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Evaluation of flood potential of Ardabil plain using fuzzy models and satellite images

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Abstract

Ardebil plain is one of the flood points that requires the understanding of the flood potential. In this study, the flooding potential of Ardebil plain was performed using environmental parameters, observations of flood points and lack of floods and prediction algorithms were made including random forest and logistics regression. Independent parameters include DEM, Slope, Aspect, Distance from waterway, distance from dam, runoff accumulation, land use, landforms and indexes Topographic Position Index (TPI), Modified Catchment Area (MCA), Terrain Ruggedness Index (TRI), Topographic Wetness Index (TWI) and Stream Power Index (SPI) Indices. The Roc-AUC assessment results showed that the RF and LR model were validated by 0.99 and 0.98, and it shows that random forest models and logistics regression have the ability to predict and prepare a flood sensitivity map in Ardebil plain. The output of parameters effective in flooding showed that the marginal areas located around the central plain of Ardabil have less flood-flooding potential than the central areas. The results also showed that by moving from the southwest of the plain to its northeast, the grade of floods increased. This increase in flooding potential around the main drainage of the plain is greater than elsewhere.

Keywords: Ardabil Plain, Flood, Logistic Regression, Random Forest.

Introduction

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Todays, the increase in demand for housing, the expansion of industrial-commercial facilities, and the lack of space for residential construction have caused changes in the morphology of watersheds (Tang et al., 2005). Land leveling for human uses, trespassing on rivers and waterways for economic use of adjacent lands and supplying water from the river, changing natural uses to human landscapes lead to changes in the natural drainage pattern has become a disturbance in the hydraulic behavior of water streams and eventually flooding (Schilling et al., 2014). The consequence of these changes is an increase in the risk of flooding, inundation of residential areas and inundation of agricultural lands, which causes great damage to the environment. The most important factor in increasing the flood risk is the expansion of residential uses in watersheds, which disrupts the morphological balance of the environment and increases the impermeability levels, which the main reason is the use of concrete and asphalt materials. This man-made component increases the volume of runoff and flood, reduces the concentration time, increases the instantaneous maximum discharge and changes in the quality of the flood (Garner et al., 2019). With the occurrence of torrential and heavy rains, a large volume of water enters the natural environment.

The water flow from the upstream tributaries of a waterway is transferred to the main river in the watershed and causes the base flow of the river to rise. When the water exits from the main channel, the plain and the surrounding areas go under water and cause flooding of residential, agricultural and natural lands in the region (Van Coppenolle et al., 2018). River floods often originate from the accumulation of runoff from main and sub-tributaries in watersheds. Flooding is one of the hydrological hazards that various factors such as weather, geology, geomorphology, environment, urban management, land use, natural resources and watershed management play a role in its creation. Although torrential and heavy rainfalls are considered to be the main generator of floods, after the occurrence of rain, other environmental factors are also involved in the intensification of floods. Land uses and the topographical position of the river bed and waterways play a major role in the occurrence of floods. If 50 mm of rainfall occurs in areas with impervious surfaces such as residential uses and mountains with rocky cover and steep slopes, the rainfall will quickly turn into runoff and cause flooding in downstream areas; but if the same rainfall occurs in areas with permeable surfaces such as forest areas, dense pasture cover or in areas with a low topographical slope, it cannot lead to flooding, because most of the rainfall penetrates the surface soil and produces less runoff.

Vegetation plays an important role in preventing floods, because it causes water to penetrate into the soil and it reduces the speed of surface runoff and slows down the flow of water and reinfiltration of water into the soil. Therefore, environmental factors play an effective role in the hydrodynamic behavior of water, and human intervention in the environment changes these factors and ultimately changes the flow of water, and when human and natural factors increase the speed of water, flooding is intensified, and when the speed of water decreases, the flood process is reduces. In the flood of July 2018, the Pacific Ocean cyclone entered the island of Japan from the north-west side, and caused flooding in the northern half of the island of Japan (Ai and Qian, 2020). In southern Brazil, heavy rainfall is often caused by a low pressure system that formed 3 days ago in the Pacific Ocean (Teixeira and Satyamurty, 2007; Seluchi and Chou, 2009). In order to manage and control floods, it is first necessary to assess the flood potential of the watersheds AAaay add Baaaaa ççç yiii ,,)))))) cc cgggggggeee ffffeeett caaaacrrrtttsss ff eee aa r eee,,, the determination and selection of criteria in the flood assessment of the watersheds are different (Zzaman et al., 2021).

The degree of influence of each criterion on the level of flooding is different (Abedini and Beheshti Javid, 2017). In the urban floods of Ilam, the criterion of the distance from the waterway has the greatest effect on flooding (Ziary et al., 2022). The researchers showed that hydroclimatic parameters are the most important criteria in Bagan watershed flood (Nasrin-Nejad et al., 2014). In the Bagh-Malek catchment area, land use is the most important factor in flooding (Mosavi et al., 2015). In Mazandaran province, the height factor has the greatest influence on the flooding of this province (Shahiri Tabarestani and Zakai, 2020). In Junqan watershed, permeability of geological formations, slope, sensitivity to erosion and depth of soil have the greatest effect on flooding in the watershed (Feiz Nia et al., 2016). Land slope is the most important factor in flooding in Yasouj catchment area (Rahmati et al., 2016). The results showed that the distance from 1 to 200 meters from the Fazih River in Taiwan has the highest flood risk (Chen et al., 2011).In the mountainous sub-basin of Barajin in Qazvin, the weather criterion with a weight of 0.65 is the most important in the occurrence of floods in the basin (Mosaffaie et al., 2020). Researchers showed that the risk of flood vulnerability in the coastal belt of the Western Ghats in India is high (Das, 2020). In the Arachtos catchment area in Greece, the slope of the land in this area has the greatest effect on the occurrence of floods (Schismenos et al., 2021).

The results of studies showed that in the Sundaraban catchment area in India, the distance from the river has the greatest effect on the occurrence of floods (Ai and Qian, 2020). In addition to heavy rains, terrestrial factors such as local geology, geomorphology, hydrology and land use play a role in floods in the island of Jamaica (Nandi et al, 2016). In the southern areas of the Gaza Strip, the logistic regression model was used to investigate the degree of flood sensitivity (Al-Juaidi et al., 2018). In the floodplain of the Savaga watershed in the Philippines, land use has made many areas vulnerable to flooding (Puno et al., 2020). Flood Susceptibility Zoning (FSZ) in Mumbai was done using models based on Geographic Information Systems (GIS), Evidence Belief Function (EBF), Frequency Ratio (FR) and Fuzzy Gamma Operator (FGO) (Ramesh and Iqbal, 2022). Other researchers such as Pham et al. (2020), Kumar et al. (2008), Wu et al. (2019), Kang et al. (2020), Xu, (2020) and Kia et al. (2012) also mentioned the flood and factors affecting its occurrence in their studies.

Ardabil plain in the northwest of Iran has many heavy rains throughout the year due to being exposed to Mediterranean and Eastern European rainfall systems in winter and convective rains in sunny slopes in spring. Changes in land use and conversion of permeable lands to impervious lands, climate changes and desertification of lands have caused severe floods to occur in this plain. Although the floods of Ardabil plain have been investigated from synoptic and environmental view, the possibility of flood risk in this Ardabil plain has not been investigated from the environmental management view. The first step in the flood management is to identify sensitive and flood-prone areas so that by extracting these areas, management and control solutions can be provided in the direction of this approach. In recent years, floods in the Ardabil plain have intensified due to climate changes, poor drainage and expanding agricultural industries.In the management of this natural disaster, flood risk maps serve as an important tool for local governments in empowering them to respond and properly plan against disasters. Therefore, it is very important to evaluate the possibility of flooding and the vulnerability of Ardabil plain to flood risk. This research, with an ecosystem approach, tries to model floods and identify flood-prone areas of the Ardabil plain, so that by knowing these areas and using multi-criteria decision techniques, identify the points that are the priority of crisis management planning. Identifying effective parameters in flooding and zoning of Ardabil plain in terms of flood probability is one of the most important goals of this article.

Materials and methods

Ardabil plain has located in the northwest of Iran in Ardabil province and between the Baghrudagh mountains in the east, Anbaran in the north, Sablan and Bozghosh in the west and south. Ardabil plain is located between 38° 05' to 38° 28' N and 48° 10' to 48° 41'E (Figure 1). Balikhochai, Hirchai and Namin Chai rivers, which are sub-basins of the Qarasu River, flow in the Ardabil plain and exits from the north side of the Ardabil plain. The alluvial deposits resulting from the erosion of the heights and its transport by the main waterways have spread in the Ardabil plain. The approximate length of this plain is 40 km, its width is 25 km, and its average height above sea level is 1350 meters. The lowest altitude point of the plain near the Samian bridge (in the northwest corner of the plain) decreases to 1296 meters. The area of this plain is almost elliptical, about 900 square kilometers. This plain is connected to Gilan province from the east by the Hiran pass and from the west by the Balikhlochai valley and the Saein pass to the East Azarbaijan province. Ardabil plain was formed as a closed tectonic pit in the late third and early fourth geological period. For this reason and also due to the presence of heights in its margin, all the surface currents of the western slopes of Baghrudagh, the eastern and southern slopes of Sablan, Anbaran and Bezghosh are drained into it and out through the Qarasu River. After receiving all the surface flows, the Qarasu River in this area (northwest of the plain) has connected the Ardabil plain to the northeastern slopes of Sablan and the Lahrud and Mishkinshahr.

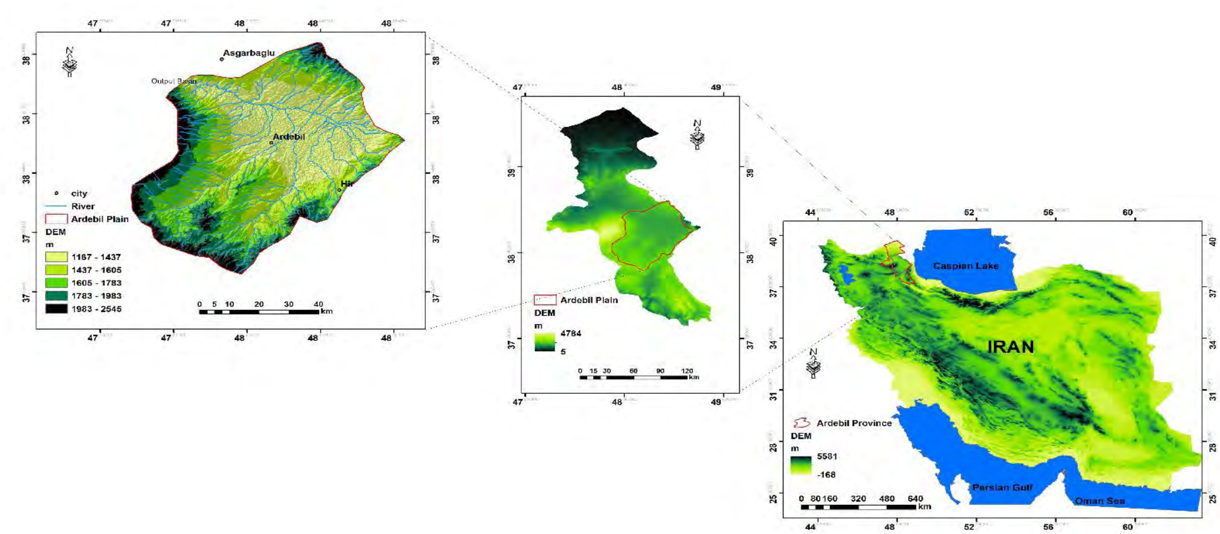

Figure 1. Geographical and topographical location of Ardabil plain in Ardabil province and northwest of Iran

Zoning of sensitivity of Ardabil plain is the purpose of this article. This research is quantitative type, in which information about environmental elements is obtained, categorized and processed by statistical techniques. This study is practical from the point of view of the goal, and from the point of view of data collection, it is a descriptive one, that its method is a survey.The aim of this study is to obtain information about the spatial distribution of environmental parameters and their role in flooding in Ardabil plain. In this study, in order to prepare a flood map of Ardabil plain, random forest algorithm was used. First, the effective parameters in the flooding of Ardabil plain were extracted using existing maps and Landsat satellite images, and their information layer was drawn in ArcGIS software. The effective parameters in flooding of Ardabil plain include DEM, land slope, drainage density, runoff accumulation, distance from the waterway and the main channel of Qarasu river, geology and soil science, erosion, land use and geomorphological parameters of Ardabil plain including landforms, Topographic Position Index (TPI), Modified Catchment Area (MCA), Terrain Ruggedness Index (TRI), Topographic Wetness Index (TWI) and Stream Power Index (SPI) indices.

The DEM map of the area was obtained from ASTER satellite images with 30-meter pixels.Then, slope maps, geomorphological landforms, waterways, runoff accumulation and other geomorphological indicators were prepared from the DEM map of the region. In the preparation of the land use map, first, the LANDSAT OLI image was obtained from the USGS website on June 2022, and a land use map was prepared from the image using the SVM algorithm. To prepare the map of the Ardabil plain's landforms, the map prepared by the Iranian Mapping Organization was used, and its information layer was prepared in the ArcGIS 10.7 software environment. Lithology and geological formations are important parameters in flood due to their direct influence on permeability potential and surface runoff. The maps related to this variable were obtained from the geological maps of the Ardabil plain. The waterways in the watershed carry out the discharge of surface currents, and the risk of flooding decreases as the distance from them increases. First, the map of waterways was digitized in ArcGIS 10.7 software through topographic maps with a scale of 1:25000 prepared by the Iranian Mapping Organization. Then, the distance map from the waterway was drawn with the Euclidean distance function.

The drainage density was obtained by dividing the total length of all waterways in the area by the area of the area. The drainage density of the study area was calculated from the functions available in the ArcGIS 10.7 software from the elevation digital model map. In calculating the drainage density, first the total area of the waterways in the range was obtained and divided by the total area of the range. In evaluating the erosion resistance of different rocks, in addition to the texture, the mineralogical composition and the relative abundance of the components are also important and affect the rock resistance. Mineralogical classification of rocks was used in order to prepare the erosion sensitivity map. After preparing the desired parameters map, the layers were converted into numbers in GIS. Then these numbers were entered into the Spyder software and by running the random forest algorithm on these numbers, the probability of flooding at any point in the Ardabil plain was calculated between zero and one. The closer the number is to zero, the lower the probability of flooding, and the closer to one, the higher the probability of flooding. The fuzzy numbers obtained from the random forest algorithm, which shows the degree of flooding, were entered into the GIS software, and by applying the point to raster command, a raster map was prepared that shows the degree of flooding in the Ardabil plain.

Prediction and modeling of interval variables can be estimated by linear regression, but if the dependent variable is at the level of a nominal variable, logistic regression should be used. In this research, in order to draw a linear equation and draw a flood map of Ardabil plain, in addition to the random forest model, logistic regression was also used; In such a way that there were two levels for the occurrence of flooding: 1) occurrence of flood (code one), 2) no occurrence of flood (code zero). Therefore, the dependent variable was divided into two levels with two codes of zero and one, which is a nominal variable. The predictor variables also included the same variables that were used in the random forest model (16 parameters), which are interval variables. The results of this model show what relationship and influence the predictor variables have on the occurrence of floods (code one) and non-occurrence of floods (code zero). The logistic fitting model is a generalized linear model that uses the logit function as a link function. The general equation of logistic regression is as follows:

$$Logit(p) = Log\left[\frac{p}{1-p}\right] = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k \quad (1)$$

In this equation, p is the probability of flood occurrence, β is the width from the origin and β_k is the coefficient related to the independent variable (predictor) of x. The dependent variable, y_i, is the logarithm of the ratio of the probability of flooding to the probability of no flooding.

Results

Figure 2 shows that the lowest air temperature in Ardabil province, with an average of 9.2 to 10.6 degrees Celsius, is in the Ardabil plain (Abi-Biglo) and the heights of Khalkhal. After that, the slopes of Sablan are ranked second with a temperature lower than the average annual temperature. Meshkinshahr is located in the western slope of Sablan in this temperature range. Contrary to the latitude, in Ardabil province, as we move towards the north, the air temperature increases, until in Parsabad and Moghan plain, the average air temperature reaches 15.1 to 16.5 degrees Celsius. The reason for this is the decrease in altitude, proximity to the Caspian Sea and distance from the path of European high pressures (Figure 2). Precipitations in Ardabil province, which occur in late autumn, winter and early spring, appear as rainfall in autumn and spring and as snowfall in winter. In autumn and winter, the cold and high-pressure system of Siberia, the polar-continental air mass and the marin air mass originating from the Atlantic Ocean are the main reason for the occurrence of rains in Ardabil province. In spring, the Mediterranean and Sundance systems lead to precipitation. In terms of geographical distribution, Sablan and Khalkhal foothills have the highest amount of rainfall, which is mainly in the form of snow. (Figure 3).

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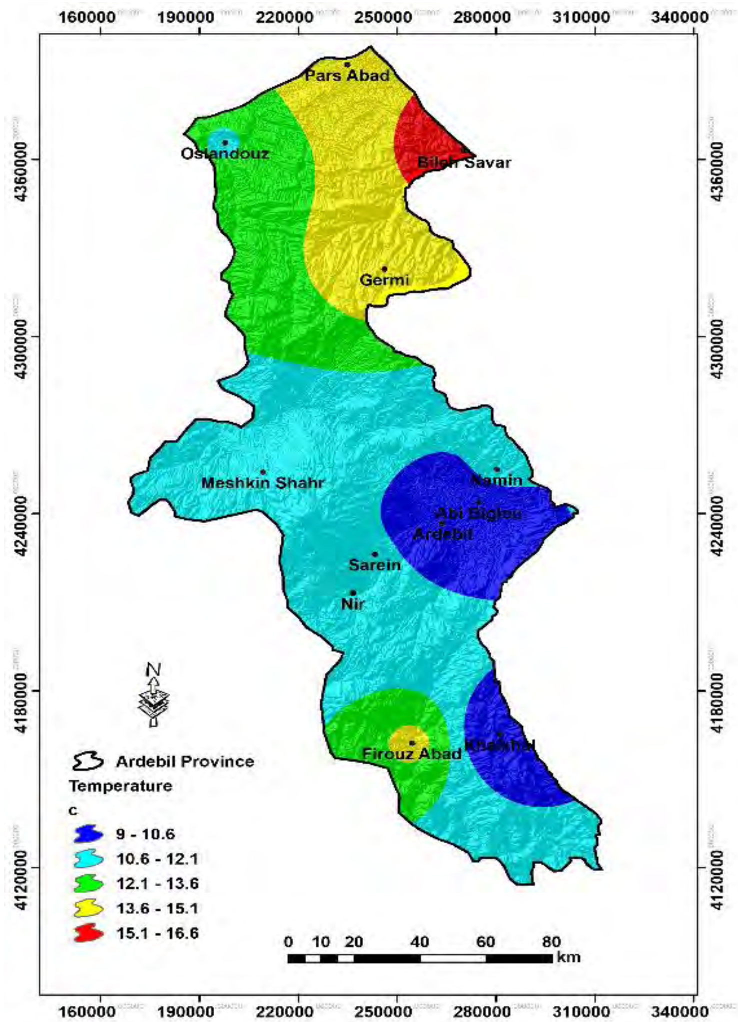

Figure 2. Average annual air temperature in Ardabil province

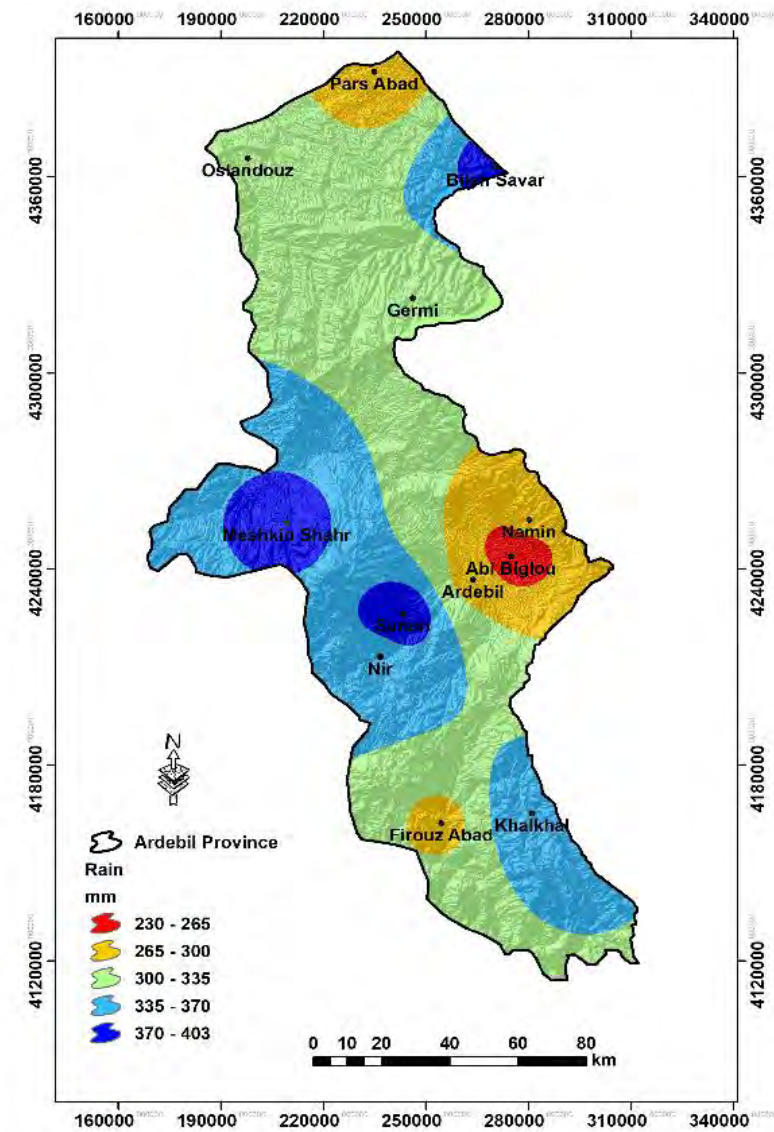

Figure 3. Average annual rainfall in Ardabil province

The relative humidity is caused by temperature conditions, land use and cover, microclimate conditions and the amount of water vapor in the air. The higher the air humidity, if there is an ascension factor, the more conditions are prepared for precipitation. In Ardabil province, the relative humidity of the air throughout the year in the Ardabil plains is about 15% higher than the mountainous areas in the west of the province, the main reason for which is the proximity to the Caspian Sea and the humidity from the forests of Arsbaran and Fandoqlu. In the mountainous areas west of Ardabil plain, with the increase of relative air humidity and the abundance of the ascent factor, conditions are prepared for rainfall; but in the eastern and northern plains of Ardabil province, although the annual average relative humidity is more than 70%, but because the ascension factor is low in these plains, precipitation does not occur and these conditions have caused the amount of rainfall in the western areas of Ardabil province to be higher than the eastern areas, especially in the Ardabil plain (Figure 4). Stormy days are the result of accumulation of cumulonimbus clouds that occur in spring. Due to the topographical conditions and sunny slopes, there are more thunderstorm days in the southern areas of Ardabil province than in the northern areas of Ardabil province. Around 32 to 40 storm days are reported in Khalkhal city to Ardabil plain and Meshkinshahr city every year (Figure 5).

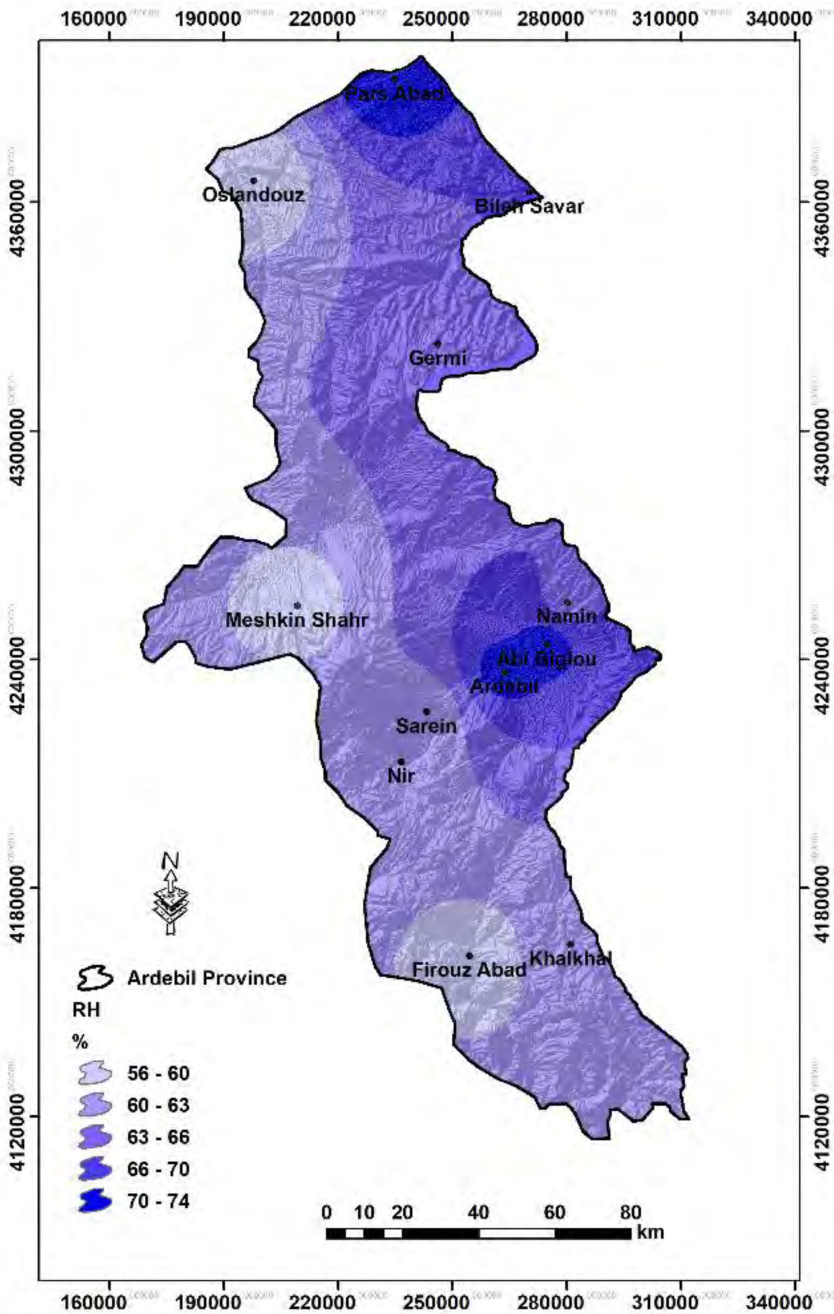

Figure 4. Average annual relative humidity in Ardabil province

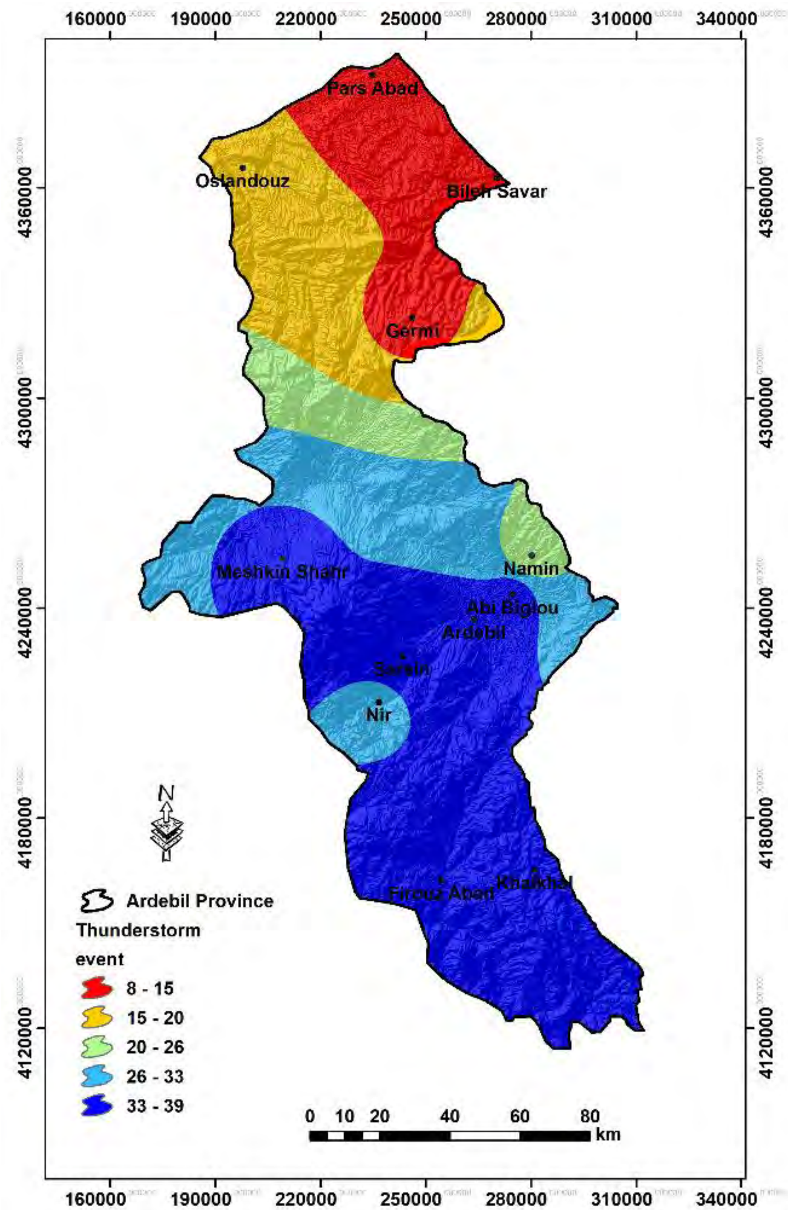

Figure 5. Annual average of stormy days in Ardabil province

The examination of the average monthly and annual temperature of Ardabil plain during the years 2000-2018 (Figure 6) shows that the minimum air temperature was in January, the average of which is -0.39 degrees Celsius. Also, the maximum temperature was in August, the monthly average of which is 19.61 degrees Celsius. By averaging the monthly temperature of the Ardabil plain, we come to the conclusion that the annual temperature in the Ardabil plain is about 9.83 degrees Celsius. The monthly relative humidity survey of Ardabil plain shows the high humidity of this region and in all months, the average relative humidity is more than 60%, the main reason for which is low temperature and moderate rainfall in Ardabil plain. In general, the average relative humidity in the cold months of the year is higher than in the hot months of the year, and its maximum is in November and its minimum in August, where the relative humidity is 77.17 and 66.20%, respectively (Fig. 7).

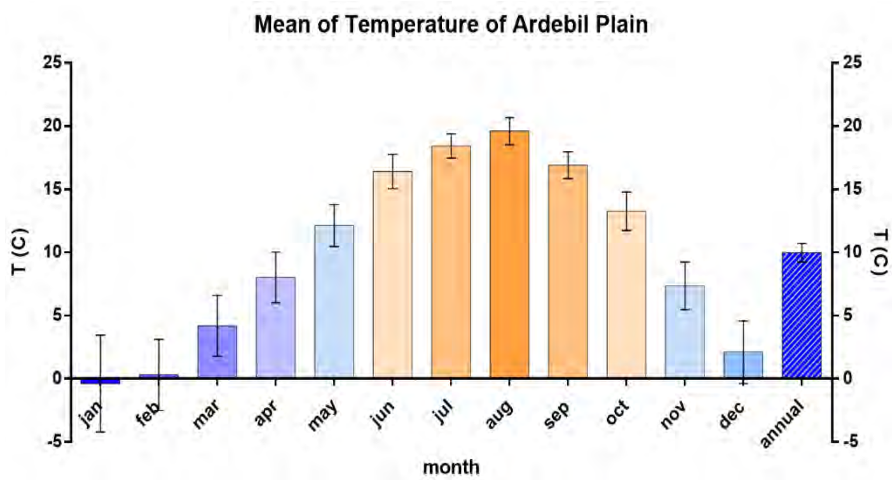

Figure 6. Average monthly temperature of Ardabil plain during 2000-2018

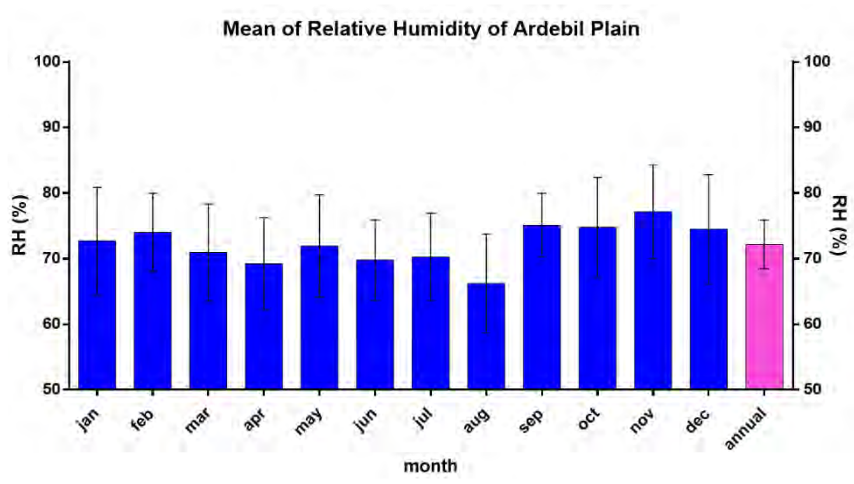

Figure 7. Average monthly relative humidity of Ardabil plain during 2000-2018

Examining the average monthly rainfall of Ardabil plain showed that the peak of rainfall is in the cold months of the year and its maximum occurs in February, the average of which during the years 2000-2018 is about 48 mm in February. The lowest amount of precipitation also occurs in April, May and June (Figure 8).

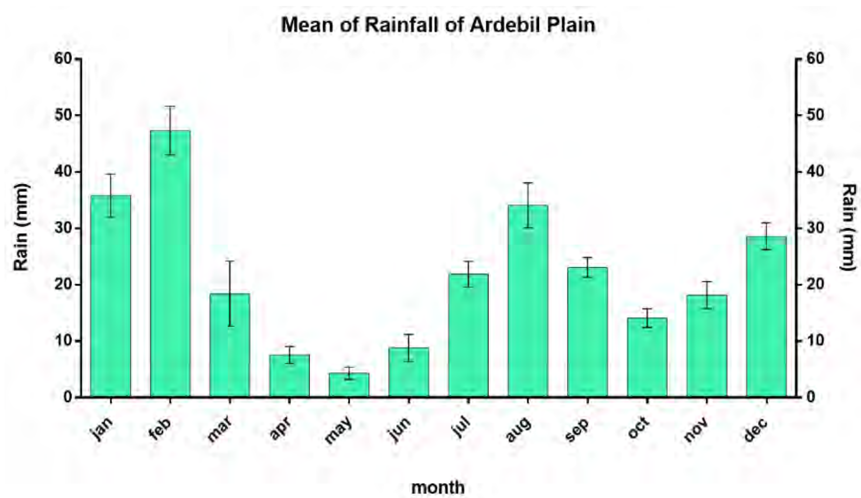

Figure 8. Average monthly rainfall of Ardabil plain during 2000-2018

Model evaluation

Ardabil plain flood was predicted by random forest technique and logistic regression. The evaluation results of the logistic regression model were examined as follows and its results were used to prepare a flood susceptibility map. Omnibus test results show the evaluation of the entire logistic regression model. This test shows how powerful the parameters are in explaining and predicting floods. According to the significance level of the model, the fit of the model is acceptable and it is significant at an error level of less than 0.05 (Table 1).

Table 1. Evaluation results of logistic regression model for flooding with Omnibus test

Omnibus Tests of Model Coefficients				
		Chi-square	df	Sig.
Step 1	Step	477.25	16	.000
	Block	477.25	16	.000
	Model	477.25	16	**.000**

The approximate coefficients of Cox and Snell R Square, Nagelkerke R Square for the final fitted model are calculated in the table. The results showed that the power of the model is suitable in explaining the variance of the dependent variable by the independent variables. The values of two R^2 statistics were obtained as 0.749 and 1, respectively, which means that the independent variables were able to explain between 74 and 100 percent of the changes in the dependent variable (flooding) (Table 2).

Table 2. R^2 coefficients and fitting of the optimal logistic regression model on flooding

Model Summary			
Step	-2 Log likelihood	Cox and Snell R Square	Nagelkerke R Square
1	0.000	**0.749**	**1**

To explain the power of the model in differentiating the occurrence of floods in dependent variable classes, the results of table (3) were used. From this table, we can understand the level of accuracy and correctness in the classification of floods.

The total accuracy of flood classification in Ardabil plain was 100%. Therefore, the logistic regression model has great explanatory power in predicting the occurrence of floods.

Table 3. The explanatory power of the logistic regression model for flooding

Classification Table					
	Observed		Predicted		
			inversion		Percentage Correct
			0	1	
Step 1	Flood	0	163	0	**100**
		1	0	182	**100**
	Overall Percentage				**100**

Table 4 shows the effect of each independent variable in the logistic regression model. The square of the ratio of the coefficient of each variable (B) to its standard error (std. Error) is equal to the Vald statistic. If the significance level of the Vald statistic is less than 0.05, the parameter is far from zero; In other words, the parameter affects the results. Based on this table, all the investigated parameters have an effect on the flooding of Ardabil plain.

Table 4. Estimation of logistic regression model parameters

Variables in the Equation								
		x	B	S.E.	Wald	df	Sig.	Exp(B)
Step 1	Erosion	x1	7.45	1817	0.977	1	0.000	1728
	Aspect	x2	0.037	14.14	0.988	1	0.000	1.038
	Distance Dam	x3	-0.002	0.205	0.991	1	0.000	0.998
	Distance flood plain	x4	-0.002	0.331	0.996	1	0.000	0.998
	Distance river	x5	-0.015	1.70	0.993	1	0.000	0.985
	Flow direction	x6	0.052	28.82	0.999	1	0.000	1.05
	Geology	x7	-0.031	2.02	0.988	1	0.000	0.969

	Landform	x8	12.96	4335	0.998	1	0.000	426858
	Land use	x9	-1.045	444.3	0.998	1	0.000	0.352
	MCA	x10	-0.002	0.547	0.997	1	0.000	0.998
	Floe density	x11	38.24	9505	0.997	1	0.000	4
	Slope	x12	-5.49	4183	0.999	1	0.000	0.004
	TPI	x13	0.041	2376	1	1	0.000	1.042
	TRI	x14	0.781	2866	1	1	0.000	2.183
	TWI	x15	8.25	4615	0.999	1	0.000	3835
	DEM	x16	-0.422	34.96	0.990	1	0.000	0.656
	Constant	-	1208	157524	0.994	1	0.000	-

According to the coefficients of the variables in this fitting, the final model with independent variables was obtained according to the following equation:

$$\mathbf{y} = 1208 + 7.45\, x_1 + 0.037\, x_2 - 0.002\, x_3 - 0.002\, x_4 - 0.015\, x5 + 0.052\, x_6 - 0031 x_7 + 12.96 x_8 - 1.045 x_9 - 0.002 x_{10} + 38.24 x_{11} - 5.49 x_{12} + 0.041 x_{13} + 0.781 x_{14} + 8.25\, x_{15} - 0.422 x_{16} \quad (2)$$

The evaluation of the random forest model and also the logistic regression for predicting the sensitivity and flood potential of Ardabil plain was measured with the ROC curve. AUC number equal to 0.996 and 0.996 was obtained, which shows that the mentioned models had the best training and the results are reliable. Also, the validation metrics show that the models have received proper training and their predictions can be used (Table 5)

Table 5. Evaluation of random forest model in Ardabil flood forecasting

Validation	**Random Forest (RF)**	**Logistic Regression (LR)**
ROC_ AUC	0.996	0.982
Mean Absolute Error	0.0451	0.0449
Mean Squared Error	0.02603	0.039
Root Mean Squared Error	0.1613	0.14
R^2 Training score	0.99	0.98
ooB score	0.93	0.96
R^2 Validation score	0.90	0.93

Flooding level of Ardabil plain

After overlaying the layers of information effective in the flooding of Ardabil plain, including DEM, bed slope, distance from the channel, distance from the waterway, TPI, TRI, MCA, TWI index, distance from the dam, accumulation of waterways, drainage density, waterway flow, land use, geology, soil erosion, geomorphological landforms and implementation of RD algorithm, a flood map of Ardabil plain was prepared. Due to the limitation of the pages of the article, the final map, which is the result of the model and predicts the degree of flooding, is presented. The results of the model show that the marginal areas located around the central plain of Ardabil, which are around the foothills, have less flood potential than other areas. By moving from the southwest of the plain to its northeast, the degree of flooding increases. This increase in flood potential around the main drainage of the plain is more than other places. In the middle part of Ardabil plain, the density of drainage and accumulation of waterways has increased, and these waterways flow into the main Qarasu River in the central part of Ardabil plain. The runoff flows at a high speed from the surrounding foothills on the slope of the land towards the Ardabil plain, and with the decrease of the slope in the plain, the speed of the runoff has decreased and caused the accumulation and rise of the water level in the waterways. Therefore, the Ardabil plain gets flooded, which has happened a lot in the last few years and has caused damage to agricultural products in this plain.

The TPI index, which shows the shape of the topography of the land, has decreased in the Ardabil plain and indicates the low gradient of the slope of these lands. But in the high places around the Ardabil plain, this index indicates the low volume of runoff, and in the high places, the water absorption of the land is reduced and it drains the runoff quickly.

In the Ardabil plain, due to the low slope and smoothness of the land, the degree of water retention is higher than in the highlands, and after heavy rainfall, the runoff accumulates in this plain and causes flooding and inundation of lands. On the other hand, the Topographic Wetness Index (TWI) shows that in Ardabil plain, the amount of this index is higher than the high places around the plain. The high level of this index indicates that the soil of Ardabil plain has more moisture than the soil of the highlands, and with the occurrence of rain and the flow of runoff, the amount of water infiltration in the Ardabil plain is very low due to the saturation of the soil a most of the precipitation flows as runoff.

These factors have caused the degree of flooding in Ardabil plain to be higher than other areas, and about 22% of the studied area has a severe degree of flooding (Figure 9). In general, the maps obtained from logistic regression model and random forest show that the central part of Ardabil plain due to geomorphological conditions, slope and topography, runoff flow and their accumulation, land use and waterway strengths, is the most flood-prone part in the study area, and with the distance from the middle part of the plain to the surrounding area, where the height increases and the slope also increases, the intensity of flooding and the probability of its occurrence decreases (Figure 9). The map obtained from hydrological observations and reports (Figure 10) shows that the central part of Ardabil plain is the most flood-prone area in the study area, and its results are similar to the results of flood forecasting with the random forest algorithm.

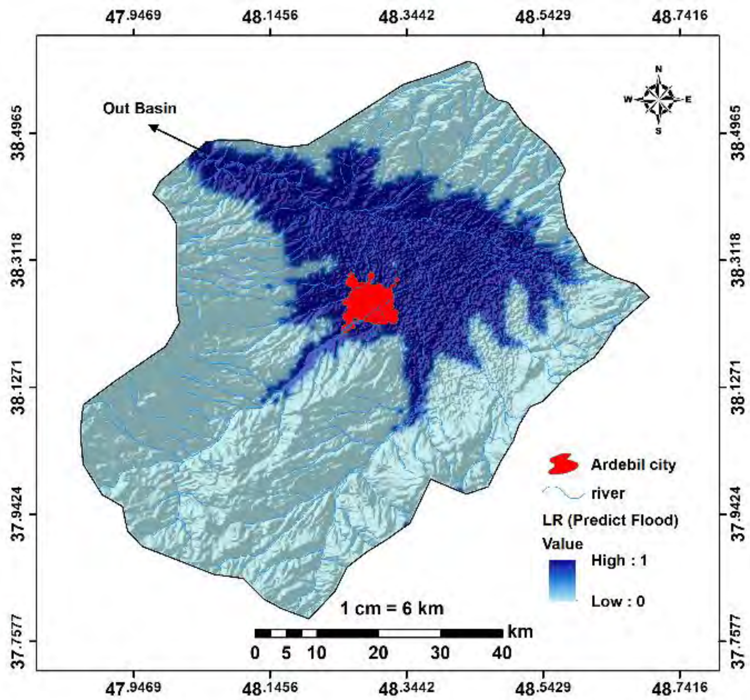

Figure 9. Flood level map of Ardabil plain using random forest model and logistic regression

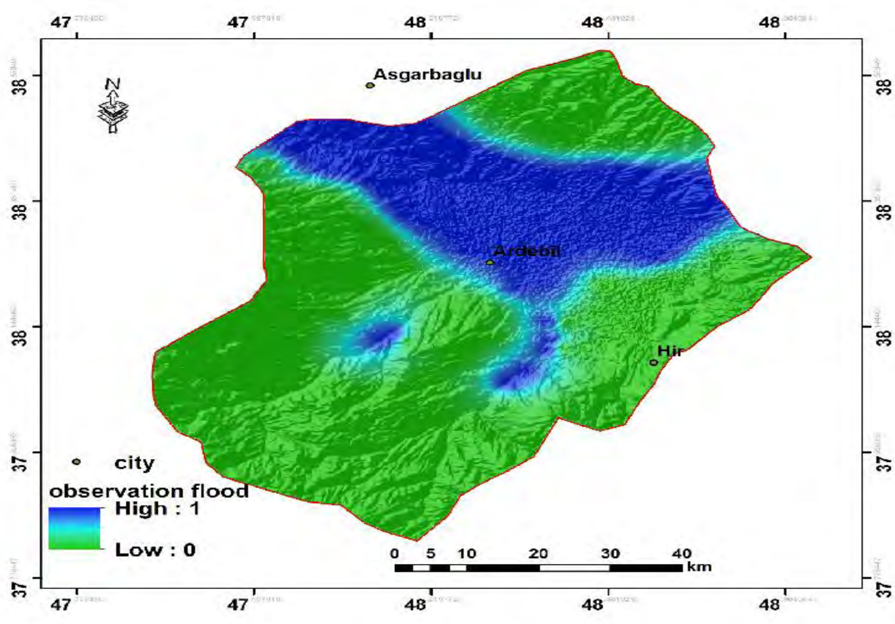

Figure 10. Degree of flooding in Ardabil plain

Conclusion

This article was carried out with the approach of identifying and the role of hydrogeomorphological parameters in the occurrence of floods in Ardabil plain, and its results also indicated the usefulness of the model and the investigated parameters. The results showed that the DEM parameters, distance from the main river, topographic wet index, topographic position index, land slope, watercourses gathering place, watershed modification index and distance from secondary waterways play the most role in the occurrence of floods in Ardabil plain. The central pit, which is the place where waterways gather and the main Qarasu river passes, has the greatest potential for flooding. The results showed that the marginal areas located around the central plain of Ardabil have less flood potential than other areas. The degree of flooding increases by moving from the southwest of the plain to its northeast. This increase in flood potential around the main drainage of the plain is more than other places.

Despite the efforts in recent decades to reduce the effects of floods, the number of accidents and economic and human casualties of floods in the world is increasing. The problem of preparing a flood susceptibility map has been studied by various researchers who have used different methods to prepare a flood susceptibility map, such as statistical and probabilistic models, but because watersheds have spatial, spatial, geometrical and hydraulic complexities, modeling with simple and linear hydraulic methods cannot represent the real world. For this reason, various methods are used to investigate floods that have multidimensional behavior. One of the most important and advanced techniques is the Random Forest (RF) method, which researchers have used to prepare a flood sensitivity and potential map (Mosavi et al., 2022).

The evaluation of the model to prepare the sensitivity map in different studies is done with the ROC scale, the closer this number is to one, it indicates the ability to simulate the model and prepare the flood sensitivity map. Of course, various machine learning techniques have been used to predict floods, which can be artificial neural network (ANN) and logistic regression models (Ighile et al., 2022), ANFIS techniques and ANFIS-WOA (Samantaray et al., 2022), techniques of frequency ratio models, fuzzy logic and decision tree (Ghosh et al., 2022) were also mentioned. But the random forest technique has the highest reliability coefficient compared to other models (Meliho et al., 2022). In this research, this technique was used for the flood potential of Ardabil plain, and its results were in line with the results of other researchers, and the evaluation of the model was confirmed with ROC and AUC indices.

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