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IDENTIFICATION OF GROUNDWATER RECHARGE POTENTIAL ZONES IN THE DEDIAPADA BLOCK OF GUJARAT USING REMOTE SENSING & GIS AND AHP

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ABSTRACT

The proper management of both surface and groundwater resources through systematic inventory, conservation and proper planning is essential for economic and social development of any region. Identification of the groundwater recharge potential is utmost important in the water scares areas. The study was undertaken considering the present need of water for irrigation and domestic use. Five-year groundwater level data was observed from the 66 open wells in the Dediapada block. Groundwater recharge was estimated using water table fluctuation method. Ground water recharge potential of the Dediapada block in the Narmada district of the Gujarat state was identified using Remote sensing and GIS techniques with AHP techniques to include expert's opinion. It was observed that out of total land of Dediapada block, 912.03 ha. (0.90 %) area having very good groundwater recharges potentials followed by 17945.06 ha. (17.50%) having good, 61777.91 ha. (60.10%) having moderate and 22107.33 (21.50%) having poor groundwater recharges potentials. The average rate of groundwater recharge was observed as 5.25% of mean annual rainfall of Dediapada block.

***Key words*:** Groundwater recharge, Narmada district, Remote sensing & GIS, Water harvesting

Introduction

The proper management of both surface and groundwater resources through systematic inventory, conservation and proper planning is essential for economic and social development of any region. The explosive growth and uneven distribution of population, poor irrigation practices, rapid urbanization/industrialization, large-scale deforestation and improper land use practices have induced the depletion and pollution of both the surface and groundwater resources in Narmada district. The occurrence and movement of groundwater in an area is governed by several factors such as topography, lithology, geological structures, depth of weathering, extent of fractures, slope, drainage pattern, landforms, land use/ land cover changes, climatic conditions and inter-relationship between these factors. The systematic planning of groundwater estimation and exploitation using modern technologies is essential for the proper utilization of this precious natural resource. GIS and remote sensing tools are widely used for the management of various natural resources. Therefore, present investigation will be carried out.

Material and Methods

Estimation of Groundwater Recharges Using Water Table Fluctuation Method

For the recording of the groundwater level, 66 observation wells were selected considering one well in the square grid of 10 km^2 area. The groundwater level was recorded before and after monsoon from year 2017 to 2021. The water table fluctuation method provides an estimate of groundwater recharge by analysis of water level fluctuation in river basin. The method is based on the assumption that a groundwater recharge is directly proportional to the change in the water level in the shallow wells and is caused by the addition of recharge across the water table. Recharge by the WTF method is estimated as,

$$Rg = Sy * \Delta L * A \quad (1)$$

Where,

R_g = groundwater recharge, m^3

S_y = Specific yield, dimensionless

ΔL = water table difference before and after monsoon,

A = net geographical area of river basin, m^2

Land use land cover Analysis

The land use/ land covers maps for the year of 1999, 2009 and 2020 for the Dediapada taluka was prepaired. Landsat and Sentinel-2 Satellite images were downloaded from the USGS earth explorer open-source website. The Images were enhanced and LULC were prepared using ERDAS 15 software. Different five land use land cover classes were prepared, *i.e.*, Forest cover, Agricultural land, waste land, urban land and water bodies. The process flowchart is as given in Fig. 1.

Analytical Hierarchy Process (AHP)

AHP is a method of Multi Criteria Decision Analysis (MCDA) that is implemented within GIS, which defines weights for criteria. AHP was initially developed by Saaty (1980). The AHP approach can be used as a bunch of tools used for deriving weights of different criteria. The AHP has the ability to deal with inconsistent judgments (Saraf and Choudhury, 1998 and Saaty, 1980). Different six layers *i.e.*, slope, lineament, soil, geomorphology, lithology and land use land cover map was used for the determination of weights for the groundwater recharge potential zones in the GIS environment. Weights were asked from the different experts of water management discipline among universities. Experts' opinions were considered consistent if the consistency ratio less than 0.1.

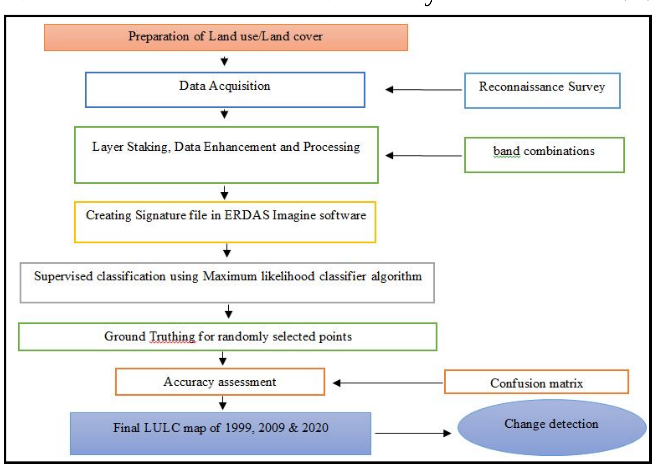

Fig. 1: Workflow chart for the preparation of LUCL of Dediapada taluka.

Results and Discussion

For the calculation of recharge from wells, Thiessen polygons were prepared considering each observation well as a center of the polygons. The groundwater recharge for the each polygons were calculated for subsequent five years and are as shown in Table 1. The Thiessen polygon map was prepared for the calculating the weighted value of water table fluctuation over the entire area. The locations of observation wells and Thiessen polygon map is as shown in Fig. 2 and 3 respectively.

For the Dediapada taluka groundwater recharge estimation, using water table fluctuation method is as shown in Table 1. The groundwater recharge for each of

Table 1: Mean Groundwater recharge (mm) of different polygons.

SN	Polygon	GWR (mm)	SN	Polygon	GWR (mm)
1	Arethi	66.4	34	Mohbi	39.9
2	Babda	96.3	35	mohbudi	89.5
3	BandiServan	46.6	36	Morjadi	51.2
4	Bebar	57.2	37	Mosit	50.8
5	Besana	228.6	38	Moskuva	49.3
6	Bhutbeda	43.3	39	Moti Bedvan	93.8
7	Bogaj	135.7	40	Moti Singloti	75.2
8	Chikda	113.4	41	Nana Sukamba	26.9
9	Chuli	74.8	42	Nani Bedvan	68.3
10	Dabaka	54.6	43	Navagam	61.2
11	Dabhvan	82.7	44	Ninghat	85.3
12	Fulsar	89.3	45	Panch-Umar	8.7
13	Gadi	57.3	46	Pangam	114.1
14	Gangapur	32	47	Pansar	78
15	Ghatoli	110.8	48	Panuda	58.6
16	Jamni	78.5	49	Patdi	99.5
17	Jankh	54.7	50	Patvali	49.9
18	Jargam	67.9	51	Piplod	51
19	Juna Mosda	88.9	52	Rakhaskundi	110.6
20	KabariPathar	73.8	53	Ralda	45.4
21	Kakarpada	80.5	54	Relva	83.1
22	Kaltar	30	55	Rohda	84.7
23	Kamodvav	79.5	56	Rojghat	52.8
24	Kanbudi	59.9	57	Sagai	47
25	Kanjai	75.7	58	Sakvafaliyu	52.9
26	Khaidipada	76.6	59	Samarpada	53.9
27	Khakhji Dabra	67.9	60	Shisha	51.6
28	Kharchipada	67.3	61	Soliya	52.1
29	Khokhra Umar	91.6	62	Sorapada	60.9
30	Korvi	67.7	63	Sukval	53.6
31	Ladava	149.7	64	SupurBorsan	81.6
32	Mal	82.6	65	Tabda	59.9
33	Mandala	115.2	66	Vedacha	71.4

Table 2: Mean Groundwater Recharge for subsequent five years in Dediapada taluka.

Year	2017	2018	2019	2020	2021
Groundwater Recharge (mm)	61.21	62.45	78.09	87.92	73.43
Groundwater Recharge (MCM)	62.81	64.04	80.06	90.17	81.46
Rainfall(mm)	1154	876	1853	2095	1465
Rainfall (MCM)	1184	898	1900	2149	1502
Recharge in % of Annual rainfall	5.30	7.13	4.21	4.20	5.42

the observation well was calculated by multiplying the water level rise with the specific yield values of the aquifer material in which the wells are situated as suggested by Bhanja *et al.,* (2016). Groundwater level data of pre monsoon and post monsoon was measured during month of March-May and November-December of consecutive five years *i.e.*, 2017 to 2021 respectively. The groundwater recharge of the entire taluka was estimated by area weighted method. The highest and the lowest mean groundwater recharge was observed in the Besana and Panchmahal polygons as 228.59 mm and 8.73 mm respectively. Annual rainfall and annual recharge estimated using water table fluctuation method is given in Table 2.

It was observed that as the rainfall increases the groundwater recharge increases. But as the amount of rainfall increases, its contribution in to the groundwater recharge decreases. The highest ground water recharge was observed in the year 2020 as 87.92 mm and lowest

Fig. 2: Selected well locations.

ground water recharge was observed in year 2017. In the year 2018, highest percent of rainfall was contributed to the groundwater. The reason behind high recharge may be due to more number of days having less rainfall depth, so the major part of the water get infiltrated in to the soil and contributed to groundwater recharge, and as the depth of one day rainfall increases the runoff and overland flow become dominant and less time of opportunity to get infiltrated in to the soil so recharge is less in the year 2019 and 2020 even though annual rainfall is more.

Land use land cover change analysis

Land is an important natural resource available to man and is the interface for most human activity, which is greatly impacted by humans (Sondarva, *et al.*, 2023). Different three scenario of the change in land use land cover was estimated using satellite images. For the year 1999 and 2009 Landsat 8 image and for 2020 sentinel image was used for the preparation of Land use land cover map of the Dediapada taluka. The Land use land cover classification was done in four different classes, *i.e.*, Water bodies, Forest cover, Agricultural land and Residential/Fallow land. The classified image is as shown in Fig. 6. The accuracy assessment of the classified image was done with selecting the random point location and ground truthing with Google earth for the past scene. The classification accuracy for the year 1999, 2009 and 2020 was found as 85%, 80% and 90% with Kappa value of 75.23, 68.11 and 81.50 respectively.

It was observed that the decrease of forest cover

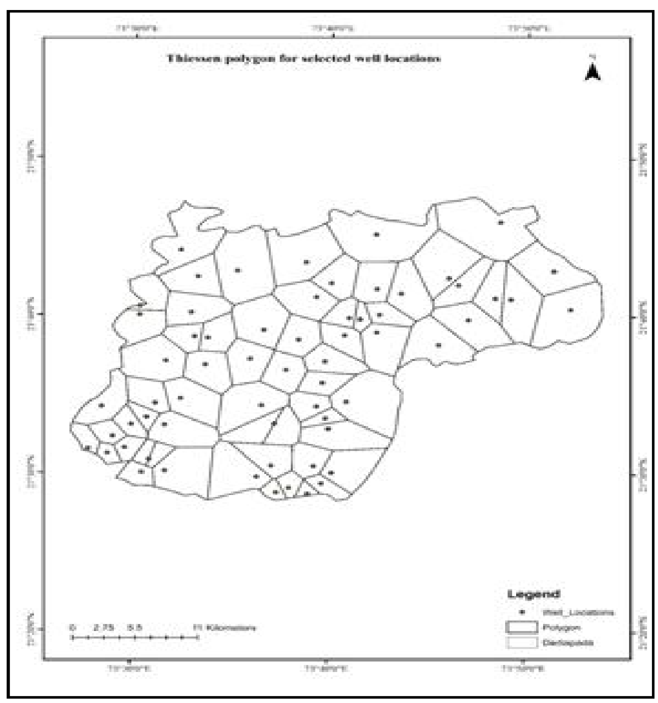

Fig. 3: Thiessen polygon map.

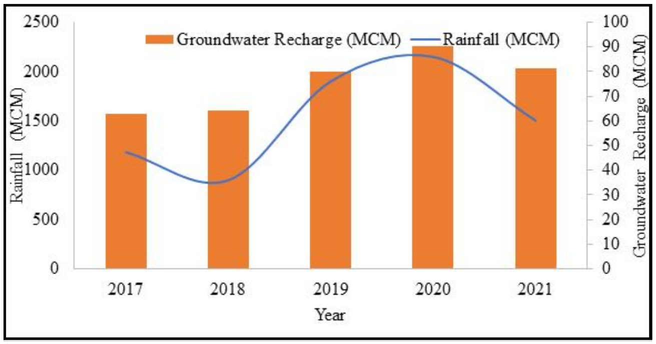

Fig. 4: Five-year groundwater recharge in the Dediapada taluka.

over time of 1999 to 2020. The forest cover was 43.18% in year 1999 which was reduced to 30.86 and 26.57% in year 2020. The rate of deforestation in the period of 1999 to 2009 was observed as 71.46 % and in the time span of 2009 to 2020 was about 86.08%. The deforested area was observed to convert to fallow land or residential land. There is increase in residential land and agriculture land was observed during time span of 1999 to 2009. Onwards agriculture land nearly stabilised and the forested area either converted to resident area or fallow land.

During this time there is no more changes observed in the surface water bodies in the Dediapada taluka. Area under forest land was reduced from 443.64 km^2 (43.18%) to 272.99 km^2 (26.57%) while fallow land was increased from 13.05 km^2 (1.27%) to 149.59 km^2 (14.56%) during last 20 years duration of 1999 to 2020 in Dediapada block.

The rate of deforestation was observed as 71.46% during 1999 to 2009 while it was observed as 86.08% in the next decade of 2009 to 2020 which shows that the deforestation in study area increases with higher rate in second decade as compare to first decade. It is observed that, shifting cultivation may be the main reason behind deforestation in this tribal region of Dediapada block.

Thematic Layers Used for GWR Potential Zones Identification

There were 6 different thematic maps were prepared for the identification of groundwater recharge potential zones in Dediapada taluka *i.e*, Slope map, Geomorphology map, lineament map, lithology map, soil map and LULC map as shown in Fig. 7, 8 and 9. The Groundwater recharge potential map was prepared using weighted overlay method in the ArcGIS environment. Weightages were taken as suggested by the experts as shown in Table 3.

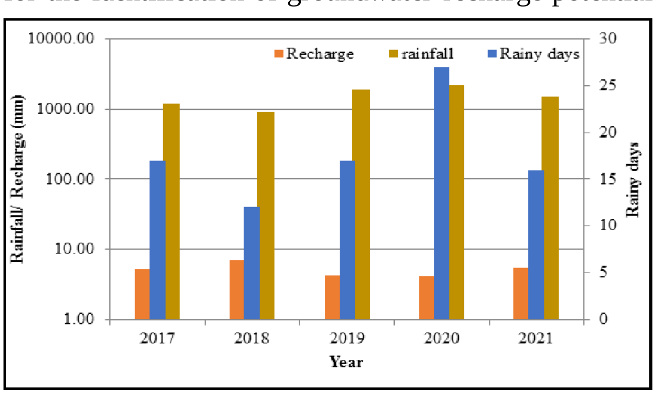

Fig. 5: Rainy days and according rainfall and recharge (mm).

Table 3: Assigned weights for groundwater potential zones.

Sr. No.	Thematic Layers	Allotted Weight
1.	Slope	12
2.	Soil	22
3.	Land Use / Land Cover	28
4.	Drainage Density	15
5.	Lineament Density	13
6.	Geomorphology	10

Land use land cover have more influence of groundwater recharge process followed by soil texture, drainage density, lineament density, slope and geomorphology. Details of each thematic layer is as given below.

Slope map: Slop is crucial thing for identifying the groundwater potential zones. Slop controls the groundwater recharge processes of the region. The slope map was prepared in ArcMap software using SRTM DEM data as shown in Fig. 7. Slop represents the infiltration characteristics of the profile, which indicates the opportunity time of surface water to get absorbed in the soil (Mseli *et al.*, 2021). the flat and gentle slope

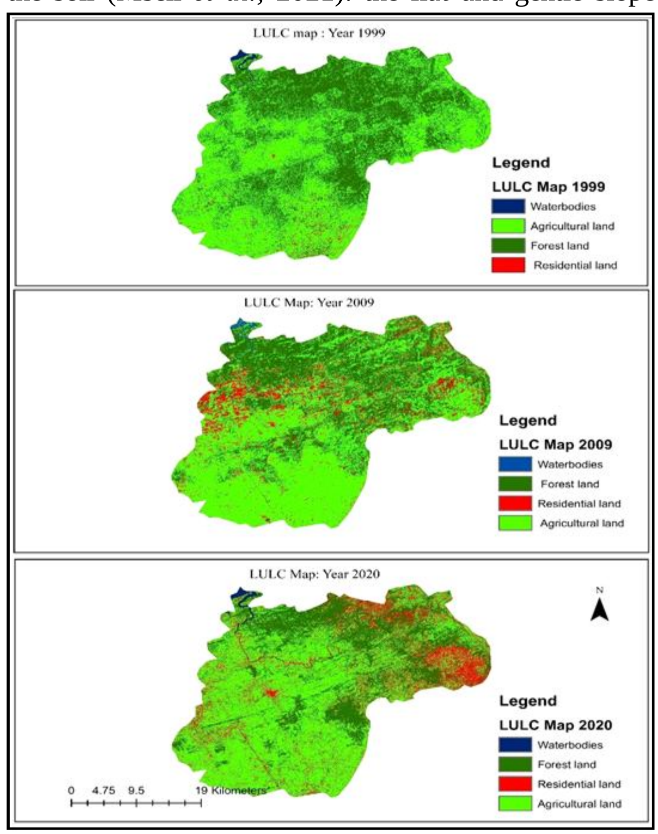

Fig. 6: Land use land cover change in the Dediapada block.

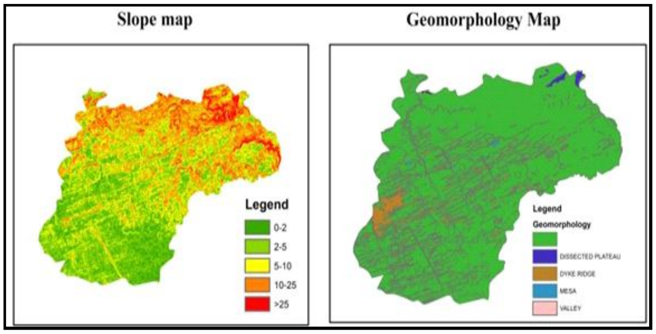

Fig. 7: Slope map and Geomorphology map of Dediapada block.

considered to very high potential for groundwater recharge because high infiltration rate. High slope of the area shows less opportunity time and results in high runoff while less or gentle slope suggest more opportunity time and less runoff potential. The locations with slope percentage 1-3% considered for the suitable for groundwater recharge, slope 10-15 % more runoff and less infiltration and groundwater recharge (Sondarva, 2024).

Geomorphology: Geomorphology deals with the different configurations of the earth surface. It represents the morphological features like mountains, rivers. Geomorphology exhibits various landform and structural features. The geomorphology map of Dediapada block

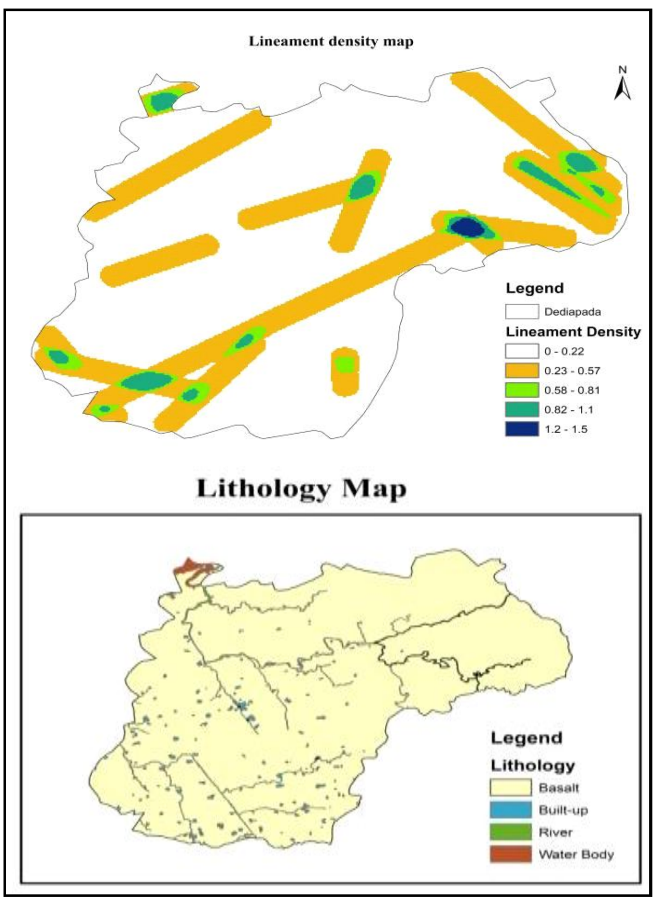

Fig. 8: Lineament map and Lithology map of Dediapada block.

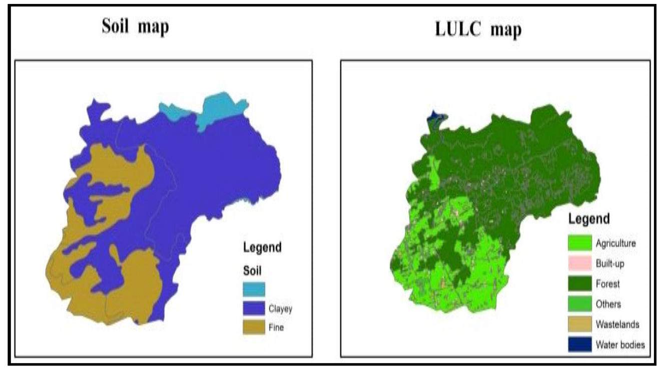

Fig. 9: Soil map and LULC map of Dediapada block.

is as shown in Fig. 7. Many of these features are favorable for the occurrence of groundwater and are classified in terms of groundwater potentiality. Dissected plateau shows relatively more weathered material ranging from 4m to 12m. These are found almost major drainage basins. In the groundwater recharge context, these portions are found moderate to good depending upon the thickness of the weathered zone.

Lineament density map: Lineaments are the linear features of tectonic origin that are long, narrow and relatively straight alignments. A lineament may represent a surface manifestation of structurally controlled features such as faults and/or joints (Jayswal *et al*., 2021, Jayswal *et al.*, 2023). A high lineament density is indicative of areas of outcropping bedrock and thin regolith whereas low lineament density implies buried bedrock and thick regolith. In hard rock terrains, Lineaments are represented by areas and zones of faulting and curvilinear features that are significant for groundwater, mineral and

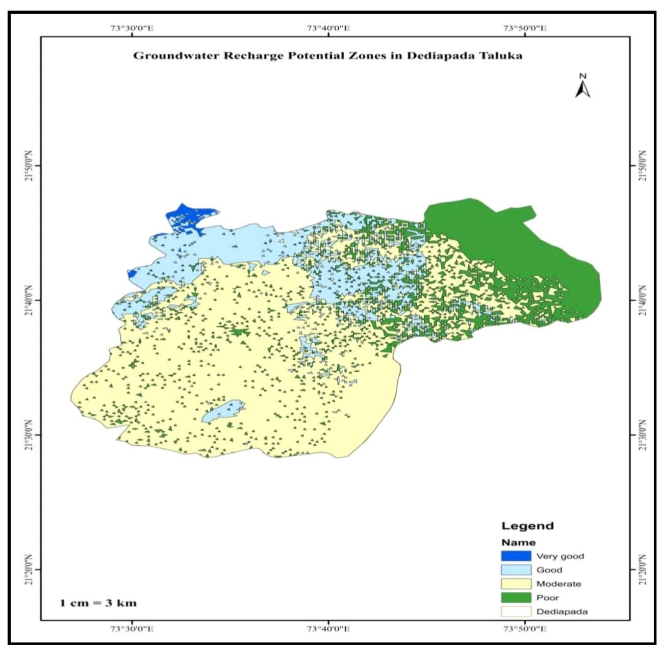

Fig. 10: Groundwater recharge potential map of Dediapada block.

metal explorations and explorations. The lineament map of the Dediapada block is as shown in Fig. 8.

Lithology map: Groundwater recharge is influenced by the types of lithological settings and compositions found on the surface (outcrops) by limiting the amount of water penetrating and determining the recharge zones (Souissi *et al.,* 2018, Vasileva, 2019). As shown in Fig. 8, The study area is predominant rocks are basalt with clay and fine textured soils.

Soil map: Soil texture and soil depth is most important factor to determine the capacity of area to infiltrate. As shown in Fig. 9, the soil map of the study area was prepared in the vector form representing structural class, soil depth, hydrological soil group etc. The parent material of the soil is Deccan trap. Clay and fine clay structure soil was observed in the Dediapada taluka.

LULC map: Land use land cover map tells the information about soil moisture, infiltration capacity, groundwater and surface water resources. The land use land cover map was prepared from the Sentinel 2 false color composite (FCC) as shown in Fig. 9. There were five classes, *i.e.*, Agricultural land, forest land, waste land, urban area and water bodies prepared using supervised classification in the ERDAS imagine software. In the Dediapada taluka, major area falls under the Forest land followed by Agricultural land, waste land, urban land and water body.

Based on the weighted overlay technique in ArcGIS environment, the thematic maps were integrated with one another as per their importance. The groundwater recharge potential for the Dediapada block is classified into (1) Very good, (2) Good (3) Moderate and (4) poor. Out of total land of Dediapada block, 912.03 ha.(0.90 %) area having very good groundwater recharges potentials followed by 17945.06 ha. (17.50 %) having good, 61777.91 ha. (60.10 %) having moderate and 22107.33 (21.50 %) having poor groundwater recharges potentials.

Conclusion

In the Dediapada block, out of total geographical area, 0.90 % area having very good groundwater recharges potentials followed by 17.50 % area having well, 60.10 % area having moderate and 21.50 % area having poor groundwater recharges potentials. Soil conservation and water harvesting structures are needs to be established to regenerate and restore the vegetative layer/forest cover of the Dediapada block, which can protect the land against soil erosion and further land degradation.

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