IDENTIFICATION OF ARTIFICIAL RECHARGE SITES FOR NEYYAR RIVER BASIN

Suresh D 1, Colins Johnny .J 2, Jayaprasad B K 3
Regoinal centre of Anna University, Tirunelveli 1,2
National Centre for Earth Science Studies (NCESS) , Thiruvananthapuram 3

Abstract

Groundwater security is recognized as one of the major challenges for India's economic and social development. According to the report from the Central Ground Water Board (CGWB), India's groundwater tables are plunging at an alarming rate with reserves in some states dwindling to critical levels. Unregulated use of groundwater in southern peninsular India has also led to over extraction, resulting in threshold to be 'critical'. Over 30 million groundwater structures in play, India is hurtling towards a crisis of over-extraction which would result in 60% of all aquifers in a critical condition within 20 years. Various groundwater renewable methods must be adopted to overcome the issue. Artificial recharge is the process by which the groundwater is augmented at a rate much higher than those under natural condition of replenishment which could provide a solution. The present study is carried out for Neyyar river basin, Thiruvananthapuram district, Kerala. The methodology adopted for the investigation of artificial groundwater recharge sites is based on the integrated Remote Sensing and GIS. Thematic maps such as geology map, soil map, geomorphology map, Landuse/Landcover map, slope map, drainage density map, lineament density map, relative relief map and infiltration number map are prepared and weighted overlay analysis is performed to determine the sites suitable for artificial recharge.

Introduction

Water is one of the most precious natural resources. In many regions, the pressures of economic development are producing a surface-water scarcity. Groundwater is a dynamic and replenishable natural resource and it is the portion of the earth's water cycle that flows underground. It originates from precipitation that percolates into the ground soil and porous/fractured rock. India is the largest user of groundwater in the world. It uses an estimated 230 cubic kilometers of groundwater per year - over a quarter of the global total. More than 60% of irrigated agriculture and 85% of drinking water supplies are dependent on groundwater. The groundwater scenario in India receives a substantial amount of annual rainfall and is not very encouraging primarily due to the imbalance between recharge and groundwater exploitation. A large amount of rain water is lost through run off, a problem compounded by the lack of rain water harvesting practices. Exploitation of subsurface water from deep aquifers, also replenish resources that have taken decades or centuries to accumulate and on which the current annual rainfall has no immediate effect. Few sustained efforts have been made for identification of zones where artificial-recharge techniques can be implemented to conserve groundwater. There is an urgent need for artificial recharge of groundwater by augmenting the natural infiltration of precipitation into subsurface. For the past four decades, artificial groundwater recharge in India has been of great importance. In recent years, the role of Remote Sensing and GIS techniques has received much attention with regard to artificial recharge. Many scientists have suggested suitable sites for artificial recharge to groundwater on the basis of geological and geomorphological data, with less emphasis given to subsurface geological and hydrogeological data.

Jyoti sarup et al. (2011) developed methodology based on integrated remote sensing and GIS for the evaluation of groundwater resources for Kalwan taluka of northern part of Nasik district. Weighted index overlay method has been followed to delineate groundwater prospective zones and a combination of weighted index overlay and Boolean logic method has been used for the selection of artificial recharge sites. Amartya Kumar Bhattacharya (2010) explained the need for artificial recharge of groundwater for augmenting the natural infiltration of precipitation or surface-water into underground formations. The data for the project has been collected from National Centre for Earth Science Studies (NCESS), Thiruvananthapuram. NCESS is a central Government premier institute in India that has strong linkages to researches and studies related to the Earth System. . Various layars are prepared and weighted overlay analysis is performed to determine the sites suitable for artificial recharge.

Study Area Description

The Neyyar river is a river of south-western India in the western ghats as shown in figure 1. It originates from the Agastya mala hills in of Thiruvananthapuram District of Kerala state at an elevation of about 1866m above mean sea level. The river passes through Neyyattinkara taluk into the Lakshadweep sea near Poovar. It has a total length of 56 km and catchment area of 497km^2. Tributaries include the Kallar (river), Mullayar river, and the Karavaliyar river.

The Neyyar river basin lies between 8º 15´ - 8º 40´ north latitudes and 77º 0´ - 77º 20´ east longitudes.

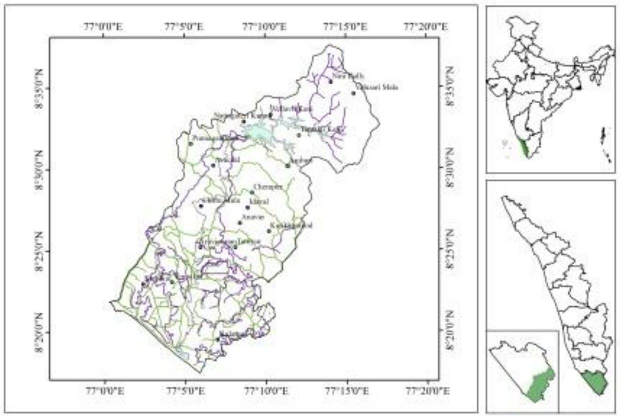

Figure 1. Study Area

Methodology

The Methodology applied for identification of artificial recharge site using Integrated Approach of RS and GIS is described in figure 2.

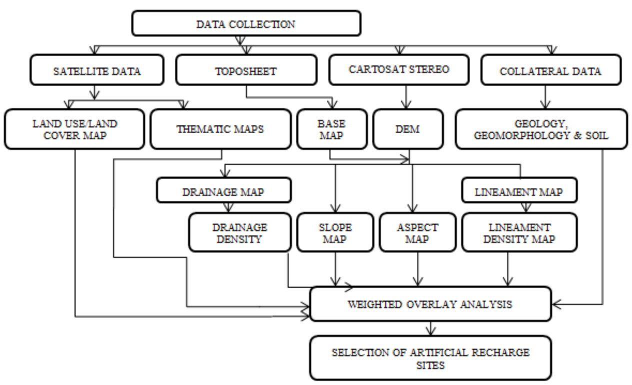

Figure 2. Flow chat showing the methodology

The Toposheets for the study area was georeferenced and projected to WGS 84 zone 43N for the preparation of base map. Various thematic maps such as geology map and soil map are collected from NCESS, Trivandrum and geomorphology map, landuse/landcover map are prepared from LISS III image. Drainage network for the study area was extracted from toposheets of 1:25,000 Scale. DEM was prepared from cartosat stereopair at 2.5m resolution. slope map, aspect map, relative relief map are prepared from DEM. Hillshade was prepared from DEM at various azimuth angle (0^o to 315^o) and illumination angle of 15^o and 34^o, from which lineament map was prepared. Lineament density and drainage density was prepared by using kernel density for the obtained lineament and drainage network. Weighted overlay analysis was performed using various thematic maps for the identification of suitable site for artificial recharge.

Results and Discussion

Base Map Preparation

The Survey of India toposheets (scale 1:25,000) were scanned and converted into TIFF (.tiff) format. The raster map was opened in ArcGIS environment for geo-referencing. The latitude, longitude points were given at the corners of the topo maps to convert from computer co-ordinate system to real world co-ordinate system and projected to WGS 84 Zone 43 N. Various toposheets was mosaiced into a single image for the preparation of base map. The raster image was digitized to generate different vector coverage's such as study area boundary, drainage network, road/railway networks, water bodies, settlement etc. as shown in figure 3.

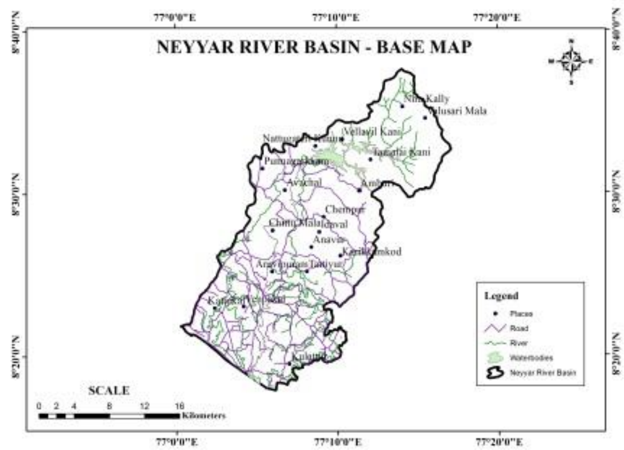

Figure 3. Base map

Preparation of Digital Elevation Model

In Erdas Imagine 2015, Imagine Photogrammetry suite (formerly Leica Photogrammetry Suite) was used for the preparation of DEM from Stereopair. The bands (Band A and Band F) are loaded in Photogrammetry suite and automatic common tie points are generated. Triangulation process was carried out, the RMS value was checked for least error and DEM was generated at 2.5m resolution as shown in figure 4.

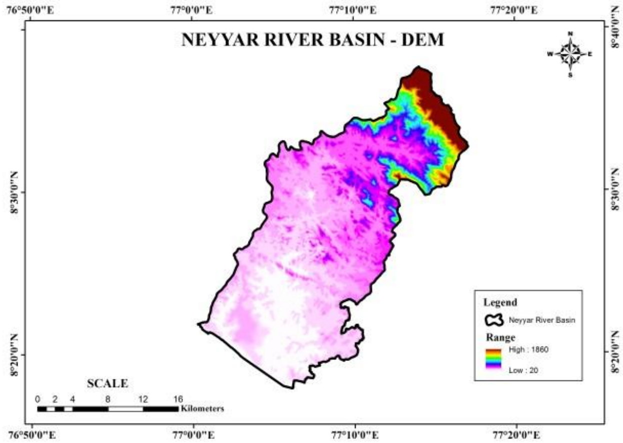

Figure 4. DEM

Preparation of Slope Map and Aspect Map

Slope map was prepared for each pixel/cell through raster surface 'slope' option in 3D Analyst toolbox in Arc GIS software. The DEM was used as input parameter for the generation of slope map as shown in figure 5. Aspect map was prepared for the study area by using slope as shown in figure 6. It was prepared for each pixel/cell through raster surface 'Aspect' option in 3D Analyst toolbox in Arc GIS software.

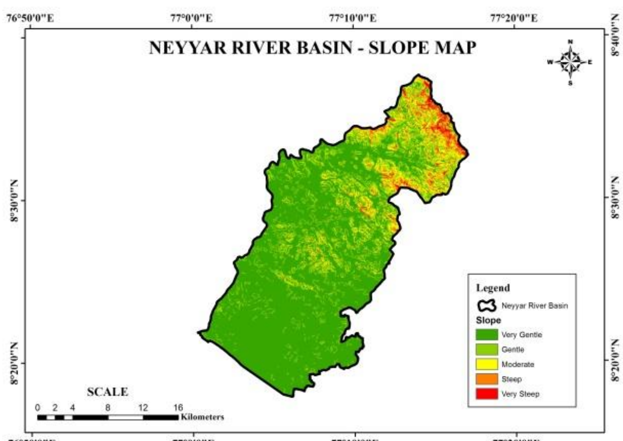

Figure 5. Slope map

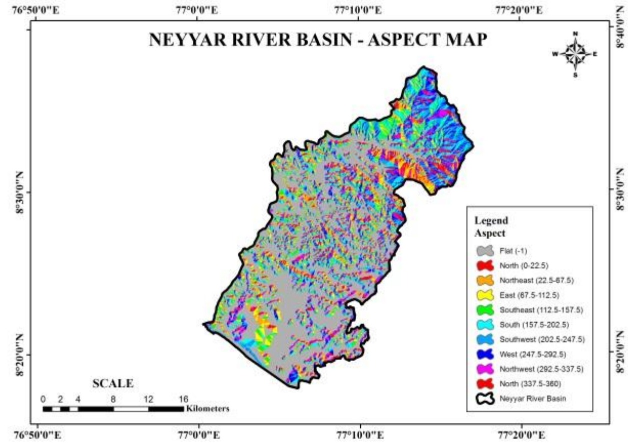

Figure 6. Aspect map

Preparation of Geology, Geomorphology and Soil Layer

Geology, geomorphology and soil layer were collected from National Centre for Earth Science Studies, Thiruvananthapuram and georeferenced in ArcGIS environment. Vector layer was created and digitized from the scanned map. Thus the geology, geomorphology and soil map was generated for the given study area as shown in figure 7, figure 8 and figure 9.

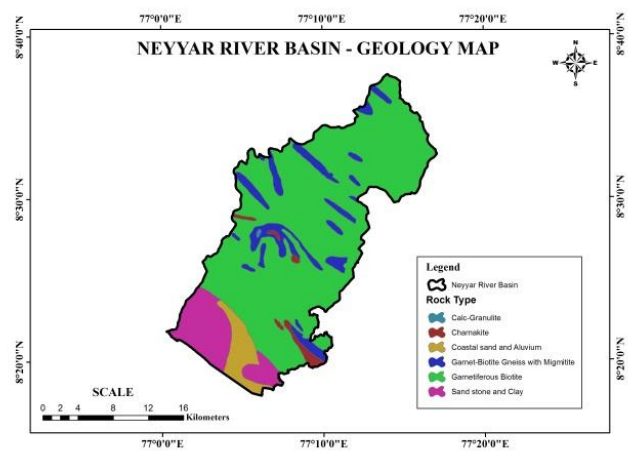

Figure 7. Geologymap

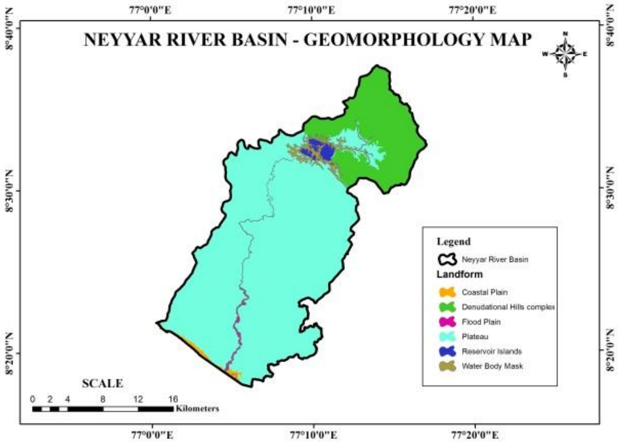

Figure 8. Geomorphology map

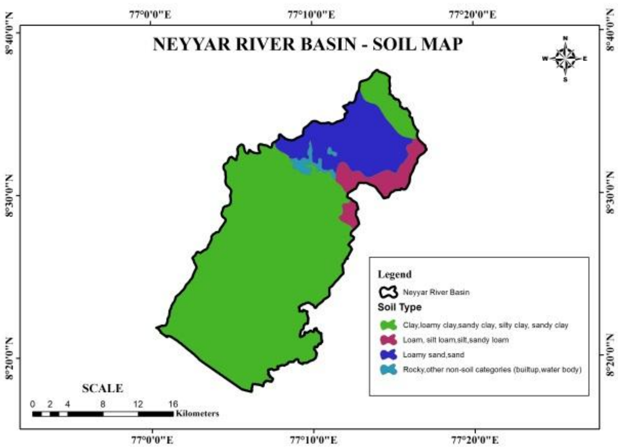

Figure 9. Soil map

Preparation of Relative Relief Map

Relative relief map was prepared by calculating the lowest and highest values of each cell in the given study area. It is found by using the focal statistics of neighborhood toolset in Spatial Analyst toolbox. The minimum DEM and maximum DEM were calculated and the difference between them was calculated by using raster calculator. The resultant map obtained was the relative relief map which was shown in figure 10.

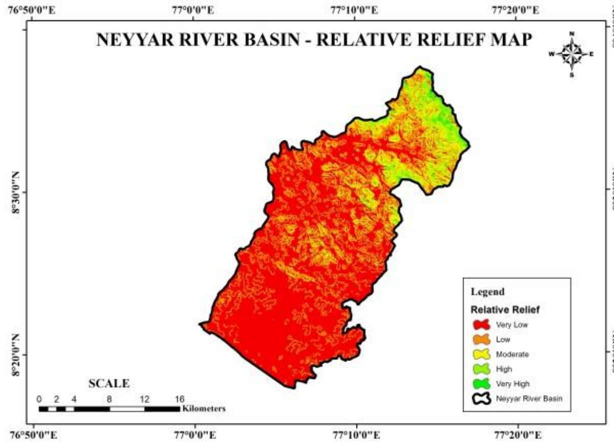

Figure 10. Relative Relief map

Preparation of Lineament Map and Lineament Density Map

For the preparation of lineament map, hillshade was prepared at various azimuth angles (0^o, 45^o, $90\ ^o$, $135\ ^o$, $180\ ^o$, $225\ ^o$, $270\ ^o$, $315\ ^o$) and illumination angle ($15\ ^o$ and $34\ ^o$). Using the 16 hillshade prepared, the lineament map was prepared from the study area as shown in figure 11. For the lineament obtained the length was calculated and using which the lineament density map was prepared by using kernel density of Spatial Analyst toolbox. Lineament is provided as input along with population field as length. The output Lineament density is shown in figure 12.

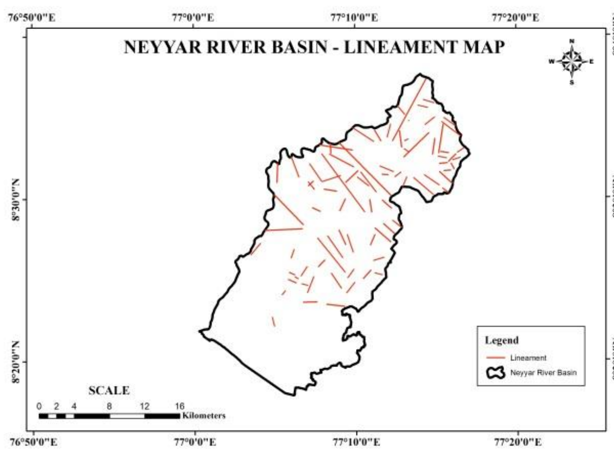

Figure 11. Lineament map

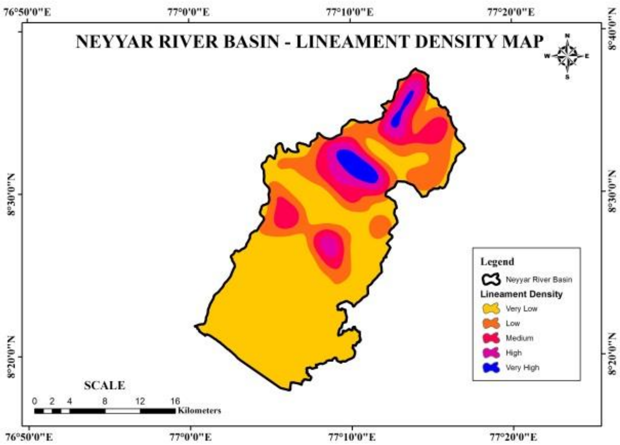

Figure 12. Lineament density map

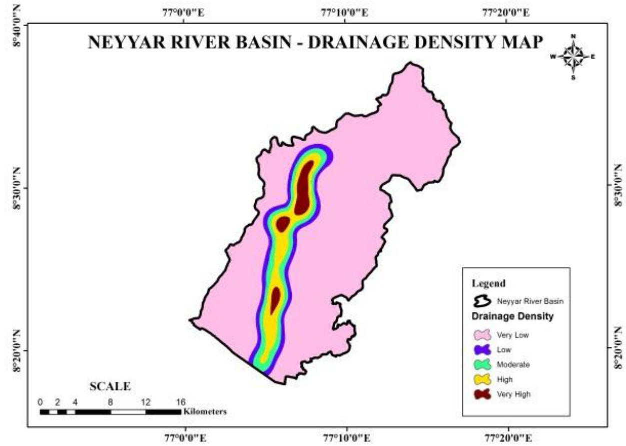

Figure 14. Drainage density map

Preparation of Drainage Map and Drainage Density Map

The drainage network for the study area was extracted from toposheets and the streams were ordered by hierarchical rank with reference to Strahler (1964) shown in figure 13. For the streams digitized the length were calculated and the drainage density was obtained by using kernel density with drainage network as input along with population field as length. The output drainage density is shown in figure 14.

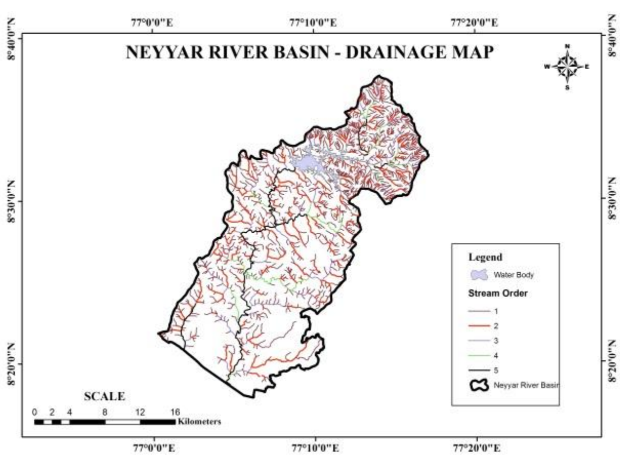

Figure 13. Drainage map

Preparation of Landuse/Landcover Map

Landuse map was prepared from IRS P6 Linear Imaging Self Scanning Sensor (LISS-III). LISS III is a multi-spectral camera operating in four spectral bands, three in the visible and near infrared and one in the SWIR region. The image was opened in GIS environment. The study area was clipped from satellite image with the help of boundary layer. ArcGIS software cut polygon feature was used for digitizing various land use features from satellite image as shown in figure 15.

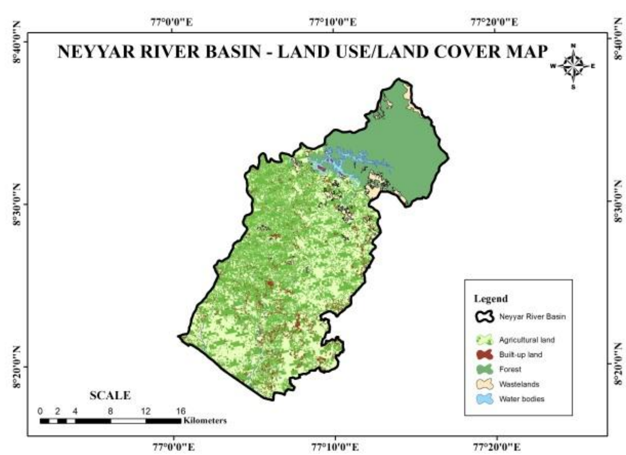

Figure 15. Landuse/Landcover map

Drainage Density (D_d)

Drainage density (D_d) [Horton (1945)] for the basin is defined as the total stream length per unit drainage area as shown in table 1. It depends on climate (mainly rainfall), geology, vegetation cover, erosability, infiltration capacity and permeability of the basin. As the drainage density increases the infiltration decreases and for decrease drainage density the infiltration increases.

Stream Frequency (F_S)

Stream frequency for the basin [Horton (1932)] is defined as the total number of stream segments of all order per unit area as shown in table 1. Low value of stream frequency indicates low runoff and higher value indicates higher runoff.

Infiltration Number (I_g)

Infiltration number [Faniran (1968)] is defined as the product of drainage density and stream frequency of the corresponding watershed as shown in table 1. Infiltration number is directly proportional to runoff. As the Infiltration number of the basin remains high, the runoff remains high for the corresponding basin and for low infiltration number the run off is low. Runoff is indirectly proportional to infiltration which can be used to identify the places of high infiltration. A runoff characteristics was determined from the infiltration number map for the Neyyar river basin.

Table 1. Formula for Drainage Density, Stream Frequency and Infiltration Number

Drainage Density (D_d) (km/km^2)	$D_d = \frac{L}{A}$ Where, D_d =Drainage density L =Total stream length of all order A =Area of the basin
Stream Frequency (Fs) (km^{-2})	$F_s = \frac{N_u}{A}$ Where, F_s= Stream Frequency N_u =Total number of stream segment of order 'u' A=Area of the Basin (km^2)
Infiltration Number(I_g)	$I_g = D_d * F_s$ D_d = Drainage density F_s= Stream Frequency

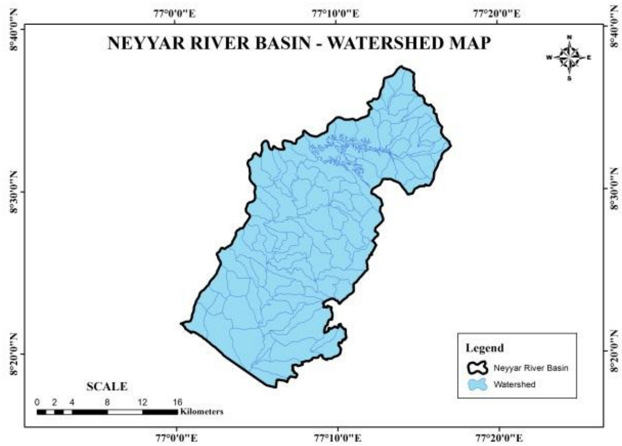

Figure 16. Micro level Watershed map

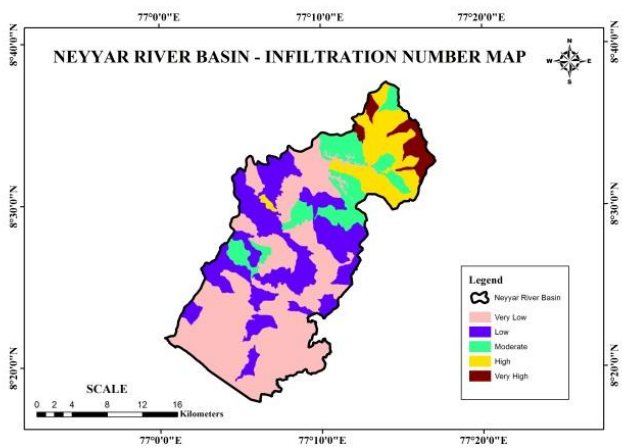

Figure 17. Infiltration Number map

Weighted Overlay Analysis

For the identification of artificial groundwater recharge zone, various thematic maps obtained were overlayed using weighted overlay analysis. Various layers obtained were converted to raster layer and reclassified to perform weighted overlay analysis. Weight and rank for various thematic layers were assigned and overlay analysis was performed.

The result obtained from the weighted overlay analysis shows the region that is well suited for artificial groundwater recharge. From the analysis performed for the Neyyar river basin it is found that the suitable site for artificial groundwater recharge is the site where the Neyyar dam is located. Neyyar dam is a gravity dam located in Thiruvananthapuram district. The Neyyar dam is a rubble masonry gravity-type dam with a height of 56 m and length of 295 m with structural volume is 105,000 m^3.

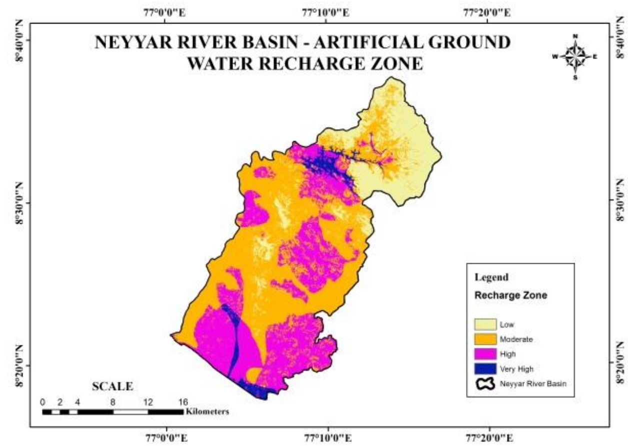

Figure 18. Map showing suitable sites for artificial recharge

Conclusion

Due to rapid urbanization and high density of population in the basin, demand for water consumption has increased at an unprecedented rate. Remote sensing and GIS have demonstrated their capability in conservation of water in Neyyar river basin. This integrated approach proved to be useful for selecting suitable sites of groundwater for deficit areas which requires immediate measures. The study showed that GIS techniques have efficient tools in delineation of the drainage pattern in understanding various terrain parameters such as nature of bedrock, infiltration capacity, surface run off etc., which helps in better understanding the land form and their characteristics. It also helps in identification of groundwater recharge site for the watershed and for future planning and management of the basin. This work can be useful for natural resources management at micro level of any terrain for sustainable development by planners and decision makers.

Acknowledgments

The authors are thankful to IJRSG Journal for the support to develop this document.

References

[1] Anupriya Gupta, Anil Kumar Misra, Nikita Gupta, Ankur Shivhare, Manav Wadhwa, 2013. Morphometric and Hydrological Analysis of North East Punjab Region: With Special Reference to Groundwater Management, Vol. 3, Issue 4, pp. 1-3.

[2] Amartya Kumar Bhattacharya 2010. Artificial ground water recharge with a special reference to India, IJRRAS Vol 4, Issue 2.

[3] Bharadwaj A K , Pradeep C, Thirumalaivasan D, Shankar C P, Madhavan N , 2013. Morphometric Analysis Of Adyar Watershed, IOSR Journal of Mechanical and Civil Engineering, pp. 71-77.

[4] Dr. Jyoti sarup, Manish K. Tiwari and Vardichand Khatediya, 2011. Delineate Groundwater Prospect Zones and identification of Artificial Recharge Sites using Geospatial Technique , International Journal of Advance Technology & Engineering Research (IJATER), Vol. 1,Issue 1.

[5] John Wilson J S, Chandrasekar N and Magesh N S, 2012. Morphometric Analysis of major sub-watersheds in Aiyar & Karai Pottanar Basin, Central Tamil Nadu, India using Remote Sensing & GIS Techniques, Bonfring International Journal of Industrial Engineering and Management Science, vol. 2, Special Issue 1, pp. 8-15.

[6] Kartic Bera and Jatisankar Bandyopadhyay, 2013. Prioritization of watershed using Morphometric Analysis through geoinformatics technology: A case study of Dungra sub-watershed, WestBengal, India, Int. Journal of Advances in Remote Sensing and GIS, Vol. 2, No. 1.

[7] Manju E K and George A V, 2014. A comparative study of the Morphometric Analysis of High land sub-watersheds of Meenachil and Pamba Rivers of Kerala, Western Ghats, South India, International Journal of Innovation and Scientific Research, Vol. 11 No. 2, pp. 527-532.

[8] My Hachem Aouragh and Ali Essahlaoui, 2014. Morphometric Analysis of a Guigou sub-watershed, Sebou basin, Middle Atlas, Morocco using GIS based ASTER (DEM)image, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 4, pp. 11503-11512.

[9] Paul M Jai and Inayathulla M, 2012. Morphometric Analysis and Prioritization of Hebbal Valley in Bangalore, IOSR Journal of Mechanical and Civil Engineering, Volume 2, Issue 6, PP 31-37.

[10] Rekha V B, George A V and Rita M, 2011. Environmental Research, Engineering and Management, No. 3(57), pp. 6 – 14.

[11] Sandeep Kr Soni, Shashikant Tripathi, Abhishek Kr Maurya, 2013. GIS based Morphometric Characterization Of Mini Watershed - Rachhar Nala of Anuppur District Madhya Pradesh, International Journal of Advanced Technology & Engineering Research, Volume 3, Issue 3, pp. 32-38.

[12] Swati Uniyal and Peeyush Gupta, 2013. Prioritization based on Morphometric Analysis of Bhilangana watershed using spatial technology, International Journal of Remote Sensing & Geoscience, vol. 2, pp. 49-52.

[13] Umamathi S and Aruchamy S, 2014. Morphometric Analysis Of Suruli Ar Watershed, Theni District,

Tamil Nadu, India: A GIS Approach, Ind. J. Sci. Res. and Tech, 2(1):35-45.
[14] Vandana M, 2013. Morphometric Analysis and Watershed Prioritisation: A case study of Kabani river basin, Wayanad District, Kerala, India, Indian Journal of Geo-Marine Sciences, vol.42(2), pp. 211-222.
[15] Vishal T. Chavhan and Pankaj S. Gadge, 2013. Morphometric Analysis of Januna mini watershed Nandgoan (kh.), dist. Amravati, Maharashtra using GIS, International Journal of Science, Environment and Technology, Vol. 2, No 5, pp. 1072-1079.
[16] Waikar M L and Aditya P. Nilawar, 2014. Morphometric Analysis of a Drainage Basin Using Geographical Information System: A Case study, International Journal of Multidisciplinary and Current Research, Vol. 2, pp. 179-184.
[17] Arun K., Saraf, Kundu P and Sarma B. (1998) 'Integrated Remote Sensing and GIS in Groundwater Recharge Investigation and Selection of Artificial Recharge Sites in a Hard rock terrain', Tanzania Journal of Engineering and Technology, Vol.2.
[18] Kannan S P.V. and Mathew E.K. (2008) 'GIS and Remote Sensing for Artificial Recharge Study in a Degraded Western Ghat terrain', M.E Thesis, Kelappaji College of Agricultural Engineering and Technology, Tavanur, Malappuram, Kerala.
[19] Kumar A.S.R. and Saraf A.K. (2007) 'Delineation of Groundwater Recharge Sites using Integrated Remote SensIng and GIS in Jammu district, India', International Journal of Remote Sensing, Vol.28, No.22, pp.5019-5036.
[20] Kumar M.G., Agarwal A.K. and Rameshwar Bali (2008) 'Delineation of Potential Sites for Water Harvesting Structures using Remote Sensing and GIS', J. Indian Soc. Remote Sens., Vol.36, pp.323-334
[21] Pandey A. and Sahu A.K. (2002) 'Estimation of Runoff using Remote Sensing and Geographic Information Systems', presented and published in International Conference on Hydrology and Watershed Management, Jaipur, India, Vol.2, pp.503-509.
[22] Prasad R.K., Mondal N.C., Pallavi Banerjee, Nandakumar M.V. and Singh V.S. (2008) 'Deciphering Potential Groundwater Zone in Hard Rock through the Application of GIS', Environ. Geol., Vol.55, pp.467-475.
[23] Rao Toleti B.V.M., Chaudhary B.S., Mothi Kumar K.E., Saroha G.P., Manoj Yadav, Ajeet Singh, Sharma M.P., Pandey A.C. and Singh P.K. (2000) 'Integrated Ground Water Resources Mapping in Gurgaon District, (Haryana) India using Remote Sensing and GIS Techniques', Proceeding ACRS 2000.

Biographies

SURESH D received the Bachelor of Civil Engineering from Vel Tech (Afflicated to Anna University), Avadi, Chennai, Tamil Nadu in the year 2013. He is currently pursuing M.Tech in remote sensing at Regional Centre – Anna University, Tirunelveli. Phone: +91-8438246678, Author's contact e-mail: devaraj.suresh1991@gmail.com.

MR. J. COLINS JOHNNY is working as assistant professor in Regional centre of Anna University, Tirunelveli. Author's contact e-mail: colinsjohnny@gmail.com.

MR. B.K. JAYAPRASAD received B.A. in Geography from University of Kerala in the year 1979. He completed M.Sc in Cartography from University of Madras in 1989. Currently, he is working as Scientist E in Central Geomatics Lab of National Centre for Earth Science Studies, Thiruvananthapuram. Author's contact e-mail: jayaprasadbk@cess.res.in.