



Fuzzy C-Means Clustering Algorithm for Site Selection of Groundwater Artificial Recharge Areas (Case study: Sefied dasht Plain)

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ABSTRACT

Artificial recharge can be an effective method to raise the groundwater table and to resolve the groundwater crisis in Sefid dasht plain. The most important step to successful accomplishment of artificial recharge is locating suitable areas for artificial recharge. Hence this research carried out with purpose of determining suitable areas for artificial recharge in Sefid dasht plain. Slope, surface infiltration, alluvial thickness, alluvial quality and land use parameters were analyzed, classified and map of every parameter prepared using GIS. To overlay the affective parameters in artificial recharge was Fuzzy c-mean models. Results showed that 16.2 percent of Sefid dasht plain is suitable for artificial recharge based on Fuzzy c- mean model. Using land use layer this value decreased to 4.5 percent. So land use in is a limitative parameter in study area.

Keywords: GIS, Artificial Recharge, Sefieddasht plain, Fuzzy C-Mean.

INTRODUCTION

Groundwater resources provide the most important amount of water resources, and many agricultural units have been subjected to negative balance of water due to overharvesting of wells (Ahani et al., 2012). Also water is indispensable for any life system to exist on earth and is a very important component for the development of any society (Sayana et al., 2010). A growing population and changing dietary trends mean a steeply rising water demand (Berndes, 2008) Demand for the worlds increasingly scarce water supply, is rising rapidly, challenging its availability for food production and putting global food security at risk, even as demand for water by all users grows, groundwater is being depleted (Rosegrant et al., 2002). Groundwater as a source of water supply has great advantages over surface water from streams, rivers, or lakes (Hofkes, 1986) and with increasing demands for water, ground resources are gaining much attention (Jasrotia et al., 2007). Due to climatic condition, a large portion of Iran is considered as arid and semi- arid areas (Mehrvarz, 2007), More than 50 % of precipitations take place in winters while less than 15 % occur in summers. Thus, most of the rivers are dry in the mid springs until mid-fall range. Underground water substitutes the water shortage. Overuse of underground water resources, decrease the

ground water level in many aquifers. According to recent studies on water resource development in Iran, the total amount of annual precipitation is about 430 billion m³, of which about 20 % is lost in the form of flash floods to the playas and seas (Alesheikh et al., 2008). It is therefore important to augment the groundwater resource by artificial recharge, using floodwaters (Kheirkhah et al., 2008). Many studies have been used GIS for locating most suitable sites for artificial recharge. As Nirmala et al (2011) used GIS to studying artificial recharge of groundwater in Sathyamangalam and Melur villages, Chennai (Nirmala et al., 2011). Balachandar et al (2010) and Ravi Shankar & Mohan (2005) used GIS for identification of site- specific artificial- recharge techniques in deferent parts of India. Ghayomian et al (2007) applied Fuzzy Logic among GIS techniques to determine most suitable areas for artificial groundwater recharge in a coastal aquifer in Gavbandi Drainage Basin (Ghayoumian et al., 2007). Also Nouri et al (2005) have had same studies using GIS techniques and used Fuzzy to carry out their study (Nouri et al., 2005). Sefiddasht plain has located in west of Iran country. Unfortunately, the groundwater condition in this plain is critical and its balance is negative. So, artificial recharge of groundwater will be helpful to control floods and also to rising water table in this plain. Hence this study was performed with the purpose of locating most suitable sites for artificial recharge in Sefiddasht plain using Fuzzy C-Mean.

Materials and methods

Study area

Sefiddasht plain has been located in Chaharmahal va Bakhtiyari province in Iran. Coordinates of Sefiddasht plain (center of plain) in UTM coordinate system are X=513205 and Y=3562547. Its altitude is 2150m from sea level. Area of this plain is 201km². Due to irregular use of groundwater resources in Sefiddasht plain, this plain is now barred. Figure1 show Study area and its position in Iran country (Figure 1).

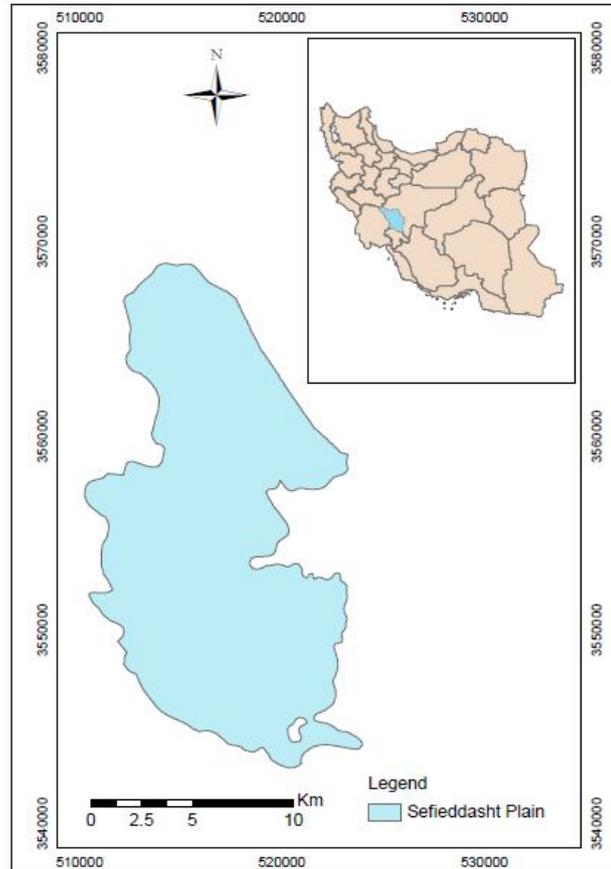


Figure.1. Study area and its position in Iran country

Thematic layers

Among effective factors in locating suitable areas for artificial recharge slop, alluvial thickness, infiltration rate, Electrical Conductivity (EC) and Landuse factors were selected and examined (ASCE, 2001). Among these, slop, alluvial thickness, infiltration rate, Electrical Conductivity (EC) factors were used as principle factors and land use were used as a filter. So maps based on these factors were prepared using GIS software and then Fuzzy C-Mean was used to overlay these layers.

Fuzzy C-Means Clustering Algorithm:

The fuzzy c-means (FCM) is the best known fuzzy clustering method and we know that there are broadly extended types of FCM in the literature (Wu, 2002). Fuzzy c-mean cluster (FCM) is a method of clustering which allows one piece of data to belong to two or more clusters. The algorithm is an iterative clustering method that produces an optimal c partition by minimizing the weighted within group sum of squared error objective function J_{FCM} (Islam, 2005):

$$J_{FCM} = \sum_{i=1}^n \sum_{j=1}^c (u_{ij})^m d^2(x_i, v_j)$$

Equation 2

where $X = \{x_1, x_2, \dots, x_N\} \subseteq R^n$ is data set, n is the number of data set, $2 \leq c < N$ is the number of clusters, u_{ij} is the degree of membership of x_i in the i^{th} cluster, m is the weighting exponent on each fuzzy membership which can have influence on the clustering performance of FCM [24], v_j is the center of cluster, $d^2(x_i, v_j)$ is a distance measure between x_i and v_j . Fuzzy partitioning is carried out through an iterative optimization of the objective function shown above, with the update of membership u_{ij} and the v_j cluster centers by

$$u_{ij}^{(b)} = \begin{cases} \left[\sum_{k=1}^c \left(\frac{d_{ij}}{d_{ik}} \right)^{\frac{2}{m-1}} \right]^{-1} & \text{if } d_{ij} > 0 \\ 1 & \text{if } d_{ij} = 0 \end{cases} \quad 1 \leq j \leq C, \quad 1 \leq i \leq n \quad \text{Equation 3}$$

$$c_j^{(b+1)} = \frac{\sum_{i=1}^n u_{ij} x_i}{\sum_{i=1}^n u_{ij}} \quad 1 \leq j \leq C \quad \text{Equation 4}$$

This iteration will stop when

$$\max_{ij} \left\{ U_{ij}^{(k+1)} - U_{ij}^{(k)} \right\} \quad \text{Equation 5}$$

Results and discussion

Ordinary Kriging Geostatistical method (Barcae, 2008; Fetouani et al., 2008; Moradi et al., 2011) have been used to preparing Alluvial thickness and Alluvial quality maps in this research. Classes of Alluvial thickness, Infiltration rate, Electrical conductivity and slope have been shown in tables (1), (2), (3), and (4), respectively.

Table (1): Alluvial thickness (m) in Sefieddasht plain

VALUE	Classes	Area(km2)	Area (%)
1	20-30	4.2	2.09
2	30-45	26.5	13.17
3	>45	170.3	84.73

Table (2): Infiltration Rate (mm/hr) in Sefieddasht plain

Classes	Area(km ²)	Area(%)
0-15	67.315	33.49
15-25	67.395	33.53
25-45	16.6	8.27
>45	49.62	24.69

Table (3): EC ($\mu\text{mhos/cm}$) in Sefieddasht plain

Classes	Area(km ²)	Area(%)
0-500	9.828	4.89
500-1000	188.21	93.64
>1000	2.93	1.458

Table (4): classification of slope in Sefiddasht plain

Value	Area(km ²)	Area (%)
0-2	31.05	15.45
2-4	52.66	26.20
4-6	52.01	25.88
6-8	62.22	32.45

Topographic maps of the Sefiddasht plain at the scale 1:25,000 were used to develop a slope map using Digital Elevation Model (DEM). On the slope map (Ghayoumian et al., 2005; Saraf, 1998), slopes are classified into four classes (table4).

Using Fuzzy C-Mean model to overlay thematic layers, map of most suitable areas for artificial recharge was developed (Figure2).

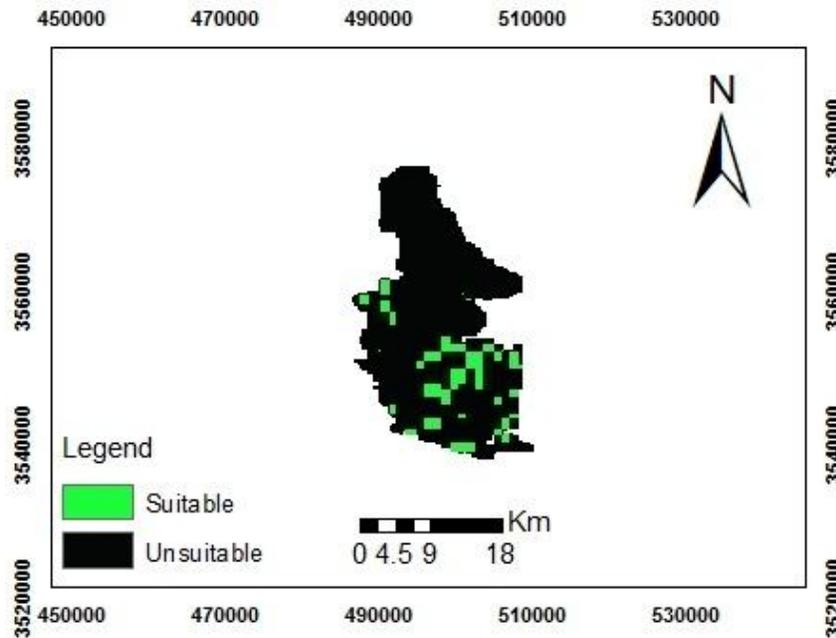


Figure (2): Suitable Areas for artificial recharge in Sefieddasht based on Fuzzy c-mean model

Also table (5) shows suitable and unsuitable areas of artificial recharge in sefiddasht plain based on Fuzzy C-Mean model.

Table (5): areas of suitable and unsuitable sites for artificial recharge based on Fuzzy C-Mean

Value	Area (km ²)	Area (%)
Unsuitable	168.43	83.8
Suitable	32.54	16.2

Comparing table (5) can be observed that suitable areas for artificial recharge in Fuzzy C-Mean are 16.2 percent.

According to different types of land-use, only rangelands are appropriate for artificial recharge. Therefore, rangelands and non-rangelands regions are distinguished on the land-use map and coded as one and zero, respectively. This classification is applied to the map of suitable areas for artificial recharge, as a filter (table 6).

Table (6) Land use in Sefieddasht

Land use	Area (km ²)	Area (%)
Rangeland	111.15	55.3
Agri	88.51	44.038
Lake	1.32	0.658
Sum	201	100

Based on table (6), 55.3% of sefiddasht plain is rangeland that its area is equal to 111.15 Km². Table (7) and figure (3) show suitable and unsuitable areas of artificial recharge using land use filtering.

Table (7): areas of suitable and unsuitable sites for artificial recharge based on Fuzzy C-Mean using land use filtering

VALUE	Area (km ²)	Area (%)
Unsuitable	191.93	95.5
Suitable	9.04	4.5

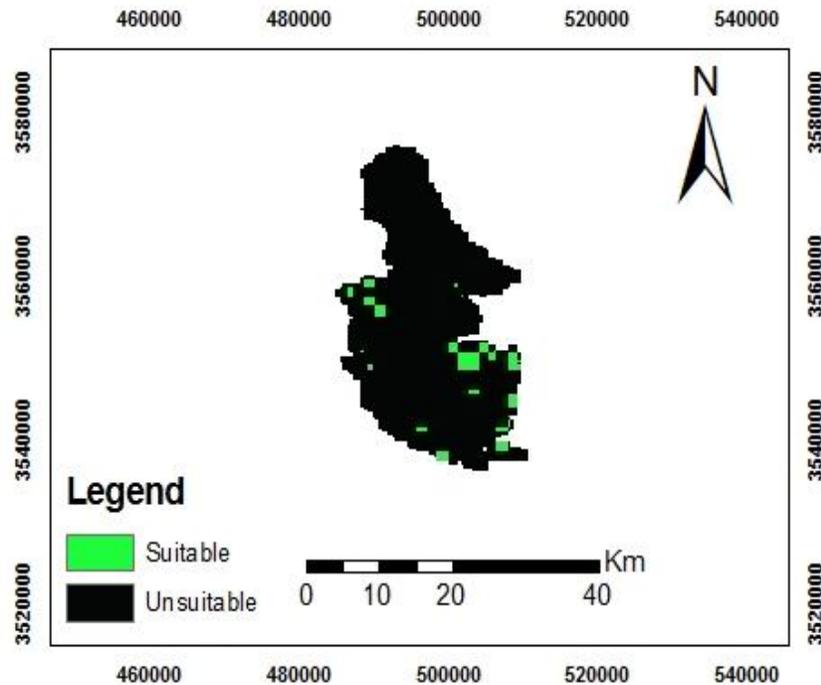


Figure (3): Suitable Areas for artificial recharge in Sefieddasht based on Fuzzy c-mean model using Land use filtering

Suitable and unsuitable areas of artificial recharge based on Fuzzy C-Mean model using land use filtering shows in tables (5) and (7) and figure (2) and (3). It can be said that using land use map as a filter, suitable areas for artificial recharge have decreased. Table (7) shows that 4.5% of area is suitable area of artificial recharge in Fuzzy C-Mean Model using land use filtering.

Conclusion

Demand for the worlds increasingly scarce water supply is rising rapidly, challenging its availability for food production and putting global food security at risk, even as demand for water by all users grows, groundwater is being depleted (Rosegrant et al., 2002). Because of increase of demand and decrease of water quality due to human excess interference occurred, integrated management of groundwater resources is essential. Hence artificial recharge of groundwater can be helpful in management of groundwater and increasing the groundwater table. One of the most important factors in successful recharge of groundwater resources is locating suitable areas for these projects. Of course if site selection of artificial recharges areas occur correctly. Four factors namely, alluvial quality, alluvial thickness, slope, and infiltration rate parameters were explored, classified, weighted and overlaid using GIS system. To overlay these layers was used Fuzzy C-Mean and the study areas were divided into two suitable and unsuitable classes for artificial

recharge. Results showed that based on overlay Fuzzy C-Mean 4.5 percent of study area was suitable for artificial recharge. Generally speaking, it can be said that suitable areas have been decreased from 16.2 percent to 4.5 percent using land use filtering. In fact, one of the important limitations for artificial recharge is land use.

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