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Feasibility study of potato cultivating of Ardabil province in Iran based on VIKOR model

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ABSTRACT

One of the agricultural planning methods is the identification of areas susceptible to planting according to the climatic conditions. Understanding the climate is one of the most important factors in the production of the product. Knowing this will enable farmers to plant their crops according to climatic conditions and reduce the damages caused by adverse conditions to their products, which is one of the main ways to develop and enhance agricultural activities. The aim of this study is to investigate the role of some of the climatic elements such as temperature (minimum temperature, maximum temperature, daily temperature, maximum absolute temperature, and minimum absolute temperature), rainfall and relative humidity in determining areas suitable for potato cultivation in the Ardabil plain. For this purpose, the data of eight meteorological stations were collected since the year of establishment until 2013 and the relevant information database was formed. Then, the best option was selected by using multi-criteria decision making methods such as Vikor, and the maps of favorable regions for cultivation were designed using GIS. The results of this research indicate that, the best region based on Q is the Abi-Biglu station for cultivating potatoes in Ardabil Plain, which has a Q =1 and is ranked first, and Ardabil and Samian stations with Q= 54% and Q= 42% are second and three, respectively and the Nir station with Q=16% is inappropriate for potato cultivation.

Introduction

The climate is one of the most important factors affecting on agriculture. So the quantity and quality of agricultural products are related to the environmental conditions (Shahivandi et al., 2013). Weather and climate are one of the most important information used in agriculture. In fact, the good quality of product is related to the study of the climate and the agriculture will not be economically justifiable without regard to the climatic factor in a region. In other words, the agriculture is one of the most important economic activities that is strongly dependent on climate factors. Potato is one of the most important food products that is in the fourth rank in terms of nutrients after cereals (rice, wheat, and corn) (Ahmadi and Shaemi, 2012). Based on agricultural statistics, the area under cultivation of potato is estimated 186000 ha in Iran in 2009-2010, which 99.8% have been irrigated and the rest have been dry-farming. Ardabil province is in the second rank with 13% country potato lands and 14.8% the

production of this product (agricultural statistics, 2010). It is needed to identify areas suitable for cultivating a crop due to that each plant has the best conditions in a particular climate, and so there are special areas with special crops and special agricultural systems. Therefore, location of potato in each region is one of the factors that plays a significant role in the yield of this product. The agricultural climate is a practical science that applies the principles of agro-climate. Among all environmental factors, the climate has a major role. The climate change can increase or decrease the yield of agricultural products even when other factors of production are at an optimum level (Karimi, 2003). The limits and boundaries of crops production is dependent on climatic conditions. Of course, these products are affected by the soil, roughness, insects, etc. but, no doubt, no product reaches to its true value, unless it conforms to the existing environmental conditions. The most important climatic elements in agriculture are temperature, humidity, sunlight, wind, and evaporation. A product that grows must find the proper forms of these elements inside the micro-climate of its environment. All agricultural products have natural and real thresholds of climatic elements that are not able to grow naturally outside of the threshold (Mohammadi, 2014). Considering all these factors, it is necessary to investigate the relationship between climatic elements and Crops yield and identify favorable areas for crop production. A lot of researches have been made in this field. A number of studies done on agro-climate the potato includes Alejandro (2003), determined the suitable areas for corn products and potato using a multi-criterion method (MCE) in central Mexico and prepared the maps required for each product using the criteria of the crops and the appropriate level by the GIS. Ana Dranistaks (2004), studied the correction of temperature and humidity prediction using the Kamen Filter method in northern Greece and suggests the appropriate areas for potato cultivation with the analysis of temperature and relative humidity. Andre et al. (2005), studied the agro-climate and potato production and stated that the heat and water stress mainly are the limiting factors for the production of potato. Andre et al. (2008), modeled the potential performance of potato based on climate elements and stated that humidity and temperature are important elements in modeling agro-climate. Sreyashi & Nirmali (2013), examined the effect of high temperature on potato growth and yield and identification of resistant varieties and concluded that low potato yield is caused by temperature increase during the growing season and high temperatures have a significant effect on the growth stages and gland bulk.
Peter (2010), presents the optimal climate normal for potato in Table 1., P.A.J et al. (2012), studied the effect of climate on potato production, Haverkort (1990), searched on potato planting at altitude, Haverrkort and Verhagen (2008) and Hijmans (2003), studied the effect of climate change in potato production, Rosenzweig et al. (1996), Kroschel et al. (2013) and Daniel et al. (2002), worked on prediction of the change climate and its relation to potato yield. Guoju Gioji et al. (2013), investigated the effects of climate change on potato and barley performance. We can be pointed to the study of the Meteorological Organization of the country, in cooperation with the Quanta (1975), on the conditions of cultivation of 15 important crops in Iran, as the first research on agriculture. In this research, the climatic elements of the land were studied on the products and map of susceptible areas were prepared for cultivation by data analysis. Rasuli et al. (2006), investigated the role of rainfall and temperature in determining the suitable location and appropriate date for potato cultivation in Ardebil plain and considered the most suitable date for potato cultivation in Ardebil plain from April 21 to April 30 and the most favorable areas of cultivation are Ardebil and Namin stations. Sobhani et al. (2011), identified the susceptible areas for potato planting in Kurdistan province, considering the climatic and physiological conditions, and stated that knowledge of the climate and the eco-physiological needs of crops are the most important factors in producing the product. The aim of the presenting of agro-climate regions is the zoning of lands based on the capabilities and talents of agricultural production with emphasis on the aspects of the climate. Therefore, temperature and precipitation can be considered as the most important climatic factors during the development of potato according to the findings of domestic research and external studies.
The aim of this research is the agro-climatic zoning of potato cultivation in Ardabil plain using VIKOR method in GIS environment.

Materials and methods

Study area

The area of this plain is about 95000 ha at altitudes of 1200 to 1600 meters above sea level that is surrounded by Sabalan, Heyran, Salavat-Daghi, and Baghru. Ardabil plain is one of the important agricultural centers in the country, located in the center of Ardebil province. The geographical range of the studied area is between 37° 45′ to 38° 24′ N latitude and 47° 50′ to 48° 30′ E longitude (Fig. 1).

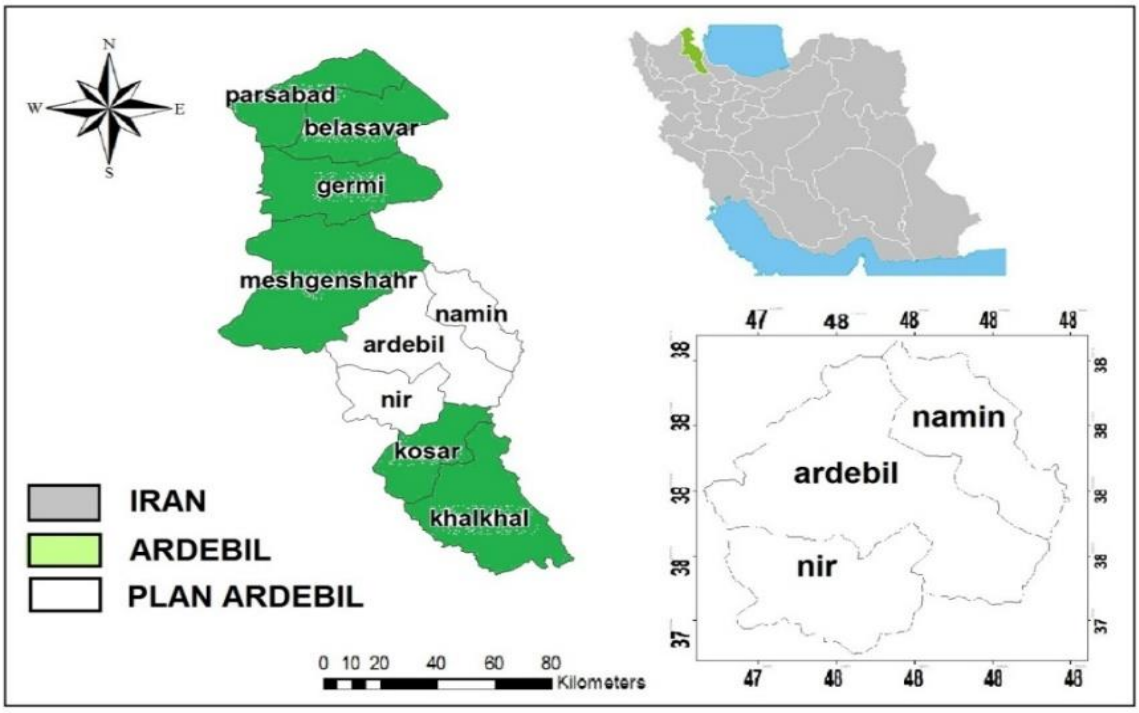

Figure 1. Geographical location of Ardabil Plain

Research Methodology

In the study, climatic data such as precipitation, maximum temperature, minimum temperature, maximum absolute temperature, minimum absolute temperature, daily temperature and relative humidity were prepared from the statistics and information of the synoptic station (Meteorological station of Ardabil province) and rain-gauge stations (Water Organization of Ardebil province). Then, we created databases in the GIS environment through the statistical calculations using SPSS and EXCEL software.

Subsequently, each of the relevant parameters was transformed into informational layers and map in the GIS environment by generalizing point data (stations) to their peripheral levels, and optimal climatic normal were obtained for potato plant growth (Table 1). In this research, the zoning of suitable cultivating lands of potato in Ardabil plain was carried out by analyzing the climatic elements using VIKOR method to achieve the desired objective. This method defines a ranked set of available alternatives according to the opposite indexes. The main purpose of the VIKOR method is more approaching the ideal answer to each indicator (Pourahmad and Khalili, 2014). The VIKOR method focuses on categorizing and choosing a set of alternatives and defines compromise responses for an issue with conflicting criteria that can help decision makers to reach a final decision. The main difference between this model and the hierarchical or network decision-making models is that, unlike those models, there are no paired comparisons between criteria and alternatives in these models, and each alternative is independently by one the criterion is measured and evaluated (Opricovic and Tzeng, 2007).

Table 1. Potato climate normal, according to Peter

Annual precipitation (mm)	Growth period rainfall (mm)	Annual temperature (c)	Average temperature (c)	Cultivation time temperature (April), (c)	April temperature (c)	April precipitation
650-800	280	17	9	8-10	8-10	45
May temperature (c)	May precipitation (mm)	July temperature (c)	July precipitation (mm)	June temperature (c)	June precipitation (mm)	Relative humidity (%)
14-15	70	17	90	20	90	70-75

Temperature is one of the determining factors in the geography of crops. A certain thermal threshold is defined for each plant. In this study, the daily temperature, maximum absolute temperature, maximum temperature, minimum absolute temperature, minimum temperature has been used. The highest daily temperature in the center of the plain is at Ardabil and airport stations, and the lowest daily temperature is in the stations located in the surrounding slope (Fig. 2). The maximum temperature and maximum absolute temperature have been recorded in the northern parts of Ardabil Plain. The minimum and minimum absolute temperature in the highlands of the plain is the slopes of the surrounding mountains. The precipitation is also one of the most important climate variables for potato cultivation. Figure 3 shows the map of precipitation values of Ardabil plain stations.

As you can see, the maximum rainfall is less than 400 mm in highlands, where it is not possible to plant the potato. But in areas where potatoes are planted, its annual precipitation is less than 300 mm. Therefore, potato cultivation in the Ardabil plain is faced the severe restriction of water requirement during the growth period, despite the moderate temperature constraint. Therefore, this plain is not suitable for potato cultivation. Farmers have to supply potato water from other sources from flowering to seeding. The other important element is relative humidity, which has a significant effect on evapotranspiration and water requirements of plants and is one of the important determinants of water use. In this research, the relative humidity distribution map of Ardabil plain was prepared using relative humidity of each station studied during the statistical period (Fig. 4). The highest relative humidity is recorded in the eastern and central parts of the plain, as seen in the figure.

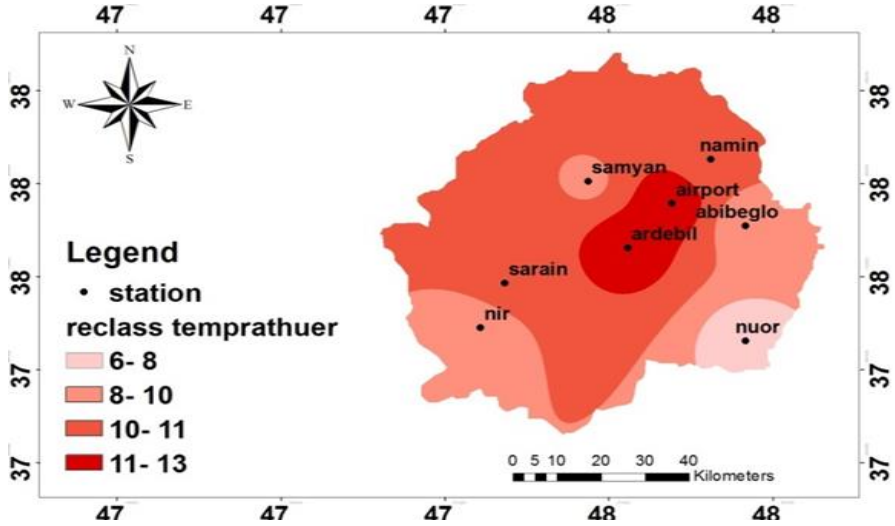

Figure 2. Distribution of temperature of Ardabil plain

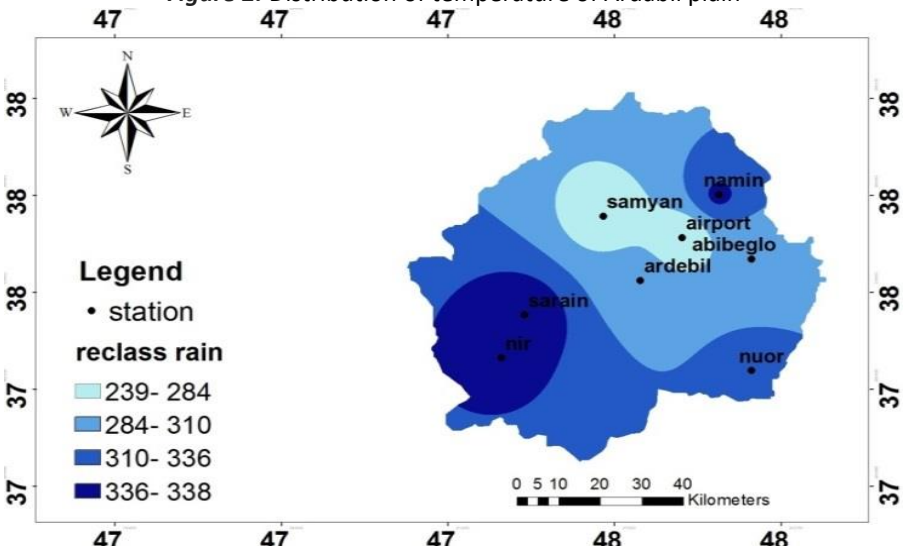

Figure 3. Distribution of annual rainfall in Ardabil Plain

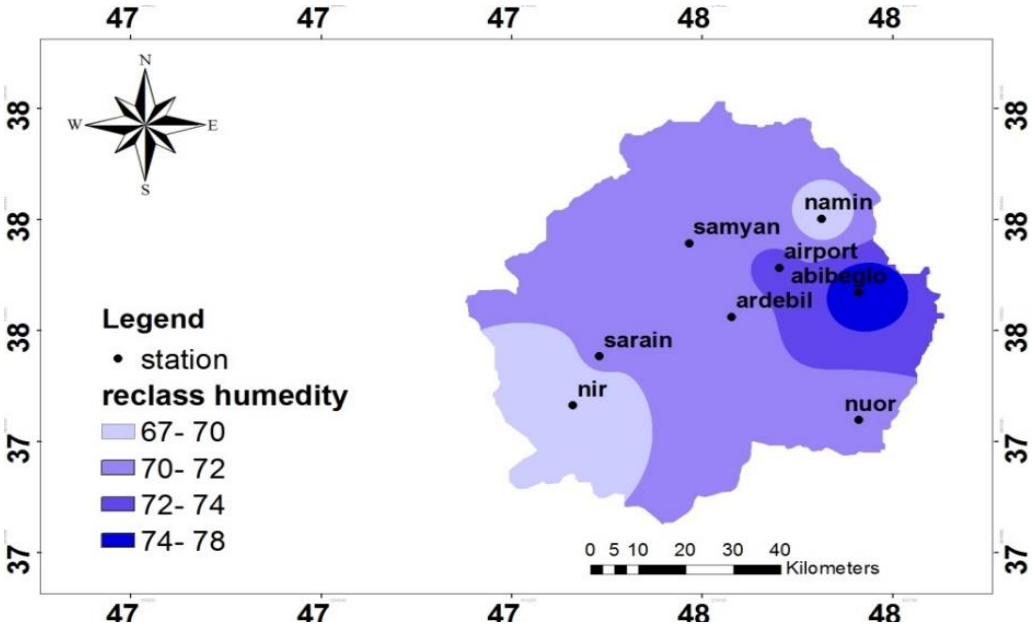

Figure 4. Distribution of relative humidity of Ardabil Plain

Results and discussion

The raw data matrix of each criterion was defined in the scope of the study, after collecting data. The decision-making matrix consists of alternatives (columns) and criteria (rows). The alternatives are stations in the Ardabil plain, and the criteria are listed in Table (2).

Table 2. Decision making Matrix

***	Humidity	Absolute maximum	Absolute minimum	Daily temperature	Maximum temperature	Minimum temperature	Precipitation
Aji	0.331	0.148	0.021	0.089	0.047	0.267	0.098
Ardabil	72	24	-5	13	19	6	295
Nir	67	27	-1	8	19	7	361
Namin	68	28	1	10	20	7	358
Sarein	70	22	-3	11	14	4	388
Samian	72	29	-1	9	22	4	243
Abi-Biglu	78	27	0	8	17	6	283
Neor	71	19	-1	6	13	5	335
Ardabil airport	73	25	-6	13	20	3	239

Source: Organization of Meteorology and Rain- Gauging

The matrix normalization was carried out using the formula after formation of the decision-making matrix, the results are given in Table (3).

Table 3. Normal Matrix- exponentiation numbers and sum each column

***	**Humidity**	**Absolute maximum**	**Absolute minimum**	**Daily temperature**	**Maximum temperature**	**Minimum temperature**	**Precipitation**
Aji	0.331	0.148	0.021	0.089	0.047	0.267	0.098
Ardabil	5184	576	25	169	361	36	87025
Nir	4489	729	1	64	361	49	130321
Namin	4624	784	1	100	400	49	128164
Sarein	4900	484	9	121	196	16	150544
Samian	5184	841	1	81	484	16	59049
Abi-Biglu	6084	729	0	64	289	36	80089
Neor	5041	361	1	36	169	25	112225
Ardabil airport	5329	525	36	169	400	9	57121
Total	40835	5129	74	804	2660	236	804538

Source: Writer's calculations

Then, it was necessary to determine their relative weight to express the relative importance of the criteria; therefore, the AHP method was used to determine the weight of the criteria. The correlation coefficients of the criteria were determined in SPSS software to weigh them and each criterion was measured according to the correlation coefficient. Then, we calculated the weight of each criterion in the framework of Analytical Hierarchy Process (AHP) (Table 4 and 5).

Table 4. Paired comparisons of indicators

Indicators	Minimum absolute	Maximum temperature	Rainfall	Daily temperature	Maximum absolute	Minimum temperature	Humidity
Humidity	9	5	6	4	2	3	1
Minimum temperature	9	6	2	7	5	1	0.33
Maximum absolute	7	4	2	3	1	0.2	0.5
Daliy temperature	4	3	2	1	0.33	0.14	0.25
Rainfall	6	4	1	0.5	0.5	0.5	0.16
Maximum temperature	4	1	0.25	0.33	0.25	0.16	0.2
Minimum absolute	1	0.25	0.16	0.25	0.14	0.11	0.11
Importance factor	0.021	0.047	0.098	0.089	0.148	0.247	0.331

Source: Writer's calculations

Table 5. Normalized Matrix of Paired Comparison of Indicators

Indicators	Minimum absolute	Maximum temprature	Rainfall	Daily temprature	Maximum absolute	Minimum temprature	Humidity	Weight
Humidity	0.264	0.127	0.437	0.248	0.173	0.584	0.386	0.331
Minimum temprature	0.264	0.272	0.145	0.435	0.434	0.194	0.127	0.267
Maximum absolute	0.205	0.181	0.145	0.186	0.086	0.038	0.193	0.148
Daliy temprature	0.117	0.136	0.145	0.062	0.038	0.027	0.096	0.089
Rainfall	0.176	0.182	0.072	0.045	0.051	0.097	0.064	0.098
Maximum temprature	0.118	0.045	0.018	0.021	0.021	0.032	0.077	0.047
Minimum absolute	0.029	0.012	0.012	0.015	0.012	0.027	0.042	0.021

Source: Writer's calculations

At this stage, after the existing status matrix is normalized based on the formulas, the normalized matrix was multiplied by the weight of each of the indicators obtained by AHP (Table 6), which obtained a weighted normalized matrix (Table 7).

Table 6. Normal Matrix- Root the sum of each column and divide it by the number of decision matrix

***	Humidity	Absolute maximum	Absolute minimum	Daily temperature	Maximum temperature	Minimum temperature	Precipitation
Aji	0.331	0.148	0.021	0.089	0.047	0.267	0.098
Ardabil	0.356	0.335	-0.581	0.458	368	0.391	0.329
Nir	0.332	0.377	-0.116	0.282	0.368	0.456	0.402
Namin	0.337	0.391	0.116	0.353	0.388	0.456	0.399
Sarein	0.346	0.307	-0.349	0.388	0.271	0.260	0.433
Samian	0,356	0.405	-0.116	0.317	0.427	0.260	0.271
Abi-Biglu	0.386	0.377	0.000	0.282	0.330	0.391	0.316
Neor	5041	361	-0.116	0.212	0.252	0.325	0.373
Ardabil airport	0.361	0.349	-0.697	0.458	0.388	0.195	0.266

Source: Writer's calculations

Table 7. Normal Weight Matrix: Multiply the weight of each criterion by the number of each section

***	Humidity	Absolute maximum	Absolute minimum	Daily temperature	Maximum temperature	Minimum temperature	Precipitation	Total
Aji	0.331	0.148	0.021	0.089	0.047	0.0267	0.098	
Ardabil	0.356	0.335	-0.581	0.458	368	0.391	0.329	0.350
Nir	0.110	0.056	-0.002	0.025	0.017	0.122	0.039	0.367
Namin	0.111	0.058	0.002	0.031	0.018	0.122	0.039	0.382
Sarein	0.115	0.045	-0.007	0.035	0.013	0.070	0.042	0.312
Samian	0.118	0.060	-0.002	0.028	0.020	0.070	0.027	0.320
Abi-Biglu	0.128	0.056	0.000	0.025	0.015	0.104	0.031	0.359
Neor	0.116	0.039	-0.002	0.019	0.012	0.087	0.037	0.307
Ardabil airport	0.120	0.052	-0.015	0.041	0.018	0.052	0.026	0.249

Source: Writer's calculations

Step 5: At this stage, the highest value fi^+ and the lowest value fi^- criteria function of the decision matrix were extracted. Formula (1), (Table 8).

$$fi^* = \max fij \qquad fi^- = \min fij \tag{1}$$

Table 8. The minimum and maximum number of each column and its difference minus the previous value of fmax

fmax	0.042	0.122	0.020	0.041	0.002	0.060	0.128
fmin	0.026	0.052	0.012	0.019	-0.015	0.039	0.115
f+ - f-	0.016	0.070	0.008	0.022	0.017	0.021	0.013

Source: Writer's calculations

Step 6: At this point, the distance of each alternative is calculated from the positive ideal and then sum them is calculated based on the following formulas. In other words, at this stage, Sj (utility index) and Rj (dissatisfaction index) to calculate the VIKOR index were calculated in Table (9) after calculating the normalized matrix and weighted matrix and extracting the highest and lowest values for each index, . Formula (2).

$$Sj = \sum_{i=1}^{n} Wi.\frac{Fi^*-Fij}{Fi^*-Fi^-} \quad Rj = max\left[Wi.\frac{Fi^*-Fij}{Fi^*-Fi^-}\right] \tag{2}$$

Table 9. Positive and Negative Ideals

***	Humidity	Absolute maximum	Absolute minimum	Daily temperature	Maximum temperature	Minimum temperature	Precipitation
Aji	0.331	0.148	0.021	0.089	0.047	0.0267	0.098
Ardabil	0.010	0.010	0.015	0.000	0.003	0.017	0.010
Nir	0.018	0.004	0.005	0.016	0.003	0.000	0.003
Namin	0.016	0.002	0.000	0.009	0.002	0.000	0.003
Sarein	0.013	0.014	0.010	0.006	0.007	0.052	0.000
Samian	0.010	0.000	0.005	0.013	0.000	0.052	0.016
Abi-Biglu	0.000	0.004	0.002	0.016	0.005	0.017	0.011
Neor	0.011	0.021	0.005	0.022	0.008	0.035	0.006
Ardabil airport	0.008	0.008	0.017	0.000	0.002	0.070	0.016

Source: Writer's calculations

Step 7: At this stage, the VIKOR Index (the final score of each alternative) is calculated, the Q value represents the rank of each station from the total of the seven indexes studied. Formula (3), (Table 10).

$$Q = v.\frac{Sj-S^-}{S^*-S^-} + (1-v).\frac{Rj-R^-}{R^*-R^-} \quad (3)$$

Table 10. Utility and disutility of alternatives

***	Humidity	Absolute maximum	Absolute minimum	Daily temperature	Maximum temperature	Minimum temperature	Precipitation	***	
Aji	0.331	0.148	0.021	0.089	0.047	0.0267	0.098	s	R
Ardabil	0.248	0.074	0.018	0.000	0.016	0.067	0.061	0.248	0.484
Nir	0.455	0.030	0.006	0.064	0.016	0.000	0.018	0.455	0.588
Namin	0.414	0.015	0.000	0.038	0.010	0.000	0.020	0.414	0.497
Sarein	0.331	0.104	0.012	0.025	0.042	0.200	0.000	0.331	0.714
Samian	0.248	0.000	0.006	0.051	0.000	0.200	0.095	0.248	0.601
Abi-Biglu	0.000	0.030	0.003	0.064	0.026	0.067	0.069	0.069	0.258
Neor	0.290	0.148	0.006	0.089	0.047	0.134	0.035	0.290	0.748
Ardabil airport	0.207	0.059	0.021	0.000	0.010	0.267	0.098	0.267	0.663

Source: Writer's calculations

The rankings are based on Q value so that the highest value is the highest priority. Abi- Biglu station is ranked 1 in the best condition and the Nir station is in the worst condition with the rank of 8 according to the Q value of the studied climate indices, as Table 11 shows.

Table 11. Station Rankings

Station	Q	Ranking
Abi-Biglu	1	1
Ardabil	0.54	2
Samian	0.42	3
Ardabil airport	0.33	4
Namin	0.31	5
Neor	0.21	6
Sarein	0.20	7
Nir	0.16	8

Source: Writer's calculations

Lands suitability assessment for potato cultivation based on the VIKOR model

The ranking of the studied stations was carried out for climatic elements to select the appropriate place for potato cultivation by selecting and evaluating appropriate indicators, statistical methods, multi-criteria decision-making techniques and using the VIKOR model. The Ardabil plain is divided into four levels according to the final map from the VIKOR model, the first level indicating the best and most suitable area and the fourth level identifies the most inappropriate area in terms of potato cultivation, which are accounted for 6% and 31% of the total area of the plain (Fig 5).

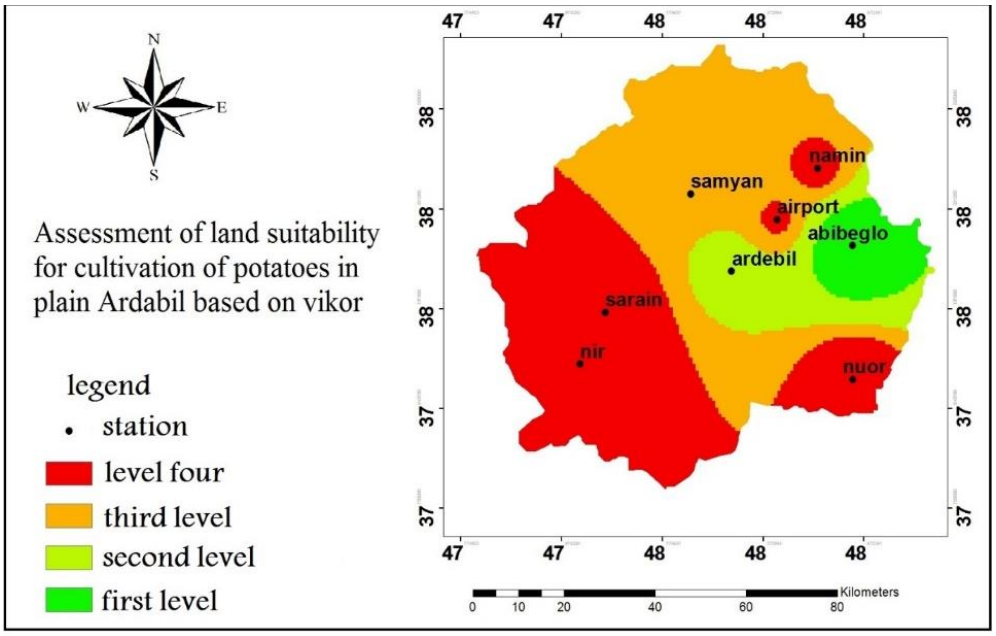

Figure 5. Lands suitability for potato cultivation based on the VIKOR model

Many studies have shown that precipitation and temperature are the most important climatic factors affecting the process of potato cultivation (Peter, 2000). For this reason, the parameters used in the research were analyzed using the VIKOR method and GIS. It is evident that the amount of precipitation has a significant role in potato crop cultivation according to the final findings. According to the Quanta studies (1975), the annual rainfall required and the growth period for potato are estimated at least 650 and 400 mm, respectively. While the annual and monthly rainfall reported in the study area is lower than the threshold. Of course, irrigation will provide the required scarcity. Rainfall changes during the growth period are also important in determining suitable areas for potato cultivation. In this study, the amount of rainfall during the growth period indicates that rainfall is only available in April and May months at some stations, and the rest of the months are faced with the shortage of rainfall. In most studies on potato, the role of temperature is higher than other climatic factors. Therefore, both elements (temperature and precipitation) play a decisive role in potato cultivation despite the shortage of rainfall in Ardabil plain. The correlations between temperature and potato showed that the minimum temperature has a significant effect on the growth period of potato in the plain of Ardabil. According to Alejandro (2003), the minimum temperature for potato cultivation is 4 to 6℃.

Conclusions

While the minimum temperature of the stations studied is less than 4℃ in April. Therefore, the Ardabil plain is not suitable for potato cultivation. The temperature fluctuations, especially in Ardabil plain isn't under the control of the human. Therefore, if the potato is cultivated without regard to this variable climatic element, damage to the product will be irreparable. The results of the VIKOR method in lands suitability evaluation indicated the high capability of this method for assessing the potential of the studied area in terms of climatic elements. This method allocates the final weight to each of the criteria based on the utility rate as well as its priority the areas in terms of

the climatic elements, so that, we can find the difference between the stations of the Ardebil Plain in terms of temperature dispersion and precipitation using this score. The Ardebil Plain is divided into four levels by analyzing the selected criteria based on VIKOR method. the first level represents the best and most suitable area and the fourth level is the worst area for the potato cultivation. The best area is the Abi- Biglu station in the first rank and Ardebil and Samian stations are in second and third rank. The main reason of the utility of the Abi- Biglu station is that it has more humidity and suitable temperatures for cultivation, which in total, a more favorable rating is given to this station and finally, the worst region is the Nir station.

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Confllct of Interest

The author declares that there is no conflict of interests regarding the publication of this manuscript.

Author Contributions

B.S, did the calculations. and V.SZ, analyzed the results and wrote the paper and F.MD, Collect Data Research.

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