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Zoning Analogy of Favorable Areas for Rice Cultivation Using Two Methods of Hierarchical Analysis (AHP) and Artificial Neural Network (Case Study of Kermanshah Province, Gilanegharb City)

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Abstract

One of the main pillars of sustainable development in each country is the provision of adequate food at reasonable prices for the people of that community and, given the increasing population and the need for food, identifying and introducing favorable rice cultivation areas in each region is essential. For this purpose, two methods of hierarchical analysis (AHP) and a multilayer perceptron neural network (MLP) using Levenberg-Markov teaching algorithm were used in this study. The effective layers of rice cultivation were compiled and the required maps were compiled including twelve layers including land use map, average annual rainfall, average rainfall Spring season, average autumn rainfall, average temperature Spring season, average autumn temperature, slope, altitude, relative humidity, degree-day distance from the river. Analytic hierarchy model structure is used to determine the weight of layers by analyzing AHP questionnaires. Digital layers the environmental factors in the GIS environment were combined and integrated after assigning AHP weight to each layer. The grid structure is composed of twelve input layers above and eight intermediate layers and an output layer. Land zoning map of rice cultivars was obtained for both models. Thus, in the final map, the results of each of the two models, including five classes, very unfavorable, unfavorable, relatively favorable and favorable, are respectively 22, 43, 25, 7 and 3 percent for the network and results from the hierarchical model are 15, 20, 25, 22, and 18 the total area of the city. The results show that the neural network model is more accurate than the hierarchical model. The total regression coefficient of ninety-four percent of the network, which is the result of all data in the network, indicates the high efficiency of the multilayer perceptron neural network in this zoning.

***Keywords**:* Rice, Zoning, Neural Network (MPL), Analytical Hierarchy Model

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1. Introduction

Necessary security for food supply has always been one of the problems of developing countries (Molden et al., 2007: 58). Therefore, self-sufficiency in providing food for nations is very important in order to break the dependence. In this regard, increasing the area under cultivation and achieving the highest output per unit area has always been hold. In the present era, resource constraints and increasing population and consequently increasing demand for food products, it necessitates that limited resources be used optimally (Kamali, 2009). Today, global and regional agriculture is obliged to counter the needs of different communities (Tucker. 1379: 8). Rice is half of the world's population (Sinha and Talti, 2007). In terms of world production can also equalize with wheat. Rice production in the world with an area under cultivation of 153.2 million hectares and with an average yield of paddy of 4.25 tons per hectare, is 651.1 million tons per year. About 90% of the world's rice is produced and consumed in Asia. Among rice producing countries, Iran is the 11th largest rice producer in the world with an average production of 4/9 tons per hectare, is the eleventh rice producer in the world (IRRI, 113:2010). Iran rice production until the early 1940s could partially provide the inner needs of the country. But, at present, due to the rapid increase in population and improving the purchasing power of the people, the internal product does not response the needs and considerable amounts of rice are inevitably entered from abroad every year (Fahimifar, 1992). Gilangharb has more than 40,000 hectares of agricultural lands, due to the variety of climate and soil fertility, more than 20 types of agricultural products are cultured in it. 100 hectares of lands related to rice cultivation. In agricultural planning, climatic information is used to select the type of crop, planting time, harvest, field irrigation, to justify crop production fluctuations, etc. (Hosseini, 1998). Rice cultivation as an ecological and economic phenomenon and a behavioral pattern caused by human-environment interaction, is affected by environmental conditions, especially climate, water and soil resources, and the above natural factors play an important role in providing suitable conditions for rice cultivation (Izadi Kharameh, 1994). Proper and wise planning for the optimal use of land and natural resources should be in the way that by recognizing the resources, while obtaining the maximum product and thus the maximum profit for the users of these lands, resources as well as the environment to be safe (FAO, 1976).

In this planning for the proper use of land, gathering information is the main problem of planners. Agricultural zoning can be used as a very effective tool to better resource assessment, planning and management of land resources (FAO, 2002). Identifying and explaining proper places for growing different crops according to different climatic needs, soil type and suitable topographic conditions are the factors that rise crop production. In the same context, various jobs have been done both globally and nationally to assess the local capabilities of different products. Mohammadi and Moghtadari (2004) evaluated the climatic potentials of palm cultivation in Golestan province, Mohammadi and Karampour (2005) examined Feasibility study of saffron cultivation in the south of Sabzevar city, Farajzadeh and Mirzabiati (2007) Feasibility study of saffron cultivation in Sabzevar city. Samantha et al. (2011) Using geographic information system, and multi-criteria decision-making method, zoned the province of Moorebe in New Guinea for rice cultivation. In this study, soil, climate, topography, water resources and land data were used and the results showed that only four percent of this area has a very good proportion and 21 percent has a moderate proportion for rice cultivation. Jarais et al. (2002) analyzed the data of climatic elements in GIS environment by interpolation method and performed agro-climatic zoning of crops. Khan et al. (2009) started a study on the evaluation of arable land for agricultural products. In this study, they used climatic factors and elements including altitude, slope, soil type, temperature, rainfall during the day and the rate of evapotranspiration and finally prepared a map of suitable areas for cultivation of these plants. Despite the strategic importance of rice in supplying the country's food needs, no studies have been conducted to identify suitable places for rice cultivation, except in the northern part of the country, where almost all places have the potential to grow rice. GilaneGharb, which has traditionally been cultivated for this crop, is very important, and by identifying suitable places for the development of rice cultivation, its cultivation capabilities can be examined in the geographical areas of the city and its cultivation can be developed. The purpose of this article is to identify places with Rice cultivation potentials by using a comparison of two models of multilayer perceptron neural network and hierarchical analysis (AHP).

2. Materials and Methods

Gilanegharb city is in the west of Kermanshah province with an area of 1465 square kilometers are located between 33 degrees and 49 minutes to 34 degrees and 28 minutes northern latitude and 45 degrees and 51 minutes to 46 degrees and 37 minutes eastern longitude toward the Greenwich meridian. The city has 40,186 hectares of agricultural lands. This city has a temperate climate and due to the diversity of climate in the seasons, it has fertile soil, abundant water and good weather.

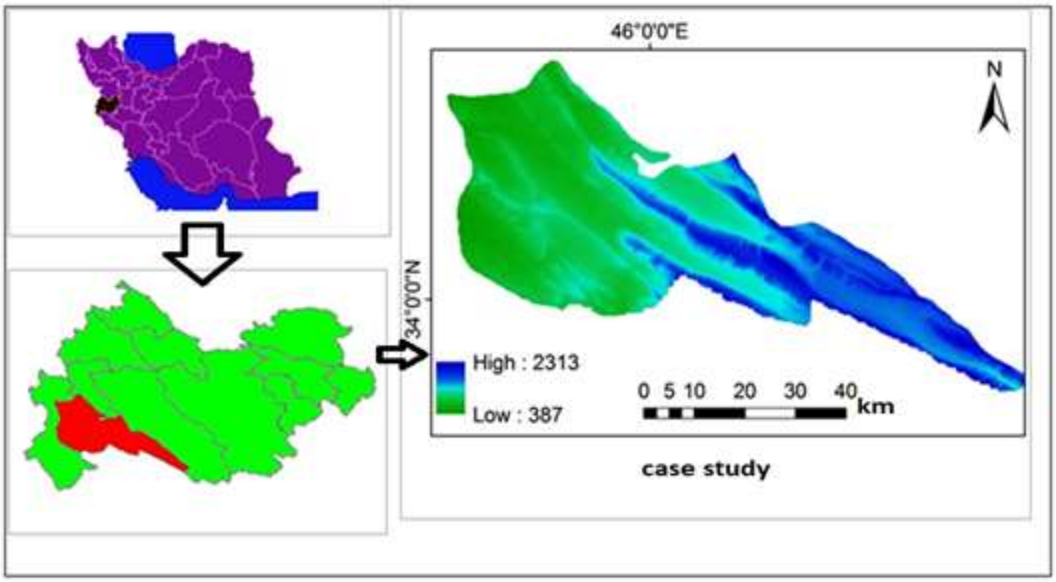

Figure 1. Geographical location of the study area

2.1. Determining and Extracting Important Parameters on Rice Yield

In conducting this research to extract effective and key layers in rice zoning, important and determining factors in rice yield that have been previously studied by other people and also the natural characteristics of the study area were used. For this purpose, 12 parameters include: mean annual precipitation (Figure 2), average autumn rainfall (Figure 3), average spring rainfall (Figure 4), average annual temperature (Figure 5), average autumn temperature (Figure 6), average Spring temperature (Figure 7), slope (Figure 8), distance from the river (Figure 9), altitude (Figure 10), relative humidity (Figure 11), degree-day (Figure 12) and land use (Figure 13) was determined and prepared.

DEM with a resolution of 30 m IRS was used to prepare the altitude map and the slope was prepared from DEM. Maps of average annual rainfall, autumn and spring were extracted from rainfall stations data in Gilanegharb city in a period of 40 years. Maps of mean annual temperature, autumn, spring, degree-day and relative humidity were performed by using data from synoptic stations in the province. The river layer was obtained from the rivers of the city and the land use obtained from the Landsat 8 image classification was used.

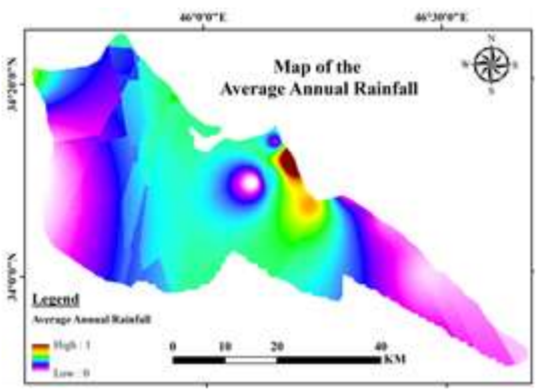

Figure 2. Map of average annual rainfall

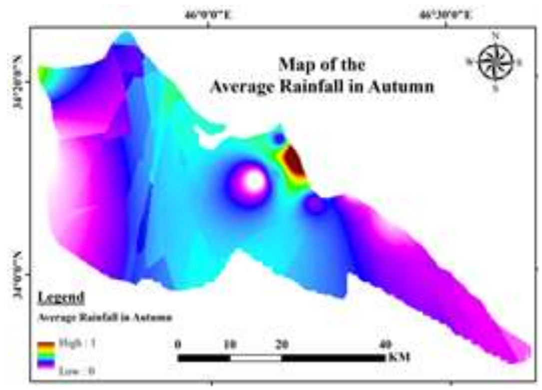

Figure 3. Map of autumn average rainfall

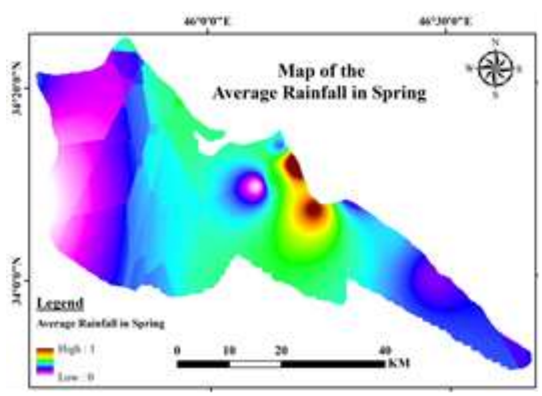

Figure 4. Map of spring average rainfall

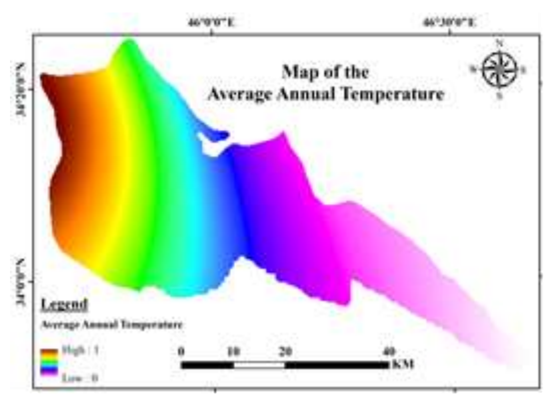

Figure 5. Map of average annual Temperature

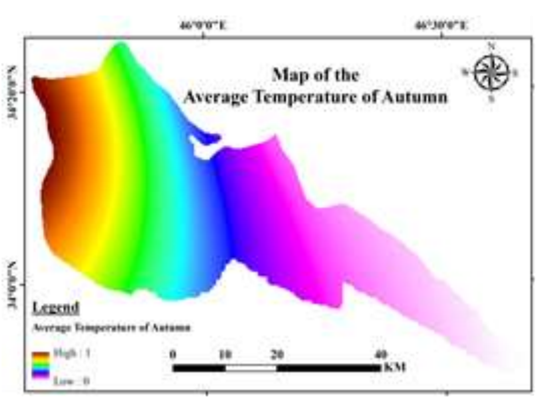

Figure 6. Map of average of autumn Temperature

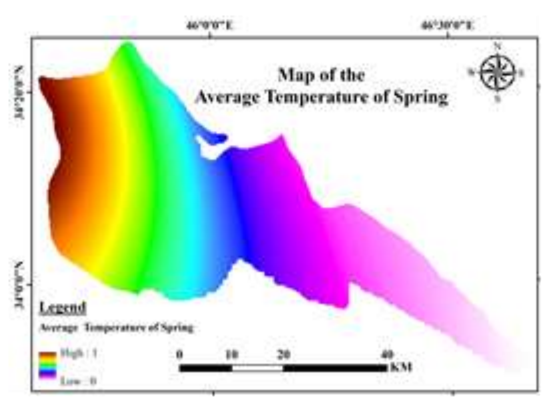

Figure 7. Map of spring average Temperature

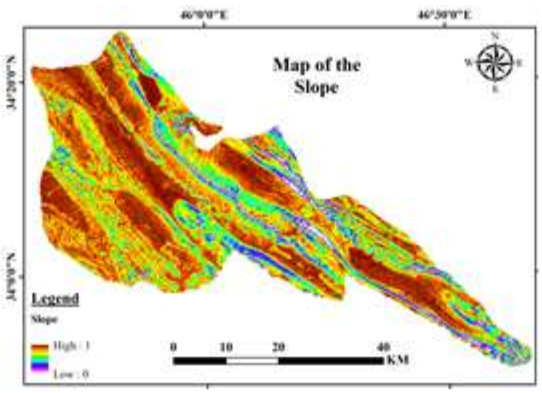

Figure 8. Slope Map

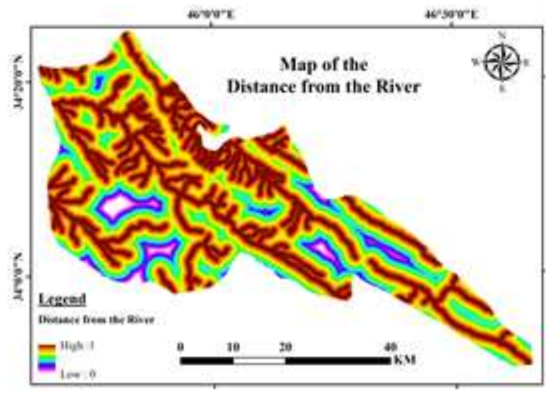

Figure 9. Distance map of the river

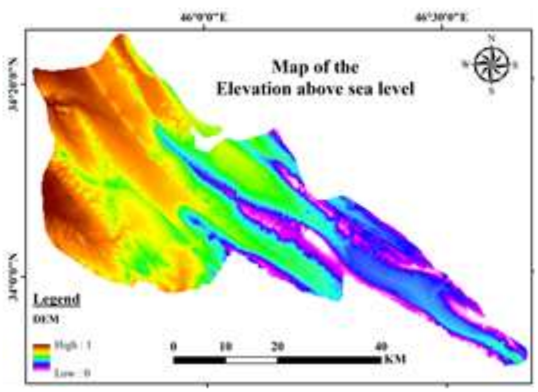

Figure 10. DEM map

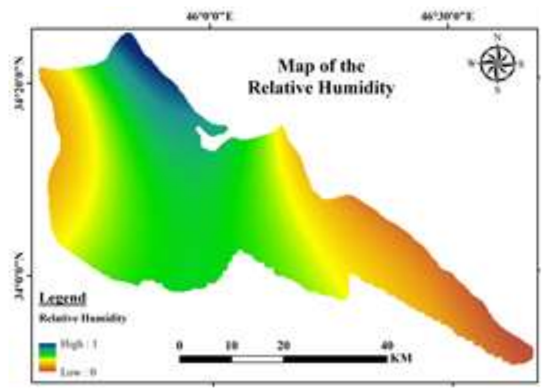

Figure 11. Relative humidity map

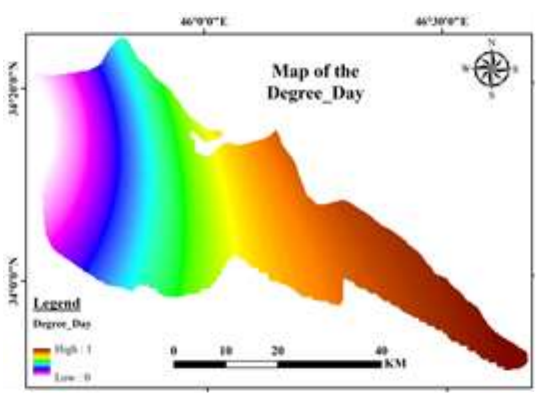

Figure 12. Day degree map

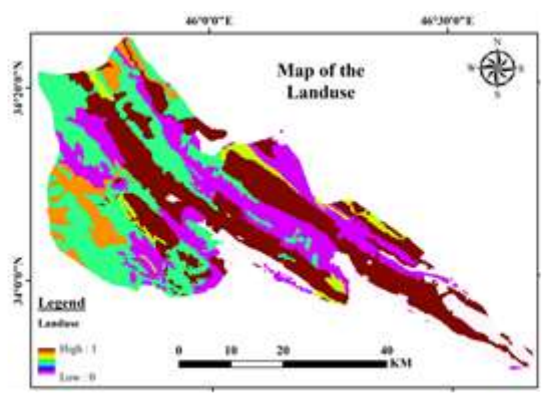

Figure 12. Land use map

2.2. Analytic Hierarchy model (AHP)

A questionnaire was used to collect data on the hierarchical analysis process and the weight of the criteria. These questionnaires contain a common comparison for all factors affecting zoning, which was completed by agricultural experts in the city of GilaneGharb based on Table 1, and after collecting the questionnaires, their analysis was performed by Expert Choice software. Expert Choice software is a specialized statistical software that it operates on the basis of the AHP method and the task of the AHP, which based on the calculation method determines the priority of the options given based on the numbers and values given to it.

Table 1. Hourly scale to determine the degree of preference for pairwise comparisons.

Numerical value	preferences (oral judgment)
1	Same preference
3	A little preferred
5	More preference
7	Much more preferred
9	Absolutely preferred
2, 4, 6, 8	Preferences between the above distances

2.3. Neural Network

After preparing the input and output vectors of the MLP neural network were trained by training data in MATLAB software environment. Considering the variable yield of rice and its extreme dependence on environmental factors, it can be said that rice yield depends on many factors. To work with the artificial neural network, first the effective parameters in the performance of the rice crop must be given to the network as input layers and then a number of training points must be provided to the network by using these points to determine the extent of the impact of each of the input layers, In fact the network has received the necessary training to encounter new areas, after preparing the input indicators or the INPUT to prepare TARGET, 160 training samples were selected (Figure 14). These training points are divided into three parts: the first part is related to network training, the second part is divided to stop the calculations when the error increases and the third part is divided to verify the network (Jalili Ghazizad and Nouri, 2008: 13 Kiar Tuys, 1995: 2 Hong "et al., 245: 2002). Among the 160 training samples, 70% of the data is used in network training, 15% for the validation that the software uses to calibrate the model, and finally the remaining 15% for evaluation and inference. To facilitate convergence in artificial neural network, the numbers of input neurons should be normalized because entering data into raw causes reducing network speed and accuracy. The following formula was used to normalize the data in this study.

$$x_y = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}} \tag{1}$$

x_y the normalized value (value) of the desired layer, x_i input layer value, x_{min} minimum is the lowest layer value and X_{max} is the highest layer value. There are many methods for selecting the number of neurons in the middle or hidden layers, one of the methods which is studied in this research, is the trial and error method. In this method, the best choice for the number of middle layer neurons is made when network error is minimized during the network training and testing process.

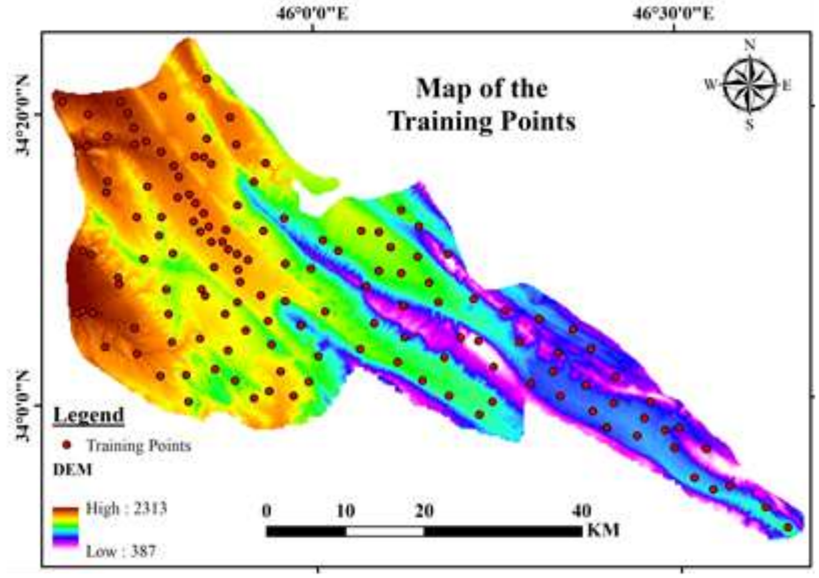

Figure 14. Dispersion map of educational points

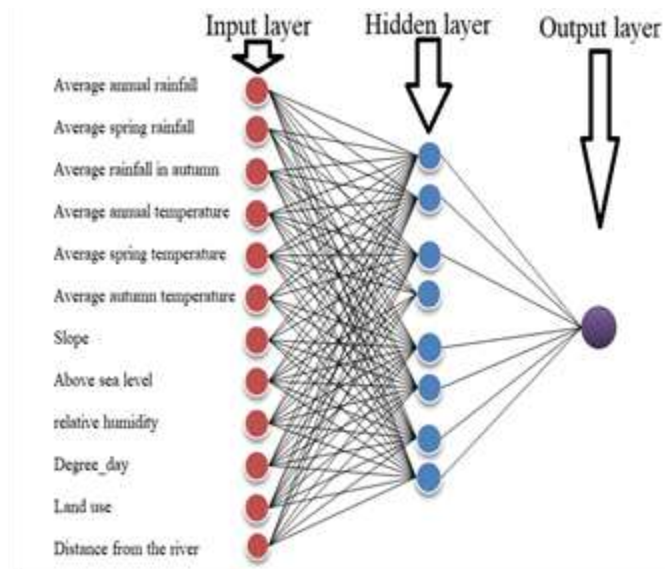

Figure 15. Research neural network structure

3. Results

Figure 15 shows the schematic structure of the proposed neural network. According to Figure 15, the network has 12 neurons in the input layer, which are the same factors that determine the performance of rice, one neuron in the output layer, which causes an output map, and the number of desired neurons in the middle layer which are determined for network by trial and error equals to 8 neurons. In this case, the network has the lowest error and the highest correlation coefficient. The error propagation algorithm has three learning algorithms: a network with simple learning coefficient (trainbp), a network with variable learning coefficient (trainbpx) and a network that uses the Lunberg-Marquat method (Nouri et al., 2010: 439. Nouri et al., 2011: 5856). In this study, the Lunberg-Marquat method was used to train the MLP network. The MLP network was run with a structure of 12 input layers, 8 middle layers, one output layer and the Levenberg-Marquat training algorithm, and the necessary training was given to the network to encounter new examples.

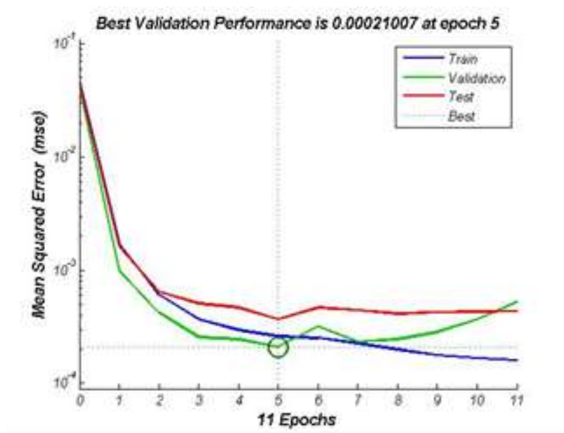

Figure 16. Fitting the number of repetitions in the neural network

Figure 16 shows the number of multiplicities in the network, as shown the network has obtained to necessary trains after 11 times repetition that the best result has repetition in repetition 5.

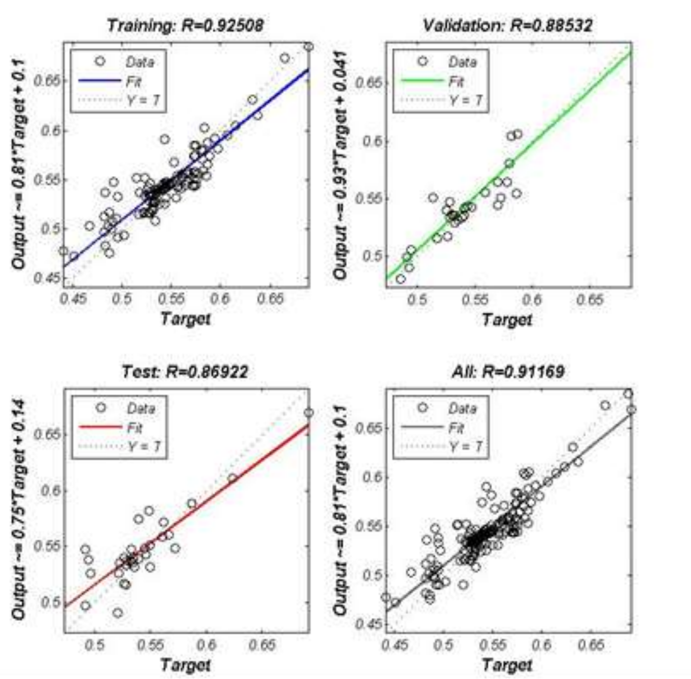

Figure 17. Fitting diagram and correlation coefficient at different stages of the network

Figure 17 shows the fitting diagram and regression coefficients of the training, validation and final neural network stages, which show the high values obtained for these stages. One thing that is very important in working with the network is to prevent the network from learning too much, because in this case, instead of learning and understanding the relationships between the parameters, the network starts memorizing the information that has been provided to it (Gomez et al., 2002: 23). As mentioned earlier, 160 training samples are divided into three sections, and the second section, the section to stop calculations when the error increases, is embedded in the network structure to prevent over-learning of the network. Due to the high correlation coefficient of this step, it can be ensured that the network over-learning is well prevented, and finally the high regression coefficient of the network, which is the result of joining all the data in the network, was 94%. After completing all these steps, the network will receive the necessary training to face new areas and can evaluate the new areas based on what it has learned, so the entire study scope, which contains 160,000 pixels, is available to the network and Based on the weight of the criteria obtained from the training, the network performed zoning on the entire study scope. The output obtained from this stage was a layer with a value between zero and one, which was divided into 5 floors. Table 2 shows the zones and values obtained from the neural network model and Table 3 shows the zones and values of the hierarchical analysis model. Figures 18 and 19 show the zoning map of both models.

Table 2. Neural network results

Class	Very unfavorable	Unfavorable	Relatively favorable	Very favorable	Very favorable
Percentage of area	22	43	25	7	3
Area (square kilometers)	322	630	366	103	44

Table 3. Hierarchical analysis model results

Class	Very unfavorable	Unfavorable	Relatively favorable	Very favorable	Very favorable
Percentage of area	22	43	25	7	3
Area (square kilometers)	322	630	366	103	44

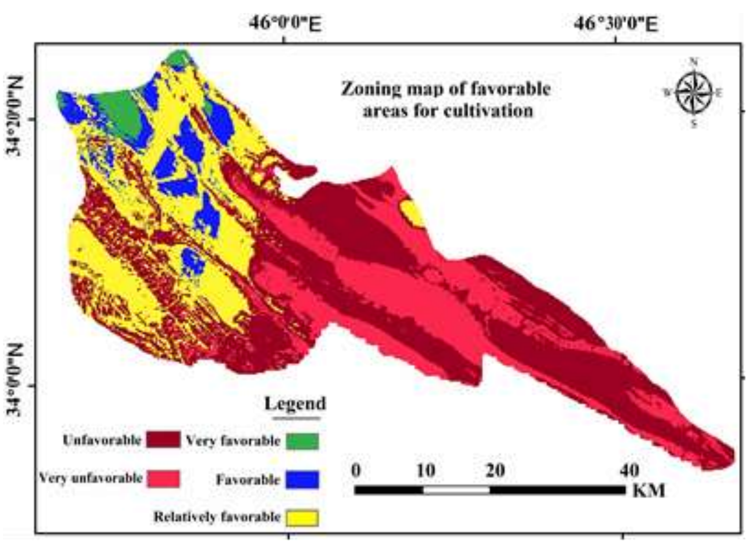

Figure 18. Zoning map of rice cultivation areas in Gilangharb city with neural network model

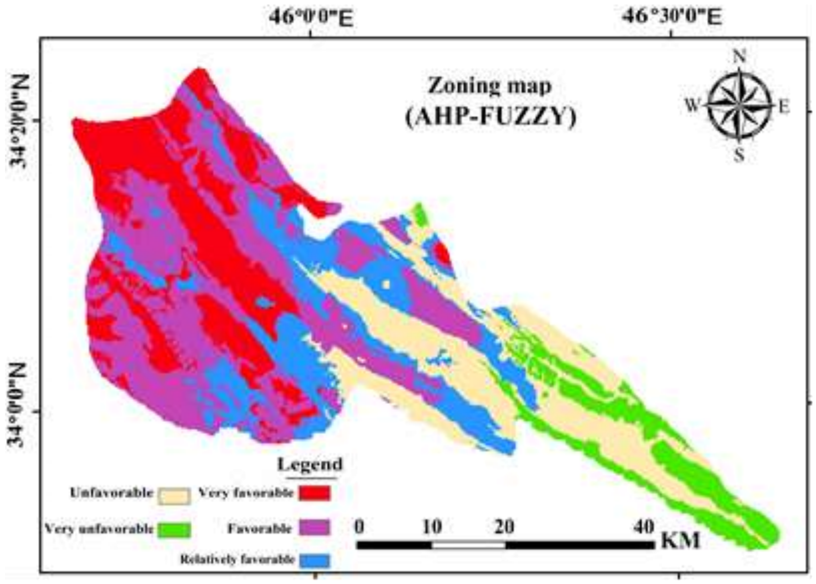

Figure 19. Zoning map of rice cultivation areas in Gilanegharb city with hierarchical analysis model

4. Conclusion

Considering the importance and role of rice in feeding the people of the country, identifying and introducing favorable areas for its cultivation in each region, in addition to increasing the production efficiency, will also improve the economic conditions of the people. To achieve this goal, in this study, a comparison of two methods of multilayer perceptron neural network and hierarchical analysis model was used. Other studies in this field, for example: Farajzadeh and Pournasir (2010) studied the environmental conditions and especially the climatic conditions affecting rice cultivation and determining its climatic thresholds to identify potential areas for rice cultivation in Lorestan province. The results of this study, which was performed using a simple weighting method, show that the appropriate area for rice cultivation in Lorestan province is about 28,000 square kilometers, which covers about 27% of the province. In the present study, more effective results were obtained by adding more effective layers such as distance from water sources and using the neural network intelligent method and comparing it with the hierarchical analysis model method. The results showed that 22% equivalent to 322 square kilometers of the total area of the city is very unfavorable in terms of potential rice cultivation, 430% equivalent to 630 square kilometers unfavorable, 25% equivalent to 366 square kilometers relatively favorable, 7% equivalent to 103 square kilometers favorable and 3% equal to 44 square kilometers is very favorable in the neural network model and 15% equals 220 square kilometers of the total area of the city is very unfavorable, 20% equals 293 square kilometers unfavorable, 25% equals 366 square kilometers is relatively favorable, 22% equals 322 square kilometers is favorable and 18% Equivalent to 264 square kilometers is very favorable in the hierarchical analysis model. According to the statistics obtained from the city, only the northern and northeastern regions, of which Deira plain is one part of them, are suitable for rice cultivation due to their proper climate. According to the result obtained from the hierarchical zoning map, it is observed that more favorable areas continuously cover the area of the city, which is discretely displayed in the map obtained from the artificial neural network method of the mentioned areas. According to the results obtained from both methods, it is clear that the accuracy of the artificial neural network method is higher than the hierarchical analysis model method. The neural network model has allocated a smaller percentage of the province area to a favorable area for cultivation, while the hierarchical model has shown a large percentage to be suitable for the cultivation of this crop. According to environmental conditions of Gilanegharb, geographical location and accessing to area water, certainly the artificial neural network method is more than the series analysis model method. The total area of the city in terms of rice cultivation potential is not at the same level and crop yield in each class is different from another class. Therefore, knowing the best areas for growing this crop will increase production efficiency, reduce losses and waste resources.

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