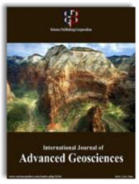
International Journal of Advanced Geosciences, *4 (2) (2016) 54-61*

International Journal of Advanced Geosciences

Website: www.sciencepubco.com/index.php/IJAG
doi: 10.14419/ijag.v4i2.6228
Research paper



GIS based approach to understand the factors influencing the water level of the coastal aquifers in the ramnad district, Tamilnadu, India

Sivakarun N [1], Chidambaram S [2], Thivya C [3]*, Udayaganesan P [1], Paramaguru P [2], Pradeep K [2], Ganesh N [2], Anandhan P [2]

[1] *Department of Geology, Alagappa Government Arts College, Karaikudi -630006, Tamilnadu India*
[2] *Department of Earth Sciences, Annamalai University, Annamalai Nagar-608002,Tamilnadu, India*
[3] *Department of Geology, University of Madras, Guindy campus, Chennai-600025, Tamilnadu, India*
**Corresponding author E-mail: thivyac1988@gmail.com*

Abstract

An attempt has been made in this study to understand the factors influencing the variation in water level of the groundwater of the Ramnad district. The different factors considered for study were average water level, Land use pattern, tanks and rainfall pattern of the study area. The water level contours were spatially plotted for four months interval and their average was considered for comparison. The rainfall trend of the district was obtained by the Thiessen polygon method. Further the Average water level contour was overlaid over the land use, tanks and rainfall distribution maps to understand the spatial influencing factor and it was identified that the agricultural return flow and the tank intensity play a major role in the recharge of the groundwater of this coastal aquifers.

Keywords: *Water level; Rainfall; Tanks; Coastal aquifers; Landuse/landcover.*

1. Introduction

Continuous increased withdrawals from a groundwater reservoir in excess of replenishable recharge may result in regular lowering of water table. In such a situation, a serious problem is created resulting in drying of shallow wells and increase in pumping head for deeper wells and tube wells. This has led to emphasis on planned and optimal development of water resources. An appropriate strategy will be to develop water resources with planning based on conjunctive use of surface water and groundwater. For a sustainable development of water resources, it is imperative to make a quantitative estimation of the available water resources. Tank is a centre of socio economic activities of a village catering to the multifarious needs of the village community. The tank is not simply an irrigation system appended to big reservoirs. It has multiple uses and serves diverse needs of people, animals and plants. Apart from the above, the tanks contribute to the recharge of ground water, microclimate and the environment to keep the surrounding area green and cool. Since, about 90% of the tanks are non-system or rain-fed the effect on area reduction will be more significant (Palanisami et al. 1997). Even though the share of tanks is decreasing part of it is replaced with groundwater irrigation in the tank command areas. Besides variation in rainfall and tank filling, several factors such as siltation, encroachment, and channel obstruction have reduced the tank irrigated area over the years. Increasing dug well irrigation in the tank commands has complicated the water allocation and management in the tanks (Palanisami and Easter 2000). Most of the tanks in Tamil Nadu have become degraded due to open access, weak institutional arrangements, poor structures and breakdown of the local authority system (Ludden 1987). Rainfall is the major source of recharge to the study area. Part of the rain water that falls on the ground is infiltrated into the soil. A part of this infiltrated water is utilized in filling the soil moisture deficiency while the remaining portion percolates down to reach the water table, which is termed as rainfall recharge to the aquifer. The dependability on tank water is declining due to availability of groundwater and its easy extraction by using powerful electrical gadgets. Thus the significance of tank on the recharge of the aquifers is to highlighted in the coastal aquifers system. The proposed study area is a coastal region with lesser rainfall. Hence, this paper focuses mainly on the causes of groundwater fluctuation and the trend of groundwater level fluctuation as well as to determine the amount of recharge in the study area.

2. Study area

The Ramanathapuram is underlined by the coastal aquifers where the rural people have been coping with ponds locally it is known as Ooranis. It is located in semi-arid and highly prone areas situate at the lower end of gundar river basin. The study area is located in Ramanathapuram District in Tamil Nadu State, India, and it covers an area of 4,123 km^2 (Fig. 1). It forms a part of the Gundar basin and Vaigai river basins, and is located 498 km towards North of Chennai city. It has an average elevation of 2 metres (6 feet). The district receives the rain under the influence of both southwest and northeast monsoons. The northeast monsoon chiefly contributes to the rainfall in the district. Most of the precipitation occurs in the form of cyclonic storms caused due to the depressions in Bay of Bengal. The southwest monsoon rainfall is highly erratic and summer rains are negligible, with an average annual rainfall of 827mm. Vaigai and Gundar are the important rivers and in addition, Virusuli, Kottakariyar & Uppar are the other rivers draining the district. The drainage pattern, in general, is dendritic. All the rivers are seasonal and carry substantial flows during monsoon period. The rivers in this region flow only for a few days in a year, especially after heavy rains during the monsoon period (www.mapsofindia.com).

Most of the area is covered by the unconsolidated sediments of Quaternary age except in the northwestern part, where isolated patches of Archaean Crystallines and Tertiary sandstone are exposed. It is overlain by thin alluvium and exposed towards north of Vaigai River. Detached exposures of laterite and lateritic soil are seen in the northwestern part of the district. A major part of the district is covered with the fluvial, fluvio-marine, Aeolian and marine sediments of Quaternary age. The fluvial deposits which are made up of sand, silt and clay in varying degree of admixture occur along the active channels of Vaigai, Gundar, Manimuthar and Pambar rivers. The Aeolian deposits comprise red sands which are in nature of ancient dunes and occur over a 3.2 Km wide and 8 Km long stretch and lie parallel to the sea coast. These are separated by marshy deposits of black clays. The sands are underlain by calcareous hardpan.

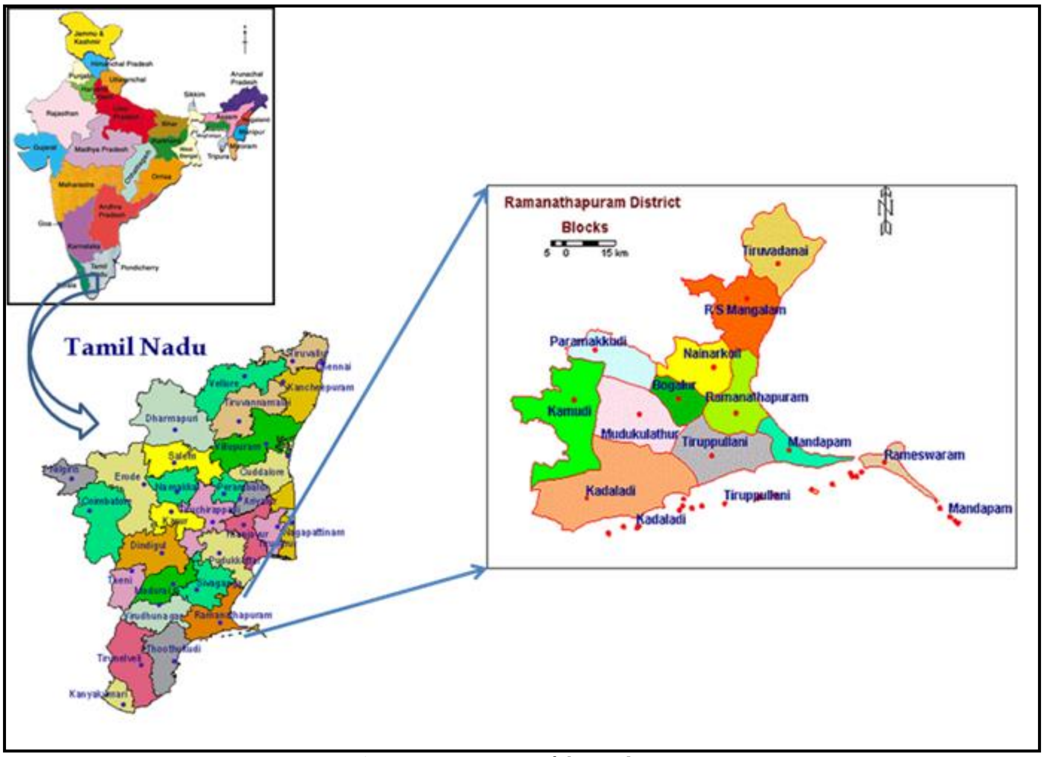


Fig. 1: Location Map of the Study Area.

3. Hydrogeology

The district is underlain by both porous and fissured formations. The important aquifer systems in the district are constituted by i) unconsolidated & semi-consolidated formations and ii) weathered and fractured crystalline rocks The porous formations can be grouped into three aquifer groups, viz., Cretaceous sediments, Tertiary Sediments and Quaternary Sediments. The cretaceous aquifer is semi confined to confined in nature and consists of two zones. The top unit comprises fossiliferous sandstone red in colour and compact in nature, while the bottom is pinkish or grayish sandstone intercalated with shales. The aquifers are characterized by freshwater and occurs at the depth range of 116-407 and 205-777 m bgl and has thickness in the range of 68 to 535 m. The aquifer is made up of compact sandstone and the potential is limited. The wells may yield a discharge of 5-10 lps and can sustain a pumping of 10-15 hours a day. However, because of the presence of potential shallow tertiary aquifer, this aquifer has not been extensively developed. The groundwater occurs under unconfined condition with thickness varying from 15-20m and under confined condition in deeper depths. The unconfined aquifer can be tapped by dug well/ dug cum bore well and can yield about 10-15 lps and can sustain a pumping of 10-15 hours a day. The deeper tube wells can yield about 15-20 lps and can sustain a pumping of 10-15 hours a day (CGWB, 2009).

4. Methodology

Rainfall and water level data have been collected for the year 2010. The water level data is collected for monthly wise from major selected 25 locations distributed spatially throughout the district.The rainfall data have been collected for monthly wise from major six rainfall stations namely Ramanathapuram, Rameshwaram, Thiruvadanai, Kadaladi, Kamuthi and Paramagudi. These data has been processed by the Theisson polygon system using Map Info professional software. In order to achieve accurate estimation of the spatial distribution of rainfall, it is necessary to use interpolation methods, for this, the Thiessen method is considered as the most important in engineering praxis. This method assigns weight at each gauge station in proportion to the catchment area that is closest to that gauge.

The method of constructing the polygons implies the following steps:

1) Gauge network is plotted on map of the catchment area of interest.
2) Adjacent stations are connected with lines.
3) Perpendicular bisectors of each line are constructed (perpendicular line at the midpoint of each line connecting two stations)
4) The bisectors are extended and used to form the polygon around each gauge station.
5) Rainfall value for each gauge station is multiplied by the area of each.

5. Results and discussion

5.1. Land use/ land cover

Land use/land cover provides a better understanding of the cropping pattern and spatial distribution of fallow lands, forests, grazing lands, wastelands and surface water bodies, which are vital for developmental planning (Vijith et al. 2007). In this study area covered geographically 409.0 and forest Area 4.5 land under non agriculture land 86.7, permanent pastures 0.2, and Cultivable wasteland 4.2 land under miscellaneous tree crops and groves 38.9 Barren and uncultivable land 4.6 , Current fallows 32.9 other Fallows 49.9 (Values considered in Area '000 ha) (Fig.2). The variations in area covered under agriculture and fallow land attributed to changes in crop rotation, harvesting time and conversion of these lands into plantation. Available land can be effectively used in the most rational way by knowing land use/land cover data (Chaurasia et al. 1996). Apart from these processes, evaporation and irrigation return flow influence the major-ion chemistry in groundwater (Stigtera et al. 1998; Hudak, 2000; Guo and Wang 2004).

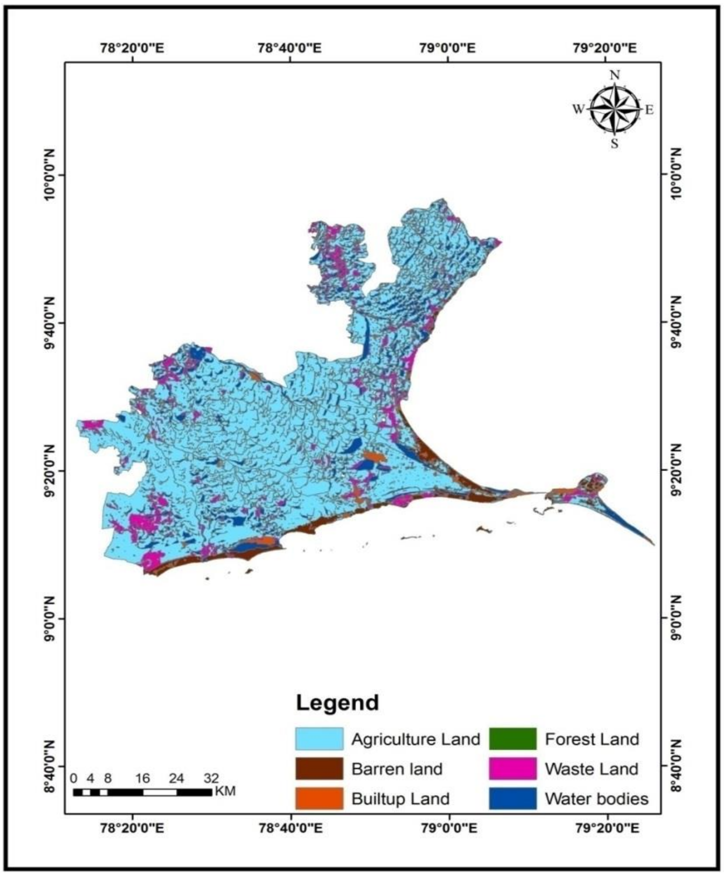


Fig. 2: Landuse/ Landcover Map of the Study Area.

5.2. Tanks

In Tamilnadu the biggest tank is present in Ramnad district. There is huge number of tanks that are interlinked to each other for infiltration and recharge. The huge number of tanks is observed in the northern part of the study area (Fig.3). The tanks are recharged from the rivers like Gundar, Vaigai and some may be recharged by the direct precipitation. The drainage pattern is dentritic. All the rivers are non-perennial in nature and they carry the substantial flows during monsoon period. Hence the tanks are monsoon dependent in form. Tank irrigate a registered command area of 60, 541 ha which is around 90% of the net irrigated area and around 32% of the net area sown in the district (Vasudha pangare, 2003). According to the CGWB report (2010) 1694 tanks irrigates the 57, 034 ha in this district. Scheytt (1997) and Poulichet et al. (2002) reported on the importance of groundwater recharge on seasonal variation in the major-ion concentration of groundwater. Schuh et al. (1997). Earlier studies reported that the rising water table in the post-monsoon period dissolves more saline matter from the soils and increases the salinity of water after the monsoon.

5.3. Rainfall

The amount of rainfall recharge depends on various hydro meteorological and topographic factors, soil characteristics and depth to water table. Due to uneven distribution of rainfall both in time and space, the surface water resources are unevenly distributed. Monthly rainfall data of sufficient number of rainguage stations lying within or around the study area, along with their locations (Fig.4 and Table.1). The district receives the rain under the influence of both southwest and northeast monsoons. Most of the precipitation occurs in the form of cyclonic storms caused due to the depressions in Bay of Bengal. The southwest monsoon rainfall is highly erratic and summer rains are negligible (CGWB, 2007). From the observation of Thesion polygon the highest rainfall is observed in the Ramanathapuram taluk due to the influence of cyclones where this taluk is present towards the coastal side. The lowest overland flow calculated by Theissen method shows that the lowest flow is observed in the southern, northern, and western part of the study area, ranging from $14,227x10^4m^3/yr$ to $30,807x10^4m^3/yr$. Further the highest overland flow is noted in the south eastern coastal region of the district ($60,672\ x10^4m^3/yr$ to $64,115x10^4m^3/yr$). This overland flow results in the excess surface water filling up the interconnected tanks and the alluvial aquifers of this part of the study area.

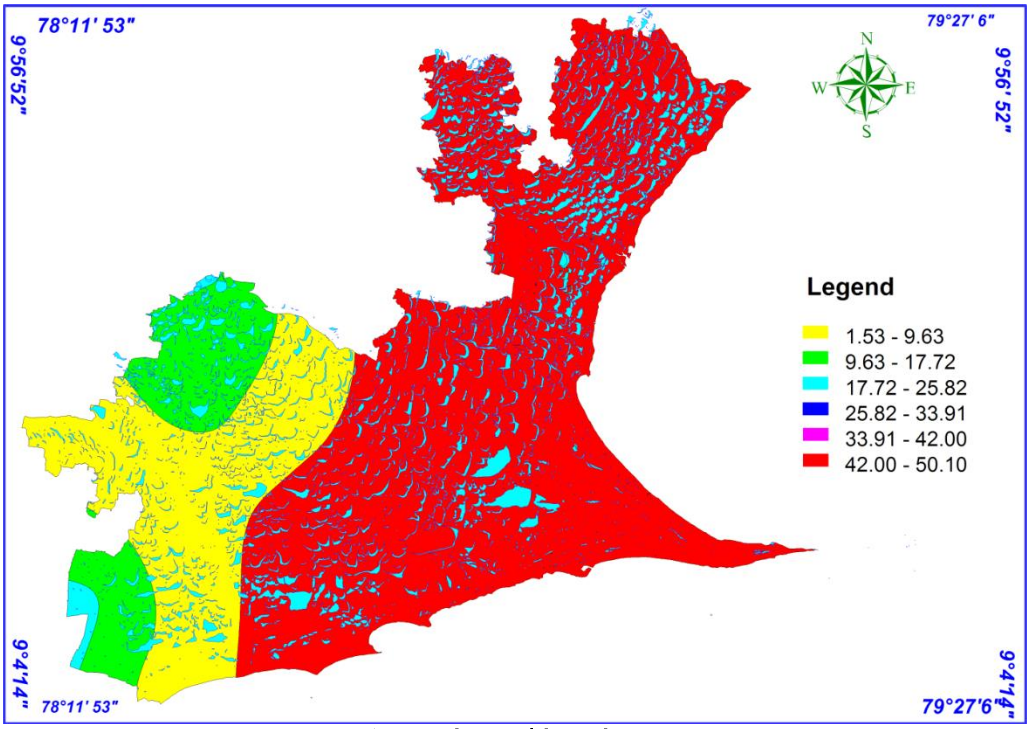


Fig. 3: Tank Map of the Study Area.

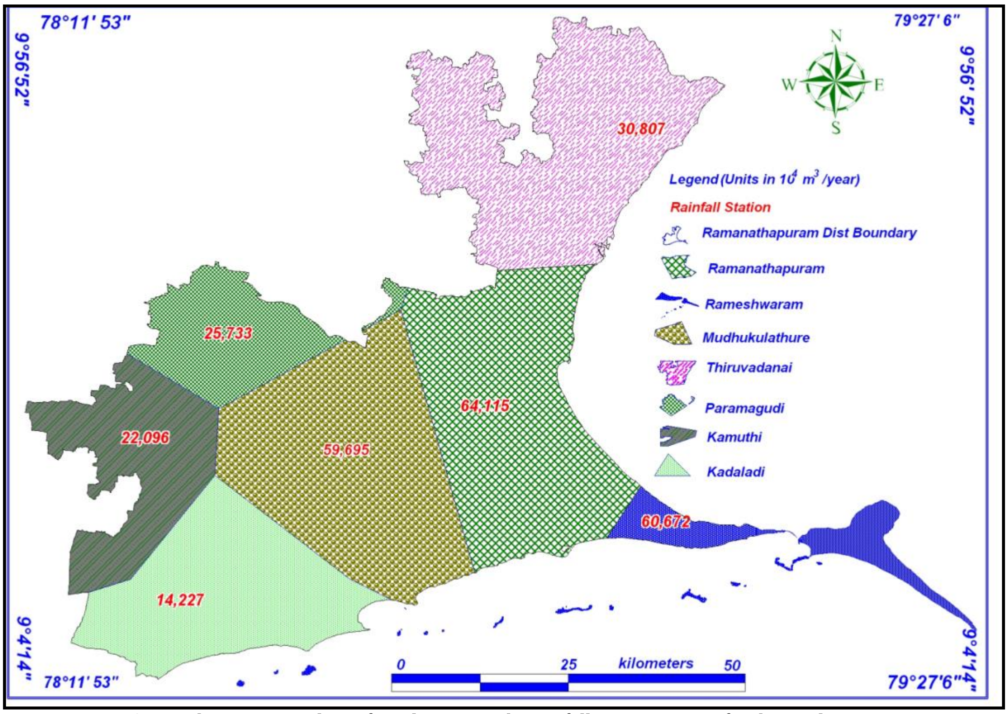


Fig. 4: Theissen Boundary of Study Area with Rainfall Concentration for the Study Area.

Table 1: Annual Rainfall from Ramnad District (in mm)

Location	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Ramanathapuram	35.2	11.2	12.8	26.5	26.2	8.5	12.4	10	23.8	200.6	238.7	130.8
Rameswaram	49	9.8	3.3	29.9	23.6	6	3.8	5.5	16.6	195.1	221.7	173
Thiruvadanai	31.4	4.5	8.1	22.6	14.4	18.7	11.4	14.9	43.2	168.2	194.9	91.2
Kadaladi	21.6	12	2.1	13	37.6	8.6	8.4	14.6	13	180	182.4	134
Kamuthi	30.9	4.3	22.9	33.2	39	19	21.3	34	66.3	221.2	144	51.6
Paramakudi	84.8	5.2	12.2	33.7	45.4	25	28.4	53.1	53.9	180.8	161.4	62

5.4. Water level fluctuation

Water-level measurements from observation wells are the principal source of information about the hydrologic stresses acting on aquifers and how these stresses affect ground-water recharge, storage, and discharge (Solomon et al. 2007). Measurements of water levels in wells provide the most fundamental indicator of the status of this resource and are critical to meaningful evaluations of the quantity and quality of ground water and its interaction with surface water. These include: (1) selection of observation wells,

(2) determination of the frequency of water level measurements, (3) implementation of quality assurance, and (4) establishment of effective practices for data reporting. Seasonal water level fluctuations result in higher summer water levels and lower winter levels. In general water level fluctuations vary with cumulative rainfall departure from the average rainfall series. Most of the north east and south west part of the region is covered by shallow water level where the deepest part is on the western part of the study area. It depends on the topography, lithology, and geomorphology of the study area. The lowest water level is observed in the coastal aquifers towards the eastern side (Fig.5a, b, c, d). The groundwater level is a key parameter for evaluating spatial and temporal changes in groundwater environments. The groundwater level is governed by various factors. Climate change, as reflected in precipitation and evaporation rates, influences the groundwater level fluctuation. (Vijith et al. 2010) study also found that climate trends have high correlations with groundwater level variations in southern part. In plain areas, precipitation infiltration and evapo transpiration in the vertical direct ion are the major recharge and discharge processes of the water cycle. In the study area, most of rainfall falls between October and December with seasonal variation in climate. The fluctuation is noted in the southern part of the study area, with shallow groundwater during august and the deeper during May. This is mainly due to the rainfall received in the coastal region and the greater influence in water level is noted after South West Monsoon.

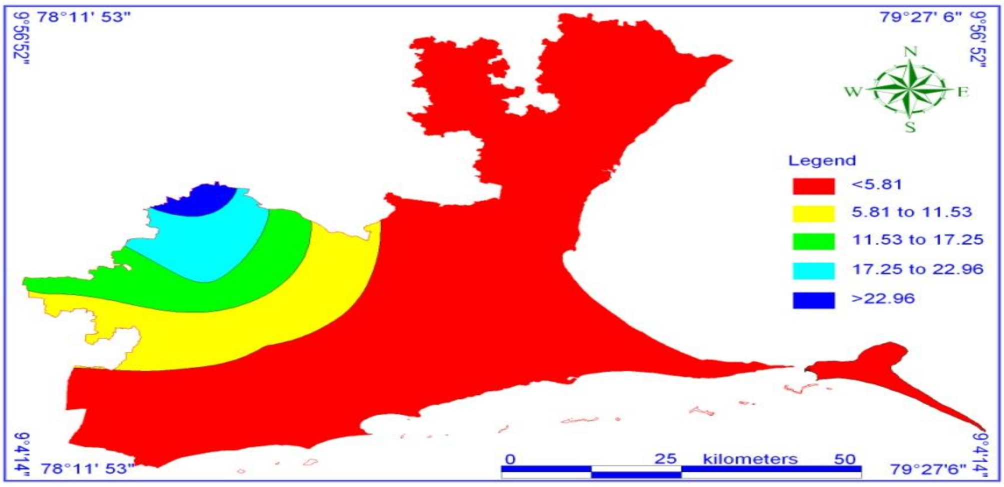


Fig. 5a: Water Level Concentration for During January 2007

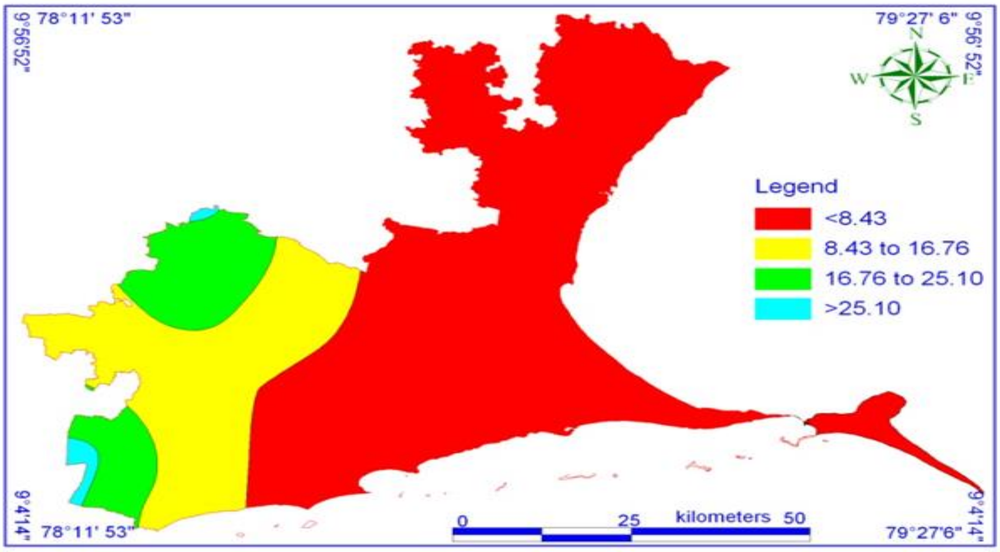


Fig. 5 B: Water Level Concentration for During May 2007.

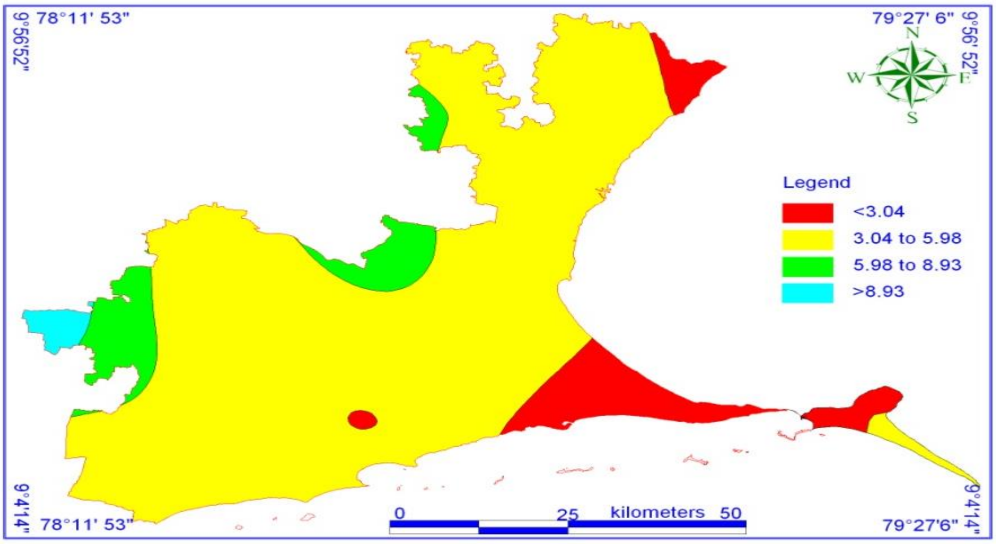


Fig. 5 C: Water Level Concentration for During August 2007.

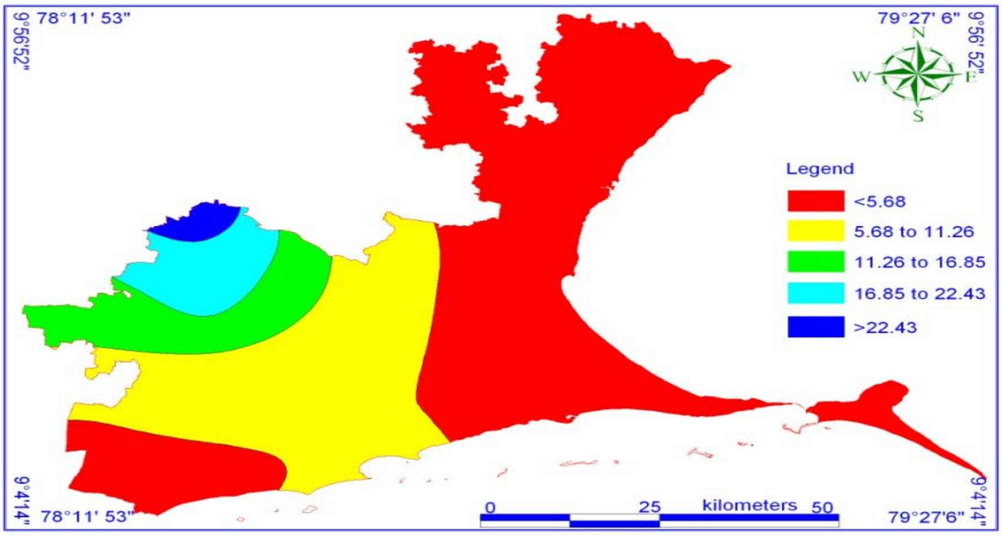


Fig. 5d: Water Level Concentra-Tion for During Nov 2007.

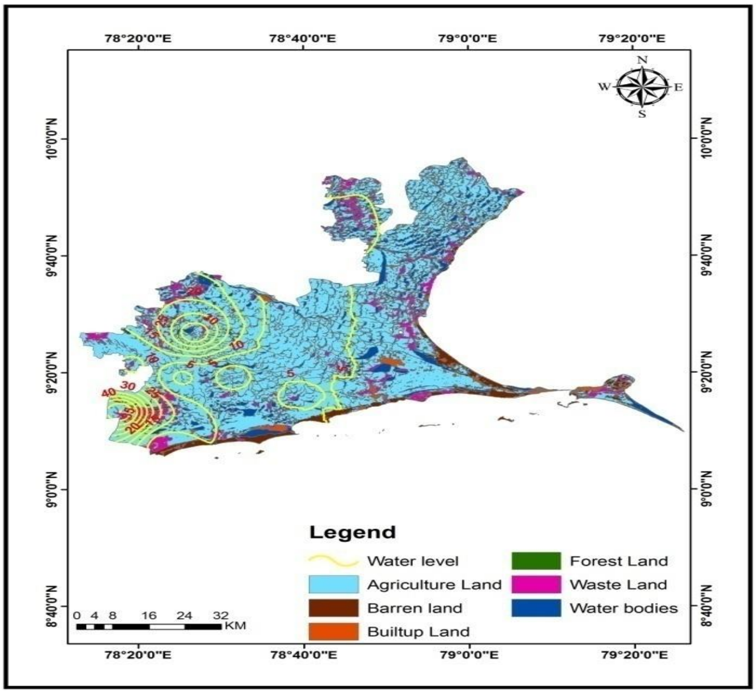


Fig. 6a: Overlay Map of Land Use Land Cover and Water Level.

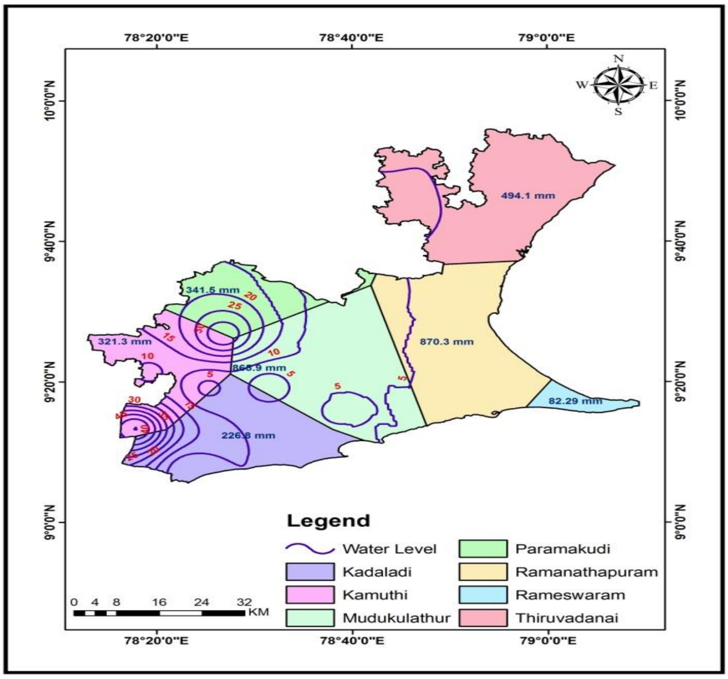


Fig. 6b: Overlay Map of Rainfall and Water Level.

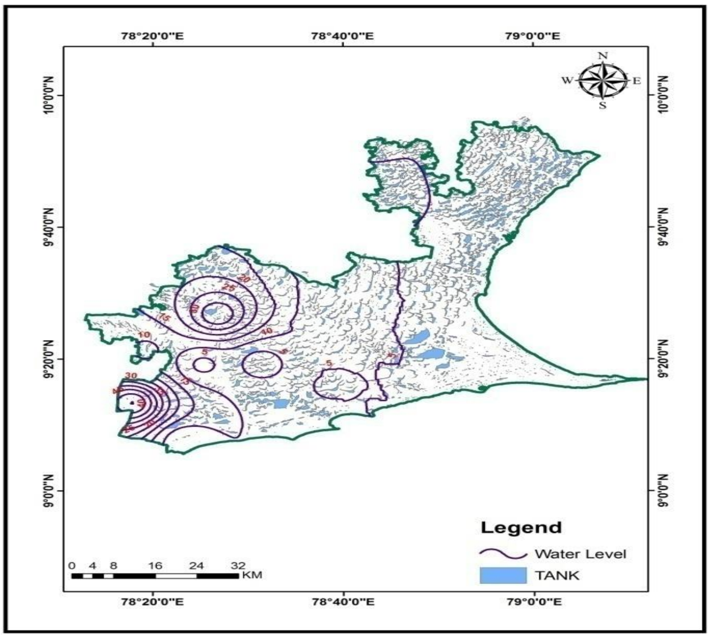


Fig. 6c: Overlay Map of Tank and Water Level.

The average water level for the year 2007 is compared with the land use/land cover, rainfall and tanks (Fig.6a, b, c, d) to identify the overall processes that influences the water level in the region. The deeper water level is observed in the south west part of the region and shallow water level is observed along the costal side from north to southern region which may be due to the over exploitation of the coastal aquifers.

Impacts of LU/LC change on atmospheric components of the hydrologic cycle (regional and global climate) are increasingly recognized (Bonan, 1997; Pielke et al., 1998; Pitman et al., 2004). The most direct approach is relating LU/LC changes to water table fluctuations. Unsaturated-zone profiles of metric potential and water-borne tracers (natural and anthropogenic) archive past variations in recharge from LU/LC change, particularly in thick unsaturated zones in arid and semiarid regions. Agriculture is the major activity observed in the study area (Fig.6a). The highest water level is observed in the agricultural land which may be due to the irrigational activities return flow. The lowest water level is observed in the along the coast which is covered by waste lands, built uplands and barren land.

The process of variation of water level due to rainfall is a complex one. The process involved flow which varies according to the geological formations through the unsaturated regions of the aquifer. The rate of infiltration depends upon several parameters. A study by PWD (2012) of water level and monthly rainfall data reveals that the wells retain the water level to higher range irrespective of the magnitude of rainfall and it is however, not clearly observed in some places because groundwater is overexploited during the non-monsoon seasons (Fig.6b). Drainage pattern is one of the most important indicators of hydro geological features, since it is controlled by underlying litho logy (Charon, 1974). The deeper water level is observed in the region with lesser intensity rainfall may be due to the lesser infiltration. The shallow water level is observed in the highest rainfall region may be due to the surface runoff and infiltration.

Tanks contribute to the recharge of ground water, microclimate and the environment to keep the surrounding area green and cool. There exist 500,000 irrigation tanks in the country, of which

150,000 tanks are located in the semi arid region of Deccan plateau. Most of the tanks in Tamil Nadu have become degraded due to open access, weak institutional arrangements, poor structures and breakdown of the local authority system (Ludden 1987).The stored water is utilized by gravity flow to the lands situated below, primarily for irrigation purpose. In the study area more number of tanks are observed in the north eastern part and less tanks are observed in the southern part, in this scenario the deeper water level is observed in the south west part which may be due to the influence of over exploitation (Fig.6c). The tanks of north west may be influenced by monsoons and they serve as a interconnected network which will favour the recharge of the coastal aquifers. This also reflects the fact that the groundwater is influenced by intensity of the tanks.

6. Conclusion

The study reveals that the groundwater level in the coastal aquifer of the Ramnad district is influenced by different factors. The major factors considered for the study were land use, tanks and the rainfall of the study area. The study area is predominantly agriculture based and the agriculture return flow of water from the cultivated land adds to the groundwater system moreover the higher rainfall region facilitated with more number of tanks along the groundwater flow direction shows a considerable recharge of groundwater. The study also reveals the fact that of these three factors considered, tanks play a significant role in recharging the shallow aquifers of the Ramnad district.

References

[1] Bonan GB (1997) Effects of land use on the climate of the United States. Climatic Change, 37, 449–486. http://dx.doi.org/10.1023/A:1005305708775.

[2] CGWB (2007, 2009, 2010) Central Ground Water Board, District groundwater brochure, Ramanathapuram district, Tamilnadu, Government of India, Ministry of water resources, south eastern coastal region, Chennai.

[3] Charon JE (1974) Hydrogeological applications of ERTS satellite imagery. In Proc UN/FAO, Regional seminar on "Remote Sensing of Earth Resources and Environment", Cairo: Commonwealth Science Council, pp.439–456, 1974.

[4] Chaurasia S S, Gupta P, Kar A & Maiti P K (1996) Lead induced thyroid dysfunction and lipid peroxidation in fish, Clarias batrachus with special reference to hepatic type-I 5'-on odeiodinase activity. Bull. Environ. Contam. Toxicol, 56, 649-654

[5] Guo H & Wang Y (2004) Hydro geochemical processes in shallow quaternary aquifers from the northern part of the Datong basin, China. Applied Geochemistry, 19: 19–27. http://dx.doi.org/10.1016/S0883-2927(03)00128-8.

[6] Hudak PF (2000) Sulfate and chloride concentrations in Texas aquifers. Environment International 26: 55–61. http://dx.doi.org/10.1016/S0160-4120(00)00078-7.

[7] Ludden D (1987) Patronage and Irrigation in Tamil Nadu: A Long-Term View. Indian Economic and Social History Review, 16, (3): 347–365.

[8] Palanisami K & Easter KW (2000) Tank irrigation in the 21st century - what next? New Delhi: Discovery Publishing House.

[9] Palanisami K, Balasubramanian R & Ali Mohamed A (1997) Present status and future strategies of tank irrigation in Tamil Nadu. Bulletin/97. Coimbatore: Water Technology Centre, Tamil Nadu Agricultural University Press.

[10] Pielke RAS, Avissar R & Raupach M (1998) Interactions between the atmosphere and terrestrial ecosystems: influence on weather and climate. Global Change Biology, 4, 461–475. http://dx.doi.org/10.1046/j.1365-2486.1998.t01-1-00176.x.

[11] Pitman AJ, Narisma GT & Pielke RAS (2004) Impact of land cover change on the climate of southwest Western Australia. Journal of Geophysical Research, 109, http://dx.doi.org/10.1029/2003jd004347.

[12] Poulichet FE, Favreau G, Leduc C & Seidel JL (2002) Major ion chemistry of groundwaters in the Continental Terminal water table of southwestern Niger (Africa). Applied Geochemistry, 17: 1343–1349 http://dx.doi.org/10.1016/S0883-2927(02)00024-0.

[13] PWD, "Groundwater perspectives - A profile of Salem District", Tamil Nadu Public Works Department (PWD), Government of Tamil Nadu, India, 2008.

[14] Scheytt T (1997) Seasonal variations in groundwater chemistry near Lake Belau, Schleswig Holstein, northern Germany. Hydrogeology Journal, 5, 86–95. http://dx.doi.org/10.1007/s100400050123.

[15] Schuh G, Heiden AC, Hoffmann T, Kahl J, Rockel P, Rudolph J & Wildt J (1997) Emissions of volatile organic compounds from sunflower and beech: dependence on temperature and light intensity. J Atmos Chem, 27: 291–318. http://dx.doi.org/10.1023/A:1005850710257.

[16] Solomon et al. (2007) Technical Summary. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[17] Stigtera TY, Van Ooijena SPJ, Posta Vea, Appeloa Caj & Carvalho Dillb Amm. (1998) A hydro geological and hydrochemical explanationof the groundwater composition under irrigated land in a Mediterranean environment, Algarve, Portugal. Journal of Hydrology, 208:262–279. http://dx.doi.org/10.1016/S0022-1694(98)00168-1.

[18] Vasudha Pangare, Ganesh Pangare & Binayak Das (2003) Springs of Life: India's Water Resources, Hardcover, 392 Hardcover, 2,128 Pages, Published 2003 by Oxford University Press, USA ISBN-13

[19] Vijith H, Rekha, Thomas A P and Suma M (2010). An Integration of spatial Information Technology for Ground Water potential and Quality Investigations in Koduvan AR Sub watershed of Meenachil river basin, Kerala, India.