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Application of grey GIS filtration to identify the potential area for cement plants in South Khorasan Province, Eastern Iran

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ABSTRACT

Cement-based materials are primary resources used in construction. The increase in requests for and consumption of cement products, especially in Iran, indicates that more cement plants should be equipped. This study developed a geographical information system using pairwise comparison based on grey numbers to identify potential sites in which to set up cement plants. A group of five experts compared the effective criteria using the data for South Khorasan province. After filtering numerous sites, an area with potential locations for construction of a cement plant was identified. The selection of the potential area considered the distance to mines, access roads, gas source, and faults. Classification maps were surveyed for land use, pedology, and topography. The potential area was resulted in the north of the province based on the importance weights of 0.307, 0.301, 0.17, 0.087, 0.082, 0.04, and 0.032 for the criteria of land use, proximity to mines, proximity to access roads, proximity to gas substations, topography, pedology, and proximity to faults, respectively.

Keywords : *Cement plant, limestone mine, grey pairwise comparison, geographical information system*

1. Introduction

Cement-based materials are used to build infrastructures and buildings. Fossil fuel and non-renewable raw materials are fundamental to cement production. These resources can cause pollutants in the form of particulate matter and gaseous emissions [1]. Noise pollution is another adverse effect of the cement production industry [2]. Identification of potential areas for development of a cement plant is an important decision from the economic and environmental viewpoints.

Locating a suitable site for an industrial center is a crucial step [3]. Numerous studies have been conducted to locate switching centers in communication networks and police stations on roads [4]. Some researchers have modeled the problem of locating facilities and sources in static and dynamic forms [5]. Some models have been developed to analyze suitable locations for heavy industry centers, such as warehouses [6]. *Sweeney and Tatham* developed a model for the dynamic analysis of multiple warehouse locations [7]. *Yong* located industrial sites using the technique for order of preference by similarity to ideal solution (TOPSIS) with fuzzy numbers [8]. *Azizi et al.* incorporated the analytic network process (ANP) and the decision-making trial and the evaluation laboratory method in geographical information system (GIS) software to locate a wind power plant site in Iran [9]. *Asakereh et al.* applied a fuzzy analytical hierarchy process (AHP) with a GIS-based approach to locate appropriate solar energy sites in Iran [10]. *Sozen et al.* utilized a data envelopment analysis and TOPSIS to select suitable sites for solar plants in Turkey [11]. *Lee et al.* located a photovoltaic solar plant in Taiwan using integrated fuzzy ANP and Višekriterijumsko Kompromisno Rangiranje (VIKOR) [12].

Several studies have been conducted in the mining industry. *Ataei* selected an appropriate site for a cement plant in East Azerbaijan province using AHP [13]. *Safari et al.* identified a suitable site for a processing plant for Sangan phase 1 using AHP [14]. These researchers used fuzzy TOPSIS to locate a processing plant site for Sangan phase II [15]. *Bakhtavar and Lotfian* developed an approach based on fuzzy AHP and grey multi-criteria decision-making techniques to locate a mineral processing plant site [16]. *Bakhtavar et al.* developed a fuzzy goal-programming model for locating a central processing plant site that was near small-scale dimension stone quarries [17].

Recently, especially in Iran, the consumption of cement and cement-based material has increased, and more cement plants are required. This study used GIS and developed a grey scale for pairwise comparison based on grey numbers and weights to identify potential sites for cement plants. The novelty of this study is its consideration of the uncertainties of the decision using a novel grey pairwise comparison scale in a GIS environment.

2. Material and methods

An ArcGIS tool was used with grey numbers and weights to filter and eliminate areas with low potential for locating cement plants. The important criteria were based on expert opinion about the area under study. Pairwise comparisons were made using the grey scale based on expert opinion to score the criteria.

2.1. Grey Pairwise comparison

Uncertain pairwise comparison was developed by initially reviewing the literature on grey numbers and related mathematical operations.

2.1.1. Grey numbers and operation

A grey number has an exact unknown value but a public domain. Lower and upper bounds specify it, and the interval grey number is denoted as $\otimes G = [\underline{G}, \bar{G}]$ [18]. The operations performed on the grey numbers $\otimes G_1 = [\underline{G_1}, \bar{G}_1]$ and $\otimes G_2 = [\underline{G_2}, \bar{G}_2]$ are shown in Eq. 1-7 [19].

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$$\otimes G_1 + \otimes G_2 = \left[\underline{G_1} + \underline{G_2}, \bar{G}_1 + \bar{G}_2\right] \quad (1)$$

$$\otimes G_1 - \otimes G_2 = \left[\underline{G_1} - \underline{G_2}, \bar{G}_1 - \bar{G}_2\right] \quad (2)$$

$$\otimes G_1 \times \otimes G_2 = \left[\min(\underline{G_1}\underline{G_2}, \underline{G_1}\bar{G}_2, \bar{G}_1\underline{G_2}, \bar{G}_1\bar{G}_2), \max(\underline{G_1}\underline{G_2}, \underline{G_1}\bar{G}_2, \bar{G}_1\underline{G_2}, \bar{G}_1\bar{G}_2)\right] \quad (3)$$

$$\otimes G_1 \div \otimes G_2 = \left[\underline{G_1}, \bar{G}_1\right] \times \left[\frac{1}{\underline{G_2}}, \frac{1}{\bar{G}_2}\right] \quad (4)$$

$$a \times \otimes G_1 = \left[a \times \underline{G_1}, a \times \bar{G}_1\right] \quad (5)$$

$$(\otimes G)^{-1} = \left[\frac{1}{\bar{G}}, \frac{1}{\underline{G}}\right] \quad (6)$$

$$L(\otimes G) = \bar{G} - \underline{G} \quad (7)$$

where, a is a constant and L is the length of a grey number

2.1.2. The steps of grey pairwise comparison

The novelty of this study is the development of a pairwise comparison procedure based on grey numbers. The criteria can be weighted using this procedure under uncertainty. The steps of the procedure are:

Step 1: Creation of a pairwise comparison matrix of criteria based on the grey scale proposed in Table 1.

Step 2: Normalization of the grey pairwise comparison matrix by dividing each grey value in a column by the sum of that column. This normalization is similar to AHP.

Step 3: Calculation of grey weights by taking an average of the grey values of each row.

Step 4: Conversion of the grey weights into crisp weights for simple comparison and ranking by averaging the lower and upper bounds of each grey weight.

Step 5: Determination of the degree of consistency of grey pairwise comparison using the AHP trend.

2.2. Data analysis based on GIS

The study area locates in South Khorasan Province, an area with excellent potential for construction of a cement plant. This province is located in eastern Iran, and its capital is Birjand. Existing cement plants are unable to meet the demand in this province. They also receive many requests for cement from adjacent provinces. This province has a border with Afghanistan, which is a new market for cement exports.

The conditions of the study area and expert opinion have identified proximity to limestone mines (C_1), proximity to gas substations (C_2), proximity to faults (C_3), land use (C_4), pedology (C_5), proximity to access roads (C_6), and topography dip (C_7) as the main criteria.

Table 1. Grey scale for pairwise comparison.

Crisp Value	Importance grey value*	Linguistic variables
1	[1,1]	Equal Importance
3	[3,4]	Moderate dominance
5	[5,6]	Strong dominance
7	[7,8]	Demonstrated dominance
9	[9,10]	Absolute dominance

* Intermediate grey values are [1,3], [4,5], [6,7], [8,9]

A map detailing each main criterion was provided as input data. A grey value (domain) between [1,1] (crisp value of 1) and [9,10] (crisp value of 9) was provided for each field using GIS principles according to the location requirements of the cement plant. In this case, the objective was to classify the map of each criterion using expert opinion. Table 2 summarizes the grey values for the different fields in terms of land use and pedology based on the proposed grey scale. Environmental concerns were considered with the land use criteria. Table 2 shows that barren land, a sub-criterion under land use, obtained the highest grey value ([9,10]) and is most suitable for a cement plant. By contrast, an area with aquifers, urban areas, airports, and agricultural land, with grey values of [1,1], are unsuitable for a cement plant.

Using the scores in Table 2, we created the maps based on land use and pedology shown in Figs. 1 and 2. Also, distance maps were prepared for other criteria. The concentric circles in the center of each infrastructure denote the dispersion of primary sources in each criterion map. In this case, each circle has a specific value according to the positivity or negativity of the criteria. Table 3 lists the values of the fields related to each criterion according to expert opinion. Fig. 3 is a topography map of the area prepared using an altitudinal raster. Using the scores in Table 3, we also created the maps based on proximity to mines, access roads, gas substations, and faults as shown in Fig. 4 (a-d).

Table 2. Values for the fields of land use and pedology based on the grey scale.

	Land use								
	Aquifer	Agriculture and gardens	Barren Lands	Floodway	Urban areas	Afforest	Cliff lands	Salt lake	Airport
Value	[1,1]	[1,1]	[9,10]	[1,3]	[1,1]	[7,8]	[1,3]	[1,1]	[1,1]

	Pedology					
	Pediplain	Flat and slat areas	Floodplain	Plateau and upper levels	Fan shape alluvium	Sedimentary plain
Value	[9,10]	[8,9]	[7,8]	[3,4]	[1,1]	[7,8]

Table 3. Values for the other fields based on the grey scale.

Proximity to mines (km)	Proximity to access roads (km)	Proximity to faults (km)	Proximity to gas substations (km)	Topography dip (degree)	Grey number
<10	<10	> 40	<15	0-25	[9,10]
10-20	10-20	35-40	-	-	[8,9]
20-30	20-30	30-35	-	25-35	[7,8]
30-40	30-40	25-30	15-30	-	[6,7]
40-50	40-50	20-25	-	35-45	[5,6]
50-60	50-60	15-20	30-45	-	[4,5]
60-70	60-70	10-15	45-60	45-55	[3,4]
70-80	70-80	5-10	-	-	[1,3]
> 80	> 80	<5	> 60	> 55	[1,1]

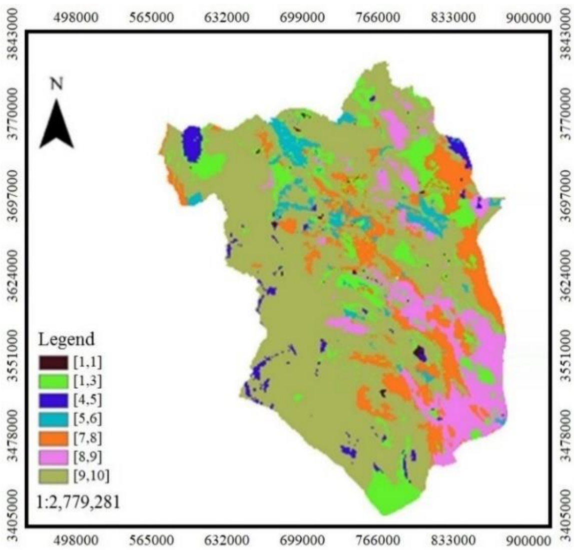

Fig. 1. Map for land use classification based on grey numbers.

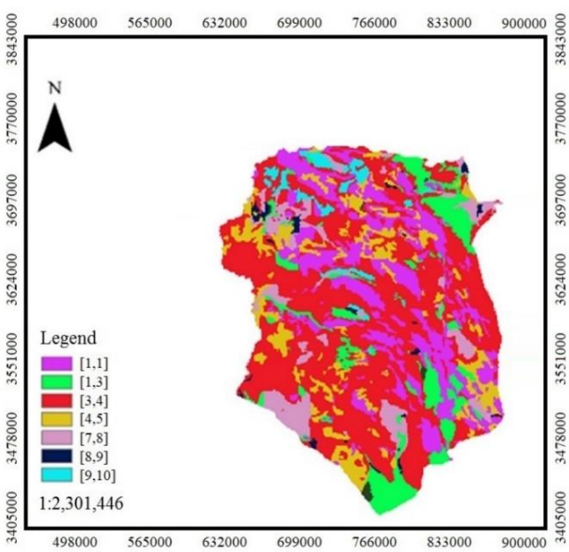

Fig. 2. Map for pedology classification based on grey numbers.

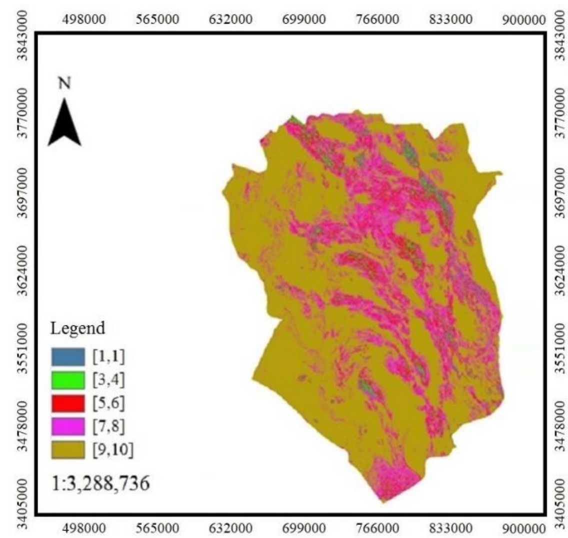

Fig. 3. Map for topography dip classification based on grey numbers.

3. Results and discussion

The classified layers were combined after preparing the layers to find suitable areas for cement plants in the ArcGIS environment based on the grey pairwise comparison. Pairwise comparison of the seven main criteria considered for the site was compiled according to the consensus of five experts. The weight of each criterion was determined according to the grey procedure.

The grey pairwise comparison matrix is given in Table 4. Table 5 lists the normalized grey pairwise comparison matrix along with grey and crisp weights. In this table, a weight of 0.307 was obtained for the land use criterion because of environmental considerations according to expert opinion. After the land use criterion, proximity to limestone mines, with a weight of 0.301 was ranked as the second important criterion because the close proximity of cement plants to mines decreases the final price of the cement product. The criterion of proximity to access roads, with a weight of 0.17, ranked third in importance. This criterion also can affect the final price of the cement product. The criterion that ranked fourth was proximity to gas substations, with a weight of 0.087, because it is the primary source of energy needed by the plant.

Table 4. Grey pairwise comparison matrix of criteria.

Criteria	Proximity to mines	Proximity to gas substations	Proximity to faults	Land use	Pedology	Proximity to access roads	Topography dip
	C1	C2	C3	C4	C5	C6	C7
C1	[1,1]	[4,5]	[6,7]	[1,1]	[5,6]	[3,4]	[4,5]
C2	[0.2,0.25]	[1,1]	[3,4]	[0.2,0.25]	[4,5]	[0.25,0.33]	[1,1]
C3	[0.14,0.17]	[0.25,0.33]	[1,1]	[0.14,0.17]	[0.33,1]	[0.17,0.2]	[0.25,0.33]
C4	[1,1]	[4,5]	[6,7]	[1,1]	[6,7]	[3,4]	[4,5]
C5	[0.17,0.2]	[0.2,0.25]	[1,3]	[0.14,0.17]	[1,1]	[0.17,0.2]	[0.25,0.33]
C6	[0.25,0.33]	[3,4]	[5,6]	[0.25,0.33]	[5,6]	[1,1]	[3,4]
C7	[0.2,0.25]	[1,1]	[3,4]	[0.2,0.25]	[3,4]	[0.25,0.33]	[1,1]
SUM	[2.96,3.2]	[13.45,16.58]	[25,32]	[2.94,3.17]	[24.33,30]	[7.83,10.07]	[13.5,16.67]

Topography, pedology, and proximity to faults were weighted 0.082, 0.04, and 0.032, respectively. These criteria are of lower importance than the other criteria under consideration. The topographical conditions of the area were evaluated to determine the areas with the lowest need for alignment and leveling. The map of the pedology of the area was assessed to avoid plant construction on clay or shale presenting a risk of subsidence during the lifetime of the plant. The criterion of proximity to faults was investigated by assessing the fault maps of the area to eliminate the risk presented by seismicity over the lifetime of the plant.

The coordinates of potential sites were used to determine sustainable sites for a cement plant using the proposed approach. A mesh network was placed over potential areas. The size of each mesh was 100 ha, which is the area required for the cement plant considering planned development and all supplementary buildings. Access roads and all inhabited areas with populations of more than ten households were included in the meshing map. The output of the GIS tool for potential sites for a cement plant based on the grey scale is shown in Fig. 5. In this figure, the sites with high potential are shown in green and magnified.

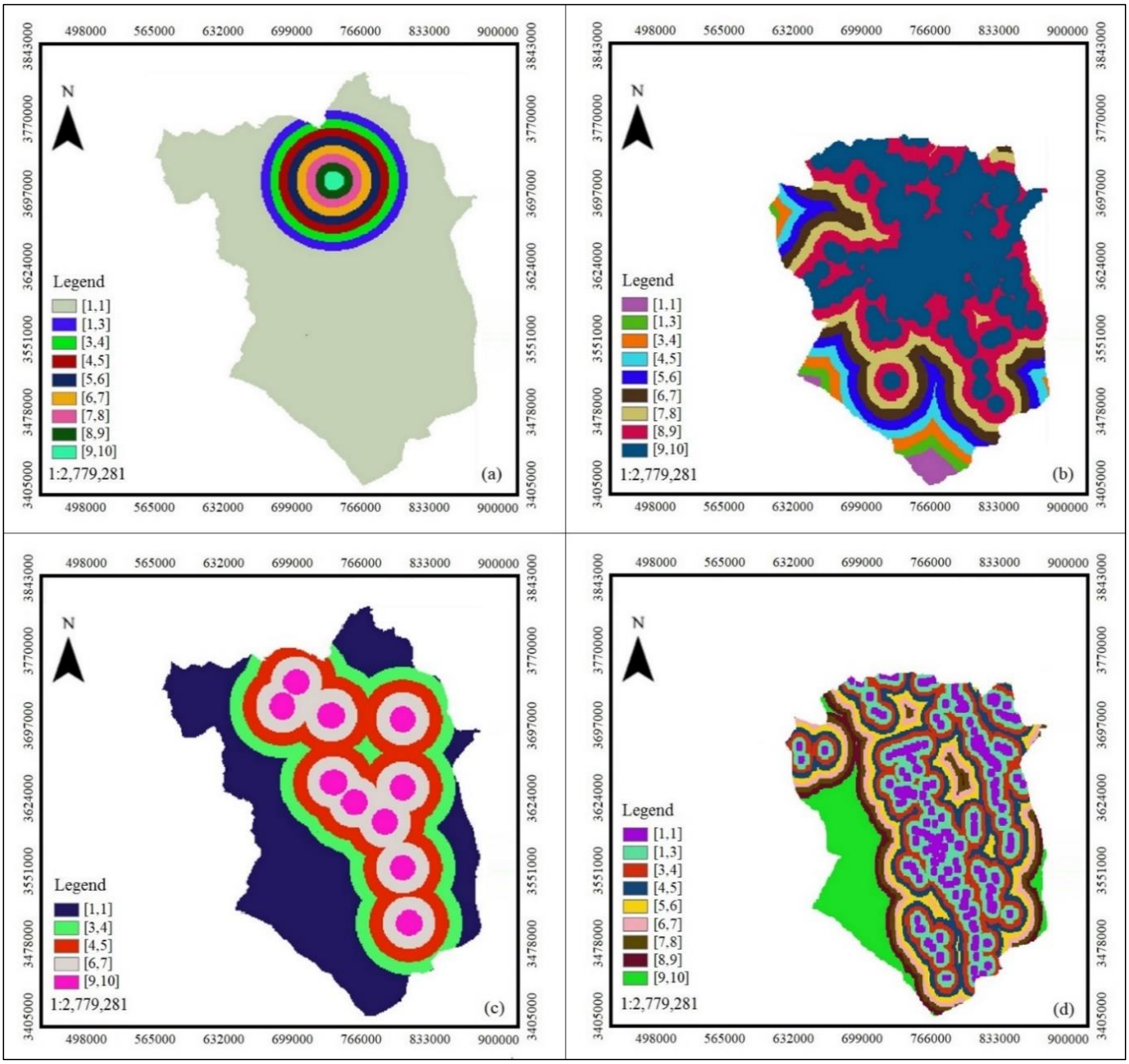

Fig. 4. Map for the criteria based on proximity using grey numbers: a) proximity to mines, b) proximity to access roads, c) proximity to gas substations, d) proximity to faults.

Table 5. Normalized grey pairwise comparison matrix and crisp weights.

Criteria	Proximity to mines C1	Proximity to gas substations C2	Proximity to faults C3	Land use C4	Pedology C5	Proximity to access roads C6	Topography dip C7	Grey weights	Crisp weights
C1	[0.313,0.338]	[0.241,0.372]	[0.188,0.28]	[0.316,0.341]	[0.167,0.247]	[0.298,0.511]	[0.24,0.37]	[0.252,0.351]	0.301
C2	[0.063,0.084]	[0.06,0.074]	[0.094,0.16]	[0.063,0.085]	[0.133,0.205]	[0.025,0.043]	[0.06,0.074]	[0.071,0.104]	0.087
C3	[0.045,0.056]	[0.015,0.025]	[0.031,0.04]	[0.045,0.057]	[0.011,0.041]	[0.017,0.026]	[0.015,0.025]	[0.026,0.038]	0.032
C4	[0.313,0.338]	[0.241,0.372]	[0.188,0.28]	[0.316,0.341]	[0.2,0.288]	[0.298,0.511]	[0.24,0.37]	[0.256,0.357]	0.307
C5	[0.052,0.068]	[0.012,0.019]	[0.031,0.12]	[0.045,0.057]	[0.033,0.041]	[0.017,0.026]	[0.015,0.025]	[0.029,0.051]	0.040
C6	[0.078,0.113]	[0.181,0.297]	[0.156,0.24]	[0.079,0.114]	[0.167,0.247]	[0.099,0.128]	[0.18,0.296]	[0.134,0.205]	0.170
C7	[0.063,0.084]	[0.06,0.074]	[0.094,0.16]	[0.063,0.058]	[0.1,0.164]	[0.025,0.043]	[0.06,0.074]	[0.066,0.098]	0.082

4. Conclusion

Cement and its related products are the primary materials used in the construction and development of urban infrastructures. This study focused on filtering and decreasing the number of potential plant alternatives by using GIS based on the grey pairwise comparison in the ArcGIS environment. Seven factors were recognized as the most important criteria for grey-based pairwise comparison based on the conditions of the study area and expert opinion. The consensus of five experts on the pairwise comparison matrix weighted land use as the environmental criterion at 0.307 and the crucial criterion. The grey pairwise comparison showed that proximity to limestone mines, proximity to access roads, proximity to gas substations, topography, pedology, and proximity to faults followed land use in the rank of importance, respectively. Numerous alternatives were filtered using GIS on criteria-based maps of the area and the grey pairwise comparison. Finally, the sites with high potential for sustainable plant construction in South Khorasan Province were obtained.

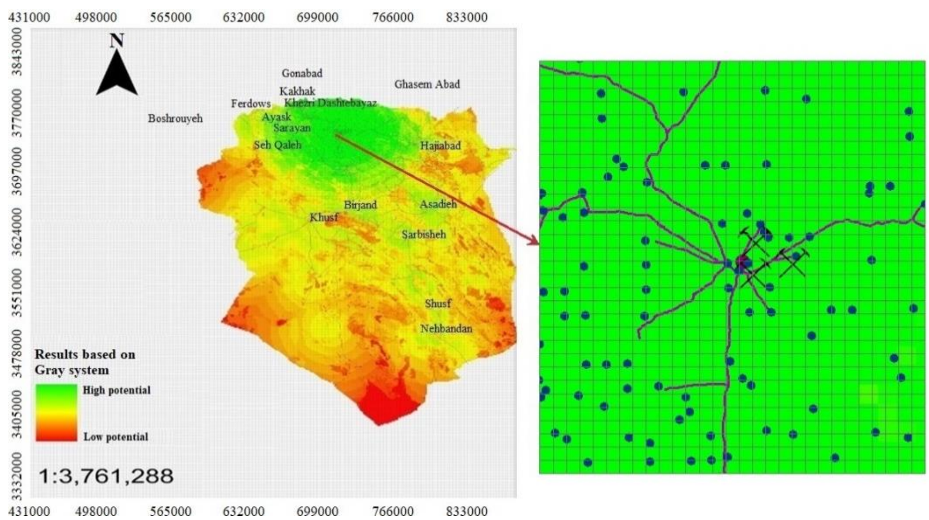

Fig. 5. GIS map output for potential areas based on grey pairwise comparison.

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REFERENCES

[1] Mishra, S., & Siddiqui, N.A. (2014). A review on environmental and health impacts of cement manufacturing emissions. International Journal of Geology, Agriculture and Environmental Sciences, 2(3), 26-31.

[2] European Commission. (2010). Reference document on best available techniques in the cement, lime and magnesium oxide manufacturing industries. European Integrated Pollution Prevention and Control Bureau (EIPPCB).

[3] Current, J., Min, H., & Schilling, D. (1990). Multiobjective analysis of facility location decisions. European Journal of Operational Research, 49(3), 295-307.

[4] Hakimi, S.L. (1964). Optimum locations of switching centers and the absolute centers and medians of a graph. Operations Research, 12(3), 450-459.

[5] Owen, S.H., & Daskin, M.S. (1998). Strategic facility location: A review. European Journal of Operational Research, 111(3), 423-447.

[6] Ballou, R. H. (1968). Dynamic warehouse location analysis. Journal of Marketing Research: 271–276.

[7] Sweeney, D.J., & Tatham, R.L. (1976). An improved long-run model for multiple warehouse location. Management Science, 22(7), 748-758.

[8] Yong, D. (2006). Plant location selection based on fuzzy TOPSIS. The International Journal of Advanced Manufacturing Technology, 28(7-8), 839-844.

[9] Azizi, A., Malekmohammadi, B., Jafari, H.R., Nasiri, H., & Amini, P. (2014). Land suitability assessment for wind power plant site selection using ANP-DEMATEL in a GIS environment: case study of Ardabil province, Iran. Environmental Monitoring and Assessment, 186(10), 6695-6709.

[10] Asakereh, A., Omid, M., Alimardani, R., & Sarmadian, F. (2014). Developing a GIS-based fuzzy AHP model for selecting solar energy sites in Shodirwan region in Iran. International Journal of Advanced Science and Technology, 68, 37-48.

[11] Sozen, A., Mirzapour, A., & Çakir, M.T. (2015). Selection of the best location for solar plants in Turkey. Journal of Energy in Southern Africa, 26(4), 52-63.

[12] Lee, A.H.I., Kang, H., & Liou, Y. (2017). A hybrid multiple-criteria decision-making approach for photovoltaic solar plant location selection. Sustainability, 9(2), 184-205.

[13] Ataei, M. (2005). Multicriteria selection for an alumina-cement plant location in East Azerbaijan province of Iran. The Journal of The South African Institute of Mining and Metallurgy, 105, 507-514.

[14] Safari, M., Ataei, M., Khalokakaei, R., & Karamozian, M. (2010). Mineral processing plant location using the analytic hierarchy process-a case study: the Sangan iron ore mine (phase 1). Journal of Mining Science and Technology, 20(5), 691-695.

[15] Safari, M., Khalokakaei, R., Ataei, M., & Karamoozian, M. (2012). Using fuzzy Topsis method for mineral processing plant site selection problem. Arabian Journal of Geosciences, 5(5), 1011-1019.

[16] Bakhtavar, E., & Lotfian, R. (2017). Applying an integrated fuzzy gray MCDM approach: A case study on mineral processing plant site selection. International Journal of Mining and Geo-Engineering, 51(2), 177-183.

[17] Bakhtavar, E., Khademi, D., & Mikaeil, R. (2017). The use of fuzzy-weighted binary integer goal programming to select the optimum site for a central processing plant. The Journal of the Southern African Institute of Mining and Metallurgy, 117, 505-510.

[18] Dong, G., Yamaguchi, D., & Nagai, M. (2007). A grey-based decision-making approach to the supplier selection problem. Mathematical and Computering, 46(3-4), pp. 573-581.

[19] Liu, S.F., & Lin, Y. (2010). Grey Systems: theory and applications. Springer Science & Business Media, ISBN 978-3-642-16158-2.