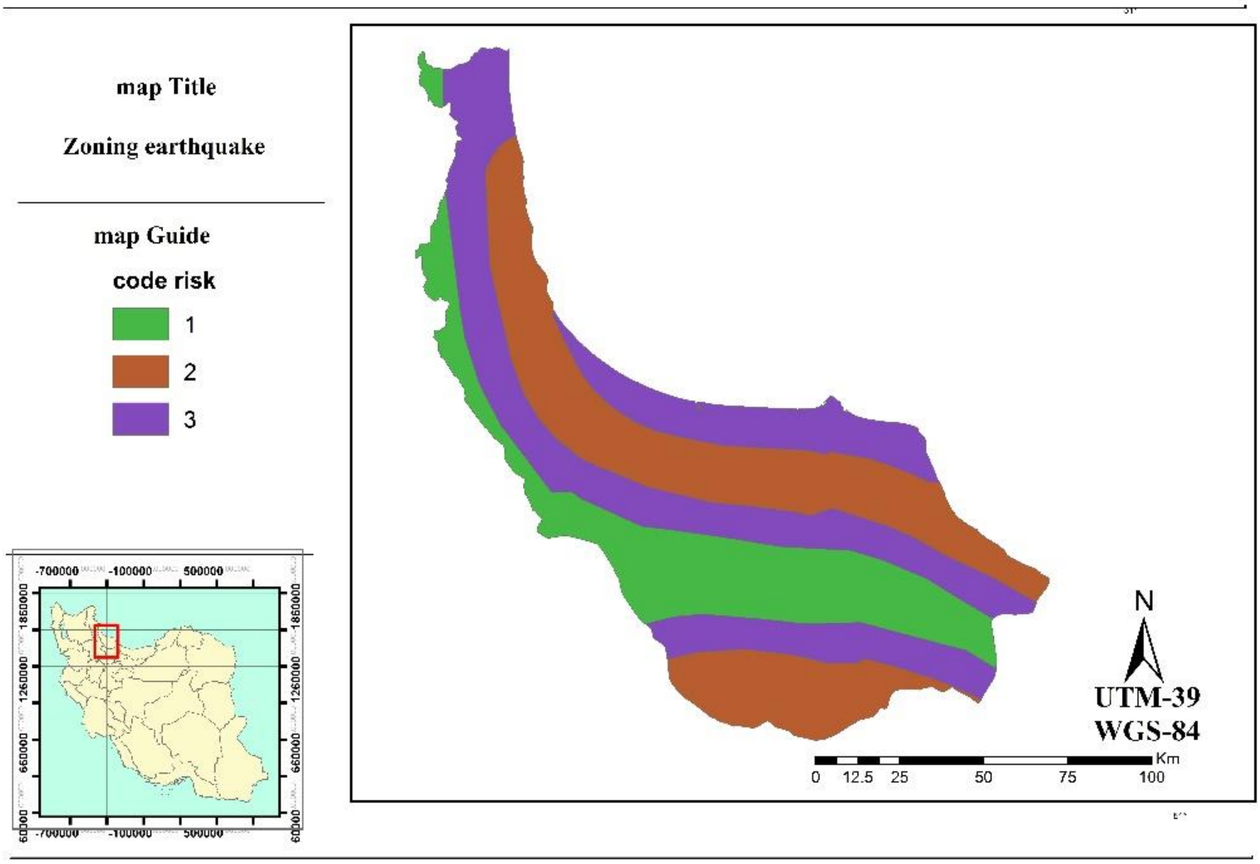

Figure 8) Classification of earthquake risk in the Guilan Province

2.11- Erosion

Soil erosion is a very important issue in many countries, particularly developing countries with arid and semi-arid climates. Among the changes in the soil, erosion has been considered as the most serious effect because erosion is irreversible and non-renewable and the rate of return, in particular with regard to factors such as amount of activity of living organisms and nature area during the growing season, temperature and humidity fluctuations are so different and require a very long time. Whereas the other effects may be modified during a decade or some of the effects may be due to human interventions and corrective actions get repaired faster. Consequences of soil erosion include; loss of soil, loss of agricultural lands and agricultural production, filling reservoir dams, deforestation, and pasture, and rural migration. Overlaying the map of severe and very severe erosion on the area of each city, the quantity index of erosion sub-criteria is achieved. Figure 9 illustrates the risk of soil erosion in the Guilan Province.

In this study, due to the use of combined approach of Entropy-TOPSIS, at first a brief description is given about both of the Entropy and TOPSIS methods. Then the combined approach of these two methods is discussed.

3- TOPSIS technique

As it was told, to rank the various indicators in the areas of natural and agricultural hazards there are several ways which do not necessarily have the same results. One of the methods of ranking that has a high power in separating options is the preference ranking technique based on their similarity to ideal solution that is called TOPSIS for short (Hwang and Yoon, 1981). TOPSIS technique as one of the Multi Attribute Decision Making (MADM) techniques and has a special place in the ranking of different concepts in the various sciences (Tzeng and Lin, 2005). The only required mental data for TOPSIS method is the importance of the weights of the criteria and this issue has made this approach attractive to the decision makers. This technique is based on the relationship that the selected alternative should have the shortest distance from the best possible positive ideal solution and have the greatest distance from the worst possible negative ideal solution. (Cavallaro, 2010). Therefore, TOPSIS concept requires an ideal point. Determining the ideal point is usually the first step to solve MCDM problems. Having the ideal point, MADM problems can be solved through the placement of alternatives or decisions, based on the fact that which on is closer to the ideal point. Now the question is that how this distance is measured from the ideal point. TOPSIS uses the Euclidean method to calculate the distance from the positive and negative points.

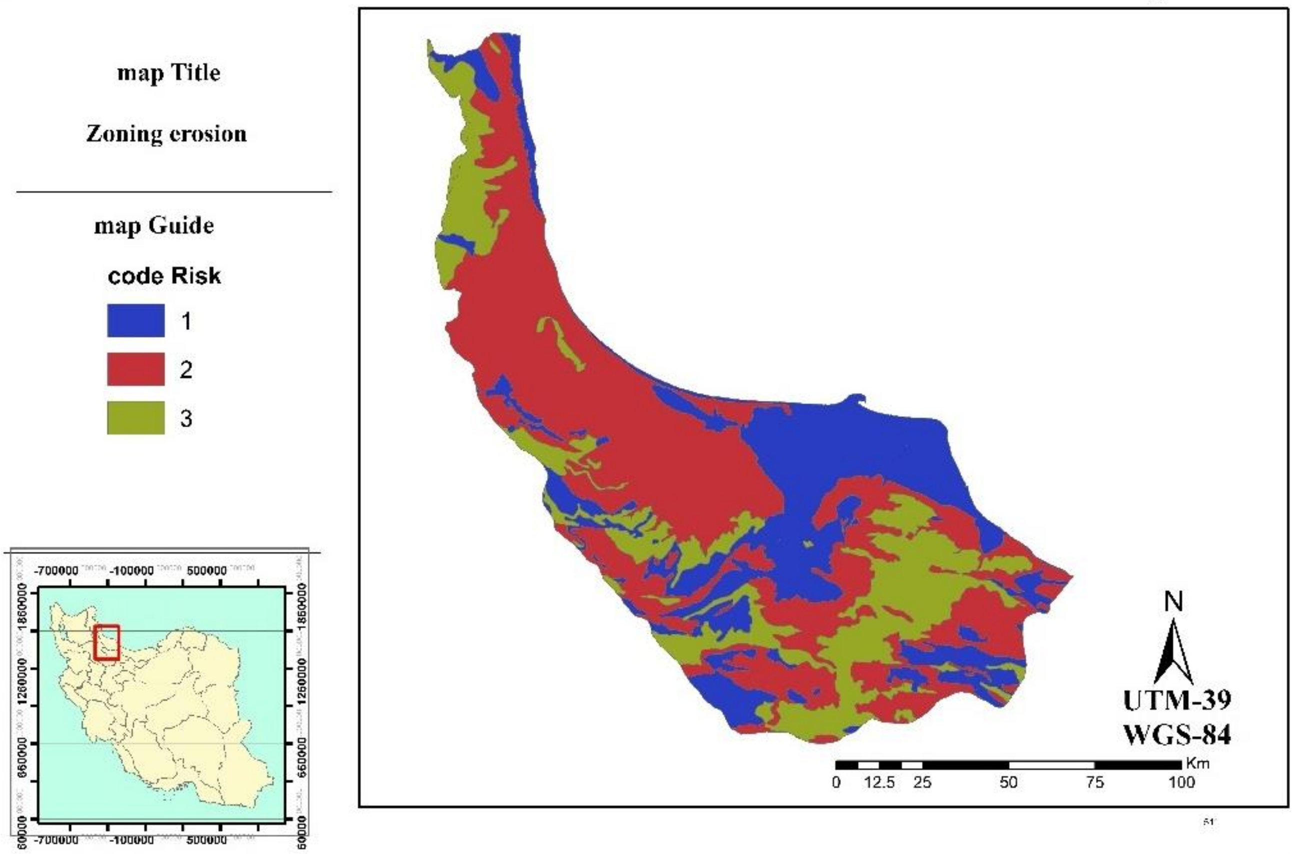

Figure 9) Soil erosion risk in the Guilan Province

4- Shannon Entropy Model

Entropy is a major concept in the physical sciences, social sciences, and information theory (Peiyue et al., 2010). The Entropy in information theory is a measure for the expressed uncertainty by a discrete probability distribution (P_i) so that the uncertainty as a dissemination of more distribution would be sharper than redundancy. Formation of decision matrix is the first step of this procedure. A decision matrix from the MCDM model contains information that Entropy can use as a criterion for evaluation. Quantifying the decision matrix is the next step. Then non-scaling the decision matrix, by using the following equation:

$$Pij = \frac{Rij}{\sum_{i=0}^{n} Rij} \qquad (1$$

Calculating the entropy of each index by the formula:

$$Ej = -\frac{1}{LN(m)} \sum_{i=0}^{n} PijLN(Pij) \qquad (2$$

Calculating the degree of information deviation of each index from the entropy amount of that index

$$Dj = 1 - Ej \quad (3$$

Calculating the weight of each index can be implemented this way:

$$Wj = \frac{Dj}{\sum_{i=0}^{n} Dj} \quad (4$$

Combining these two methods (TOPSIS and Entropy) have been implemented hierarchically in the following six steps.

a) The research method in the integrated model of Shannon Entropy and TOPSIS

Step 1: Conversion of the decision matrix to the non-scale matrix using the following formula:

$$r_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{n} r_{ij}^2}} \quad (5$$

Step 2: creating non-scale weighted matrix

To do this, the previous stage matrix is multiplied to the weight of each the criteria (vector w) so the non-scale weighted matrix will be achieved:

$$W = (w_1, w_2, ..., w_n)$$

$$V = R_D.W_{n*n} = \begin{bmatrix} v_{11},... & v_{1n} \\ v_{m1},... & v_{mn} \end{bmatrix} \quad (6$$

Step 3: Determining the ideal solution and negative ideal solution

For ideal alternative A+ and for negative ideal alternative A- are defined.

$$A^* = \left\{ \left(\max_i v_{ij} \middle| j \in J\right), \left(\min_i v_{ij} \middle| j \in J'\right), i = 1,...,m \right\} = \{v_1^+, ..., v_n^+\}$$

Negative ideal alternative:

$$A^- = \left\{ \left(\min_i v_{ij} \middle| j \in J\right), \left(\max_i v_{ij} \middle| j \in J'\right), i = 1,...,m \right\} = \{v_1^-, ..., v_n^-\}$$

Related J_s to the criteria of profit: J= **{**j=1, …, n|

Related J_s to the criteria of cost: J′ **= {**j=1, …, n|

Step 4: Calculating the distance from the ideal positive point and negative ideal point for each option using the formula. The distance of alternative from negative ideal=

$$D_i^- = \{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2\}$$

Step 5: Calculating the index relative proximity for each alternative to the point using the following equation

$$C_i = \frac{D_i^-}{D_i^- + D_i^+}$$

Step 6: Arranging the descending / ascending of the alternatives based on C_i.

4- Results

As we can see in Table 2, According to the results, the agricultural and natural risks are prioritized as follows:

The index of using fertilizer (0.466455) > Earthquake risk (0.458228) > crop production per hectare (0.457479) > flood (0.450292) > Garden production per hectare (0.411523) > Drought risk (0.388671) >the percentage of low-growing areas (0.383285) >Erosion (0.343022) > the number of landslides (0.321383).

As seen in Table 3, the final results show that in the field of natural and agricultural hazards prioritization, the greatest weight is for the amount of fertilizer consumption and lowest weight is related to the number of landslides. Finally, by overlapping the produced risk maps and entering the weights obtained from Entropy, in the raster calculate functions the points that in terms of natural and agricultural have the highest risk are obtained in the form below.

Table 2) Ranking of sub-criteria.

Environmental hazards	Cl^{+}	Ranking
The index of using fertilizer	0.466455	1
Earthquake risk	0.458228	2
crop production per hectare	0.457479	3
The area under risk of flood	0.450292	4
Garden production per hectare	0.411523	5
Drought risk	0.386671	6
The percentage of low-growing areas	0.383285	7
Erosion	0.343022	8
The number of landslides	0.321383	9

Table 3) Obtained weight of the sub-criteria by Entropy method.

Indicators	Number of landslides	Earthquake	Erosion	Drought	flood	Crops	Garden	Low Power	Fertilizer consumption
Weights	0.161392	0.039914	0.101563	0.087547	0.186211	0.041107	0.073869	0.234154	0.074243

As shown in Figure 10, based on the results, the area is divided into five classes. The first level is the very low threat class, the second level is the low threat class, the third level is medium threat class; the fourth level is the high threat class and the fifth level is critical threat class. Therefore blue areas have the highest rates of the agricultural and natural hazards and light blue areas have the lowest risk. Thus critical areas cover 15.70% of the province area. High threat area covers about 14.57% of the province, the area with average threat about 26.49%, low threat about 22.64% and arears with very low threat about 20.60% of the province area.

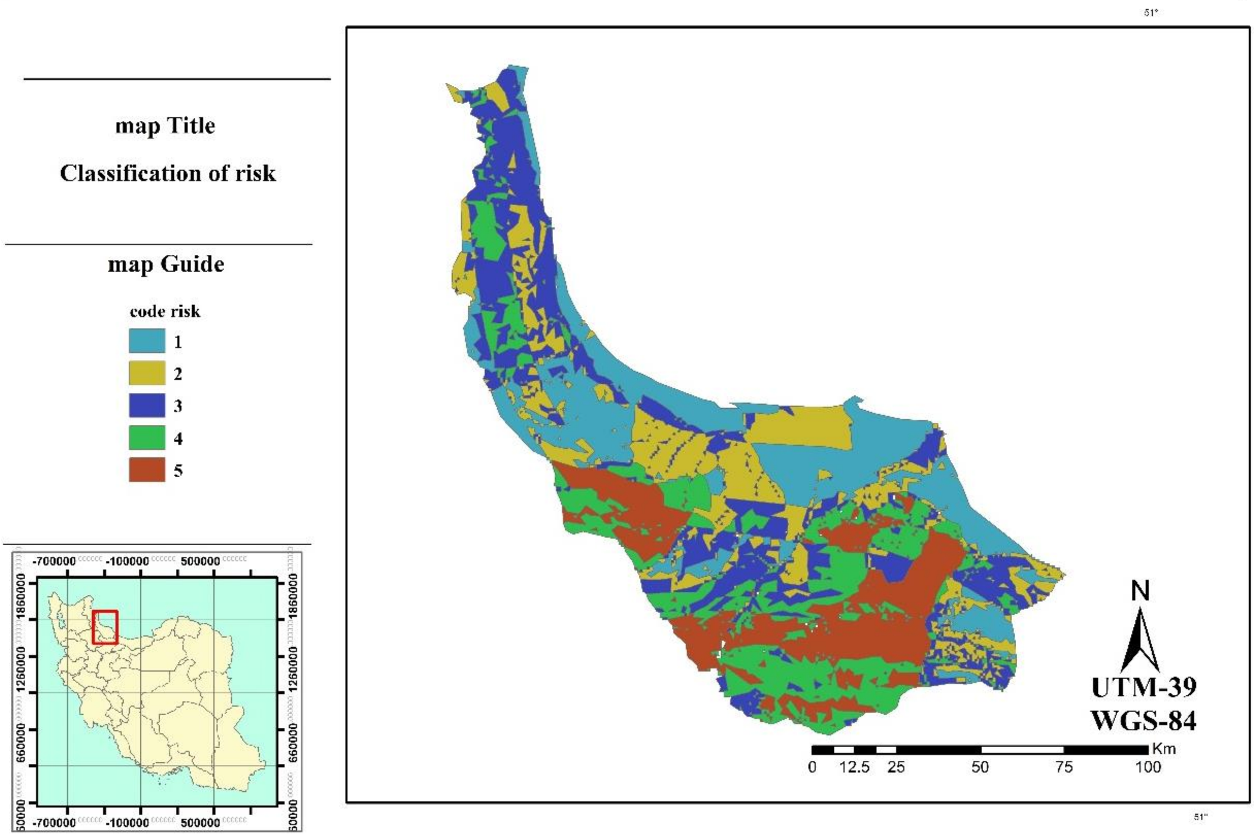

Figure 10) Natural and agricultural hazards final zoning.

5- Conclusion

This study has intended for the first time in the field of natural and agricultural hazards to compare them and also the innovation of this study is the use of integrated TOPSIS. There is a deep gap in these issues and macro risks have never been reviewed and prioritized with each other. It seems necessary that the risks in various sectors should be considered combined. TOPSIS method does not have the power of weighting the criteria so Entropy combination was used for weighting. Because of the diversity of agricultural risks and natural disasters in Guilan Province, the most important risks were selected and using the integrated model of TOPSIS and Entropy, they were identified by the priority. Given that in TOPSIS, if the result is closer to the number 1 it has a priority over the other variables. Therefore the sub-criteria of fertilizer consumption with 0.4664% with a minimum distance from the number 1, have known as the most common risk among the other sub-criteria. The earthquake risk is in the second priority with 0.4582%, crops production with 0.4574% is in third priority, flood is in the fourth priority with 0.45029%, the production of horticultural crops with 0.4115% is in the fifth priority, drought with 0.3866% is in the sixth priority, low-growing agriculture areas risk with 0.3832% is in seventh priority, erosion with 0.343 and landslide with 0.3213, respectively are in the eighth and ninth priorities. The highest level of province is average threat class with 26.49%. This shows that the province in terms of natural and agricultural hazards has the moderate risk. The main research question about the highest risk weight in the province was answered. Most of the weight is related to the fertilizer consumption in the province. Politicians by focusing on the most important priorities of the province can prevent the crisis.

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