Iran Agricultural Research (2021) 40(1) 101-112

Research Article

Shiraz University

Evaluation of soil fertility map for bean cultivation in Eghlid Plain by using Hybrid Fuzzy-AHP and GIS techniques

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DOR: 10.22099/IAR.2021.40610.1437

ARTICLE INFO
***Article history*:**
Received **6 May 2021**
Accepted **25 August 2021**
Available online **25 September 2021**

***Keywords*:**
Bean
Calcareous soil
Fars province
Soil fertility

ABSTRACT- The increase in the performance of cultivated plants is under the influence of various features including the soil properties. The nutrient elements of the soil are among the important soil features. The soil fertility should be studied to determine the proper level of fertilizer application. The improper use of chemical fertilizers with no attention to soil fertility not only does not increase the quality and quantity of the products but also imposes extra costs while unbalancing the level of nutritional elements of the soil and causing environmental problems. In this regard, the determination of soil fertility and providing a soil fertility map sounds necessary. In this study, the soil fertility of Shadkam plain in Eghlid county of Fars province was determined to prepare the soil fertility map for the cultivation of bean. The soil fertility map was obtained by a fuzzy system using a hierarchical analysis in a GIS environment. To this end, soil sampling was conducted from 210 locations and the input data including organic matter, potassium, phosphorous, iron, manganese, zinc, and copper concentrations were measured. The interpolation of each soil element was achieved by the inverse distance weight (IDW) model in the GIS environment. Then, a membership function was prepared for each factor to obtain the fuzzy map considering their corresponding critical values. Finally, each layer was allocated with weight using the analytic hierarchy process. Based on the relative weight of each criterion, the highest relative weight (0.354) was obtained for organic carbon while iron showed the lowest (0.031) relative weight. The results also indicated that 0.3, 80.3, and 19.4% of the studied region can be categorized as very poor, poor, and moderate groups in terms of fertility for bean cultivation, respectively.

INTRODUCTION

Soil plays a prominent role in the biogeochemical cycle as an important source of elements. The soil features show a complex trend of spatial and temporal variations (khazaie et al. 2017). The soil properties are the consequence of the interactions between a combination of biological, chemical, and physical processes in various scales (Stutter et al., 2004). A proper understanding of the changes in the nutritional elements of the soil as a function of location is of crucial significance as it can be employed as a guideline to manage soil elements for the rational use of fertilizers. Among the soil-related factors, the nutritional elements are of higher importance as they can be easily altered giving rise to a significant variation in the quality and quantity of the cultivated plants (Franzen et al. 1999).

The application levels of highly used nutritional elements such as nitrogen (N), phosphorous (P), potassium (K), as well as trace elements are among the important soil features. Elements such as N, P, and K are essential for plants. Lack of knowledge about the changes in the chemicals and nutritional elements of the soil in various regions and the uniform application of fertilizers will result in situations in which some soils receive fertilizers more than their actual need (Sokouti and Mahdian, 2011). The improper application of the chemical fertilizers with no attention to the soil fertility not only does not increase the quality and quantity of the products but also imposes extra costs. Furthermore, unbalancing the level of nutritional elements of the soil cause environmental issues (Malakouti and Gheibi, 2000).

Regarding the non-uniformity of the soils in each region due to their different origins and the improper use of chemical fertilizers can result in different productivity of soils for a specific crop (e.g. bean). For more precise studies, each region should be separated by various means including mapping. Today, different methods and tools are employed for studying soil properties including its fertility. The fuzzy model is one the most flexible methods which can be applied for soil mapping (Cassel- Gintz et al. 1997).

Legumes have the second rank in the list of human food sources after the cereals and are regarded as the main source of plant-based proteins(Maphosa & Jideani,. (2017). Among the legumes, beans have the first rank in terms of area under cultivation and economic value(Van Schoonhoven and Voysest, 1993). Beans are cultivated in all 5 continents of the world. The global area under cultivation for bean was about 27 million hectares in 2007 with a mean yield of 716 kg per hectare(FAO. 2008) . Bean is a short-day and thermophile plant that can be grown in regions with hot days and cold nights. The required temperature for bean growth is 20-28 ℃ on the day and 15-20 ℃ at night. Temperatures above 30 ℃ are not suitable for its cultivation. This plant will not form seeds at temperatures exceeding 35 ℃ . Temperatures below 15 ℃ are not suitable for its growth as well. The physiological zero of bean is 10 ℃ and the least tolerable temperature of the bean bush is 5 ℃ (Scully and Waines, 1987). Regarding the high sensitivity of the bean to the temperature, its planting date should be set in such a way that its growing course matches the proper temperature range (18-20 ℃). Loam and loamy-clay soils are suitable for bean cultivation. Bean is also sensitive to salinity and can only tolerate the salinity level of 2 dS/m. The decline in its yield, however, initiates at the salinity level of 0.8 dS/m. Bean can properly grow in the soil pH up to 8 but its most suitable growth occurs in the pH range of 6-7 (Khajehpour and Naeini 2002).

Various studies have recently addressed soil fertility all around the globe, including the quantitative evaluation of soil fertility in Gaio China with fuzzy and AHP techniques in the GIS environment by Zhang et al. (2004). Also, a study on soil fertility for rice cultivation in the Philippines by Dobermann et al. (1998) and Ebert and Trauth, (2015) can be mentioned. Ama Azghadi et al. (2010) used the AHP model to map soil fertility. To this end, organic matter, P, and K elements were measured for the cultivation of wheat in the Khuzestan Province. Their results indicated that 12.73% of the studied region was poorly fertile.

The fuzzy model is one of the best models for mapping purposes. Theory of fuzzy logic was introduced by Lotfi Zadeh (1965), an Iranian scientist. Fuzzy logic contradicts the bi-value logic of Aristotle and endorses ambiguity as a part of the system. This theory refers to unknown and ambiguous concepts. When machines fail in understanding the qualitative concepts- which can be easily understood by humans- fuzzy logic transfers the human thinking pattern to the technology. Lotfi Zadeh (1965) considered the fuzzy values as a class of items with a continuous degree of membership function. This function includes a degree varying from 0 to 1. This model requires fewer parameters and offers high precision despite its shorter computation time and costs. Therefore, this model can be used to map soil fertility. As the effective factors of soil fertility have a continuous effect on the plant performance, their investigation by zero-one logic will lead to ambiguous and unreal results. Therefore, the use of fuzzy models can be recommended as a proper technique to map soil fertility (Kˇremenov, 2004).

Since different elements of the soil could differently affect plant growth; each element has to be weighed according to its level of importance. To this end, the AHP method was employed. AHP is one of the most comprehensive systems designed to decide with multiple criteria (Qudsipour, 2005). AHP is of the multi-criterion decision-making methods in which the better or superior alternatives could be selected and the other options could be ranked based on a specific objective using various weight allocation criteria (Azar and Faraji, 2008). AHP was introduced by Saaty(1980) in the 70s. It was then employed by various researchers for evaluations and programming purposes. AHP includes the following steps: 1- building a hierarchy, 2- pair comparison and weight allocation, and 3- calculation of the incompatibility rate.

In the present study, the AHP technique was applied to allocate the weight to the parameters in accordance with the human mind and nature. It has been reported that in AHP, the preference of the factors can be explored by pair comparison in which the studied factors are pairwise compared with each other to determine their significance. A pairwise comparison matrix will be then created whose output shows the relative weight of the criteria (Malczewski, 1999). The preference of each factor was based on their superiority over each other which ranged in 1-9 (Parhizkar and Ghafari gilande, 2006). These judgments were quantified into values 1-9 by Saaty (1980) as listed in Table 1 (Qudsipour, 2005). This method includes a series of rational judgments and evaluations. It can be said that this technique is on the one hand related to the personal images and AHP design of a problem and on the other hand, it is associated with final decision through logic, comprehension and analysis (Qudsipour, 2005). Bijanzadeh and Mokarram, (2013) used a combination fuzzy-AHP method to evaluate the soil fertility for whet cultivation in Fars Province, south of Iran. They concluded that the AHP-fuzzy method has proper precision for mapping soil fertility. Nowadays, frequent soil sampling, evaluation of the changes in the elemental levels and the use of fertility maps play a decisive role in soil fertility management. As the soil fertility maps can properly determine the required chemical fertilizer based on the spatial variations of the nutrient elements, this research aimed to prepare the soil fertility map based on some chemical and nutritional factors of the soil for bean cultivation in Shadkam plain, Eghlid, Fars province using a hybrid fuzzy-AHP method.

MATERIALS AND METHODS

Region under Study

The studied region (Eghlid County) is located at 270-km north-west distance from Shiraz in southwest Iran, with an approximate area of 6000 km^2 (Fig 1). This city is

2375 m above sea level and its mean annual precipitation is about 320 mm. The annual mean temperature of the region is 12℃. The oldest sediments of these regions belong to the Cretaceous period. They are mainly limestone and can be categorized as the Bangestan group (upper Cretaceous). The latest sediments are the Quaternary alluvial deposits that cover the plains. To determine the number of dry months from all climate factors, temperature and precipitation were extracted. After determining the monthly mean of these factors, the temperature and humidity diagrams were plotted relative to P=2t. The dry season of the region started from late April and lasts until early November. Regarding the climate data, temperature and humidity variations, and mean annual temperature, soil moisture and temperature regimes of the study area were Xeric and Mesic, respectively (based on the Newhall model). 210 samples were collected from the region as the plain indicators.

Sampling and Analysis

Sampling was conducted based on a sampling network. The network dimensions were 1000×1000 m^2. Finally, 210 samples were collected from the depth of 0-30 cm as this depth is the effective cultivation depth. After transferring the samples to the laboratory, the samples were air-dried and sieved (2-mm mesh). The measured properties included available phosphorus (P) and potassium (K), total nitrogen (N), organic carbon (OC), and pH. The pH measurements were carried out using a pH-meter in a saturated paste. While organic matter and dissolved potassium were assessed by humid combustion (Nelson and Sommer, 1996) and flame test (Helmke and Sparks, 1996), respectively. P and total N were also evaluated by sodium bicarbonate extraction (Olsen, 1954) and Kjeldahl (Jonse, 2001) methods, respectively. Table 1 summarizes the descriptive statistics of the measured properties.

Mapping by Inverse Distance Weighted (IDW) Method

All the interpolation methods rely on this assumption that the points in closer proximity have more similarity compared to the farther points. In the IDW method, the principal assumption is that the correlation and similarity between the neighbors are proportional with their distance which can be defined by a function with inverse dependence on the distance. In the IDW technique, there is no need for spatial variation patterns. The IDW method is a medium weighing method in which the data are meshed and weighed by the standard deviation of one point relative to the others using meshed nodes (Taghizadeh Mehjerdi et al. 2009). In this technique, the weights are estimated and determined only according to the distance of a given point from an unknown one regardless of the points scattering. The closer points will be allocated with higher weights while those at farther distances will have lower weights (Delbari et al. 2010). In other words, it has to be noted that in this method regardless of their position and arrangements, the points at a similar distance from a given point have the same weight (Davis, 1987). The weights can be determined by the following equation 1:

$$\lambda_i = \frac{D_i^{-\alpha}}{\sum_{i=1}^{n} D_i^{-\alpha}}$$

in which λ_i shows the weight in the i-th site. D_i and α also denote the distance of the i-th site from the unknown point and weighing power, respectively.

Analytical methods such as profiling the chemical and nutritional elements as well as the fertility map of the region were achieved by fuzzy-AHP technique through the use of IDW interpolation in ArcGIS software (Ver 10.5).

Theory of Fuzzy Logic

The concept of the membership function is of crucial significance in the fuzzy sets theory as all the data of a fuzzy series can be described by this function. The membership function has been employed in all the applications and issues related to the fuzzy set theory. The membership function determines the level of fuzziness in a fuzzy set. This function indeed denotes the membership degree of various elements to set (Moreno, 2007). In classic logic, the membership to a series is determined by zero/one (one if being a member of the set, otherwise, zero). The membership function is a set whose range is [0, 1]. On the other hand, in fuzzy logic, the membership degree ranges in [0,1]. The significance of fuzzy logic lies in the fact that many human deductions and reasons are uncertain and approximate. A fuzzy set of A is a function in X, which is the membership function that defines the membership degree of x to A. The values of this membership function could range in [0,1]. Mathematically, a fuzzy set (Burrough et al. 1992) can be defined as:

$$A = \{x, \mu_A(x)\} \text{ for each, } \quad x \in X \qquad (2)$$

As the effective features of soil continuously change, the fuzzy method was utilized to prepare the soil fertility map. The fuzzy set is defined by a function in the range of 0-1 in which the members are allocated with a degree of membership. Each member can have more than one set with various membership degrees. Membership functions could be different depending on their applications. In a general classification by Lotfi Zadeh (1965), fuzzy functions can be categorized as linear and nonlinear. The membership function was determined for each effective element of the soil relative to its critical limit. Equation 3 was employed to map copper, iron, manganese, potassium, phosphorous, zinc, and organic matter (Oberthür et al, 2000).

$$\mu_A(X) = f(x) = \begin{cases} 0 & x \le a \\ \dfrac{x-a}{b-a} & a < x < b \\ 1 & x \ge b \end{cases} \qquad (3)$$

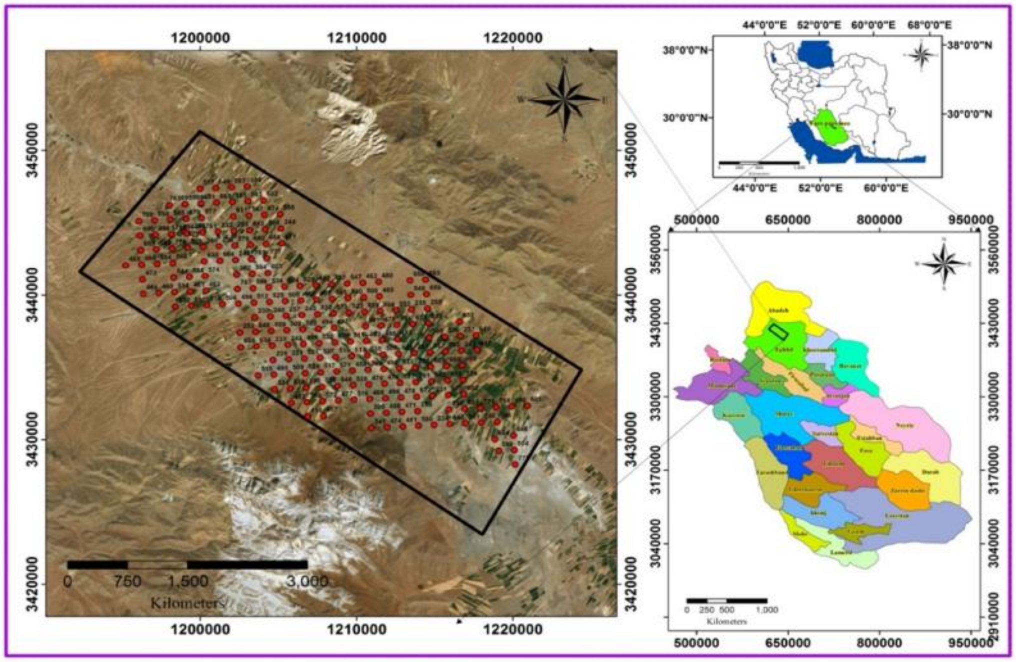

Fig.1. Map of the geographical location of sampling points in Shadkam plain used in this study

Table 1. Some of the effective parameters statistical properties of soil fertility in the study area

Parameter	Minimum	Maximum	STD	Average	CV (%)
Organic carbon (%)	0.36	2.16	0.28	0.90	31.11
Phosphorus (ppm)	3.40	46.40	4.94	16.74	29.51
Potassium (ppm)	182.0	759.9	73.3	501.8	14.62
Iron (ppm)	2.08	25.76	3.10	8.13	38.13
Zinc (ppm)	0.16	2.44	0.23	0.63	36.51
Manganese (ppm)	0.51	41.72	4.51	13.66	33.02
Copper (ppm)	0.84	3.98	0.50	1.99	25.13

Notes: STD, Standard Deviation; CV, Coefficient of variation

An asymmetric linear function was used in which x shows the input data and a and b represent the limits applied for each studied factor. These limits can be selected according to the critical limit of these factors (Ama Azghadi et al. 2010). In other words, the desired limit of these parameters can be considered as the criterion. The critical limit of the nutritional elements in the soil refers to the absorbable level of these elements below which the plant will probably respond to the fertilizer. The desirability limit shows the limit beyond which the plant will no longer exhibit an increase in the yield or show slight reactions, i.e. there is no need to add fertilizer (Kavoosi and Malakoti, 2006). The findings of Bijanzadeh and Mokaram (2017) were used to determine the critical limits of each soil parameter for the cultivation of normal bean.

Analytic Hierarchy Process (AHP)

Weight Allocation to the Studied Factors

Each factor could differently influence the bean yield. Such differences are indicated in the preference of the factors relative to each other. The values of influence of the different factors have been already determined based on their importance in the production of bean. It must be noted that the determination of this range of importance is not definite based on the predetermined standards, as it is rather based on expert opinions. The basic scales which were used for the generation of pairwise comparison matrix are shown in Table 2. Table 3 lists the ranking of factors such as usable P and K, organic matter, Fe, Mn, Zn and Cu in the production of bean according to their classification. Each of these effective factors was weighed using Expert Choice software (Qudsipour, 2005).

In AHP, the incompatibility rate shows the compatibility of the comparisons. Incompatibility rate represents the validity and accuracy of evaluations in pairwise comparisons. If the compatibility rate (CR) is equal to or lower than 0.1, the evaluations and comparisons will be correct; otherwise, the pairwise comparisons should be repeated or modified (Azar & Rajabzade, 2012).

CR can be obtained through calculating the compatibility index by the following equation (Malczewski 1999):

$$CI = \frac{\lambda_{mxc} - n}{n-1} \quad (4)$$

In the above equation, λ_{max} is the element of the specific vector, and n denotes the number of criteria. λ_{max} can be determined by the following equation (weight of the columns × evaluation matrix row/criterion weight).

Finally, by calculating the compatibility index and the randomness index (RI) the incompatibility index can be determined by the equation 5 (Malczewski 1999):

$$CR = \frac{CI}{RI} \quad (5)$$

Table 2. Basic scale was used for generation of pairwise comparison matrix

Intensity of importance	definition
1	Equal importance
2	Equal to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong
9	Extreme importance

The incompatibility rate was obtained 0.02 indicating the proper compatibility of the ratios in the pairwise comparison matrices.

Combination of Fuzzy and AHP Methods

AHP is a combination of AHP factors with the fuzzy values of each parameter. The values obtained by fuzzy function of the parameters with their corresponding weights and the sum of the obtained values (Eq. 5) were used to find the final fertility map of the studied soil.

$$\mu_A = W_1 \times \mu_{A1} + \cdots + W_K + \mu_{AK} \quad (6)$$

$$\mu_A = \sum_{J=1}^{K} W_J \times \mu_{AJ(X)} \qquad xEX$$

$$\sum_{J=1}^{K} W_J = 1 \qquad W_J > 0$$

In the above equation, μ shows the membership function of each parameter and W denotes the weight allocated to each parameter. Fig. 2 depicts a schematic diagram of the fuzzy-AHP method used to prepare the soil fertility map in the Shadkam region.

Table 3. Sub pair comparison matrix to calculate fertility factor weights for common bean cultivation

Parameter	Organic carbon	Phosphorus	Potassium	Iron	Zinc	Manganese	Copper	Weight
Organic carbon (%)	1							0.354
Phosphorus(ppm)	0.5	1						0.240
Potassium(ppm)	0.33	0.50	1					0.159
Iron(ppm)	0.20	0.25	0.33	1				0.067
Zinc(ppm)	0.25	0.33	0.50	2.00	1			0.104
Manganese(ppm)	0.14	0.17	0.20	0.33	0.25	1		0.031
Copper(ppm)	0.17	0.20	0.25	0.25	0.33	2.00	1	0.045

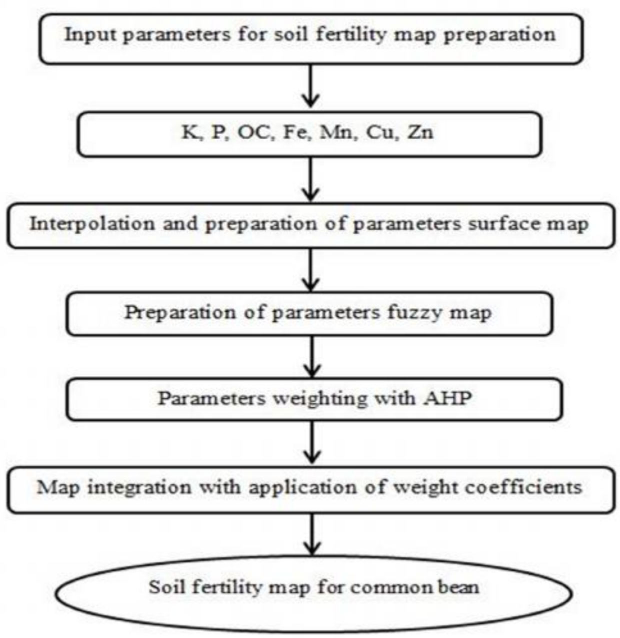

Fig. 2. Schematic diagram and hierarchy of the hybrid Fuzzy-AHP approach for the selected study area. K: Available Potassium; P: Available phosphorus; OC: Soil organic carbon; Fe: Iron; Mn: Manganese; Cu: Copper; Zn: Zinc

RESULTS AND DISCUSSIONS

Table 1 lists some of the statistical features of the parameters effective in soil fertility of the studied region. With the help of the soil fertility map, the deficient regions can be identified. Thus the plant nutrition and soil fertilizers can be properly managed according to the fertility limits. To this end, the chemical and nutritional elements of the soil including organic carbon (OC), phosphorous (P), potassium (K), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) were analyzed. Their spatial distribution in the surface soil (0-30 cm) was explored in the GIS environment using the IDW method (Fig. 3).

For better management of the fertilizer and achieving a high bean production yield, a comprehensive deal of knowledge on the levels of the chemical elements and nutrients of the soil is necessary. The organic carbon levels in the studied area varied between 0.36 and 2.16%. On average (0.9%), organic carbon was lower than the critical limit for bean production. High levels of organic carbon were found in the southern parts of the region and some scattered regions in the west, while it was very low in the northern and eastern parts of the studied area. The amount of potassium varied between 182 and 760 mg/kg (mean: 501.79 mg/kg). As can be seen, most of the studied regions possessed enough potassium for bean growth and the low-potassium areas were scattered in the form of spots. The phosphorus content of the studied area ranged from 3.40 to 46.40 mg/kg. High levels of phosphorus were found in the southeast, while low levels were mainly distributed in the west and some east and northeast parts.

The iron content was between 2.08 (yellow) to 25.76 (blue) (mg/kg), only some parts in the west and southwest exhibited high iron content. The amount of zinc varied between 0.16 to 2.44 mg/Kg and the highest amount was found in the southeast and east parts of the studied area (Fig. 3). The manganese level was between 0.51 (yellow) to 41.72 (blue) mg/kg. Except for some parts in the south and middle, other parts of the region showed almost a high amount of manganese. According to Fig. 4, the surface soil of the studied area contained between 0.84 and 3.98 mg/kg copper, the highest amount of copper was observed in south and west (blue) parts.

Then, by applying the fuzzy membership function presented in Eq. 3, the map of studied parameters was separately prepared considering that the fuzzy values of the parameters constantly changed between zero and one. The maps of each effective soil parameter are depicted in Fig. 4. As can be seen, Fig. 4 shows the continuous changes of these parameters in the studied area. The blue color indicates the maximum value of the parameters (i.e. the areas where the level of studied factors exceeded the desirable level (b)) while the red color presents the areas in which the values of these parameters are less than the critical value (a). The areas between these two modes are shown in yellow to green at different intensities.

The maps created in the next step were weighted according to their degree of importance in fertility using knowledge and expertise and the application of ratios based on the table presented by Saaty (1980) (Table 2) by the method of the hierarchical analysis process. In the present study, based on the calculated relative weights listed in the last column of Table 2, the most important factor in soil fertility was obtained for organic carbon (OC) with a weight of 0.354 and the lowest factor was for iron with a weight of 0.031 (Table 3). To obtain suitable weights, the value of the compatibility index should be less than 0.1, which was 0.02 in this study, indicating the compatibility and appropriate selection of ratios in the two-by-two comparison matrix. The values of the pairwise comparison matrix of the parameters and their weighting coefficients are presented in Table 3. Finally, the weighted layers of the parameters were combined and the final soil fertility map was prepared (Fig. 5). Changes from green to brown indicate well to poor conditions in terms of soil fertility for bean cultivation based on the measured parameters. The results indicated in Table 4 showed that about 19.4% of the studied area had medium fertility, 80.3% showed low fertility and 0.3% had very low fertility for bean cultivation. Bijanzadeh and Mokarram (2013) used a fuzzy-AHP method to evaluate fertility classes for wheat cultivation in Fars province, southwestern Iran. Their results revealed that 15% of lands had high, 23% showed moderate, 45% possessed low and 16% exhibited very low fertility. In another study (Bijanzadeh and Mokarram, 2017) conducted on bean cultivation in Shiraz, it was reported that according to the fuzzy-AHP model, 52.38% of the studied area was moderately fertile for bean production This method was introduced as a useful tool to predict soil fertility in this case study (Bijanzadeh and Mokarram, 2017). In the present research, fifteen points were randomly selected to determine the accuracy of the distinctive groups by the mentioned method (fuzzy-AHP) (Fig. 5).

The level of elements in the samples was determined in the laboratory. The results of re-sampling are shown in Table 5 and Fig. 6. Considering the data indicated in Table 5 and Fig. 6 and comparing these values with the separated groups in Fig. 5, it can be stated that these random points according to their values are exactly in the separated groups considering their defined limits in the map. Therefore, the AHP-fuzzy model can be used to determine soil fertility in the Shadkam region. Ama Azghadi et al. (2010) obtained similar results in a study on soil fertility mapping for wheat cultivation in northern Ahvaz.

Table 4. The area (HA) and percentage of the study region determined for each soil fertility group

Fertility group	Hectares (HA)	%
Medium fertility	125	0.3
Low fertility	30630.35	80.3
Very low fertility	7384.4	19.4

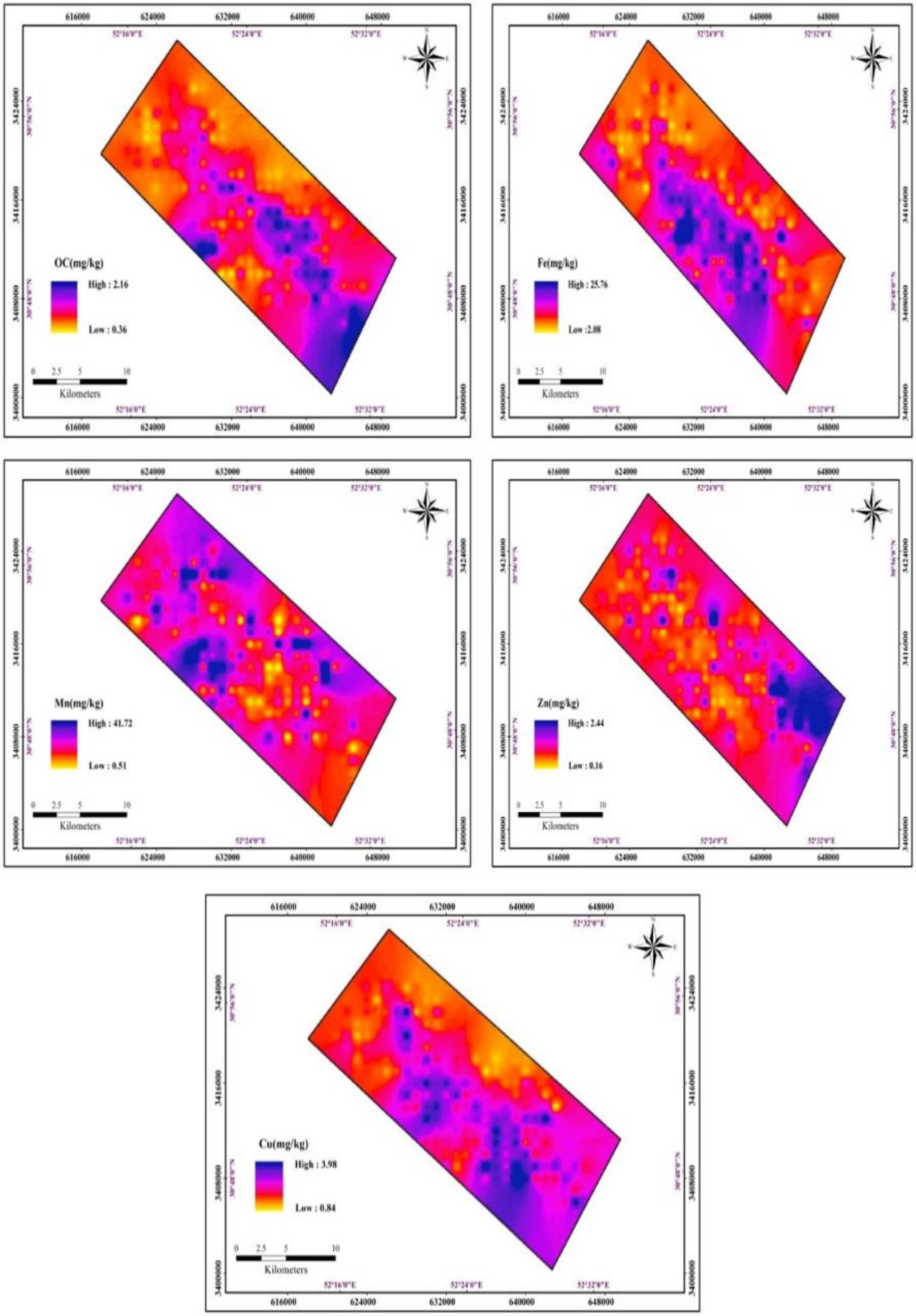

Fig.3. The zonation of soil parameters included phosphorus (P), potassium (K), organic carbon (OC),Iron (Fe), Manganese (Mn), Zinc (Zn) and Copper (Cu) using the inverse distance weighting (IDW) model in the study area for bean cultivation

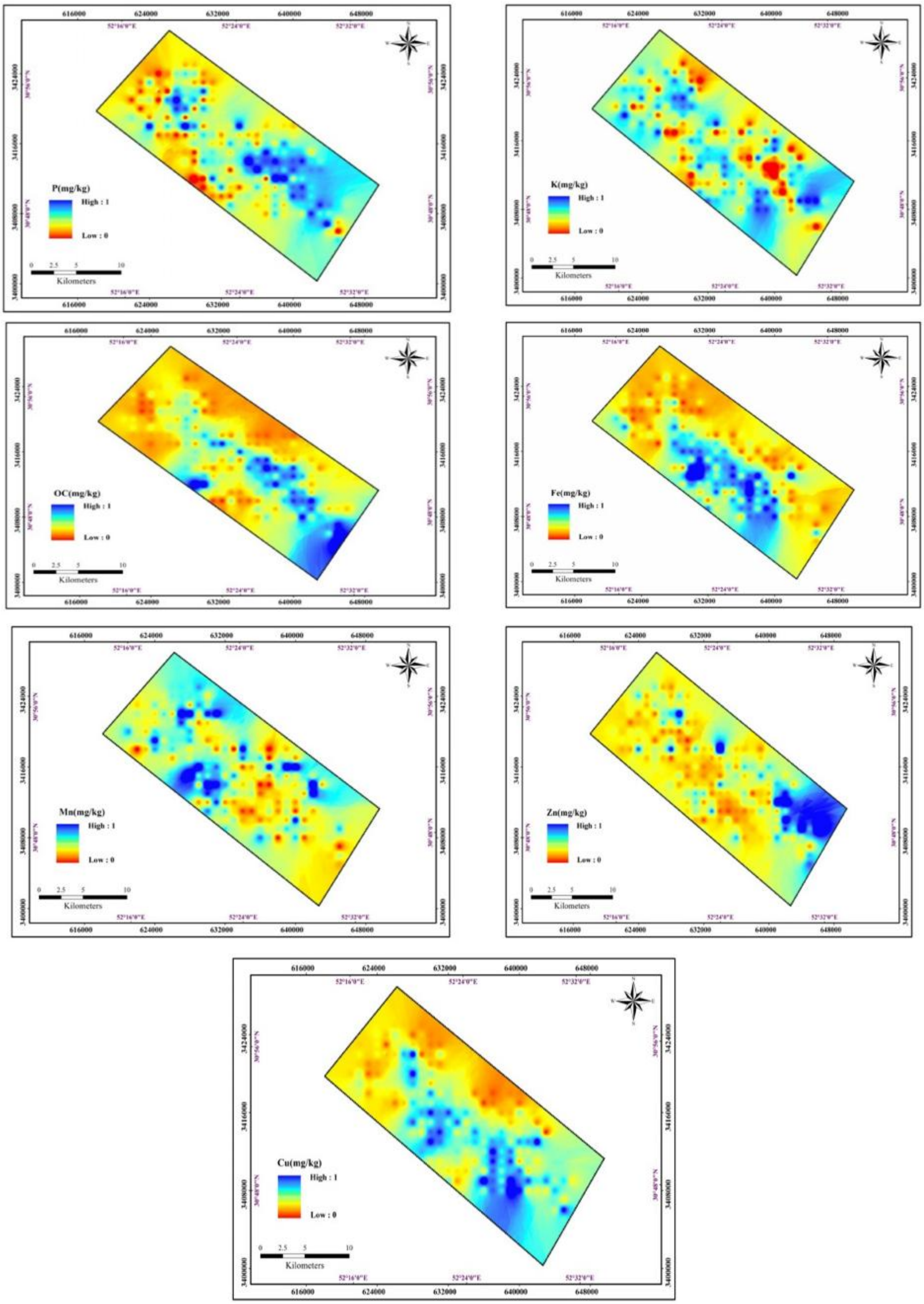

Fig. 4. Fuzzy maps of effective parameters for determining the soil fertility for common bean in the study area

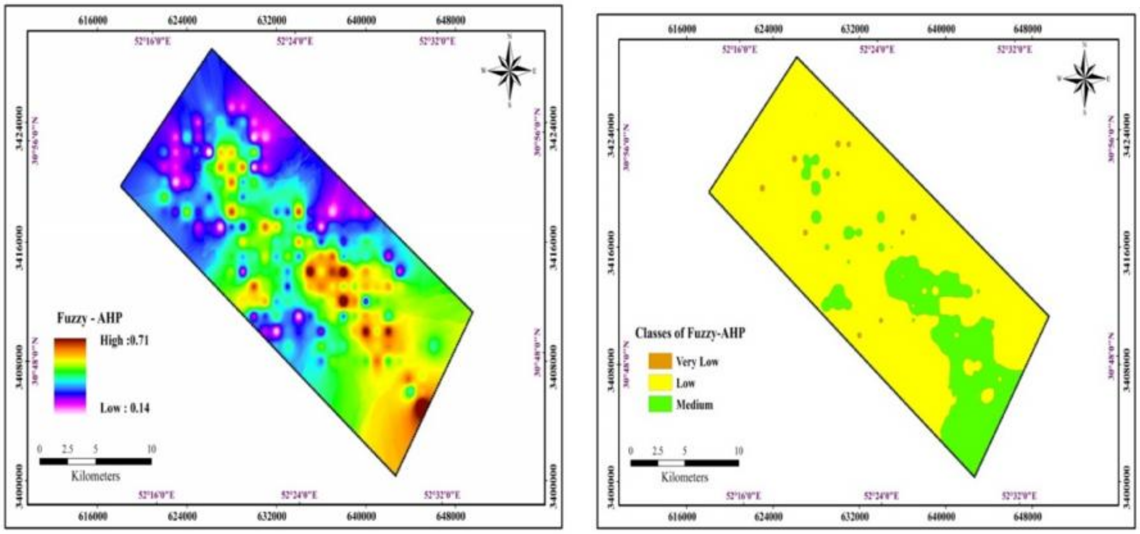

Fig. 5. Soil fertility map by Fuzzy-AHP approach for common bean in the study area

Table 5. Evaluation of effective soil parameters and Fuzzy map using control points

Soil sample	P*	OC	Zn	Fe	Mn	Cu	K	Fertility group
1	12.4	0.8	0.8	3.8	16.7	1.5	536.0	Low Fertility
2	7.0	0.4	0.6	5.0	11.3	1.5	580.0	Low Fertility
3	14.0	0.6	0.4	9.0	0.9	1.8	568.0	Low Fertility
4	10.8	0.5	0.5	7.0	21.0	1.2	328.0	Low Fertility
5	44.8	1.1	1.4	9.7	9.6	2.0	548.0	Medium Fertility
6	15.0	1.2	0.7	5.4	23.6	1.9	548.0	Low Fertility
7	19.0	1.5	0.5	12.1	15.9	2.4	580.0	Medium Fertility
8	37.2	0.9	2.4	6.7	30.8	1.7	536.0	Medium Fertility
9	11.8	0.5	0.3	7.4	7.3	1.2	472.0	Low Fertility
10	28.6	1.9	0.5	10.3	1.1	2.1	248.0	Medium Fertility
11	17.4	0.9	0.7	13.7	5.9	2.3	420.0	Low Fertility
12	7.4	0.4	0.2	3.9	10.2	1.6	496.0	Low Fertility
13	27.8	1.5	0.5	6.7	4.7	1.5	208.0	Low Fertility
14	18.0 1.1 0.7 6.0 13.0	2.7	626.0	Medium Fertility				
15	4.4 1.9 1.0 12.7 13.4	3.4	278.0	Medium Fertility				

The unit of carbon is percentage (%) and the unit of other parameters is ppm*

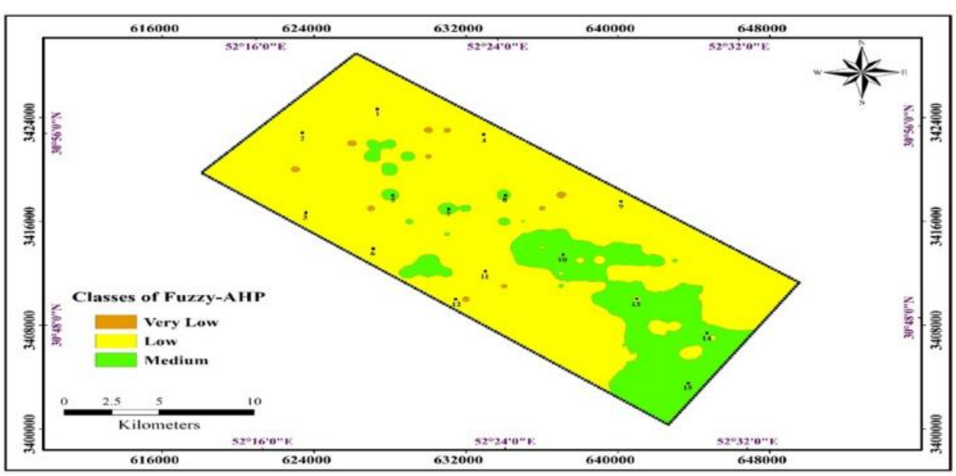

Fig. 6. Location of re-sampling points in the study area

CONCLUSIONS

In modern agriculture, it is necessary to prepare a soil fertility map to better plan for the use of chemical fertilizers and soil utilization. The hybrid AHP-fuzzy method was used in the GIS environment to profile and determine the soil fertility for bean cultivation. The results of this study showed that soil organic carbon has the greatest impact on soil fertility with a weight of 0.354. In terms of fertility, most of the area was classified in the low-fertility class. In general, it can be said that the preparation of a soil fertility classification map can be considered as an effective step in soil fertility studies and fertilizer management in different parts of the country. These maps can be used by experts to determine specific locations for nutrient distribution and their changes in different land locations. The results of the fuzzy method for determining soil fertility were closer to reality.

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تحقیقات کشاورزی ایران (۱۴۰۰) ۴۰(۱) ۱۰۱-۱۱۲

مقاله علمی- پژوهشی

ارزیابی نقشه حاصلخیزی خاک دشت اقلید برای لوبیا با استفاده از روش هیبرید فازی- تحلیل سلسله مراتبی و سامانه اطلاعات جغرافیایی

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اطلاعات مقاله

تاریخچه مقاله:
تاریخ دریافت: ۱۴۰۰/۲/۱۶
تاریخ پذیرش: ۱۴۰۰/۶/۳
تاریخ دسترسی: ۱۴۰۰/۷/۲۵

واژه‌های کلیدی:
لوبیا
خاک‌های آهکی
استان فارس
حاصلخیزی خاک

چکیده- افزایش عملکرد گیاهان زراعی تحت تاثیر عوامل مختلفی از جمله خصوصیات خاک است. از جمله ویژگی‌های خاک می توان به عناصر غذایی موجود در خاک اشاره کرد. تعیین حاصلخیزی خاک برای مشخص کردن میزان کوددهی بسیار مهم است. بدون توجه به میزان حاصلخیزی خاک، با مصرف نادرست کودهای شیمیایی نه تنها عملکرد کیفی و کمی محصولات بالا نمی‌رود، بلکه باعث می‌شود ضمن تحمیل هزینه‌های اضافی، تعادل عناصر غذایی در خاک بهم خورده و مسائل زیست محیطی نیز مطرح شود. بنابراین تعیین درجه حاصلخیزی خاک و تهیه نقشه حاصلخیزی ضروری به نظر میرسد. در این مطالعه سعی بر آن شد تا با تهیه نقشه حاصلخیزی خاک به منظور کشت لوبیا در دشت شادکام شهرستان اقلید استان فارس، درجه حاصلخیزی خاک مشخص شود. نقشه حاصلخیزی خاک با استفاده از سامانه فازی و تحلیل سلسله مراتبی در محیط GIS تهیه گردد. جهت نیل به این اهداف از ۲۱۰ نقطه منطقه مورد مطالعه نمونه برداری صورت گرفت و داده‌های ورودی برای تعیین حاصلخیزی خاک که شامل غلظت‌های ماده آلی، پتاسیم، فسفر، آهن، منگنز، روی و مس بودند اندازه گیری شدند. در ابتدا درون یابی برای هر یک از عناصر خاک با استفاده از مدل وزن دهی عکس فاصله (IDW) در محیط GIS انجام شد. سپس برای هر یک از عوامل به منظور تهیه نقشه فازی یک تابع عضویت با توجه به حد بحرانی آنها تهیه گردید. در نهایت برای وزن دهی به هریک از لایه ها از روش تحلیل سلسله مراتبی (AHP) استفاده شد. بر اساس وزن‌های نسبی هر یک از معیارها بیشترین وزن نسبی مربوط به کربن آلی به میزان ۰/۳۵۴ و کمترین وزن نسبی محاسبه شده مربوط به عنصر آهن قابل استفاده با مقدار ۰/۰۳۱ بود. همچنین نتایج نشان داد که ۰/۳، ۸۰/۳ و ۱۹/۴درصد از منطقه مورد مطالعه به ترتیب در گروه های خیلی ضعیف، ضعیف ومتوسط از لحاظ حاصلخیزی جهت کشت لوبیا قرار گرفتند.