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GIS based approach for the identification of artificial recharge sites in Annavasal Block, Pudhukkottai district, Tamilnadu

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General Note

Article is recommended to print as color version in recycled paper. *Save Trees, Save Climate*.

ABSTRACT

The selection of sites for artificial recharge is a very important task for recharge studies in the over exploited hard rock terrain. Occurrence and movement of groundwater in the hard-rock terrain are controlled by secondary porosities developed through weathering and fracturing. Groundwater occurs in the weathered residuum under unconfined condition and circulates through fractures and fissures below. Here the high weathered thickness, high lineament density, almost flat or gentle slope and low drainage density areas are more suitable for effective recharge. The Remote Sensing and GIS based method of artificial recharge on the ground water aquifer is decided to be the most effective for the restoration of balance of the hydro geological system. The systematic planning of groundwater exploitation through modern approach is essential for management and sustainability. Remote Sensing (RS) Satellite data, Geographic Information Systems (GIS) and Survey of India (SoI) top sheets for mapping & integration of geology, drainage, lineament, hydrological soil groups, slope category and Land use /Land cover the thematic maps are assigned to a suitable ranks and weightage depending on the terrain condition for groundwater recharge. These thematic layers were integrated and reclassified into four categories for artificial recharge; good (27%), moderate (31%) and poor (51%).Later on, the final results were compared with the groundwater level data from the bore wells collected by Groundwater Board, Tamilnadu, India. It was found that the integrated remote sensing and GIS techniques are the most suitable methods for delineating artificial recharge zones in hard rock terrain of Annavasal Block, Pudukkottai district, Tamilnadu.

Keywords: Groundwater, Artificial Recharge, GIS and Remote Sensing, AHP Methods.

1. INTRODUCTION

Groundwater is a precious natural resource having limited extent and volume. With the increasing use of groundwater for agricultural, municipal and industrial needs, the annual extraction of groundwater happens to be generally far in excess of its net average natural recharged. Additionally, interventions in hydrological regime and climate change have significant impact on natural recharge. Consequences of over-exploitation of groundwater all over the world include decrease of water table, resulting lower agricultural productivity, sea water intrusion in coastal aquifer, land subsidence, groundwater quality degradation, droughts etc. (Samadder et al. 2011). To protect this precious resource from overuse and contamination, it is necessary to implement groundwater recharge systems, such as farm ponds, check dams, percolation tanks and nala bunds, etc.

1.1. Aims and objectives

To delineate the favourable zones for artificial recharge by integration of various thematic layers using GIS techniques.

To recommend suitable artificial recharge based on terrain conditions and characteristics.

To suggest suitable recharge measures near the existing power house sources for sustainable development of ground water resources.

2. METHODOLOGY

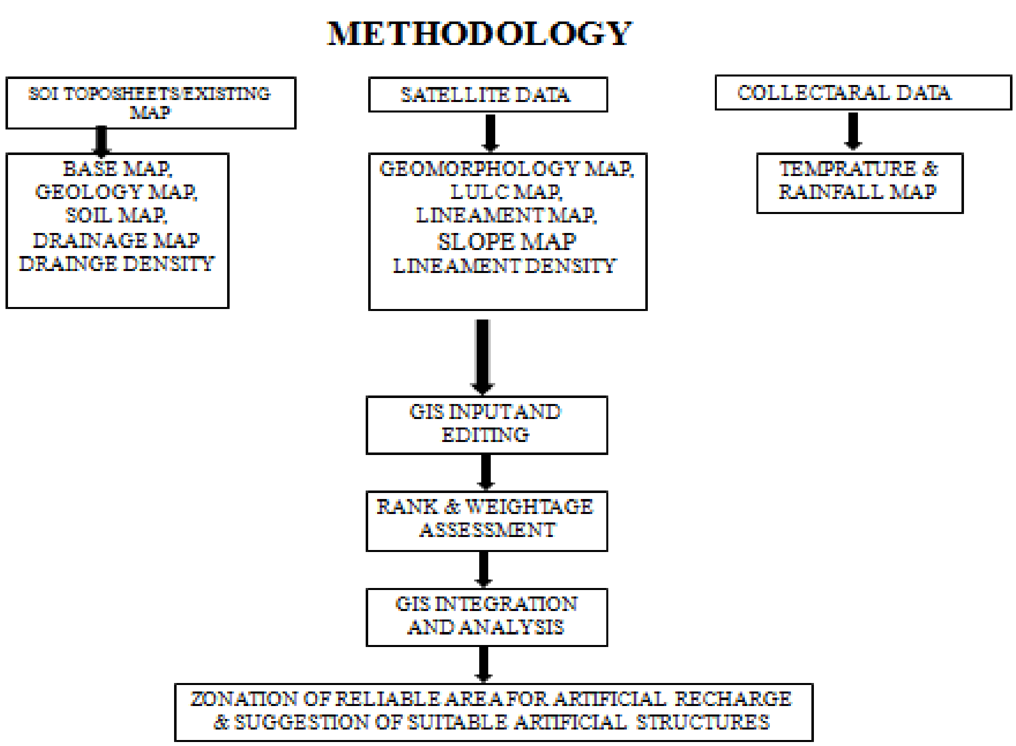

Figure 1 Methodology

2.1. Study area description

Location & Extend

This block is located at 10.47º & 10º28 ll0 lNorth Latitude, 78.7º & 78º42 ll0 lEast Longitude. It has an average elevation of 128 meter (419 feet).

Demographics

In Annavasal block Males constitute 49% of the population and Female 51%. Annavasal has an average literacy rate of 67%, higher than the national average of 59.5% ; with 55% of the male and 45% of female literate 12% of the population is under 6 years of age.

Climate and Rainfall

The block has a semi arid and sub-tropical climate. The nearby Rainfall Station is at Kudimiyanmalai. The annual precipitation of the block is 832.54 mm are recorded in the rainfall station at Kudimiyanmalai. During the 10 years period from 2001-2010 maximum rainfall of 1485.2 mm has recorded in the year 2005-06 and minimum rainfall of 771 mm has recorded in the year 2002-03. The Northeast monsoon contribute maximum amount of rainfall during the month September to December.

Water Level

The depth of water levels from 1.75 to 12.45 m and from 1.83 to 16.54 during winter and summer respectively.

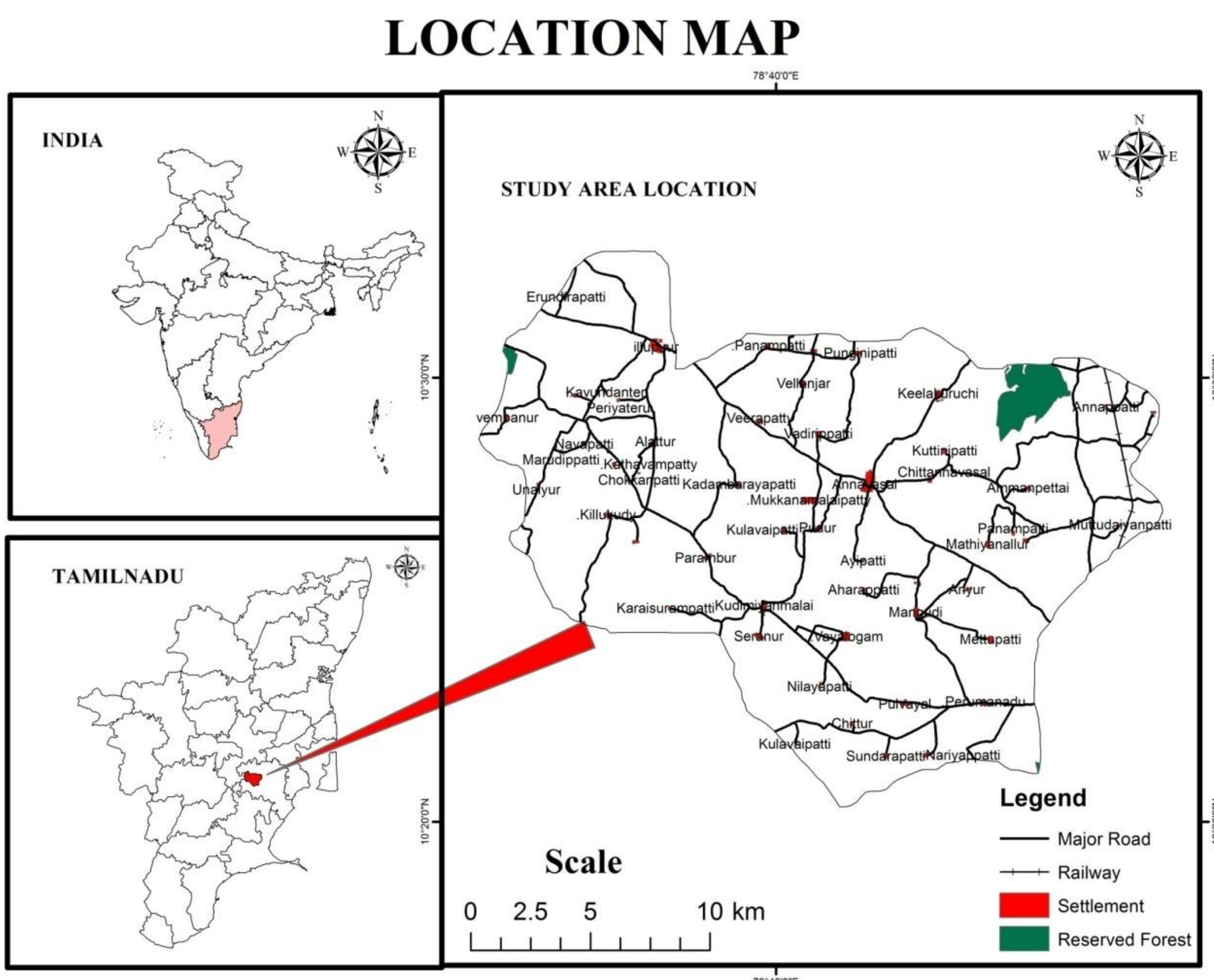

Figure 2 Study Area Location Map

3. CLIMATE AND RAINFALL

Table 1 Rainfall and Temperature Distribution

		Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	oct	Nov	Dec
1982	Rainfall					25.8		92.9	14.2	268.2	20.4	158	58.4
1982	Temperature	25.85	26.51	28.39	30.51	30.21	29.63	29.2	29.19	29.06	27.57	26.99	25.62
1987	Rainfall	0	0	0	0	0	0	0	0	0	0	0	0
1987	Temperature	26.41	26.56	28.62	30.47	30.75	29.82	29.66	28.92	29.49	28.14	28.06	26.78
1992	Rainfall	0	0	0	0	0	0	0	0	0	0	0	0
1992	Temperature	25.76	27.24	27.74	30.06	30.14	29.3	28.81	28.55	28.67	28.17	27.04	25.43
1996	Rainfall	0	0	0	0	0	0	0	0	0	54.8	0	0
1996	Temperature	26.45	27.24	28.34	29.64	30.79	28.43	28.77	28.38	28.04	28.17	27.44	25.68
2002	Rainfall	0	0	0	0	0	0	0	0	0	0	0	0
2002	Temperature	26.5	27.15	29.04	30.37	30.55	29.9	29.39	28.47	29.06	28.02	26.78	25.76

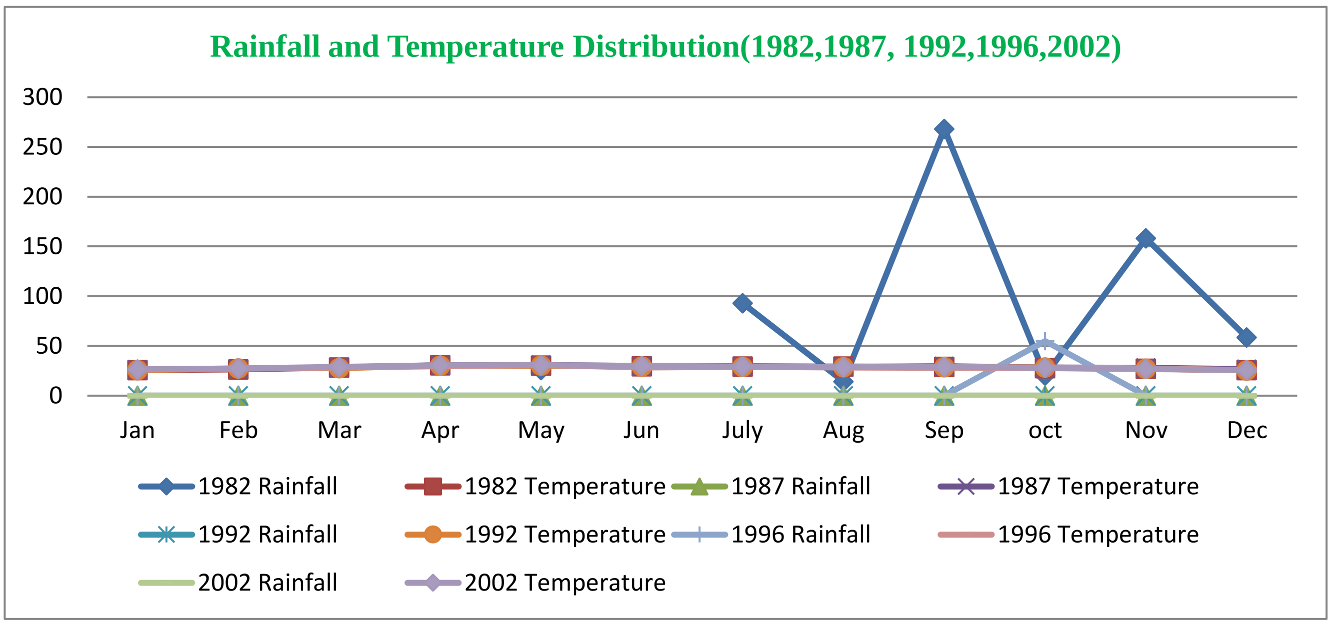

Figure 3 Rainfall and Temperature Distribution Map

3.1. Rainfall Analysis

During the present study, the Rainfall data available from 2003-2012 has been used and using the same, the following analysis has been obtained.

Table 2 Annavasal Block Rainfall-Month wise/Season wise (2003 to 2012) (mm)

Season Month	Normal	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
		Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual
Winter Season											
January	5.4	0	0	0	10.4	0	0	18.4	3.4	9.4	0
February	26.3	0	0	2	0	0	7.2	0	6.5	0	0

Total	**31.7**	**0**	**0**	**2**	**10.4**	**0**	**7.2**	**18.4**	**9.9**	**9.4**	**0**
Summer Season											
March	21.6	4.6	0	8	129	0	63.9	10.2	15	0	0
April	25.3	26.8	0	39.1	74.8	0	8.9	36.6	30	39.6	35
May	98.5	54.7	301.4	88.8	26.8	46.4	25.4	97.6	45	78.8	73.4
Total	**145.4**	**86.1**	**301.4**	**135.9**	**230.6**	**46.4**	**98.2**	**144.4**	**90**	**118.4**	**108.4**
South West Monsoon											
June	39.6	15.2	7	15.5	110.2	19.9	3.4	40.2	48.5	23.6	10
July	63	50.7	145.1	99.7	2	49.5	143	25.7	30.7	30.8	36
August	95.1	203	0	163.8	113.2	143.4	75.8	36.6	58	120.6	143.3
September	104.8	54.6	189	288.8	54.4	35.9	87.8	98.8	90	215.5	119
Total	**302.5**	**323.5**	**341.1**	**567.8**	**279.8**	**248.7**	**310**	**201.3**	**227.2**	**390.5**	**308.3**
North East Monsoon											
October	137	173	150.8	185.6	201.5	82.4	26	10.2	160	359.6	172.5
November	212.7	173.2	213.2	429.8	230.6	26.8	325.3	255.5	40	401.1	78
December	67.1	8.7	4.2	127.2	24.4	98.6	48.8	80.2	110	68.8	0
Total	**416.8**	**354.9**	**368.2**	**742.6**	**456.5**	**207.8**	**400.1**	**345.9**	**310**	**829.5**	**250.5**
G.Toatal		**764.5**	**1010.7**	**1448.3**	**977.3**	**502.9**	**815.5**	**710**	**637.1**	**1347.8**	**667.2**

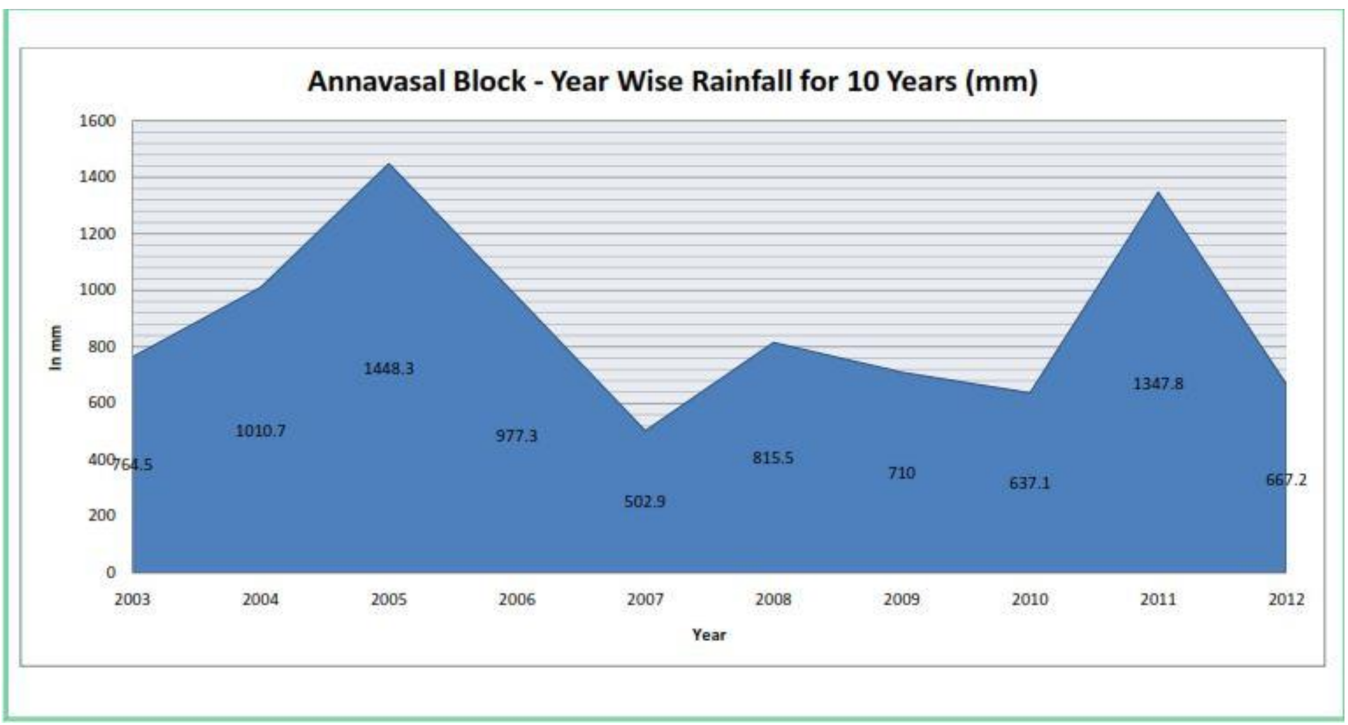

Figure 4 Annavasal block year wise Rainfall for 10 years

3.2. Rivers and drainage Map

It is slightly an undulating terrain with gentle slope towards Southeast. The block area lies in between 300m above M.S.L. The block is occupied with numerous irrigation tanks most of which rain fed.

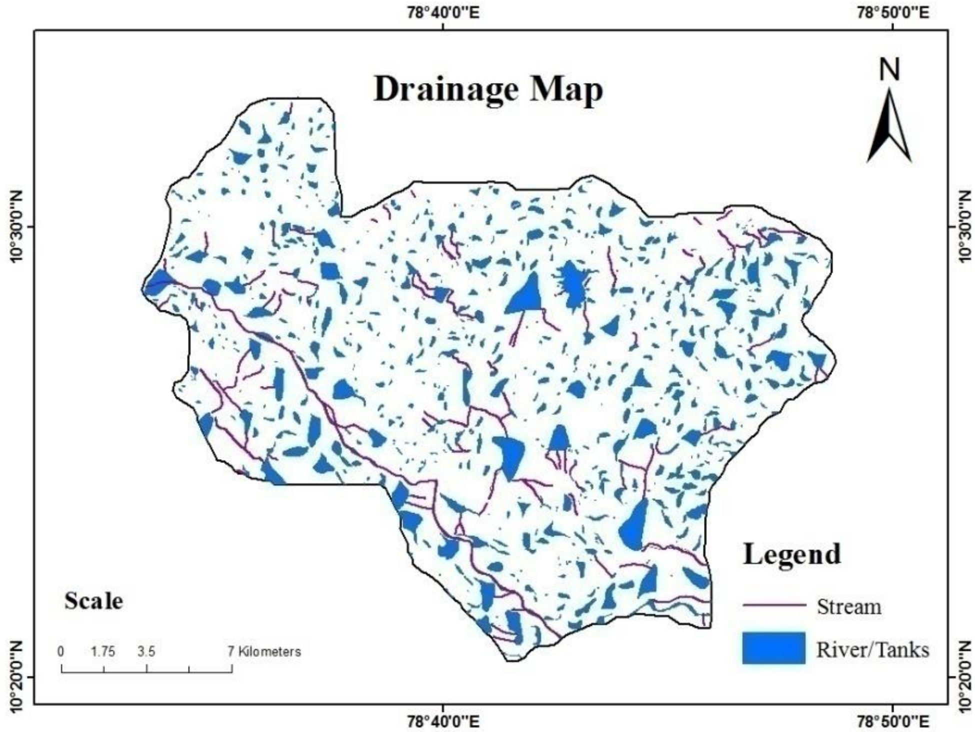

Figure 5 Drainage Map

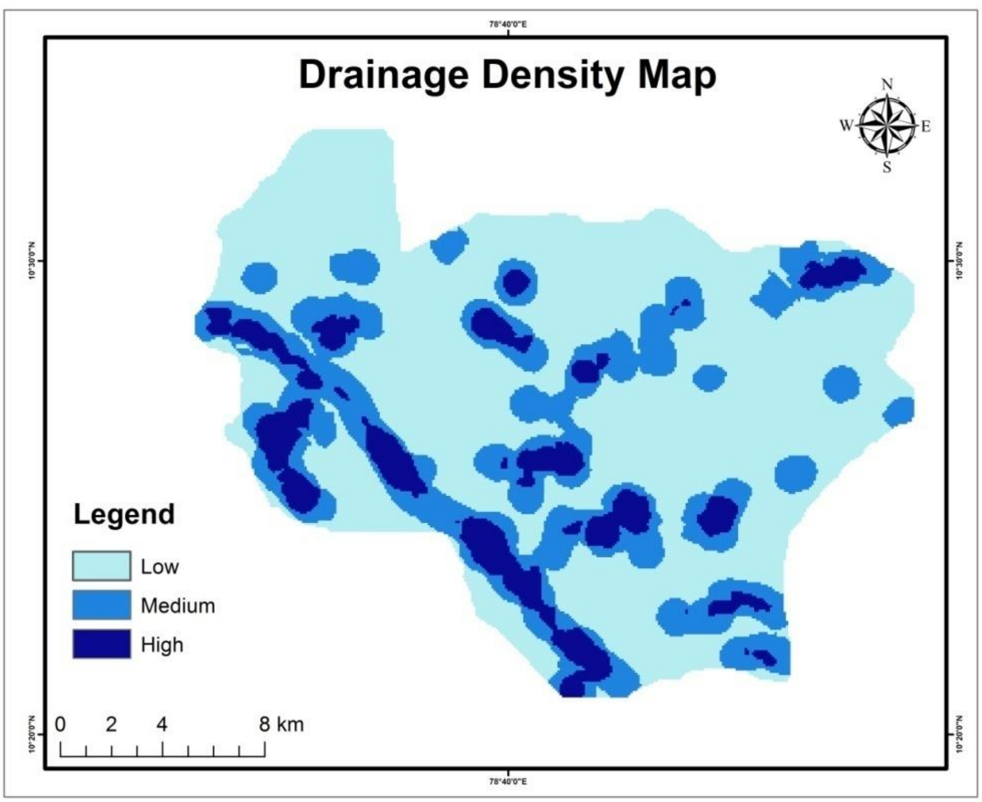

Figure 6 Drainage Density Map

3.3. Geology

The Geological formation of Annavasal block comprise of granite, Gneisses & charockites in Miocene and Pliocene formation. Clay bound sand, clay and sand stone in some portion of Annavasal Block.

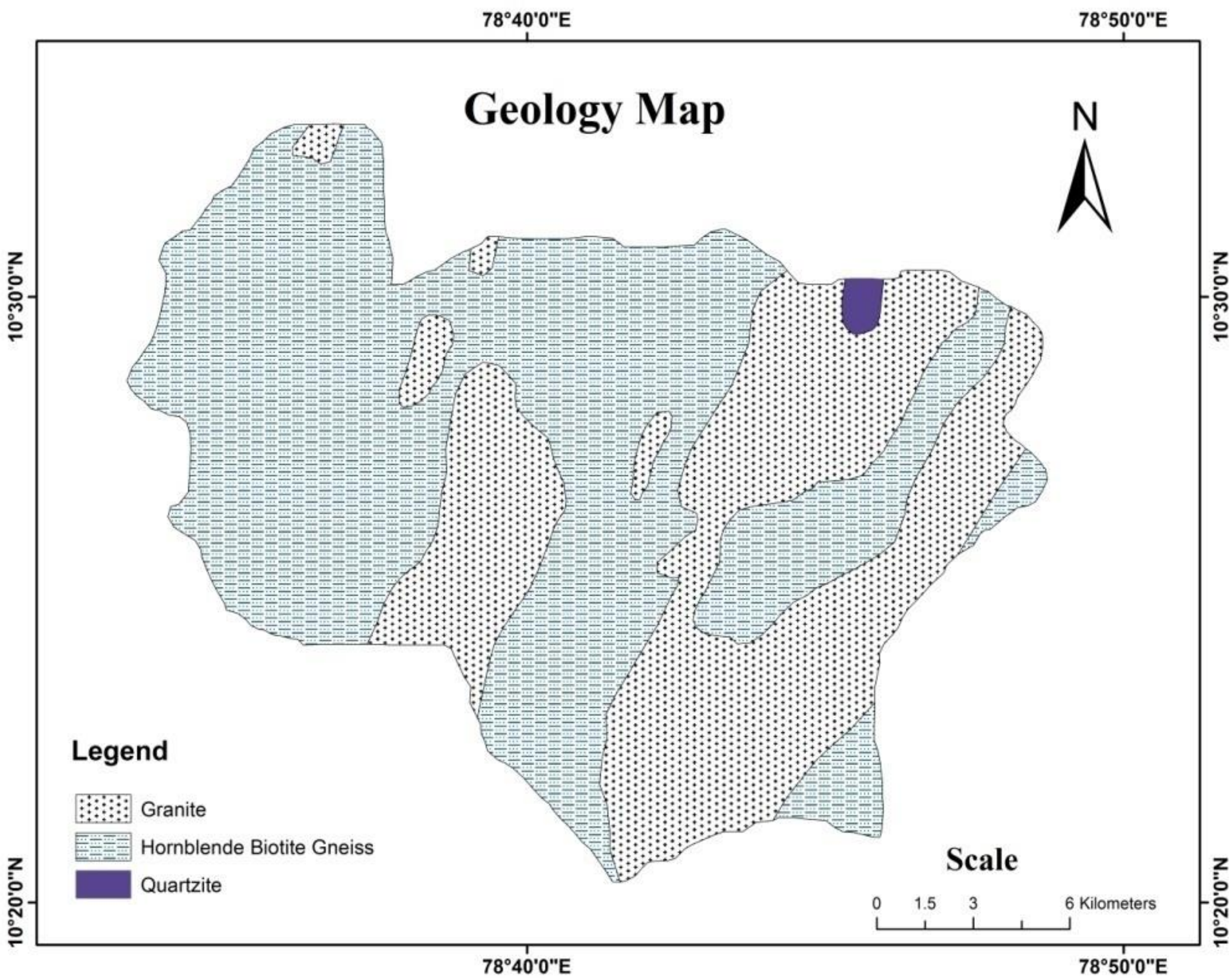

Figure 7 Geology Map

3.4. Geomorphology

Through visual interpretation, prepared geomorphology map using IRS- P6 LISS III (2007) Satellite imagery.The major features in Plain Region -Shallow Weathered/Shallow Buried Pediment & Hill- Dome Type of Residual Hill.

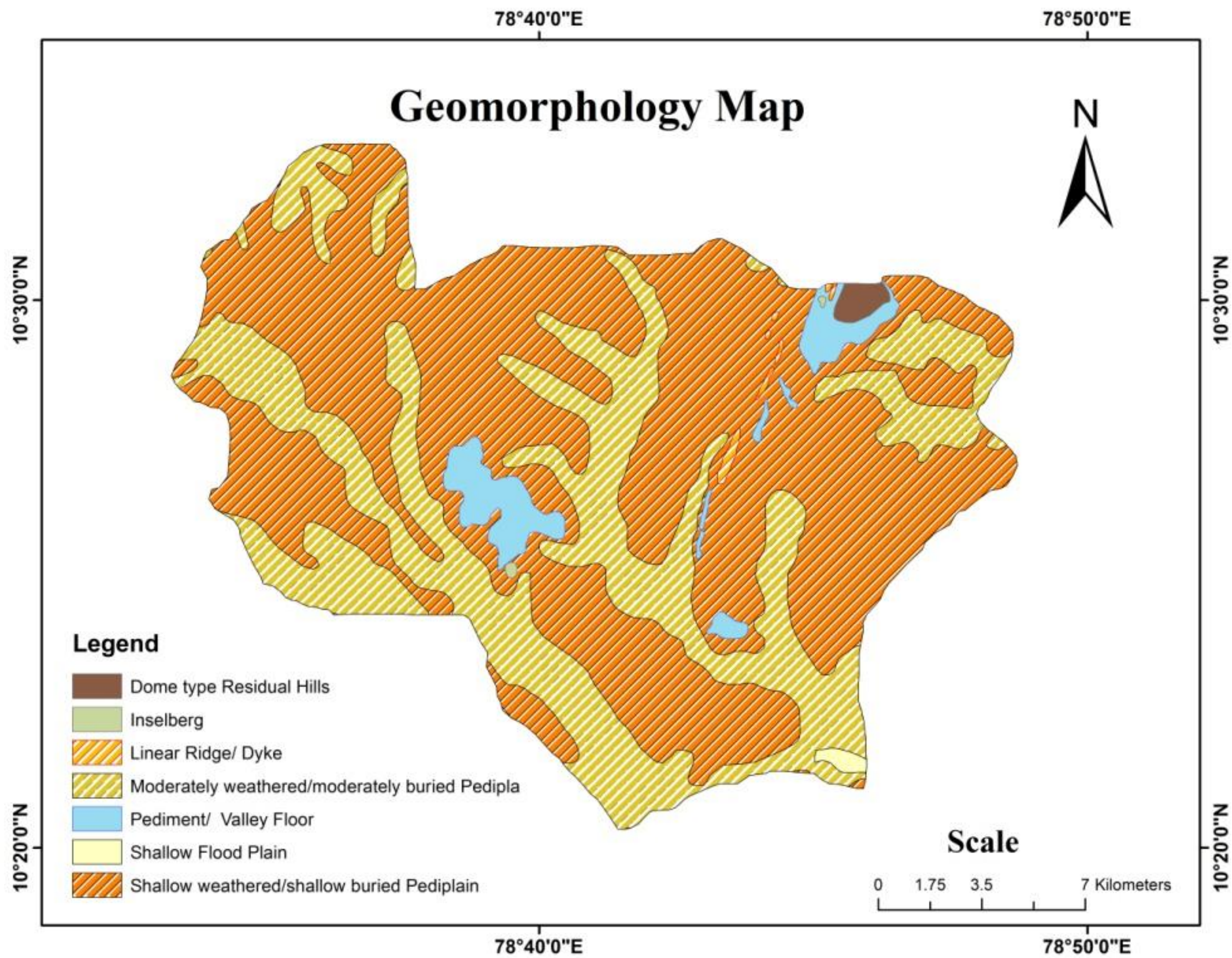

Figure 8 Geomorphology Map

3.5. Landuse / Land Cover

LU/LC was prepared using Digital Interpretation by unsupervised classification using ERDAS. Classified the features based on NRSC LEVEL II classification. In my study Area dominated by Fallow Land. Over all Study is covered by cropland and fallow land. Plantations are also found in between them due to the presence of Flood plain.

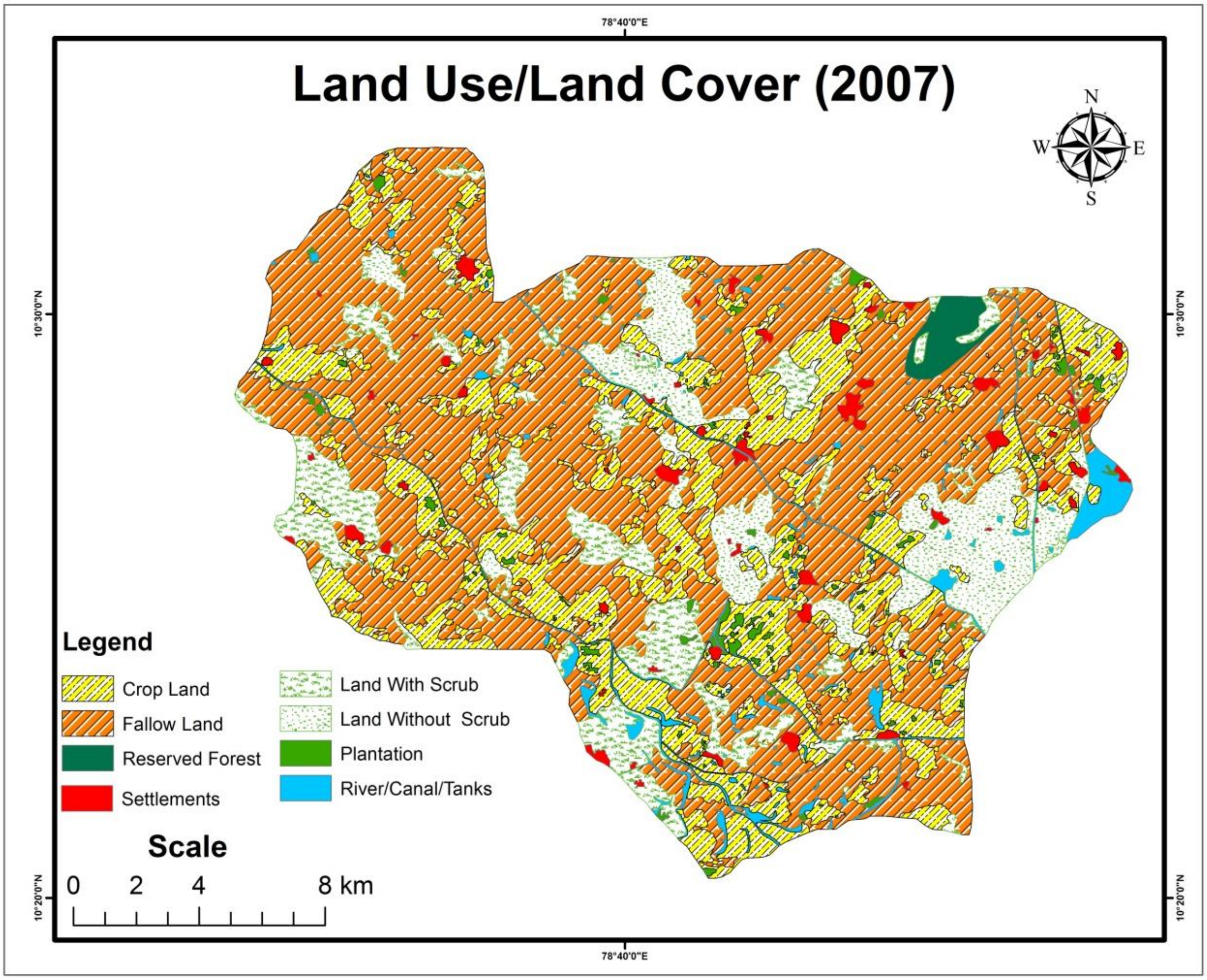

Figure 9 Land use/Land cover Map

3.6. Lineament Density

Lineament density of an area can indirectly denote the Artificial Recharge, since the presence of lineaments usually denotes a permeable zone where infiltration is more. Three zones, Low Moderate and High have been classified

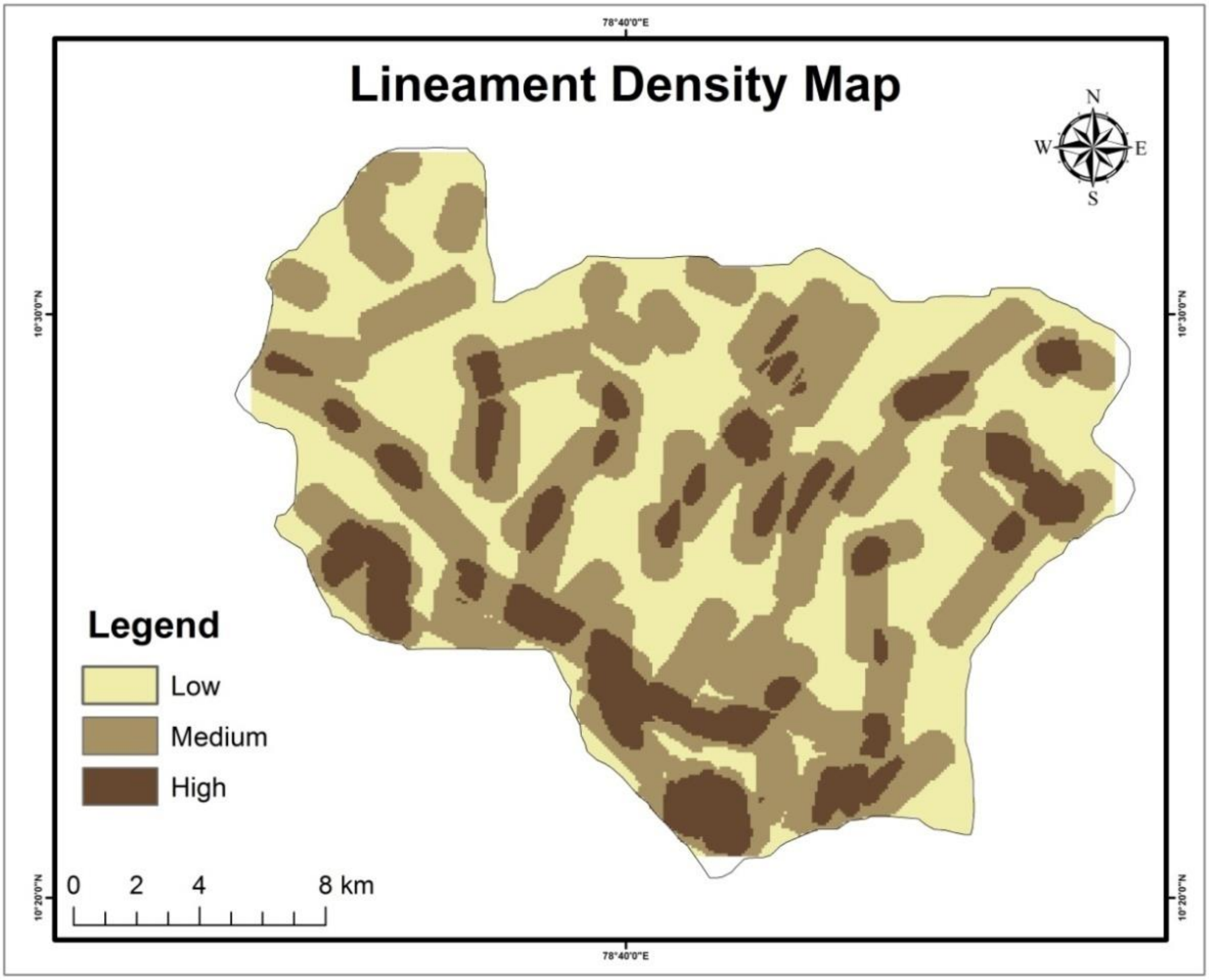

Figure 10 Lineament Density Map

3.7. Slope Map

Slope map was generated using SRTM data. Classified based on NRSC IMSD classification.

0-1 : nearly level
1 - 3 : very gentle
3 - 5 : gentle slope
5 - 10 : moderate slope
10 – 15 : strong slope
15 - 35 : moderate-steep
>35 : steep slope

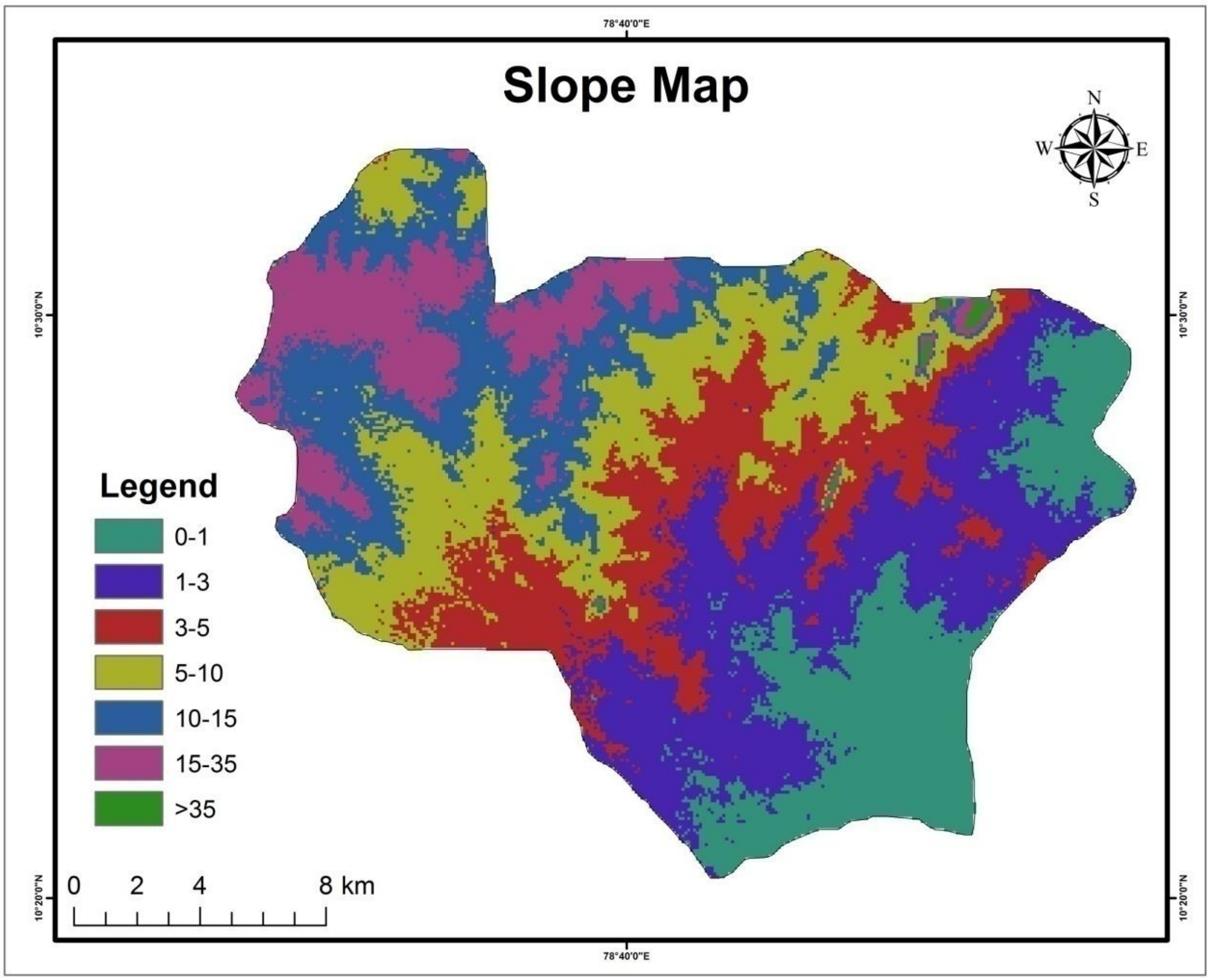

Figure 11 Slope Map

3.8. Soil Map

Soil is an important factor for delineating the groundwater artificial zones. The analysis of the soil type reveals that the study area is predominantly covered by Fine mixed Typic ustropepts. Presence of clayey soil indicates the possibility for the high run-off and less infiltration. Also the loamy skeletal soil in the plain region indicates the possibility for high infiltration.

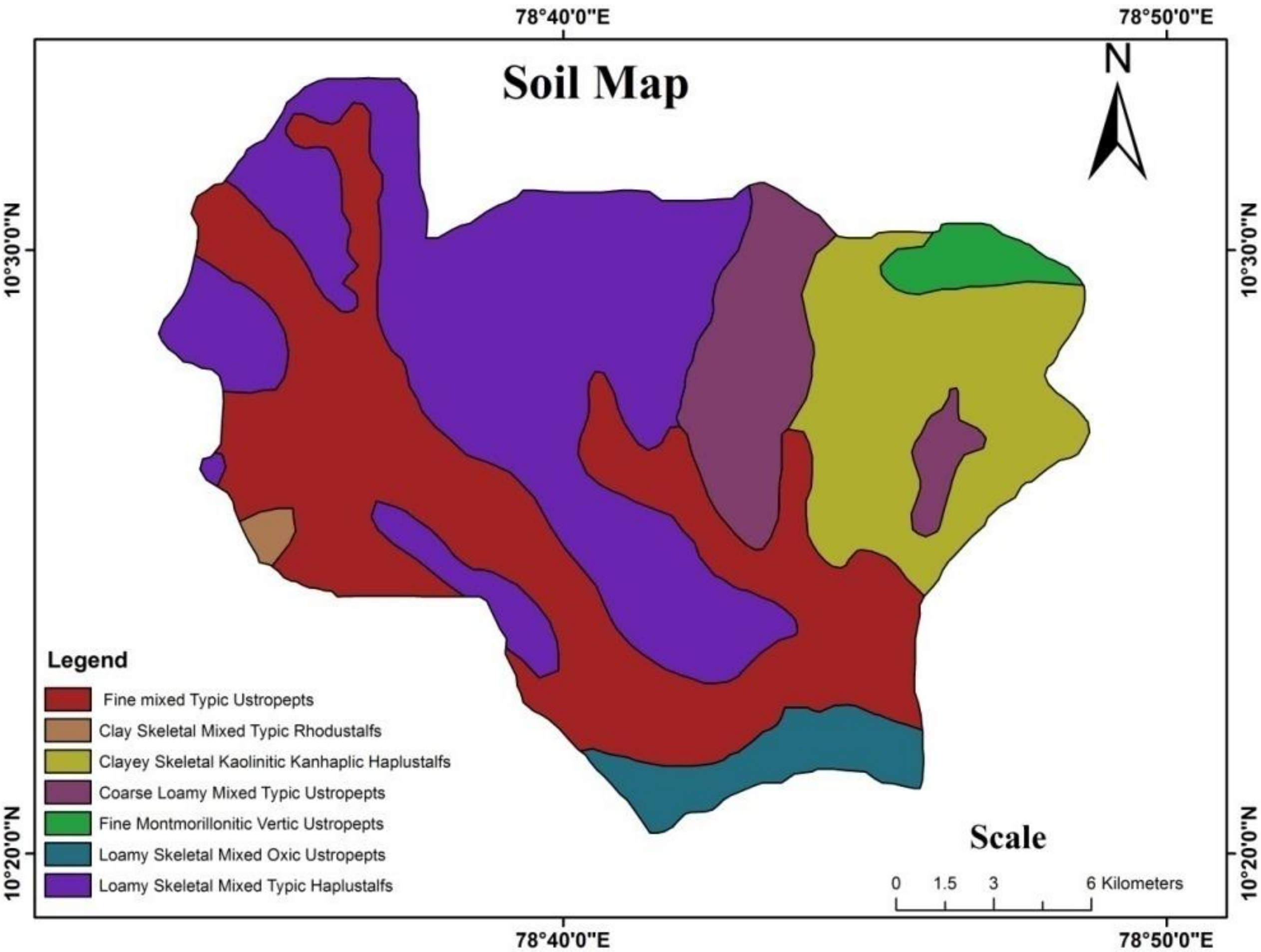

Figure 12 Soil Map

3.9. Analytical Hierarchical Process – AHP

Table 3 Saaty's 1-9 Scale of Relative Importance

SCALE	1	3	4	5	6	7	8	9
Relative Importance	Equal Importance	Weak	Moderate Importance	Strong Importance	Strong Plus	Very Strong	Very, very Strong	Extreme Importance

3.9.1. Assigning Weight to Parameters

In the present study, the GIS based AHP method was applied to integrate different thematic layers based on the assigned weights for the suitable site selection. Here; the weight of the feature class of individual parameters was assigned using Saaty's scale. All parameters were assigned with a suitable weight and integrated with geometric mean of corresponding layer to derive the normalised weighted output.

Table 4 Pair wise Comparison Matrix

	GEOLOGY(5)	GEOMORPHOLOGY(5)	SLOPE(4)	DRAINAGE DENSITY(4)	LINEAMENT DENSITY(5)	SOIL(4)	LULC(3)
GEOLOGY	1	1	4/5	4/5	1	4/5	5/3
GEOMORPHOLOGY	1	1	4/5	4/5	1	4/5	5/3
SLOPE	4/5	4/5	1	1	4/5	1	4/3
DRAINAGE DENSITY	4/5	4/5	1	1	4/5	1	4/3
LINEAMENT DENSITY	1	1	5/4	5/4	1	5/4	5/3
SOIL	4/5	4/5	1	1	4/5	1	4/3
LULC	3/5	3/5	3/4	3/4	3/5	3/4	1

Geology –1. Quartzite - 3
2.Hornblende biotite Gneiss - 5
3. Granite - 2

Add 3+5+2=10
and divide from each,
3/10 = 0.3 - Quartzite
5/10 = 0.5 - HBG
2/10 = 0.2 - Granite
these values derives the weight age.

Add these values will give 1
(i.e.) 0.3+0.5+0.2 = 1

Similarly all the values were derived and tabulated

Table 5 Relative Weight of Various Thematic Layers and Their Corresponding Classes through AHP

FACTOR	FEATURE CLASS	WEIGHTAGE
GEOLOGY	GRANITE	02
	HORNBLENDE BIOTITE GNEISS	0.5
	QUARTZITE	0.3
GEOMORPHOLOGY	DOME TYPE RESIDUAL HILL	0.09
	INSELBERG	0.09
	LINEAR RIDGE/DYKE	0.09
	MODERATELY WEATHERD/BURRIED PEDIMENT	0.22
	PEDIMENT VALLEY FLOOR	0.22
	SHALLOW FLOOD PLAIN	0.13

	SHALLOW WEATHERD/SHALLOW BURIED PEDIMENT	0.13
SLOPE	<5 5-15 >15	0.44 0.33 0.22
DRAINAGE DENSITY	LOW MODERATE HIGH	0.44 0.33 0.22

FACTOR	FEATURE CLASS	WEIGHTAGE
LINEAMENT DENSITY	LOW MODERATE HIGH	0.2 0.3 0.5
LU/LC	BUILTUP LAND CROP LAND FALLOW LAND PLANTATION RESERVED FOREST LAND WITH SCRUB LAND WITHOUT SCRUB	0.06 0.18 0.18 0.18 0.12 0.12 0.12
SOIL	FINE MIXED TYPIC USTROPEPTS CLAY SKELETAL MIXED TYPIC RHODUSTALFS CLAY SKETETAL KAOLINITIC HAPLUSTALFS COARSE LOAMY MIXED TYPIC USTROPEPTS FINE MONTROLINITIC VERTIC USTROPEPTS	0.02 0.01 0.01 0.04 0.02

	LOAMY SKELETAL MIXED OXIC USTROPEPTS	0.03
	LOAMY SKELETAL MIXED OXIC HAPLASTALFS	0.03

After assigning the weight ages to all the themes and features, the thematic layers were converted to raster format using the spatial analyst tool. Finally, an integrated groundwater artificial zone map was prepared using Raster Calculator tool in ArcGIS software.

3.10. Artificial Recharge Zone Map

By integrating all the above 7 thematic layers, we have prepared the groundwater Artificial Recharge zone map.Moderate potential zone is maximum in our study area of about 31% Poor of about 51% and Good of about 27%.

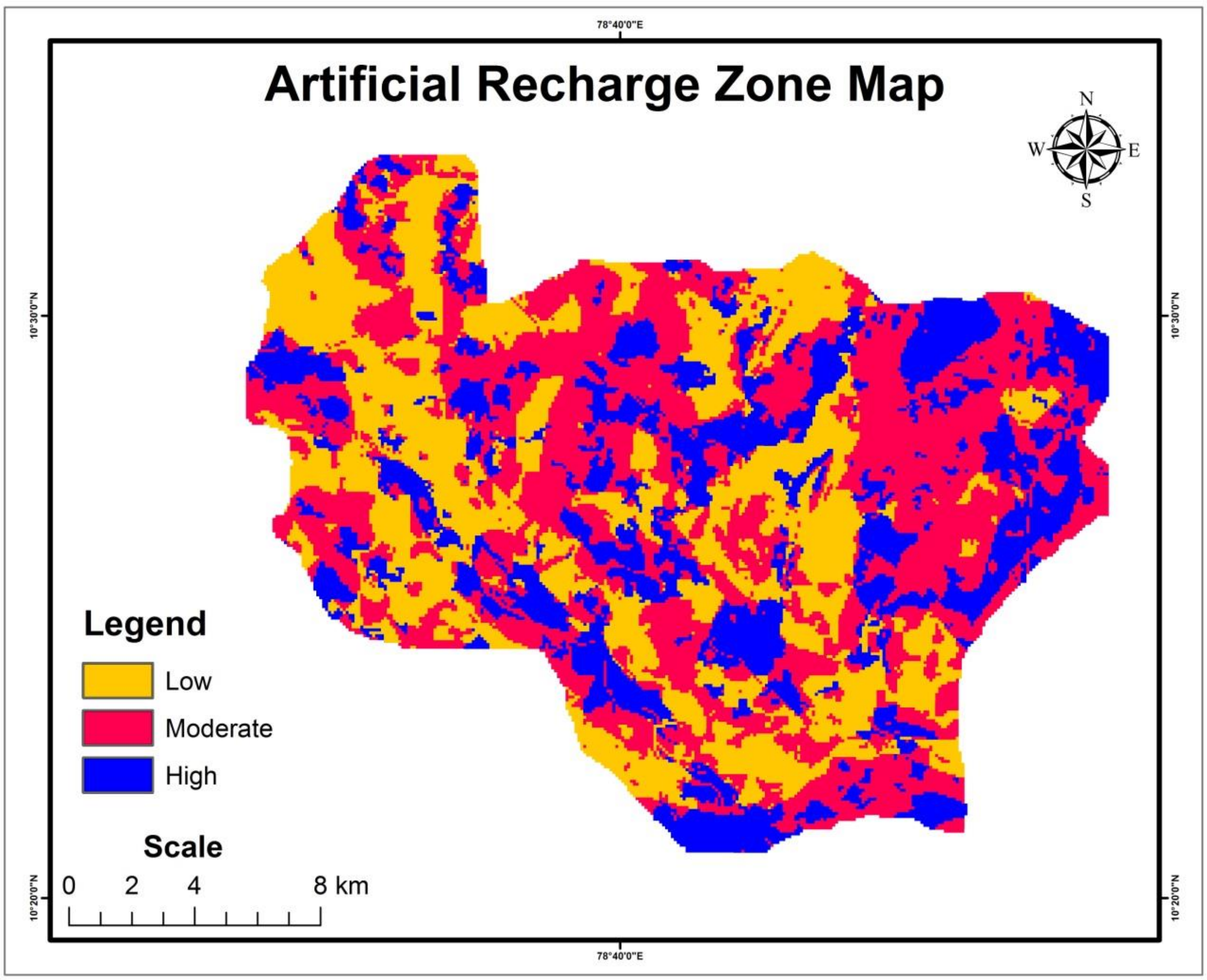

Figure 13 Artificial Recharge Zone Map

3.11. Recommended Artificial Recharge Structure

With reference to our study area lithology and geomorphological structure the following artificial recharge structures check has been identified that is Check dam across the streams and Odai, Percolation pond in and around the agricultural areas, recharge shaft inside the pond. And Recharge bore well along the road side to harvest the rain water collection along the road side and Rain water(Roof) harvesting finally desilting of all existing Pond, lake, Ooranies has been identified to increase the artificial ground water potential.

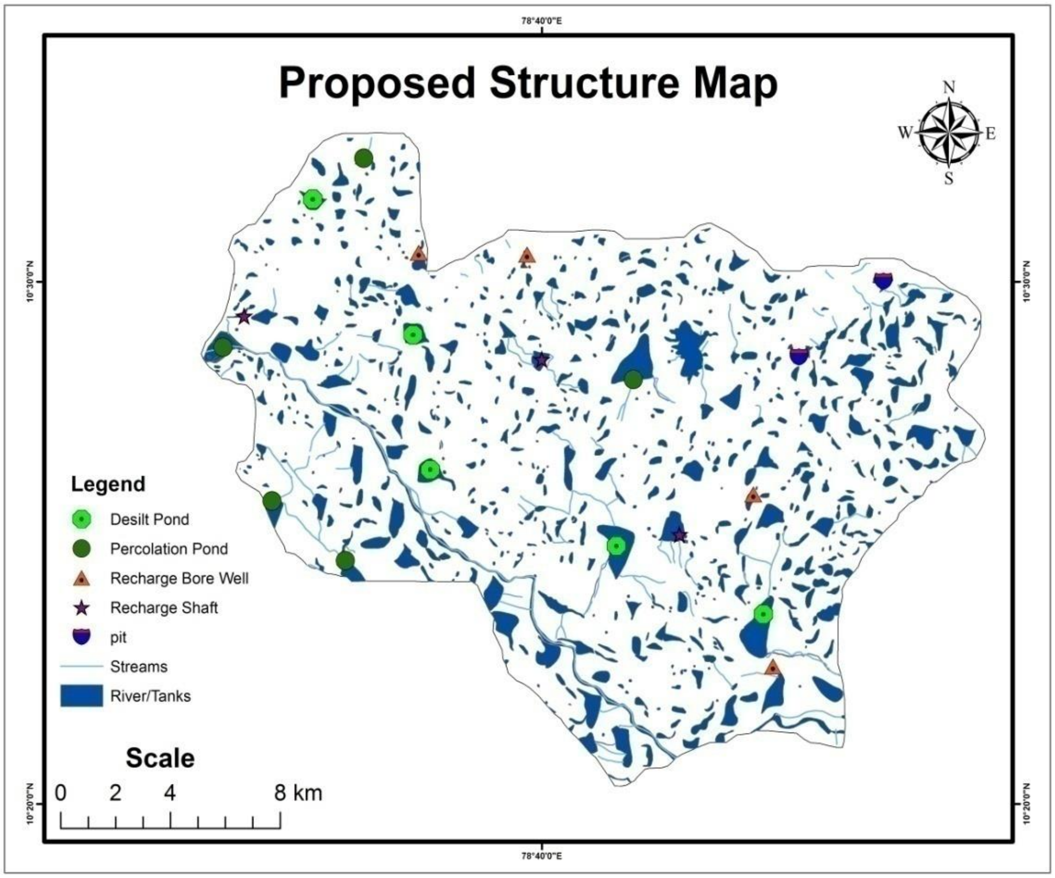

Figure 14 Proposed Structure Map

Figure 15 Recommended Artificial Recharge Structure Map

4. CONCLUSION

This study recommends that the cultivation lands, plantation areas, vegetation cover , rivers, canals and ponds should be preserved and industrial activities should not be allowed within cultivable lands; and all existing water bodies like rivers, canals and ponds should be desilted and proper embankments should be constructed all along the canals to prevent water loss. All encroachments should be removed along rivers, canals and ponds to improve the socio-economic activities for future generations. Thus land use plans at the micro level have to be prepared through the full participation of the agriculture communities. Government agencies can provide the needed technical advice on selection of crops grown based on the availability of groundwater resources of the area and the popularizing of the micro irrigation system for sustainable land use practices in this area. The agricultural department can also make a study in this regard and suggest suitable cropping patterns, which consume less water in this area. This study will be helpful to safeguard the environment for future generations.

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