

Potential Zones of Peruvanthanam and Valiyathodu Sub-Watersheds of Manimala River Basin

¹Vadakepurakkal Rekha, ²Aikara Varkey George and ³Rita Mendez

¹School of Environmental Sciences,

Faculty of Environmental Sciences, Mahatma Gandhi University, Kottayam, Kerala, India

²Department of Environmental Science, Faculty of Environment,

Energy and Earth Sciences, Central University of Kerala, Kasargode, Kerala, India

³Department of Chemistry, Faculty of Chemistry, Government Engineering College, Thrissur, Kerala, India

Received 2012-10-23, Revised 2013-03-26; Accepted 2013-03-28

ABSTRACT

Groundwater is a dynamic and replenishable natural resource. But in hard rock terrains, its availability is of limited extent. In sub-watershed studies, remote sensing and GIS techniques have the advantages of spatial, spectral and temporal data, covering large and inaccessible areas within a short span of time. Thus this technique has become a very handy tool in assessing and monitoring groundwater resources. Multi Criteria Evaluation Technique (MCE) by integration of the thematic maps such as Geomorphology, Geology, Land use/Land cover and Slope prepared from conventional and remote sensing techniques using GIS yield more and near accurate result. The groundwater potential zones are classified in to five zones viz, 'excellent to very good', 'very good to good', 'good to moderate', 'moderate to poor' and 'poor to very poor'. Critical analysis and comparison of ground water potential zones of both sub-watersheds reveals that, 26.10 km² (47.58%) area of Valiyathodu sub-watershed fall under 'excellent to very good' category where as in Peruvanthanam sub-watershed it is 7.69 km² (13.64%). In Peruvanthanam sub-watershed, 'very good to good' category covers 14.87 km² (26.35%), 'good to moderate' covers 17.65 km² (31.28%), 'moderate to poor' covers 11.62 km² (20.59%) and 'poor to very poor' covers 4.59 km² (8.14%). Where as in Valiyathodu sub-watershed, 'very good to good' category covers an area of 18.55 km² (33.82%), 'good to moderate' covers 6.65 km² (12.12%) and 'moderate to poor' covers 2.43 km² (4.43%) and 'poor to very poor' covers 1.12 km² (2.05%). Hence it is explicit that, in general groundwater potential is better in Valiyathodu sub-watershed compared to Peruvanthanam sub-watershed.

Keywords: Groundwater, Potential Zones, Peruvanthanam Sub-Watershed, Valiyathodu Sub-Watershed, Manimala River Basin

1. INTRODUCTION

Groundwater is one of the most valuable natural resources, which supports human life, economic development and ecological diversity. Over exploitation and unabated pollution of this vital resource is threatening our ecosystems and even the life of future generations (Ravishankar and Mohan, 2006).

Exploitation and utilization of groundwater requires proper understanding of its origin, occurrence and movement, which are directly or indirectly controlled by terrain characteristics (Khan and Moharana, 2002). Groundwater occurrence in hard rock terrains are essentially confined to fractured and weathered horizons. Remote Sensing and Geographic Information System (GIS) is one of the leading tools in

Corresponding Author: Vadakepurakkal Rekha, School of Environmental Sciences, Faculty of Environmental Sciences, Gandhi University, Kottayam, Kerala, India

hydrogeological science for assessing and monitoring groundwater (Mayilvaganan *et al.*, 2011). The interpretation of satellite data in conjunction with sufficient real ground information makes it possible to identify and outline various ground features such as geological structures, geomorphic features and their hydraulic characters which may serve as direct or indirect indicators of the presence of groundwater (Das *et al.*, 1997; Rao *et al.*, 2000; Ravindran and Jeyaram, 1997; Devi *et al.*, 2001; Gopinath and Saralathan, 2004). Satellite data provides quick and useful baseline information on parameters like geology, geomorphology, land use/land cover, lineaments, which controls the occurrence and movement of groundwater (Saraf and Choudhury, 1998). With the capabilities of

the remote sensing data and GIS techniques, numerous databases can be integrated to produce conceptual model for delineation and evaluation of groundwater potential zones of an area (Krishnamurthy and Srinivas, 1995; Srivastava and Bhattacharya, 2000; Taylor and Howard, 2000; Sarkar *et al.*, 2001; Prasad *et al.*, 2008). Present investigation was carried out to delineate the areas suitable for groundwater exploration in both Peruvanthanam and Valiyathodu sub-watershed using remote sensing and GIS techniques by the preparation and analysis of various thematic layers. The information, depicted in the form of prospect maps would provide first hand information about areas most suitable for search of groundwater and also the type of well, depth to local authorities and planners.

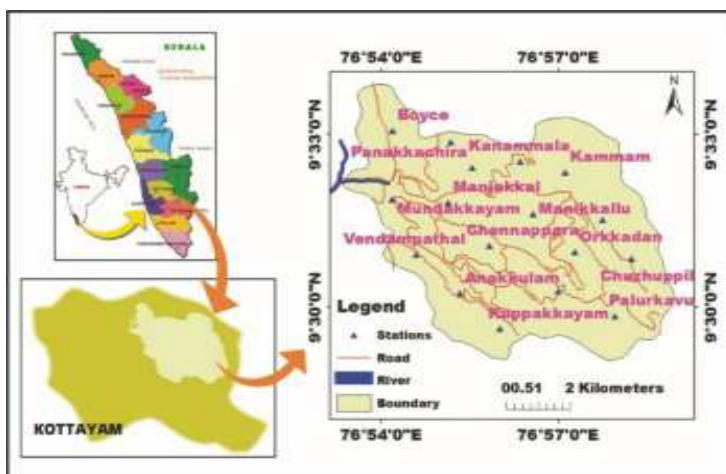


Fig. 1. Location map of Peruvanthanam sub-watershed

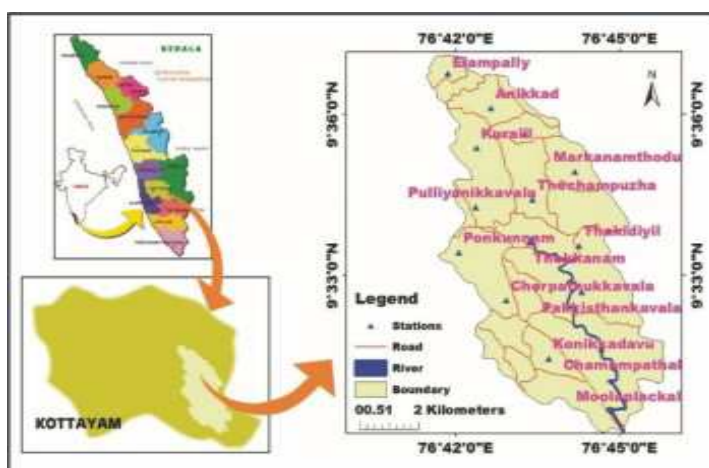


Fig. 2. Location map of Valiyathodu sub-watershed

1.1. Study Area

The area selected for the present investigation i.e., Peruvanthanam and Valiyathodu sub-watersheds belongs to a typical highland and midland sub-watersheds of the Manimala river basin. Peruvanthanam sub-watershed (**Fig. 1**) covers an area of 56.42 km² and lies between 9°29'00" to 9°34'00" N latitude and 76°53'00" to 76°59'00" E longitude. The Valiyathodu sub-watershed (**Fig. 2**) lies between 9°30'00" to 9°37'00" N latitude and 76°41'00" to 76°46'00" E longitude and covers an area of 54.85 km².

2. MATERIALS AND METHODS

Present study involves generation of various thematic maps such as geomorphology, land use/land cover, slope, geology and its analysis, for the identification of groundwater potential zones of both sub-watersheds. Multi Criteria Evaluation technique (MCE) was applied for assigning weightages and scores to assess various themes and features. Instead of taking only one character or parameter in to consideration to identify groundwater potential zones, integrated thematic maps were prepared. The themes generated and the data sources are shown in the **Table 1**.

2.1. Geomorphology

Peruvanthanam sub-watershed is characterized by denudational structural hill, denudational slope, residual hill, residual mound, escarpment, valley fill and water body (**Fig. 3**). Valiyathodu sub-watershed by linear ridge (Lower plateau), lower plateau (Lateritic)-dissected, residual hill, residual mound, valley fill and water body (**Fig. 4**). The areas covered by each geomorphic unit of both sub-watersheds are represented in **Fig. 5 and 6**.

2.2. Land Use/Land Cover

Peruvanthanam sub-watershed is characterized by rubber, tea, teak, mixed crop and cardamom plantations. Evergreen forest, land with scrub, barren rock, built up area and water bodies were also identified (**Fig. 7**). Valiyathodu is characterized by rubber, mixed crop, land with scrub, built up area and water bodies (**Fig. 8**). The areas covered by each land use/land cover unit of both the sub-watersheds were represented in **Fig. 9 and 10**.

2.3. Slope

The thematic map of slope for both sub-watersheds, were derived from Digital Elevation Modelling (DEM) using '3D analyst' an extension tool of Arc GIS.9.2.

Table 1. Prepared themes and it's sources

Themes	Sources
Geomorphology	IRS P6 LISS III image; SOI toposheets (58c/10, 58c/14 and 58c/15 of scale 1:50,000); field visit
Land use/ Land cover	IRS P6 LISS III image; field visit
Slope	Contours derived from SOI toposheets
Geology	Geological map prepared by GSI (1978); field visit

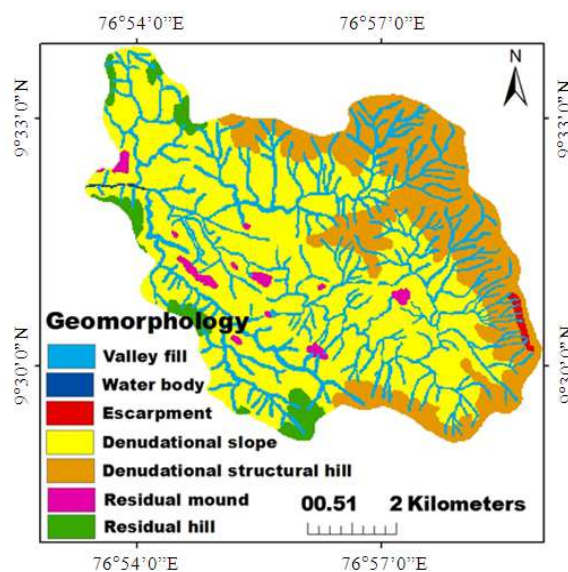


Fig. 3. Geomorphology of Peruvanthanam sub-watershed

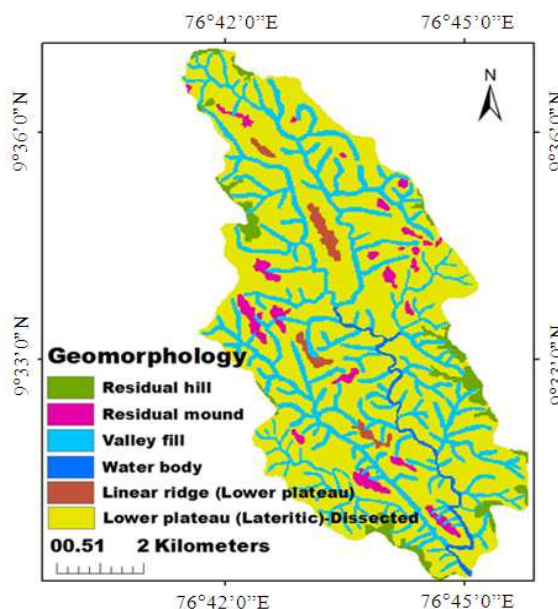


Fig. 4. Geomorphology of Valiyathodu sub-watershed

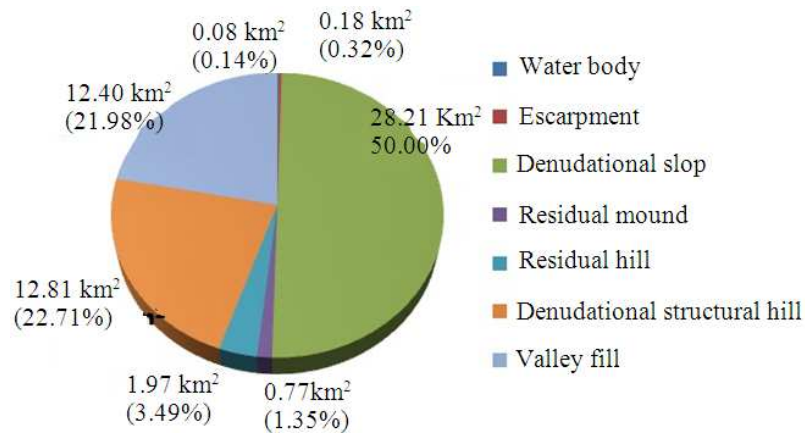


Fig. 5. Distribution of Geomorphology in Peruvanthanam sub-watershed

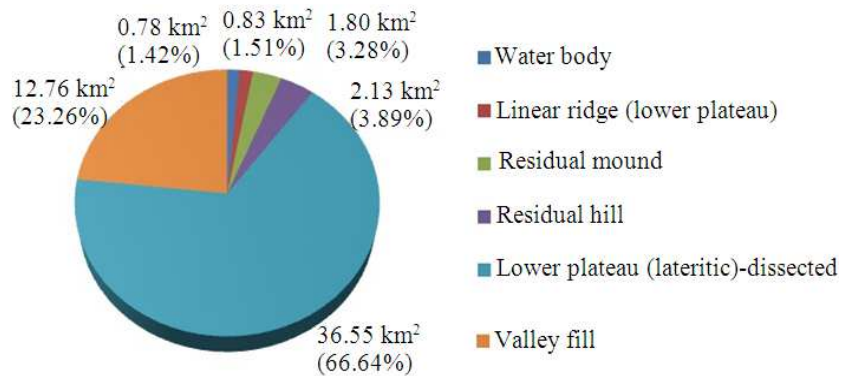


Fig. 6. Distribution of Geomorphology in Valiyathodu sub-watershed

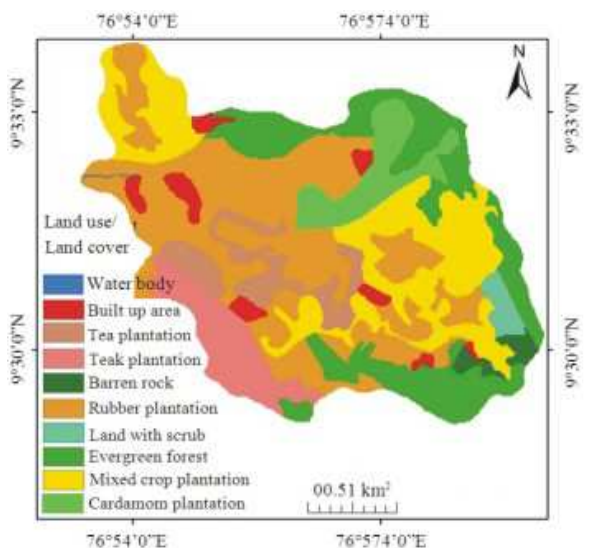


Fig. 7. Land use/Land cover map of Peruvanthanam sub-watershed

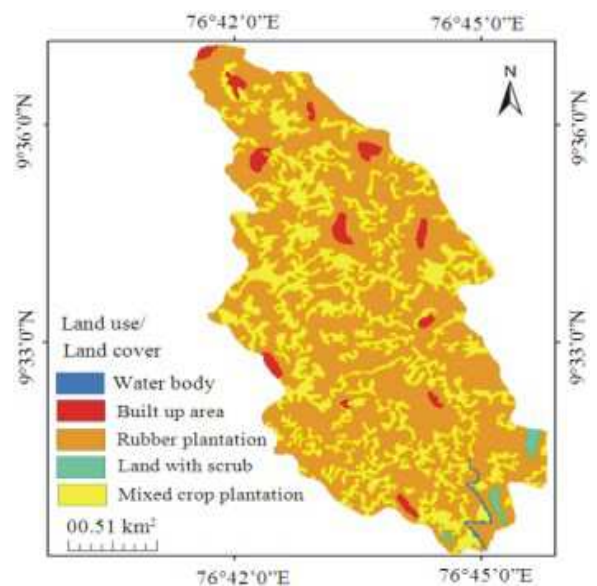


Fig. 8. Land use/Land cover map of Valiyathodu sub-watershed

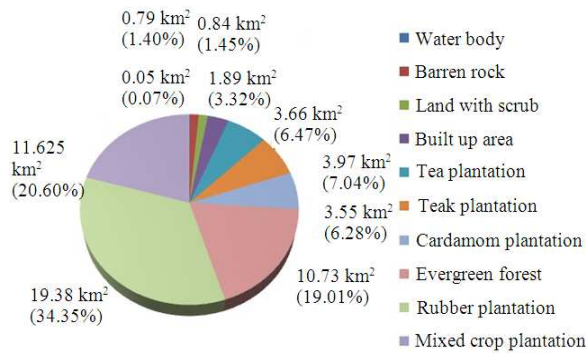


Fig. 9. Distribution of Land use/Land cover in Peruvanthanam sub-watershed

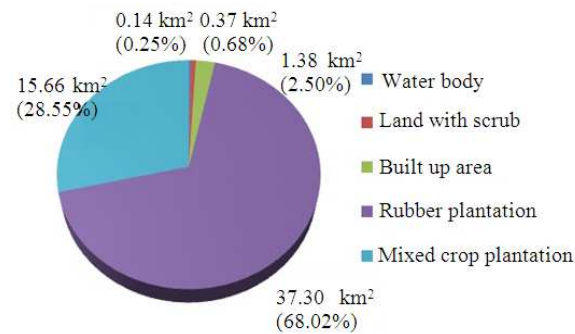


Fig. 10. Distribution of Land use/Land cover in Valiyathodu sub-watershed

DEM is the digital representation of continuous variation of topographic surface that has been carried out by the interpolation of contours, which in turn is digitized from Survey of India toposheets using Arc GIS 9.2. This generated DEM of both Peruvanthanam sub-watershed and Valiyathodu sub-watershed (**Fig. 11 and 12**) is used for generation of slope and 9 classes of DEM delineated in both sub-watersheds.

Based on critical analysis, slope of Peruvanthanam sub-watershed (**Fig. 13**) is classified in to 5 categories. Majority of the area falls under the class of 5-15⁰ (16.46km²) and minimum under the slope class of >35 (3.55km²). In general, Peruvanthanam sub-watershed has steep slopes which has important role in determining groundwater potentiality. Slope of Valiyathodu sub-watershed (**Fig. 14**) is also classified in to 5 categories. The Major area of Valiyathodu sub-watershed is covered by slope class of 0-4 (28.96 km²) and minimum area by slope class unit of >27 (1.26 km²). The area covered by each slope unit of both sub-watersheds are represented in **Fig. 15 and 16**.

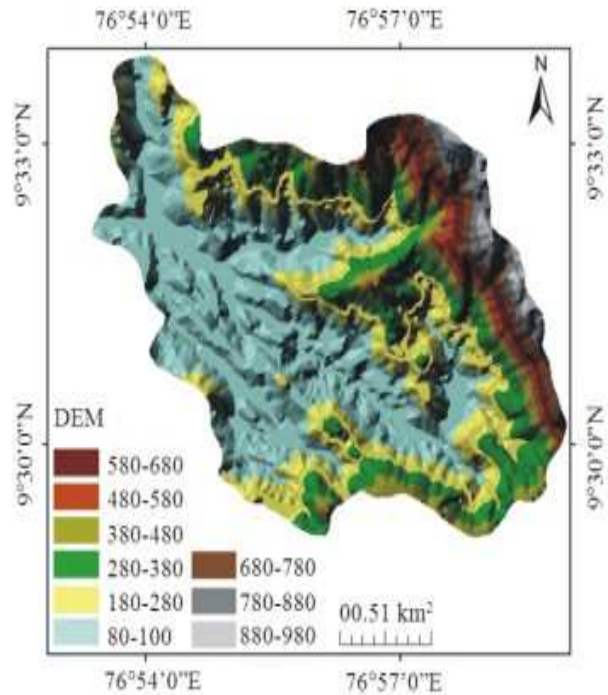


Fig. 11. DEM of Peruvanthanam sub-watershed

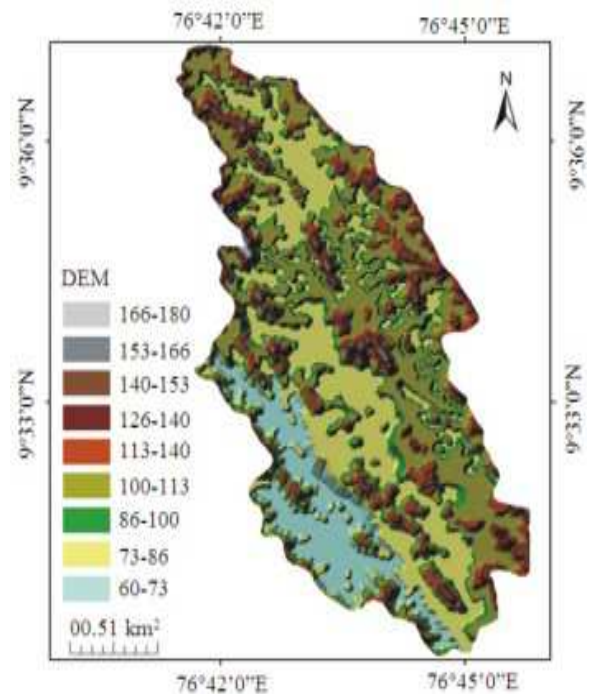


Fig. 12. DEM of Valiyathodu sub-watershed

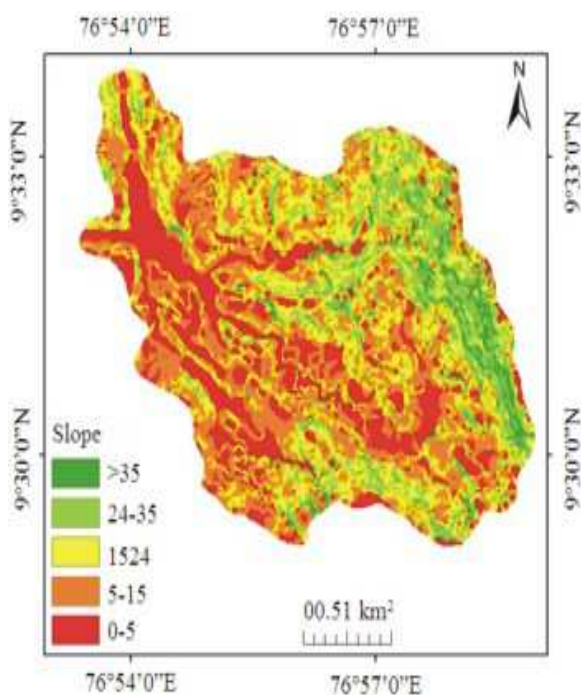


Fig. 13. Slope of Peruvanthanam sub-watershed

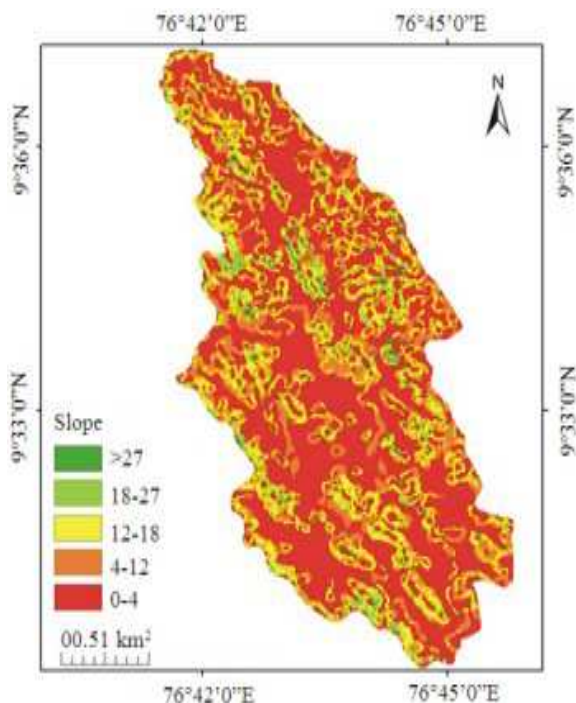


Fig. 14. Slope of Valiyathodu sub-watershed

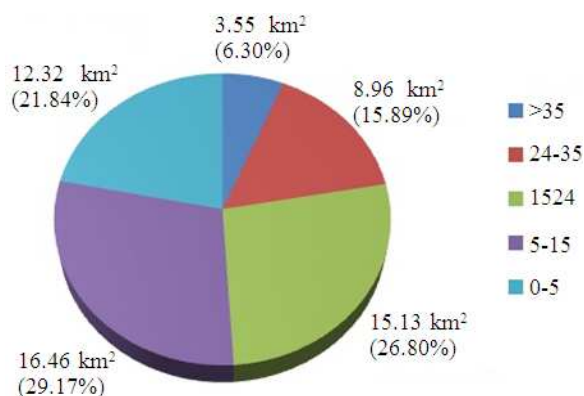


Fig. 15. Distribution of slope in Peruvanthanam sub-watershed

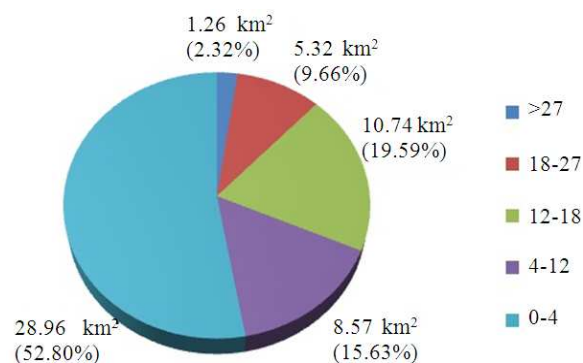


Fig. 16. Distribution of slope in Valiyathodu sub-watershed

2.4. Geology

In Peruvanthanam sub-watershed, 87.5% of the area i.e., 49.39 km² is covered by precambrian formations, mainly charnockite, gneisses and other crystalline rocks followed by intrusive rocks of quartzite and dolerite (Fig. 17). Valiyathodu sub-watershed is also characterized by charnockite and associated crystalline rocks followed by intrusive rocks such as quartzite, dolerite and gabbro (Fig. 18). The area covered by various geological unit in both sub-watersheds are represented in Fig. 19 and 20.

2.5. Criteria for Assigning Weightage and Rank

After the preparation of each theme, a specific weightage to each theme and ranks were given to individual features. The influence of different factors need not be same in any area. Therefore each parameter was assigned a weightage depending mainly on its influence on groundwater system. The weightages and scores given for each themes and layer classes of the sub-watersheds are given in Table 2 and 3 respectively.

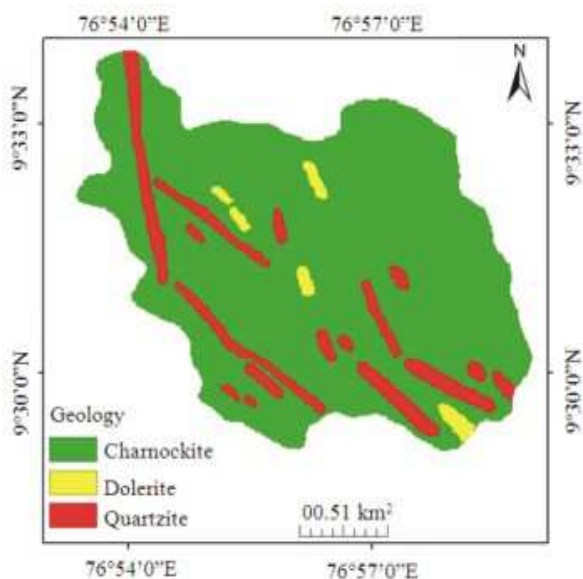


Fig. 17. Geology of Peruvanthanam sub-watershed

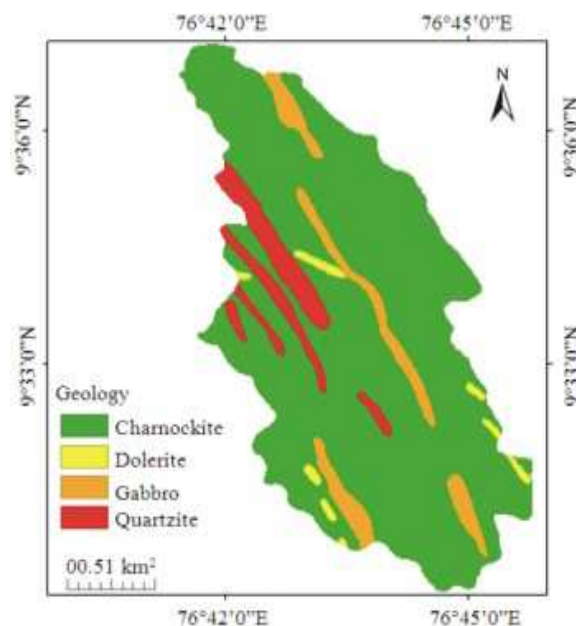


Fig. 18. Geology of Valiyathodu sub-watershed

Table 2. Weightage and rank given for each theme and individual features of Peruvanthanam sub-watershed

T	layer classes	W	R
Geomorphology	Water body		0
	Escarpment		1
	Denudational slope	40	10
	Residual mound		13
	Residual hill		15
	Denudational		
	Structural hill		16
	Valley fill		25
	>35	30	1
	24-35		5
Slope	15-24		12
	5-15		20
	0-5		25
	Water body	20	0
	Barren rock		1
Land use/Land cover	Land with scrub		3
	Built up area		4
	Tea plantation		5
	Teak plantation		7
	Cardamom plantation		8
	Evergreen forest		9
	Rubber plantation		10
	Mixed crop plantation		21
	Quartzite	10	1
	Dolerite		5
Geology	Charnockite		18

T = Theme; W = Weightage; R = Rank

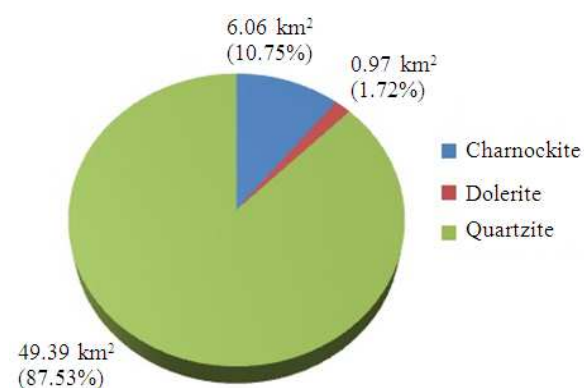


Fig. 19. Distribution of rock type in Peruvanthanam sub-watershed

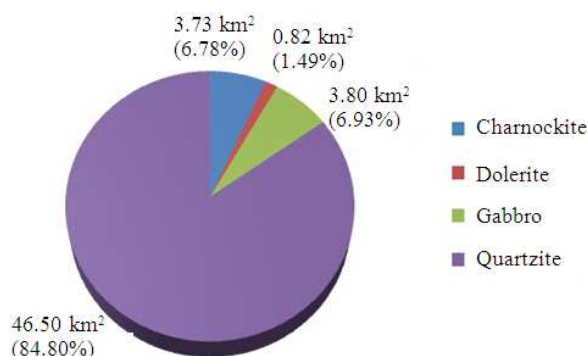


Fig. 20. Distribution of rock type in Valiyathodu sub-watershed

Table 3. Weightage and rank given for each theme and individual features of Valiyathodu sub-watershed

T	layer classes	W	R
Slope	>27		2
	18-27		6
	12-18		13
	4-12		18
	0-4	35	24
Geomorphology	Water body		0
	Linear ridge		
	(Lower plateau)		5
	Residual mound		6
	Residual hill		13
	Lower plateau		
	(Lateritic)-dissected	30	16
	Valley fill		0
	Water body		6
	Land with scrub		10
Land use/ Land cover	Built up area		14
	Rubber plantation		19
Land cover	Mixed crop plantation	25	21
	Quartzite		1
	Dolerite		5
	Gabbro		8
Geology	Charnockite	10	18

T= Theme; W= Weightage; R= Rank

In Peruvanthanam sub-watershed, higher weightage was given to geomorphology followed by slope, land use/land cover and geology, because the influence of geomorphology and slope in Peruvanthanam sub-watershed is comparatively high. In Valiyathodu sub-watershed, higher weightage was given to slope followed **Table 3**.

Weightage and rank given for each theme and individual features of Valiyathodu sub-watershed by geomorphology, land use/land cover and geology. Because the influence of slope in Valiyathodu sub-watershed is comparatively high. After assigning weightage, a knowledge based scores ranging from 1 to 25 based on their ability to hold groundwater was given; where 1 denotes poor and 25 denotes excellent prospects.

After assigning the weightages and ranks to the themes and individual features, all the themes were converted to raster format using ‘Spatial analyst’-an extension of Arc GIS 9.2 software. While converting to raster, the scores assigned to the individual features were taken as the value field and it is reclassified for the analysis. Then, the individual themes were normalized by dividing theme weightages by 100. The ‘raster calculator’ option of spatial analyst was used to prepare the integrated final groundwater potential map of the area. The map algebra used in the raster calculator for both sub-watersheds is as follows.

Thus the Groundwater Potential Map (GPM) of Peruvanthanam sub-watershed = (Geomorphology) X

0.40+ (Slope) X 0.30+ (Land use/Land cover) X 0.20+ (Geology) X 0.10 and the Groundwater Potential Map (GPM) of Valiyathodu sub-watershed = (Slope) X 0.35+ (Geomorphology) X 0.30+ (Land use/Land cover) X 0.25+ (Geology) X 0.10.

3. RESULTS

The integrated final map was reclassified to generate the output map of both Peruvanthanam (**Fig. 21**) and Valiyathodu sub-watershed (**Fig. 22**), showing five classes of groundwater potential zones. These potential zones are designated as ‘excellent to very good’, ‘very good to good’ and ‘good to moderate’, ‘moderate to poor’ and ‘poor to very poor’. The groundwater potential zones and its area in km² and percentage of Peruvanthanam sub-watershed are represented in **Fig. 23** and of Valiyathodu sub-watershed in **Fig. 24**.

In Peruvanthanam sub-watershed, the ‘excellent to very good zone’ occupies 7.69 km² (i.e., 13.64 %). Where as in Valiyathodu sub-watershed, an area of 26.10 km² (i.e., 47.58 %) fall under ‘excellent to very good’. In Peruvanthanam sub watershed ‘very good to good’ potential which covers an area of 14.87 km² (i.e., 26.35 %). On the other hand, in Valiyathodu sub watershed, an area of 18.55 km² (i.e., 33.82 %) belongs to this category. In Peruvanthanam sub-watershed, a zone of ‘good to moderate’ potential which is represented by 17.65 km² (i.e., 31.28 %). In Valiyathodu sub-watershed, ‘good to moderate’ zone, is occupied by 6.65 km² (i.e., 12.12%).

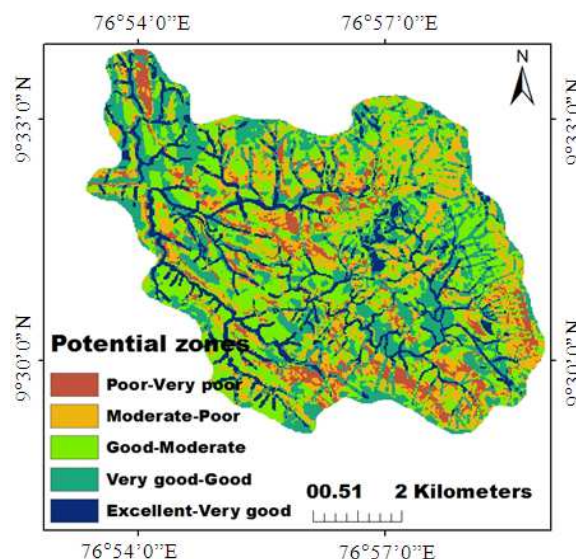


Fig. 21. Groundwater potential zones of Peruvanthanam sub-watershed

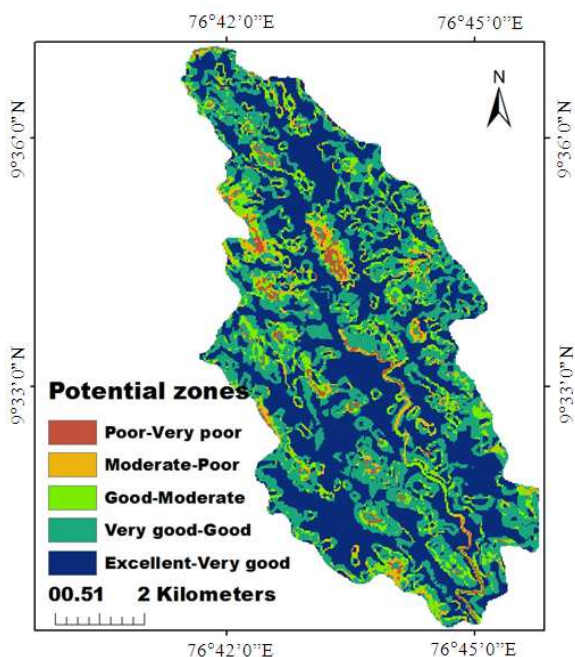


Fig. 22. Groundwater potential zones of Valiyathodu sub-watershed

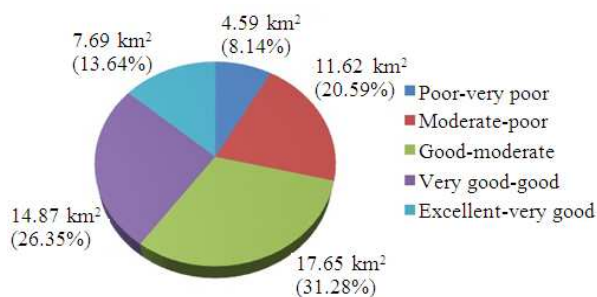


Fig. 23. Distribution of potential zones in Peruvanthanam sub-watershed

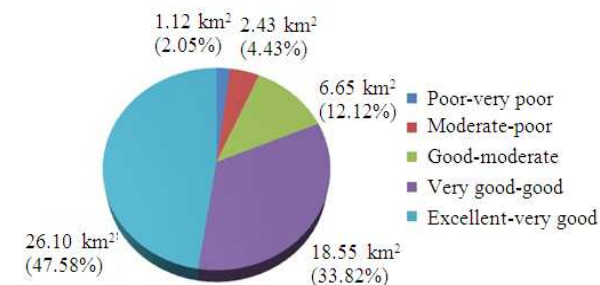


Fig. 24. Distribution of potential zones in Valiyathodu sub-watershed

In Peruvanthanam sub-watershed, the zone ‘moderate to poor’ which covers an area of 11.62 km² (i.e., 20.59 %), whereas in Valiyathodu sub-watershed, the area covered by this zone is 2.43 km² (i.e., 4.43 %). In Peruvanthanam sub-watershed, ‘poor to very poor’ zone covered by this zone is 4.59 km² (i.e., 8.14 %) whereas in Valiyathodu sub-watershed, the area covered by this zone is 1.12 km² (i.e., 2.05 %).

4. DISCUSSION

In Peruvanthanam sub-watershed, in ‘excellent to very good zone’, the slope belongs to 0-5⁰ class. This restricts the surface run off and accelerates infiltration. Along with this, geomorphologic units such as valley fills of ever green forest, mixed crop plantation, favours excellent recharge condition, whereas in Valiyathodu sub-watershed, the presence of valley fill, lower plateau of geomorphologic unit, slope of 0-4⁰ and mixed crop plantation land use/land cover unit, makes the zone excellent to very good. In Peruvanthanam sub-watershed, slope class of 5-15⁰ and land use/land cover unit of rubber plantation, cardamom plantation and teak plantation makes this a zone of ‘very good to good’. In such a situation, both dug wells and bore wells are suggested. In Valiyathodu sub-watershed, the slope unit of 4-12⁰, land use/land cover unit with rubber plantation geomorphologic units of residual hills make this zone ‘very good to good’ potential. In Peruvanthanam sub-watershed slope of (15-24⁰) and land use/land cover units of built up area, geomorphological units of denudational structural hills decelerate the infiltration and make this a zone of ‘good to moderate’ potential. In sub-watershed, the infiltration is decelerated by, the factors such as, slope of 12-18⁰, land use/land cover unit such as land with scrub geomorphologic unit of residual hill and these factors make this a zone of ‘good to moderate’ potential. In Peruvanthanam sub-watershed, slope class of 24-35⁰ characterized by geomorphological units such as residual mound, escarpment, built up area of land use/land cover units, geological units with charnockite rocks together make the zone ‘moderate to poor’. In Valiyathodu sub-watershed, slope class of 18-27⁰, geomorphological units such as residual mound, built up area of land use/land cover units and geology with charnockite rocks make the zone ‘moderate to poor’. In Peruvanthanam sub-watershed, the ‘poor to very poor’ potential zone, is represented mostly by rocky terrain with charnockite as predominant rock type. Here the slope condition (>35⁰) and land use condition that mainly covers with built up area, makes a run off zone

with 'poor to very poor' groundwater prospects. In Valiyathodu sub-watershed also, poor to very poor zone is marked by rocky terrain with geomorphology as residual mount and land use/land cover unit as built up area. Slope is $>27^{\circ}$. In these areas groundwater potentiality is very limited. Active rain water harvesting has to be initiated here in both sub-watersheds to face the water scarcity problems.

5. CONCLUSION

The study based on the utility of remote sensing and raster based GIS technique is focused on the identification and delineation of groundwater potential zones. Multi Criteria Evaluation Technique (MCE) by integration of various thematic maps prepared from conventional and remote sensing techniques using GIS yields more and near accurate result. Based on this the entire study area has been classified in to five potential zones. Critical analysis and comparison of ground water potential zones of both sub-watersheds revealed various potential zones and area represented by each zones. Further the study shows that in general a groundwater potential zone is more in Valiyathodu sub-watershed compared to Peruvanthanam. The groundwater potential map derived from the present study will provide a baseline data for any future exploration in these areas. Finally, it is suggested that, proper rainwater harvesting and artificial recharge methods and measures should be implemented in 'moderate to very poor' and 'poor to very poor' potential areas for overcoming the water scarcity problem and for future development of water use strategies.

6. ACKNOWLEDGEMENT

The Searchers gratefully acknowledge the Director, School of Environmental Science, MG University, Kottayam and Head of the Department of Central University of Kerala, Kasargode, for the support extended and facilities provided during the course of study.

7. REFERENCES

- Das, D., S.C. Behara, A. Kar, P. Narendra and S. Guha, 1997. Hydrogeomorphological mapping in ground water exploration using remotely sensed data-a case study in Keonjhar district, Orissa. *J. Ind. Soc. Remo. Sens.*, 25: 247-259. DOI: 10.1007/BF03019366
- Devi, S.P., S. Srinivasalu and K.K. Raju, 2001. Hydrogeomorphological and groundwater prospects of the Pageru river basin by using remote sensing data. *Environ. Geol.*, 40: 1088-1094. DOI: 10.1007/s002540100295
- Gopinath, G. and P. Saralathan, 2004. Identification of groundwater prospective zones using IRS-ID liss iii and pump test methods. *J. Ind. Soc. Remo. Sens.*, 32: 329-342. DOI: 10.1007/BF03030858
- Khan, M.A. and P.C. Moharana, 2002. Use of remote Sensing and geographical information system in the delineation and characterization of ground water prospect zones. *J. Ind. Soc. Remo. Sens.*, 30: 131-141. DOI: 10.1007/BF02990645
- Krishnamurthy, J. and G. Srinivas, 1995. Role of geological and geomorphological factors in ground water exploration: A study using IRS LISS data. *Int. J. Remo. Sens.*, 16: 2595-2618. DOI: 10.1080/01431169508954579
- Mayilvaganan, M.K., P. Mohana and K.B. Naidu, 2011. Delineating groundwater potential zones in Thuringapuram watershed using geospatial techniques. *Ind. J. Sci. Technol.*, 4: 1470-1476.
- Prasad, R., N. Dinesh, A. Lee, E. Miltsakaki and L. Robaldo *et al.*, 2008. The Penn Discourse TreeBank 2.0. Proceedings of the Sixth International Conference on Language Resources and Evaluation, May 28-30, European Language Resources Association.
- Rao, Y.S., T. Reddy and P. Nayudu, 2000. Groundwater targeting in a hard-rock terrain using fracture-pattern modeling, Niva river basin andhra Pradesh, India. *J. Hydrogeol.*, 8: 494-502. DOI: 10.1007/s100400000090
- Ravindran, K.V. and A. Jeyaram, 1997. Groundwater prospects of Shahbad Tehsil, Baran District, Eastern Rajasthan: A remote sensing approach. *J. Ind. Soc. Remo. Sens.*, 25: 239-246. DOI: 10.1007/BF03019365
- Ravishankar, M.N. and G. Mohan, 2006. Assessment of the groundwater potential and quality in Bhatsa and Kalu river basins of Thane district, western Deccan Volcanic Province of India. *Environ. Geol.*, 49: 991-998. DOI: 10.1007/s00254-005-0137-5

- Saraf, A.K. and P.R. Choudhary, 1998. Integrated remote sensing and GIS for groundwater exploration and identification of artificial recharge sites. *Int. J. Remote Sens.*, 19: 1825-1841. DOI: 10.1080/014311698215018
- Sarkar, B.C., B.S. Deota, P.L.N. Raju and D.K. Jugran, 2001. A Geographic Information System approach to evaluation of groundwater potentiality of Shamri micro-watershed in the Shimla Taluk, Himachal Pradesh. *J. Ind. Soc. Remote Sens.*, 29: 151-164. DOI: 10.1007/BF02989927
- Srivasthava, P.K. and A.K. Bhattacharya, 2000. Delineation of ground water potential zones in a hard rock terrain of bargarh district, orissa using IRS data. *J. Ind. Soc. Remote Sens.*, 28: 129-140. DOI: 10.1007/BF02989897
- Taylor, R. and K. Howard, 2000. A tectono-geomorphic model of the hydrogeology of deeply weathered crystalline rock: Evidence from Uganda. *Hydrogeol. J.*, 8: 279-294. DOI: 10.1007/s100400000069