Application of Fuzzy Logic in Site Selection of Artificial Groundwater Recharge Using Integrated Method of AHP and FTOPSIS

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Extended Abstract

In recent decades, duo to increase in population, demand for reliable water supplies has increased. The situation is critical in places where groundwater is the only accessible water resource and the discharge rate of water is more than the rate of recharge. In such areas, artificial recharge of groundwater is an important management strategy. In establishing an artificial recharge scheme, site Selection is the prime prerequisite and its success depends on the collection and analysis of a great deal of geographic data.

The use of fuzzy set theory in site selection projects allows the decision-makers to incorporate unquantifiable information into decision model. In new researches of site selection fuzzy multiple criteria decision making methods have been considered. In this paper, site selection of artificial groundwater recharges using an integrated method of Fuzzy TOPSIS and AHP has been carried out by raster layers in GIS.

Figure 1 presents the structure of the proposed method. As it can be seen in this figure, after determining the criteria and forming hierarchy, decision weight of each criterion is achieved by paired comparisons. For each class, by establishing the decision matrix, using fuzzy numbers and calculating distance from the positive and negative ideal class, matrixes of distance to negative and positive ideal solution are created. Thereafter, thematic layers of distance from negative and positive ideal class are created for each criterion. By integrating this layers and multiplying results by constraint layer final layer is achieved.

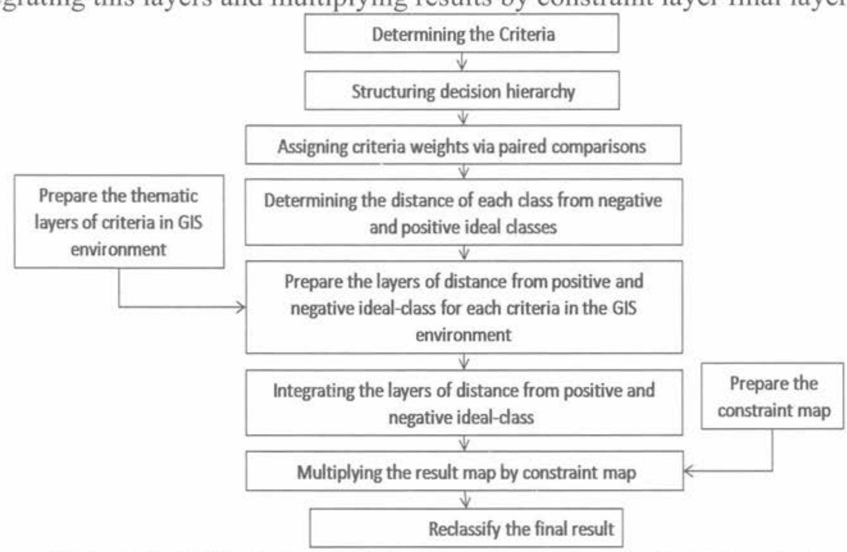

Fig.1: Schematic diagram of the proposed method for site selection

The proposed method can be outlined in the following steps:

Step 1: determining the weight vector $W=(w_1,\dots,w_m)$ of the criteria ($C=c_1,\dots,c_m$) with respect to goal by using paired comparisons with condition of $\sum_{j=1}^{m} W_j=1$.

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Step 2: choosing the linguistic values ($\tilde{a}_{ij}$, i=1,2,…,n, j=1,2,…,m) for classes with respect to criteria. The fuzzy linguistic rating ($\tilde{a}_{ij}$) preserves the property that the ranges of normalized triangular fuzzy numbers belong to (0,1); thus there is no need for normalization. Figure 2 presents the linguistic values for classes with respect to criteria.

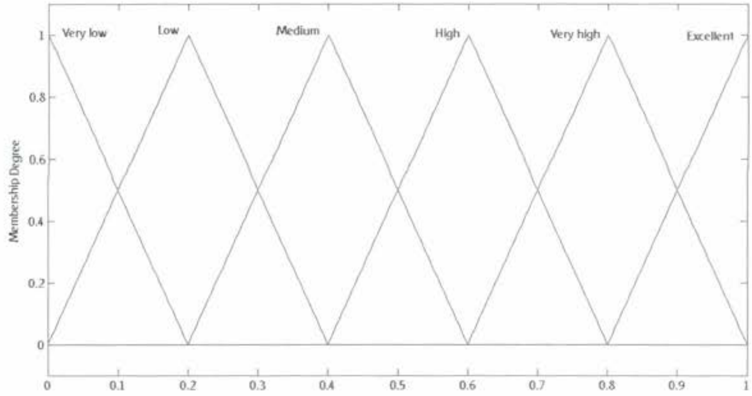

Fig.2: Linguistic values for classes rating.

Step 3: Forming fuzzy-decision matrix ($T_{(\tilde{a}ij)\ n*m}$) , where *i* is the number of class and *j* is the number of criterion.

Step 4: calculating the weighted normalized fuzzy-decision matrix ($V_{(\tilde{\upsilon}ij)n*m}$). The weighted normalized value ($\tilde{\upsilon}_{ij}$) is calculated by Equation (1).

$$\tilde{v} = (W_j(*)\tilde{a}_{ij}) \quad (1)$$

Step 5: Identifying positive-ideal (A^+) and negative-ideal (A^-) solutions. Theses ideal solutions are shown in the following equations:

$$A^+ = (\tilde{v}_1^{\max}, \tilde{v}_2^{\max}, ..., \tilde{v}_j^{\max}) \quad (2)$$

$$A^- = (\tilde{v}_1^{\min}, \tilde{v}_2^{\min}, ..., \tilde{v}_j^{\min}) \quad (3)$$

Step 6: calculating matrix of distance from positive- ideal classes ($D^+_{(dij^+)\ n*m}$) and matrix of distance from negative-ideal class ($D^-_{(dij^-)\ n*m}$). The calculations are carried out by using the following equations:

$$\tilde{d}_{ij}^+ = \tilde{v}_j^{\max}(-)\tilde{v}_{ij} = (d_{ij_1}^+ + d_{ij_2}^+ + d_{ij_3}^+), \quad d_{11}^+ = \frac{d_{ij_1}^+ + d_{ij_2}^+ + d_{ij_3}^+}{3} \quad (4)$$

$$\tilde{d}_{ij}^- = \tilde{v}_{ij}(-)\tilde{v}_j^{\min} = (d_{ij_1}^- + d_{ij_2}^- + d_{ij_3}^-), \quad d_{11}^- = \frac{d_{ij_1}^- + d_{ij_2}^- + d_{ij_3}^-}{3} \quad (5)$$

Step 7: Calculating similarities to ideal solution (RC_i) using the following equation:

$$RC_i = \frac{\sum_{j=1}^{m} d_{ij}^-}{\sum_{j=1}^{m} d_{ij}^- + \sum_{j=1}^{m} d_{ij}^+} \quad \textit{m shows the number of criteria} \quad (6)$$

This equation is used to calculate the suitability of artificial groundwater recharge for each pixel in GIS raster layers.

By selecting Shemil- Ashkara plain as a case study (figure 3), factors such as: slope, electrical conductivity, potential of run-off, geology, land use and depth of groundwater table are considered to determine the area's most suitable for artificial groundwater recharge. Thematic layers for the mentioned parameters were prepared, classified, and integrated in the raster environment of GIS by means of the proposed method. The result was multiplied by the map of constraint and its output was classified in four categories including: constrained, unsuitable, moderately suitable and suitable. The constraint map was prepared from slope and land use maps. Only barren areas with slope less than 100% have obvious potential for artificial groundwater recharge.

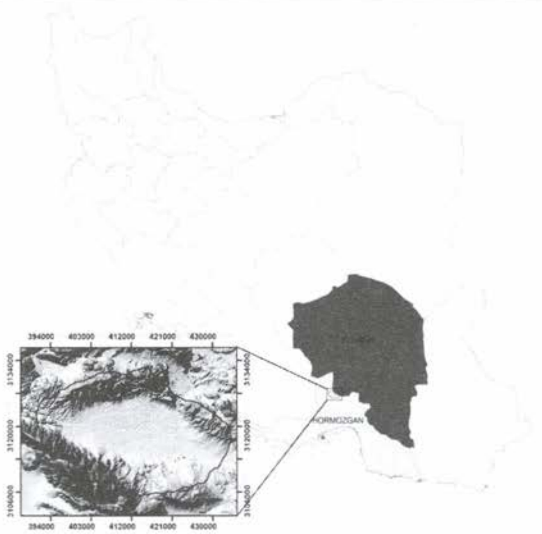

Fig.3: Geographic position of Shemil- Ashkara plain.

Figure 4 shows the potential zoning of artificial recharge for Shemil- Ashkara plain. The study indicates that 7% and 34% of the area are considered appropriate and moderately appropriate for artificial recharge, respectively.

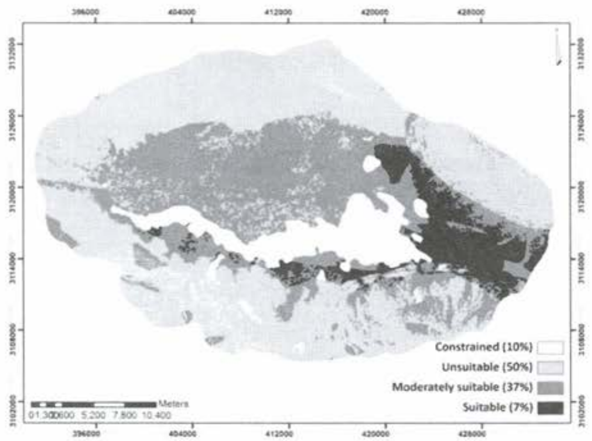

Fig.4: Potential zoning of artificial recharge by using proposed method

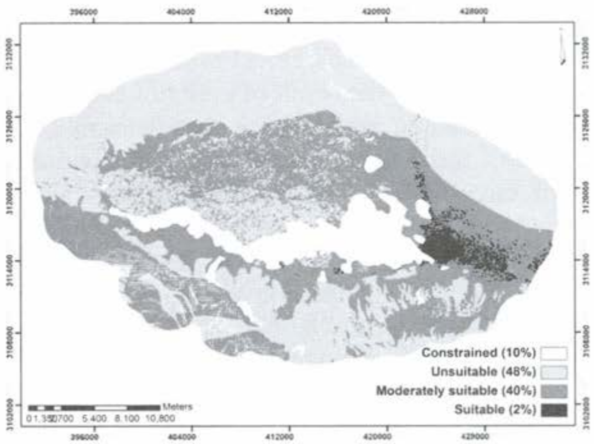

Fig.5: Potential zoning of artificial recharge by using AHP method

For validating the proposed method, the zoning of artificial recharge was carried out, using AHP method. The result map of AHP is shown in figure 5. The AHP results indicate that 2% and 48% of the area are considered as appropriate and moderately appropriate, respectively. The comparison of two methods shows that the appropriate areas in the AHP method are also indicated in the proposed method. The majority of these areas are located in alluvial fans with a thickness more than 30 meters, flat surface, high level of runoff and appropriate groundwater quality. This paper indicates that using fuzzy set theory in multiple criteria decision analysis can be an appropriate approach for site selection in artificial groundwater recharge.

Key words
Site Selection, Artificial Recharge, AHP, FTOPSIS, GIS