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Research Article

IDENTIFICATION OF GROUNDWATER RECHARGEABLE ZONE IN UPPAR ODAI (SOUTH) – AMARAVATHI BASIN USING RS AND GIS

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Abstract- Identifying groundwater rechargeable zone is important for watershed development and resource management of a region. In this work various features such as geology, lineament density, slope, drainage density, soil, land use/cover and rainfall distribution of Uppar Odai (South), Amaravathy basin was studied in order to identify the areas that are expected to be suitable for future groundwater exploration in the study region. An integrated analysis of various parameters provides better estimate of subsurface characteristics from groundwater perspective. On the basis of different weights assigned to each factor, it was found that about 16%, of the total area has good prospects of groundwater, whereas approximately 23%of the area relatively feeble prospects. Results are useful for identify the suitable locations and to recommend suitable area for construction of water harvesting structures to augment the groundwater recharge.

Key words- Aquifer, Recharge, Infiltration, Geomorphology, Drainage density, Lineament. Permeability, Porosity.

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Introduction

Groundwater is ultimate and most suitable freshwater resource for human consumption in both urban as well as rural areas. The importance of groundwater for existence of human society cannot be overemphasized. Amongst the natural resources groundwater forms an invisible component of the system and it is most essential prerequisite for increasing crop production as well as sustainable agriculture development. About 85 percent of India's rural domestic water requirements, 50 percent of its urban water requirements and more than 50 percent of its irrigation requirements are being met from groundwater resources. Ground water is annually replenishable resource but its availability is spatially and temporally varied. According to the Centre Groundwater Board, the dynamic fresh groundwater resources of India have been estimated at 432 km^2/year of which396 $km^2$is estimated to be utilizable [1]. Add references serially as [1] The total catchment area of all river basins in India is more than 25 lakh km^2.Ganga, Brahmaputra and Meghna are some of the largest rivers covering more than 43% of the catchment area of all major river systems [2]. The Amaravathy river system with its total length of 282 km and irrigates over 240 $km^2$of agricultural lands Add references serially as [2]. GIS and Remote sensing techniques are very popular techniques and widely used for various purposes such as hydrological study[3], locating the water harvesting structures [4]and seismic hazard assessment[5].It allows relatively faster assessment of groundwater condition at region scale. The identified zones of groundwater potential by this method may be helpful to enhance the subsurface information obtained from geophysical investigations [6]. This study presents an integrated analysis of a number of parameters such as geology, lineament density, slope, drainage density, soil, landuse/cover, rainfall and stream distribution which influence the subsurface groundwater availability and a detailed study for identifying the rechargeable zone in Uppar Odai (South), Amaravathy Basin. The detailed methodology is described in the following sections.

Materials and Methods

The study area of Upparodai (4B2A7a2) falls under the catchment area of the Amaravathi river basin. It is located 10⁰40' 30"N to 10⁰ 45' 30"N latitude and 77⁰ 15' 00"E to 77⁰ 30' 00"E longitude. The topography of the regions indicates the highest elevation (~287 m) in the south western part and an average elevation of ~179 m in the north. Agriculture crop is the dominant land use type and occupies about 37% of the area. With an average annual rainfall of about 670 mm occurring mostly during monsoon, the region has a well-developed drainage pattern. Add references serially as [3] (study area detail) The methodology adopted for the present study is shown in [Fig-1]. The scanned toposheet 58 F/6 at 1:50000 scale and the watershed map obtained from Agricultural Engineering Department (AED), Dharapuram covering the study area was used for base map preparation [Fig-2]. The drainage network for the study area was extracted from ASTER Global Digital Elevation Map (ASTER GDEM) and digitized in ArcGIS 9.3 platform. The slope mapwas also prepared from ASTER data using the Spatial Analysis tool. The rainfall map was prepared using the data obtained from the AED gauge stations. These data were then spatially interpolated using Inverse Distance Weighted (IDW) method to obtain the rainfall distribution map. This interpolation method combines the concepts of proximity to follow Thiessen polygons with gradual change of the trend surface [7].The lineament detail has brought from AED, Chennai. The lineament density and drainage density maps were prepared using the line density analysis tool. Satellite images from IRS LISS III PAN sharpened satellite data, on a scale of1:50,000 (geo-coded, with UTM projection, spheroid and datum WGS 84, Zone 44 North) have been used for delineation of thematic layers such as land-use, geology, lineament, and soil types. The generated thematic layers were converted into raster format with 30 m resolution before they were brought into the weighted overlay analysis. The groundwater rechargeable areas were obtained by integrating all the thematic maps in terms of weighted overlay methods using the spatial analysis tool.

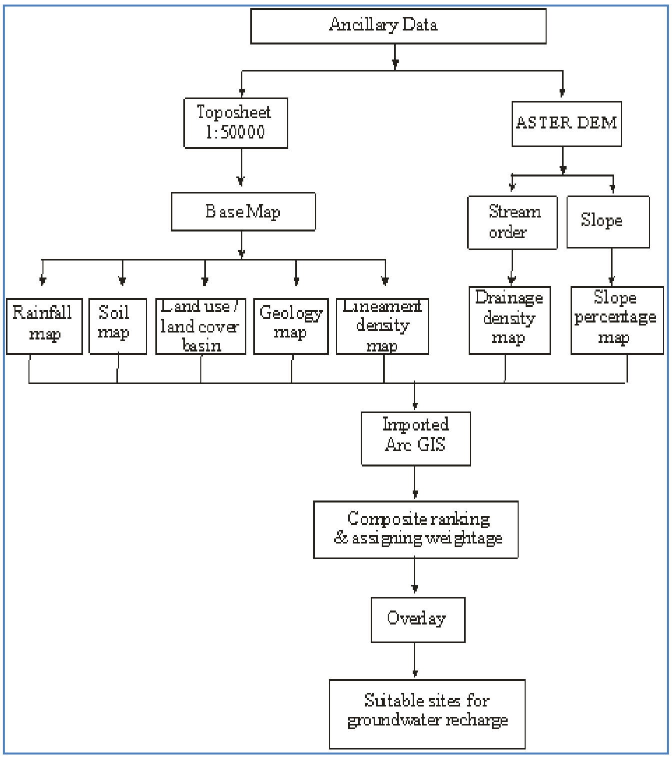

Fig-1 Flowchart for delineating the suitable recharge zones

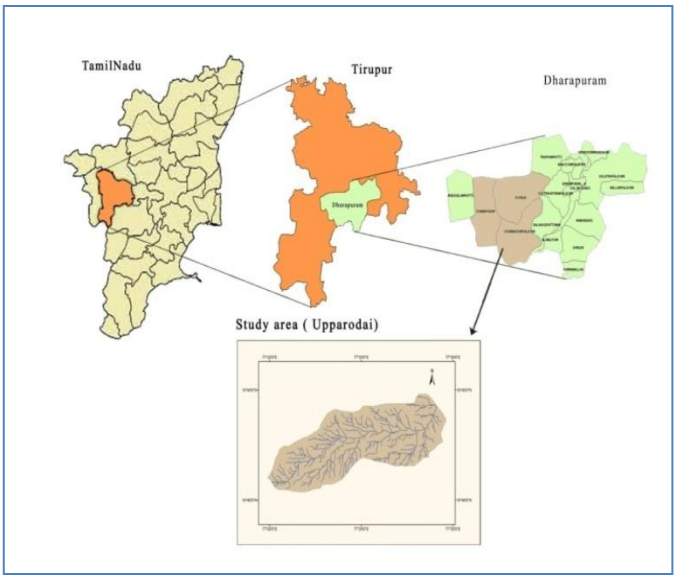

Fig-2 Location Map of Upparodai (South)

Depending on the perceived importance of their role in occurrence and movement of water resources, weightage has been assigned for individual factors. Each factor of individual units is assigned knowledge based hierarchy of ranking from 1 to 9 on the basis of recharging capacity. The final scores of each unit of factor are equal to the product of the rank and weightage. Ranking is done according to the required criteria on priority basis. First rank was given to criteria which were suitable to the location of recharge structures and last rank was given to criteria which were least suitable for recharge structures. The rank of each unit in each factor and their corresponding weighted scores are given in [Table-1].

Table-1 *Classification of weighted factors influencing the potential zones*

S.No.	Factor	Domain of effect	Rank	Weightages
1	Soil	Clay	1	15
		Clayey loam	3	
		Sandy clay	5	
		Sandy clay loam	7	
		Sandy loam	9	
2	Land-use/ cover	Settlements	3	10
		Grass land, waste land, fallow land	5	
		Water bodies	6	
		Plantation	7	
		Crop land	9	
3	Geology	Charnockites	3	20
		Garnet gneiss	5	
		Hornblende gneiss	7	
		Silt and sand	9	
4	Lineament density	0 - 0.5	1	20
		0.5 – 1	3	
		1 – 1.5	6	
		1.5 – 2	9	
5	Drainage density	0 – 2	1	15
		2 – 4	3	
		4 – 6	5	
		6 – 8	7	
		8 – 10	9	
6	Slope	0 – 1	9	10
		1 – 3	8	
		3 – 8	5	
		8 – 15	3	
		15 – 25	1	
7	Rainfall	650 – 850	5	10
		850 – 1050	7	
		1050 – 1250	9	

Determination of weightage of each factor as well as rank for each class is most crucial in integrated analysis, as the output is largely dependent on the assignment of appropriate weightage. Consideration of relative importance leads to a better representation of the actual ground situation. In the present study, each relationship is weighted according to its strength. A factor with a higher weight value shows a larger impact and a factor with a lower weight value shows a smaller impact on groundwater potential zones. Integration of these factors with their potential weights was computed through weighted overlay analysis in ArcGIS.

Results and Discussion

Geology

The study area is underlain by crystalline rocks of Archean age, which are overlain by minor alluvium of recent age along the drainage courses. Alluvium – Fluvial sediments (14%) are spread almost central and south west part of the study area [Fig-3] which is more suited in governing recharge. Around 81% of the total area is covered with Hornblende biotite gneiss followed by migmatite complex rocks of Archean age.

Land-use

The major land-use types in the study area are settlements, grass land, waste land, fallow land, water bodies, plantation and crop land. These landuse classes are delineated from IRS LISS III PAN sharpened satellite data and intense field verification [Fig-4]. Agriculture crop is the dominant land use type and occupies about 37% of the area followed by semi grass land (36%), fallow lands (19%) and the remaining area (8%) was occupied by other classes.

Lineament density

Lineaments features express the surface topography of the underlying structural features represent the zones of faulting and fracturing resulting in increased secondary porosity and permeability. These factors are hydro-geologically very important as they provide the path ways for groundwater movement. Areas with high lineament density are good for groundwater potential zones [7]. The lineament density map shows [Fig-5] that very high density is observed in areas of Hornblende biotite gneiss (2 km/km^2), indicates the high degree of hydraulic interconnection between the above lithologic units as surface water circulates through these discontinuities. The low density of the fractures (0.5 km/km^2), indicate the low degree of hydraulic interconnection. Faults are favourable for some types of structures (Percolation pond) and Unfavourable for others (Farm ponds). Thus, the zones of high lineament density are considered as feasible recharge zones for groundwater potential delineation.

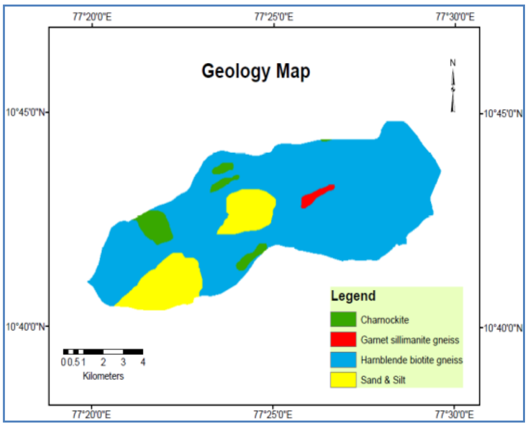

Fig-3 Geology Map of UpparOdai (South)

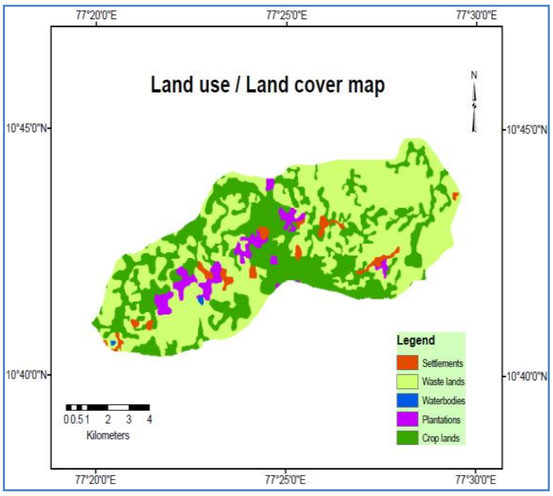

Fig-4 Landuse/landcover Map of UpparOdai (South)

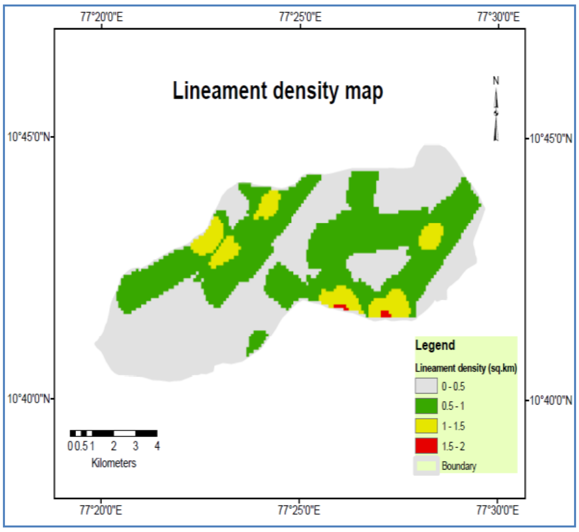

Fig-5 Lineament density Map of UpparOdai (South)

Drainage density

Drainage density is defined as the closeness of spacing of stream channels. It is a measure of the total length of the stream segment of all orders per unit area. The drainage density is an inverse function of permeability. The less permeable rock has less infiltration of rainfall, which conversely tends to be concentrated in surface runoff [7]. The stream order map was prepared [Fig-6] for generate drainage density map using the line density analysis tool. The generated drainage density map [Fig-7] was grouped into five classes' *viz.,* 'very good' (8 – 10 km/km^2), 'good' (6 – 8 km/km^2), 'moderate' (4 – 6 km/km^2), 'poor' (2 – 4 km/km^2) and 'very poor' (0 – 2 km/km^2). The maximum drainage density obtained is 9.51 km/km^2. The suitability of groundwater zones is indirectly related to drainage density because of its relation with the surface runoff and permeability.

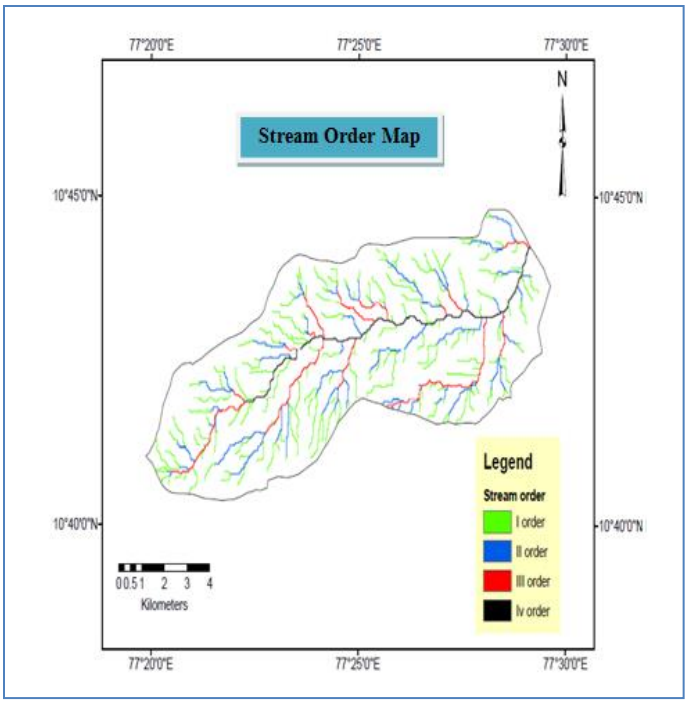

Fig-6 Stream order Map of UpparOdai (South)

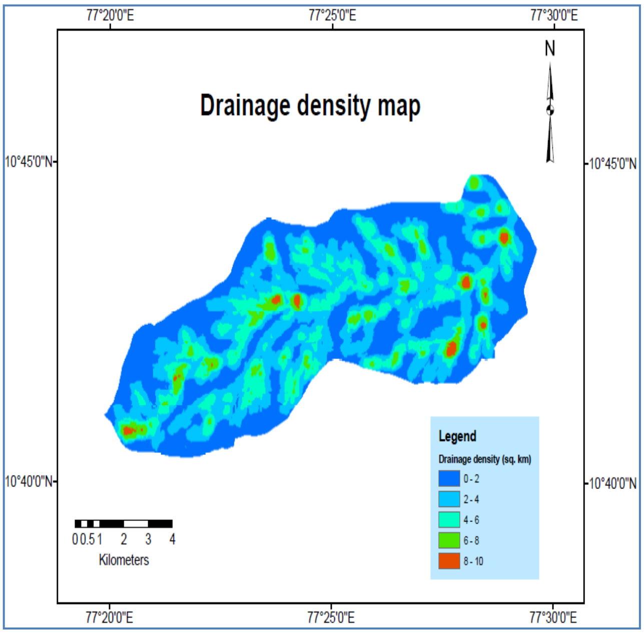

Fig-7 Drainage density Map of UpparOdai (South)

Slope

Slope is an important factor for the identification of groundwater potential zones. Higher degree of slope results in rapid runoff and increased erosion rate with feeble recharge potential [7]. The slope map of the study area was prepared from ASTER digital elevation data using the Spatial Analysis tool. The DEM has been used as an input, which internally computes the slope of each pixel and generated the slope map in percentage. Based on the slope, the study area can be divided into five slope classes. The areas having 0-1% slope fall into the 'very good' category because of the nearly flat terrain and relatively high infiltration rate. The areas with 1-3% slope is considered as 'good' for groundwater storage due to slightly undulating topography with some runoff. The area estimate 3–8 % fall into the moderate category and most of the area covered by undulating lands. The areas having a slope of 8-15% cause relatively high runoff and low infiltration, and hence are categorized as 'poor' and the areas having a slope 15– 25% are considered as 'very poor' due to higher slope and runoff [Fig-8].

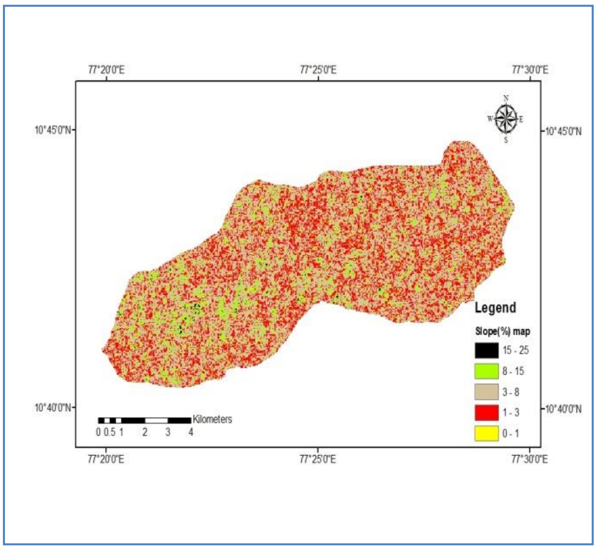

Fig-8 Slope Map of UpparOdai (South)

Soil

Soil is an important factor for delineating the groundwater potential zones. There were five types of soil texture [Fig-9] was observed, and grouped into five classes based on infiltration capacity *viz.,* 'very good' (Sandy loam), 'good' (Sandy clay loam), 'moderate' (Sandy clay), 'poor' (Clay loam), 'very poor' (Clay).The analysis of the soil type reveals that the study area is predominantly covered by clay loam soil texture followed by sandy clay loam and sandy clay (in the flood plains) at some places.

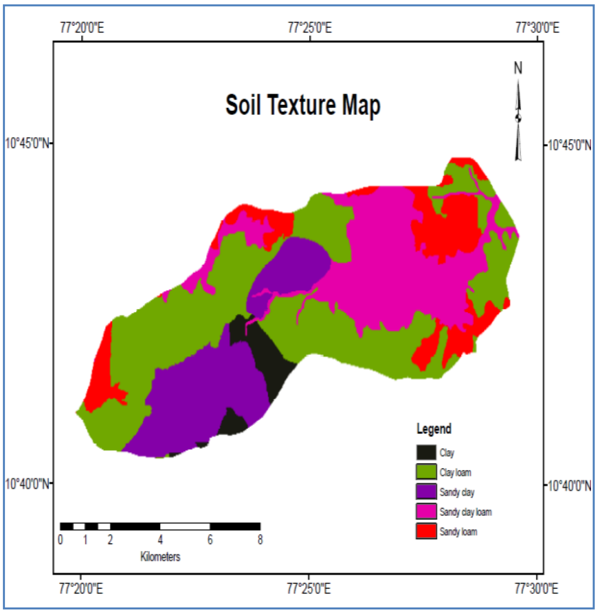

Fig-9 Soil Map of UpparOdai (South)

Rainfall

Using Thiessen polygon method, the three rain gauge stations were found nearby the study area namely Dharapuram, Udumalpet and Uppardam which has influence the area. Of these three stations, Uppar dam recorded the highest average annual rainfall of 691.5 mm followed by Udumalpet (675 mm) and Dharapuram (610.5 mm). The rainfall distribution map [Fig-10] shows that the mean annual rainfall is more in south west portion which indicates the more rainfall in the region wherein it decreases towards north east direction hence, more water will be available for surface runoff and infiltrations. These precipitation values were scored to reflect the influence of perception on groundwater.

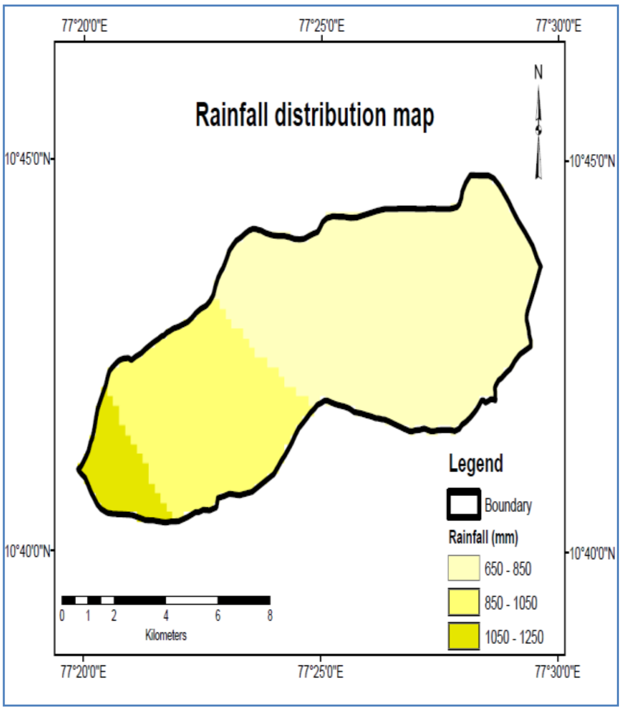

Fig-10 Rainfall Distribution Map of UpparOdai (South)

Delineating the groundwater potential zone

The groundwater rechargeable zones for the study area were generated through the integration of various thematic maps using weighted Index Overlay method. Total scores obtained by integration have been classified into five categories to facilitate the delineation of very good, good, moderate, poor, very poor ground water rechargeable zone. The overlaid map was used to find the most suitable rechargeable areas by considering the soil, land use/cover type, slope percentage, geology and lineament density, drainage density and rainfall.

The groundwater potential map [Fig-11] demonstrates that the excellent groundwater potential zone is concentrated in the South-eastern and centre region of the study area due to the distribution of alluvial plains and agricultural land with high infiltration ability. This indicates that, soil type and slope plays a vitalrole in groundwater augmentation. The concentration of drainage density and lineament density also helps the infiltration ability of the groundwater system [7] whereas the less concentration of lineament and drainage density yields the poor zones in the study area. Finally five different groundwater rechargeable zones were identified, namely 'very good', 'good' 'moderate', 'poor', 'very poor'. From the recharge zone map it was found that moderate zone had the maximum areal extent of 61.7 km^2, very good and good zone was estimated to be 15.7 % and 22.6 % for the poor and very poor zone. Finally, the cumulative effect of the weighted multi influencing factors through overlay analysis in GIS platform revealed the mapping of groundwater potential zones in the study area.

From the recharge zone map it was found that moderate zone had the maximum areal extent of 61.7 km^2. It implies that area having the moderate potential capacity for recharge the ground water. The least area of 0.62 km^2 and 1.1 km^2 was found for very poor and very good zones respectively. The result supports the hard rock aquifers are fairly heterogeneous as indicated by the variations in lithology, structure and texture within short distances. It was found that most of the data satisfy the final groundwater rechargeable map.

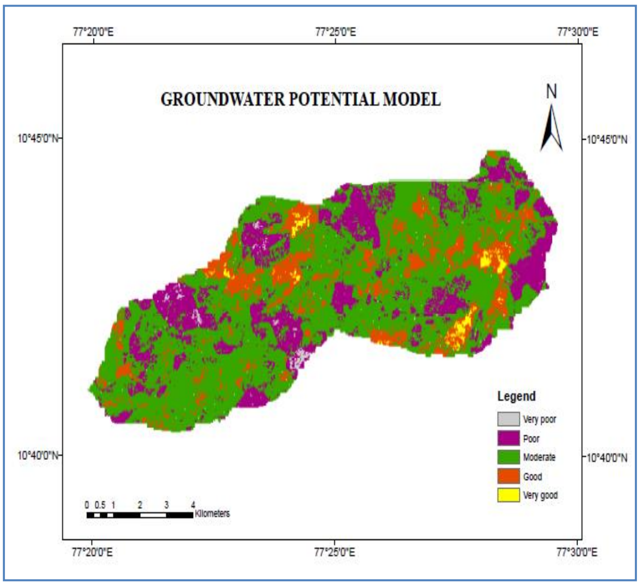

Fig-11 Recharge zonation map of UpparOdai (South)

Summery and Conclusion

The applied technique is widely used and well known. In this study some of the parameters such as geomorphology, bore well data that were not available for the region. However, this is an integrated study of all parameter could provide a high-resolution groundwater potential map.

Application of Research

The study area of upparodai (south) which comes under the water deficit zone. The good cultivable areas are being converted into waste and degraded lands due to over exploitation of land and water resources. Keeping this in view upparodai (south) is selected for groundwater augmentation and planning suitable sites for construction of water harvesting structures.

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Abbreviations

RS- Remote Sensing
GIS –Geographical Information System
ASTER - Advanced Spaceborne Thermal Emission and Reflection Radiometer
GDEM - Global Digital Elevation Model
AED- Agricultural Engineering Department

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

Conflict of Interest: None declared

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