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Determination of Optimum Site for Artificial Recharge Aided Geographical Information System (GIS) & Logical Overlay Function (Case Study: Sarpaniran Plain)

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ABSTRACT: *In dry and semi-dry regions which face acking of water, using flood is one of the suitable solutions to prevent destruction of agricultural and pasture lands and recharge of ground water aquifers. In this study, flood distribution which is the most common in Iran was examined among various methods of artificial recharge. This study has been performed in Sarpaniran catchment, located in Pasargad in Fars province, considered as one of the important agricultural, industrial and residential centers. In order to flood distribution site selection, slope, surface infiltration, thickness of alluvium (geomorphology), geology (formations) and lands application information layers have been used. Information layers were combined based on intersect logical overlay function with Boolean logic in geographical information system (GIS) and regions suitable for flood distribution were determined. The results of this study show that 2.3 percent of the total area of the district is suitable for flood distribution. In examination of relation between using parameters and suitable places showed that geological factor (formations) is the limiting factor. The results indicate that due to the existence of several properties which are effective in site selection and required analysis with evaluated criteria and their continuous changes, geographical information system is an efficient tool for management and using site data in this field.*

KeyWords: *Site location, artificial recharge, Flood Distribution, Sarpaniran Catchment, Intersect Logical Overlay Function, Geographical Information System (GIS)*

I. INTODUCTION

Concerning climatic and geographical conditions, a vast area of Iran includes dry and semi-dry regions in a way that 74% of the country has annual rainfall less than 250mm. In fact, due to lack of precipitation, its unbalanced distribution regarding time and place and also inexistence of permanent rivers to provide water requirement in dry and semi-dry regions, exploitation From groundwater resources is the most certain resource for water supply in these regions and done in a vast area (12). Therefore, groundwater resources are considered as economical and social development factors in dry and semi-dry regions (17). Helping the increment of groundwater supplies is one of the useful ways in providing required water of various parts, especially in dry and semi-dry regions and confronting drought crisis.

Recharging ground waters is possible in natural and artificial ways. Physical (natural) recharge of a region is made by water infiltration resulted from precipitations inside the ground, infiltration through river aquifers or through underground flows. Whereas water supply is a main factor of the development of a region and physical supply cannot meet needs, thus artificial recharge has been developed (8,10, 4). Site selection of artificial recharge systems, specially flood distribution, is the fundamental principles of making these systems. Selecting the location based on scientific and natural facts plays the most important role in the stability and application of these systems in the way of realizing relevant objectives (3, 19). To prevent from problems due to the accumulation of sediments and increase of useful life of design and more efficiency of system regarding to the control of flood and achievement of considered objectives, site selection should be precisely made considering return period flood and its mass, size, severity, rainfall distribution, flood quality, soil condition, geology specifications, land slope, depth of groundwater aquifer, … (12).

In a research for the examination of ground waters potential qualitatively and quantitatively by using GIS and RS, simple and weighted models were used. In this study information layers of the land's shape, geology, faults, waterway, recharge condition map, compaction of materials and soil type were used and finally have determined regions with groundwater potential and also regions suitable for ground waters artificial recharge. Results of this study show that remote sensing (RS) and GIS have high capability for the qualitative and quantitative examination of ground waters and determination of artificial recharge regions (18). In a research the application of Boolean Logic model in geographical information system with the aim of natural resources management in Eshkanan, Lamerd desert region was done. In this study, AND and OR operators of Boolean model have been used and after combining layers and different programs model of natural resources comprehensive management in deserts, suitable areas were recognized and categorized (6).

In another study capability and advantage of geographical information system and remote sensing emphasized as an acceptable solution for decreasing expenses in site selection of suitable regions for artificial recharge of aquifers (9). Using effective information layers in recharge , such as topography, surface infiltration, alluvium thickness, quality of ground water and lands usage with Boolean and Fuzzy models, ground water artificial recharges selection in Shoor desert, in geographical information system and far-distance examination were done. The results has been shown that nearly 5 percent of the studied region is suitable and 19 percent is almost suitable for groundwater artificial recharge (3). In a research using GIS and RS techniques, uitable site selection for artificial recharge of ground water resources of Semnan desert was examined and the results showed that using GIS and RS is an efficient tool for finding place for artificial recharge of ground water (9). In a study, Geo statistical models for estimation of transferability and site selection of flood distribution maps, using transferability and special capacity data were compared. Their result indicate that Co Kriging method is a suitable method of estimation when correlation coefficient is greater than 0.7(7). Using GIS techniques for determining proper regions for artificial recharge of coastal aquifers in the south of Iran a research was done and the results shown that about 12% of the analyzed region is suitable and 8% is relatively suitable for aquifers artificial recharge (1). In another research capability of artificial recharges of ground waters was addressed by using GIS and economical and environmental aspects (11). Therefore, the aim of this research is studying and determining the most suitable place for artificial recharge designs and places for flood distribution and artificial recharge bed as well as studying the relation between different parts of the earth and suitable regions for ground waters artificial recharge.

II. Materials and Methods

Studying Region: The studying limitation is Sarpaniran plain. This region has been located in the distance of 120km. east-northwards of Shiraz and 12 km. of east-northwards of Saadatshahr in Pasargad, Fars province. Sarpaniran plain is in the limitation of 53°09´ to 53°30´ east longitude and 29°52´ to 30°09´ north latitude. The area of this region is 47288 hectors and around 31663.24 m^3 in a year water harvesting, is considered as an important agricultural, industrial and residential center with about 90% water consumption in agriculture (figure 1).

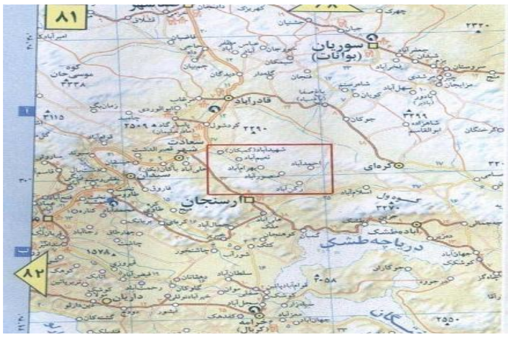


Figure 1: Geographical situation of Studying Region

For physical (natural) and topographic evaluation in the manner of aquifer hydrologic specially temporary water supply due to rainfall and its speed to the out of catchment through river system, Physical specifications of Sarpaniran catchment is observed (table 1).

Physical Specifications	Circle Ratio	Timeof Concentration	Form Factor	Gravelius
level	0.34	6.35	0.29	1.69

Table 1: Physical Specifications of Sarpaniran Catchment

For site selection of suitable regions for ground water artificial recharge through flood distribution, evaluating indexes were selected in site selection. In this research 5 parameters (slope, surface infiltration, geomorphology, geology, and lands application) are analyzed and selected among effective factors in site selection of suitable regions for artificial recharge through flood distribution. Flood distribution site selection operation performed by using GIS and logical common method (common logical overlay) in Sarpaniran plain with the area of 47288 hectors and after throwing on four information layers of slope, surface infiltration, geomorphology and geology and suitable sites were identified. Then, corresponded with lands application information layer and those regions where had application limitation separated and the best regions for flood distribution were determined.

Region slope map: To prepare slope map, digital elevation model (dem) was used. In this research elevation contour lines of digital topography maps have been used as a primary data to make digital elevation model. Using digital elevation model, the slope map of catchment plain in GIS environment was prepared based on points' elevation in the earth digital model and their distance from each other, slope map of the region on percent (figure 2). The area and percent of slope of each class has been also presented (table 2).

Table 2: Area and percentage of area of each slope class in Sarpaniran plain

Slope class	Classes range (Percent)	Area (Hectare)	Area (Percent)
apt	0 - 3	11163.4	23.61
inapt	> 3	36117.94	76.39

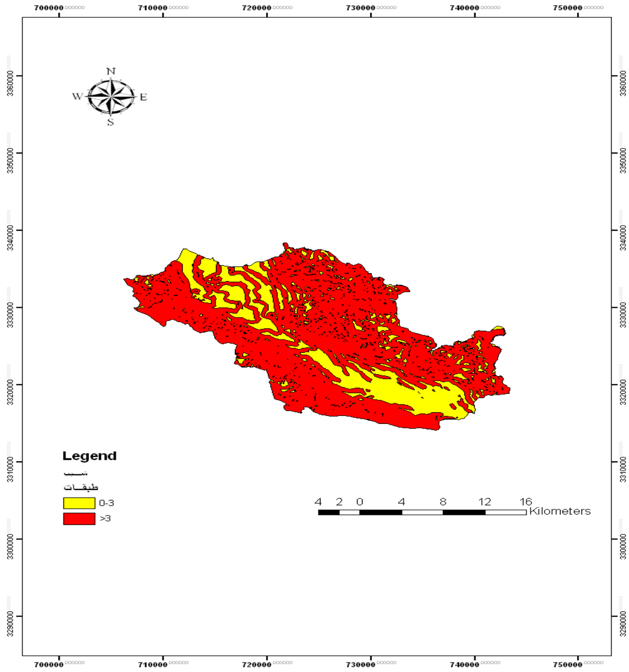


Figure 2: Slope map of Sarpaniran plain

Surface Infiltration Map: To prepare surface infiltration map by field operation, 17 points were selected for measuring the soil penetration (filtration) and double-ring method was used. The best method for variable interpolation is the one which has the least RMS. In this research the best interpolation method is Kriging model of circular type with the RMS equal to 7.876 (table 4). Thus, to convert point map to raster map the same interpolation was used. Surface infiltration map has been shown in figure 3. The extent and percent of area of each infiltration class was presented in table 3.

Table 3: Area and percent of area of each infiltration class

Table 4: RMS results, interpolation methods for preparing surface infiltration map

Interpolation method	RMS	Interpolation method	RMS	Interpolation method	RMS
Inverse Distance Weighting	10.14	Kriging (Gaussian)	8.19	CoKriging (pent spherical)	12.67
Global Polynomial Interpolation	14.47	Kriging (rational quadratic)	8.53	CoKriging (exponential)	12.61
Local Polynomial Interpolation	12.69	Kriging (hole effect)	50.93	CoKriging (Gaussian)	12.67
Radial Basis Functions	9.19	Kriging (k - Bessel)	30.57	CoKriging (rational quadratic)	12.58
Kriging (circular)	7.18	Kriging (j - Bessel)	51.45	CoKriging (hole effect)	11.34
Kriging (spherical)	7.98	Kriging (stable)	36.3	CoKriging (k - Bessel)	12.67
Kriging (tetra spherical)	8.04	CoKriging (circular)	12.68	CoKriging (j - Bessel)	11.65
Kirging (pent spherical)	8.08	CoKriging (spherical)	12.67	CoKriging (stable)	12.67
Kriging (exponential)	8.61	CoKriging (tetraspherical)	12.67		

Infiltration class	Classes range (mm/hr)	Area (Hectare)	Area (Percent)
apt	0 - 25	41490.27	87.74
inapt	> 25	5797.03	12.26

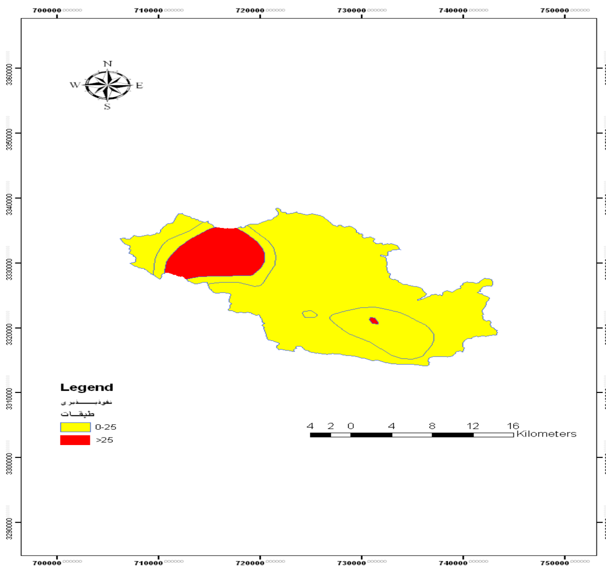


Figure 3: Surface Infiltration Map of Sarpaniran plain

Geomorphology Map: First, in order to provide the alluvium thickness plan concerning the region's area 35 well visited provided by Fars Regional Water Organization in 2010 were used. Next, for preparing raster plan from point plan, Kriging method, Gaussian type with RMS equal to 5.105 was chosen (table 6). Alluvium thickness plan has been shown in figure 4. Area extent and percentage of each alluvium thickness class was presented in table 5 as well.

Table 5- Area and area percentage of each alluvium thickness class

Alluvium thickness class	Classes range (m)	Area (Hectare)	Area (Percent)
apt	0 - 8	29157.79	61.66
inapt	> 8	18130	38.34

Table 6- RMS results, interpolation methods for preparing alluvium thickness plan

Interpolation method	RMS	Interpolation method	RMS	Interpolation method	RMS
Inverse Distance Weighting	6.8	Kriging (Gaussian)	5.1	CoKriging (pent spherical)	5.62
Global Polynomial Interpolation	9.1	Kriging (rational quadratic)	5.98	CoKriging (exponential)	6.02
Local Polynomial Interpolation	5.71	Kriging (hole effect)	6.14	CoKriging (Gaussian)	5.26
Radial Basis Functions	5.12	Kriging (k - Bessel)	5.19	CoKriging (rational quadratic)	5.83
Kriging (circular)	5.63	Kriging (j - Bessel)	6.18	CoKriging (hole effect)	6.54
Kriging (spherical)	5.59	Kriging (stable)	5.22	CoKriging (k - Bessel)	5.24
Kriging (tetraspherical)	5.61	CoKriging (circular)	5.56	CoKriging (j - Bessel)	6.56
Kirging (pent spherical)	5.63	CoKriging (spherical)	5.59	CoKriging (stable)	5.34
Kriging (exponential)	6.1	CoKriging (tetraspherical)	5.6		

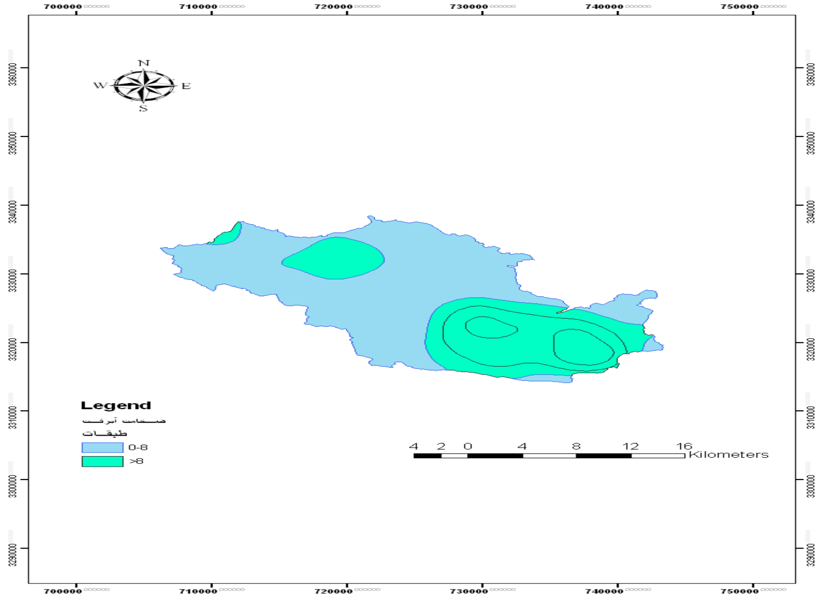


Figure 4- Sarpaniran desert alluvium thickness class.

Lands Usage Plan: In order to produce this information layer, lands usage plan provided by Agricultural Jihad Department of Pasargad, provided for the whole town in 2006 was used. For this purpose, results of combining information layers are used for determining regions suitable for distribution of flood. The resulted plan was overlaid with lands usage plan to separate the regions with usage limitations from areas suitable for flood distribution; because flood distribution operation execution in agricultural lands and other regions with limitation is not possible due to social tensions. Lands usage plan has been shown in Figure 5 and area and percentage of each usage was presented in table 7.

Table7- Area and percentage of pasture and non-pasture usage of Sarpaniran desert

Land class	User	Area (Hectare)	Area (Percent)
apt	Pasture	23011.22	48.66
inapt	non-pasture	24276.04	51.34

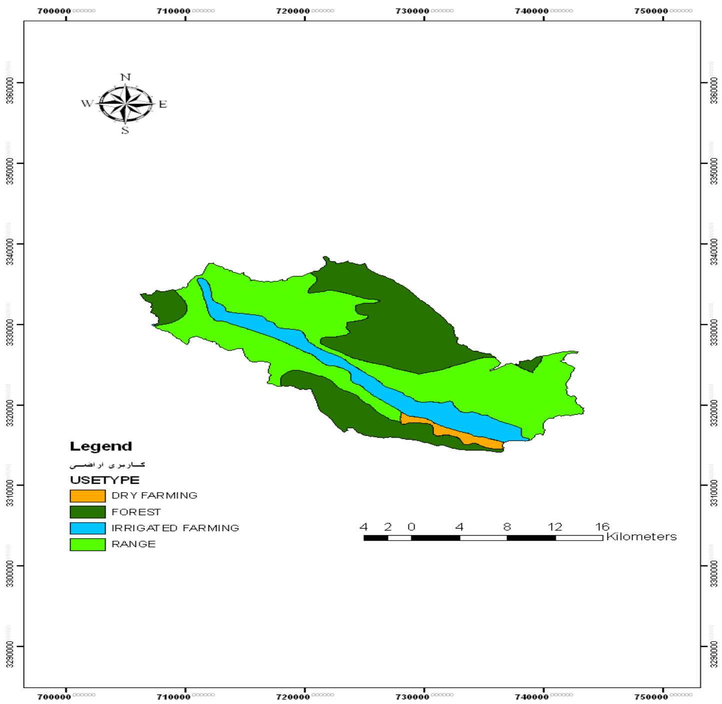


Figure5- Sarpaniran desert lands usage plan

Combining Information Layers & Data Analysis:

Slop basic map, surface infiltration, geological and desert's sediments thickness plans based on logical overlay function, intersect type have been combined in GIS and the output plan resulted from this combination was overlaid once without considering usage layer and once with land usage layer (Fig.6 & 7). Also, Suitable regions for artificial recharge by flood distribution method have been shown in satellite image of the desert in figure 8

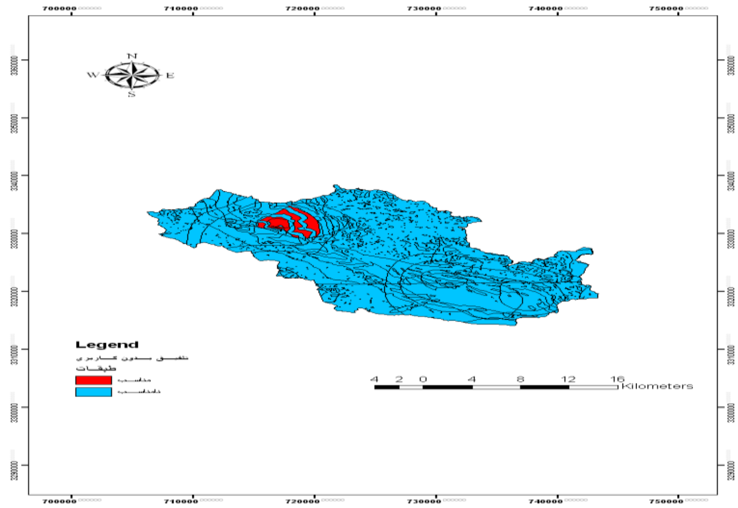


Figure 6- Plan of regions suitable for flood distribution combined without lands usage layer

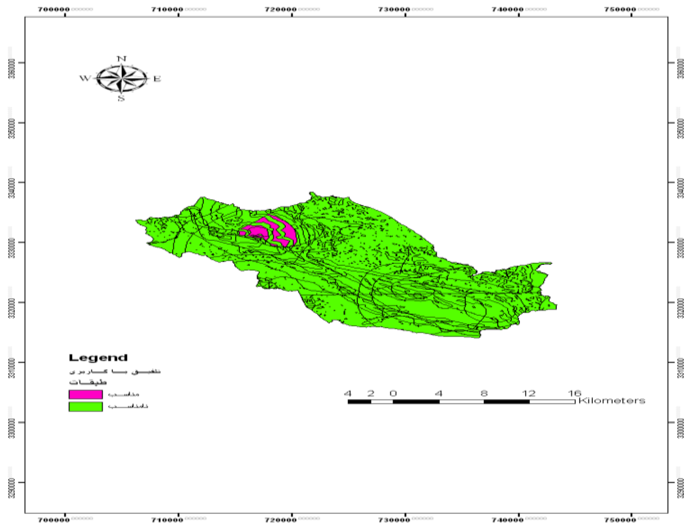


Figure7- Plan of regions suitable for flood distribution combined with lands usage layer

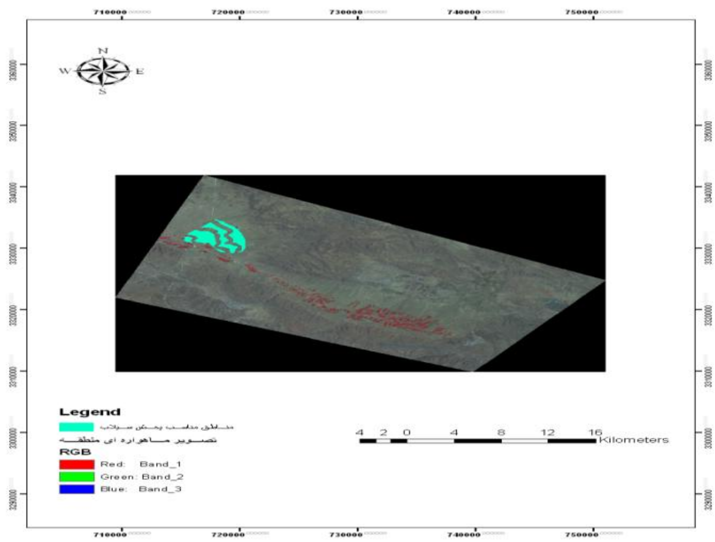
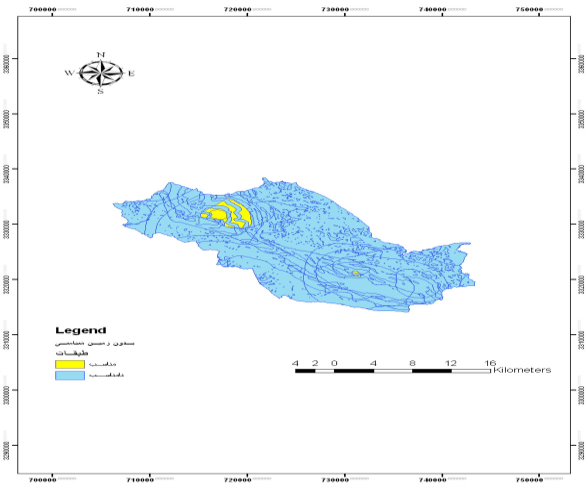


Figure 8- Sites suitable for artificial nourishment with flood distribution method.

hen results of relation between layers and sites suitable for flood distribution by omission of selected layers, amount of suitable regions changes and the most important limiting factor in the area was determined. Since slop and usage information layers made the least limitation in the final combining, started to omit other layers one by one and its results was presented in figures 9 to 11.



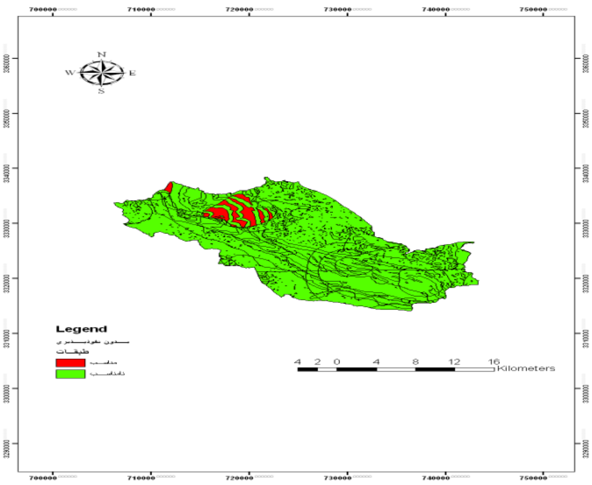


Figure 9- Plan of regions suitable for flood distribution without geological layer
Figure10- Plan of regions suitable for flood distribution without infiltration layer

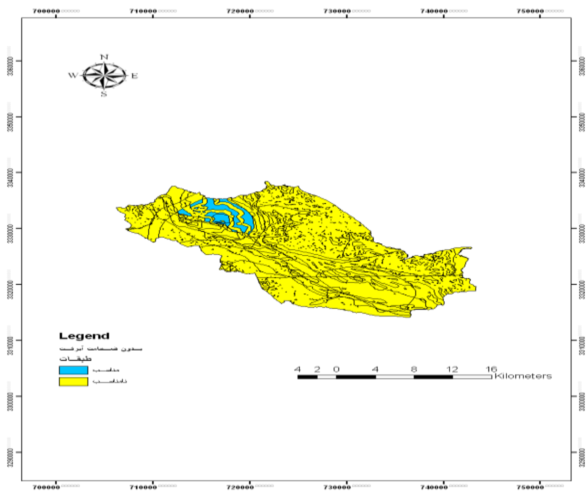


Figure11- Plan of regions suitable for flood distribution without alluvium thickness layer

III. Discussion & Conclusion

Flood distribution site selection studies are of high importance because of being the basis of aquifer and ground floor waters artificial nourishment studies. Since a group of condition (suitable and non-suitable) was used in this study and because the goal is site selection, therefore, logical overlay function, intersect type was used. Flood distribution site selection operation was done by using geographic Information System and logical intersect method in Sarpaniran desert with 47288 hectares area, after lapping 4 information layer of slop, surface infiltration, alluvium thickness and geology and suitable sites were determined. It was then combined with lands usage layer and the regions with usage limitation were separated and the best regions for flood distribution were determined. Geological plan of the region showed that Sarpaniran desert has variety of formation in a way that the most and the least formation area of the desert related to kk formation equal to 33.79 percent and Bakhtiari formation with 0.09 percent form total area of the region. Quaternary formation is the important formation for flood distribution which forms 12.05 percent of the district's area.

The results of this study showed that despite the fact that slop, lands usage and alluvium thickness layers are suitable for artificial recharge in flood distribution method, since quaternary areas form a percentage of the total district and other formations except Bakhtiari Congolmerate formation is not suitable in flood distribution view, it affects infiltration of the district in a way that 12.26 percent of the district is among regions suitable for infiltration, for executing this operation. So one could say that, geological factors (formations) and surface infiltration are among limiting factors which face such plans with limitation. Ghermezcheshmeh (2000), Al-e-Sheikh (2002), Soltani (2002) and Noori (2003) all have determined suitable sites for flood distribution using geographical information system which correspond with result of this study.

In general, after combining 4 information layers of slop, geology, surface infiltration and alluvium thickness without considering region's land usage based on figure 6 the amount of suitable regions for flood distribution is 1162.03 hectares that forms around 2.46 percent of total of the district, however after combining plan of sites suitable for flood distribution with the region's land usage plan, based on figure 7 amount of suitable regions for flood distribution decreased about 0.2 percent, it means reached an amount equal to 1088.32 hectares that forms 2.3 percent of the district. Thus from the above combination it could be concluded that geological factor is the most limiting layer in determining regions suitable for flood distribution and infiltration and alluvium thickness factors are the next limiting factors. In general, the most important limiting factor in suitable lands class, related to alluvium thickness factor and in non-suitable lands class is related to geological factor.

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