ANALYSIS ON SPATIAL VARIATION OF RAINFALL AND GROUNDWATER FLUCTUATION IN KODAYAR SUB BASIN,TAMILNADU, INDIA

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Abstract

The study covers the groundwater level variability analysis and its relationship with rainfall for the Kodayar sub-basin of Kanyakumari district (Tamil Nadu) through Geographical Information System (GIS) technique. The rainfall data from the study area for a period of ten years were analyzed annually and categorized based on the seasons: Post monsoon (Jan. &Feb.), Pre monsoon (Mar. to May), Southwest monsoon (Jun. to Sep.) and Northeast monsoon (Oct. to Dec.). By conventional method, the annual rainfall is found to be 1446mm, of which the post monsoon, pre monsoon, SW monsoon and NE monsoon are 26.6 mm (2.2%), 239mm (25.5%), 364 mm (38.8%) and 307mm (33.5%) respectively. These results were taken into GIS platform and the spatial distribution maps prepared. From these spatial distribution maps for the seasons, annual average rainfall was prepared. The maximum rainfall was recorded at Thukkalai in October, having the monthly and annual average of 283 mm and 1394mm respectively. Similarly the minimum rainfall was at Bhoothapandi in January with the average value of 2mm. The monthly rainfall curve has its peak during October and nadir during January. SW monsoon and NE monsoon almost play an equal role in their rainfall contributions, whereas the post monsoon rainfall occurrence is negligible in this region.

Introduction

The main component of the water cycle is rainfall which is the prime source of ground water re-charge. A tropical country like India mainly depends on rainfall for filling the water resources. In India, the distribution of rainfall varies from place to place owing to different physiographic and climatic setting. Hence, it throws an enormous challenge to the management of water resources. Improper or ineffective management could lead to fresh water crisis and environmental degradation, and deprive millions of people of the access to safe drinking water. More than 80% of the annual rainfall occurs during the monsoon periods in Tamil Nadu. Since the intensity of monsoon rainfall is erratic and uneven both in space and time, it results in drought over major parts of Tamil Nadu during the non-monsoon periods. Hence it is a necessity to analyse the occurrence of rainfall and groundwater level fluctuations during various seasons for evolving a system which can address these issues.

Three main characteristics of rainfall are its amount, frequency, and intensity. For the values of which vary from place to place, day to day, month to month and even year to year, accurate knowledge of these three main characteristics is essential for planning its full utilization . Kumar and Elango [1] studied the relationships between rainfall recharge and groundwater level fluctuation with respect to the Lower Palar River Basin in Tamil Nadu, India. They prepared hydrographs and isohyetal maps for carrying out an analysis of groundwater level. Kumar and Ahmed [2] studied the seasonal behavior and spatial variability of groundwater levels in a granitic aquifer during the monsoon in Andhra Pradesh, India. It is mentioned that the major portion of rainfall in India occurred during the monsoon season and most of the water-related activities, either natural such as recharge or man-made such as agriculture with groundwater extraction for irrigation, were closely related to this period. Higher or lower rainfall or changes in its spatial and seasonal distribution would influence the spatial and temporal distribution of runoff, soil moisture and groundwater reserves, and would alter/affect the frequency of droughts and floods. Further, temporal change in precipitation distribution will affect cropping patterns and productivity.

Jagannadhasarma [4] has analyzed the rainfall pattern of the c oastal zone of Krishna Godavari River Basin, Andhra Pradesh, India. He has analysed the annual, monsoon and nonmonsoon rainfall and spatial and frequency distribution of rainfall intensity. Similarly Vennila [3] studied the rainfall variation in the Vattamalaikarai sub basin in Tamil Nadu. In another study

conducted by Rathod and Aruchamy [5] spatial analysis of rainfall variation in Coimbatore District of Tamil Nadu using GIS tool.

The present study focuses on Kodayar sub-basin in Tamil Nadu, as this sub-basin assumes greater importance due to larger segment of agriculture depending on it, and this area is a non-perennial one, and no-study had been made in the past on this area. In the present study, an attempt has been made to understand the distribution of rainfall in the study area with the objectives of analysing seasonal and spatial variations in rainfall pattern at various rain gauge stations spread over the study area. The occurrence of groundwater and its quality are controlled by rainfall recharge. Since perennial water resources are remote, the agricultural activities in the study area mainly depend upon the rain fall and ground water resources. But to decide what method to be adopted in this study, an attempt had been made to understand that there were several studies carried out in the past which adopted IDW (Inverse Distance Weighted) method to assess the rainfall distribution. Hence this study adopted IDW method to examine year and season wise spatial variation of rainfall using (IDW) method in ArcGIS.

STUDY AREA DESCRIPTION

The Kodayar sub basin covering an area of 638 km^2 which lies between 08°08 ' N to 08° 22' N latitude and 77° 08' E to 77° 29' E longitude .The location map is shown in figure1.The climate of the area is sub-tropical and receives an annual average rainfall of about 1448.6 mm. It comes under the area bounded by Western Ghats in the north and Arabian Sea in the Southern west, Bay of Bengal in the East and Thirunelvelli district in the North east. The major part of study area is drained by the principal rivers namely Kodayar and Paralayar and their tributaries. Kodayar River rises in the Agastiarmalai and flows in a southerly direction flowing for a length of 10 km from its origin, leading to natural drainage called the Kodayar Lake, which serves as the main source for irrigation system with an extensive command area in the district. The Pazhayar River originated at an altitude of 1300 m MSL in the Mahendragiri hills and the river water is taken away through channels for irrigation. The river is benefited by both SW-NE monsoons. It completes its 20 km journey after joining the Arabian Sea. The river Valliyar is originated at an altitude of 950 m MSL at the Vallimalai Hills and has a very limited irrigation system. Types of soil classes such as Clayey loam, loamy sand, sand, sandy clay; sandy clay loam and sandy loam were identified in the study area. The major land-use type in the study area are agricultural land which includes crop land, coconut and plantations, Forests land, waste land which includes land with and without shrub, barren rocky ,salt affected land and water logged areas, and settlement such as industrial, residential and settlement with vegetation etc. are identified. Geologically, the area is mostly dominated by granites of Archean age. The basic lithological units present in the study area are Alluvium-Fluvial, Aeolian, Fluvial-marine, Alluvium-marine, Khondalite group, Migmatite complex and Charnockite group. Coastal sand is seen in the entire coastal belt of the study area and above which Teri sand (Aeolian group) is found and over which coastal alluvium fluvial of quaternary age is present. North western part of the study area covers the Garnet-biotite gneiss of Archean age and the western pats of area covers Khondalite group of Archean age. Around 45% of the study area is covered by Charnockite group.

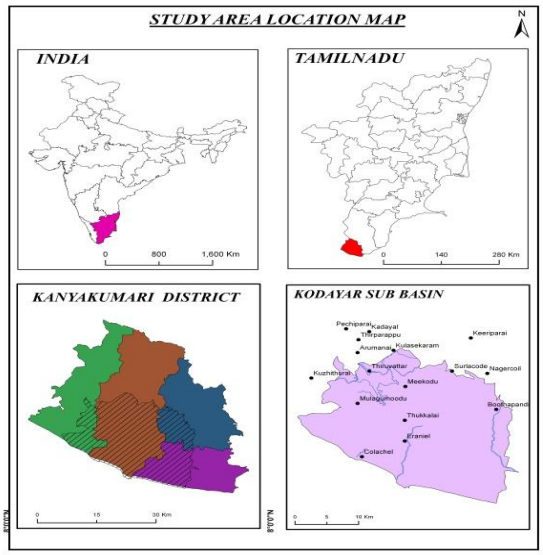

Fig.1 Layout map of the study area

MATERIALS AND METHODS

In this study, Survey of India topographical sheets numbers 58H4, 58H7 & 58H8 on 1:50,000 scales were used to delineate the watershed boundary. For analysing the average depth to water level, and its variability in the study area, the water level (WL) data of 10 years (2000-2009) recorded at 19 hydrological stations and the rainfall data of 10 years (2000-2009) for the same place was procured from the Institute of Water Studies of Public Works Department (Government of Tamil Nadu) for the respective periods are used for an analysis of the hydro system. To investigate the changes in rainfall for different seasons, a year was divided into four seasons: Post monsoon (January–February), pre-monsoon (March–May), Southwest monsoon (June–September), and Northeast monsoon (October–December). Rainfall analysis was carried out for all the seasons as well as the whole year separately. To meet the framed objectives, the collected daily rainfall data has been arranged, interpreted by preparing various graphs and maps. The water level fluctuation was analysed for the four seasons such as post monsoon, Pre monsoon, South west monsoon and the North east monsoon. In this present, estimating the trend of groundwater level and there after the water level fluctuation and the trend and the increase or decrease in rainfall from the trend of the rainfall data was calculated using average values of water level and rainfall, using Microsoft office Excel 2010. The special variation of

seasonal, annual rainfall and groundwater level fluctuations are also prepared using ArcGIS. The spatial coverage maps for each data series were prepared using spatial interpolation techniques available in the spatial analyst module in Arc GIS.

Results and discussion

Average Annual Rainfall Variation

The annual average rain fall of the study area is 1448mm; the annual mean varies from 541.00 mm to 1394.5mm. Fig.2 explains the variation of annual average rainfall over a period of ten years. Kanyakumari and Mulagumoodu received rainfall of 276 mm and 958 mm respectively in the year 2003 which recorded the lowest rainfall. Likewise Bhoothapandi and Thukkalai received rainfall of 541 mm and 1816 mm respectively of the year 2008 with the highest rainfall of the study period. Southwest and northeast monsoon shares 71.6 % of rainfall and summer contributes by 25.5 % and winter shares 2.9%. The spatial variations in rainfall (Fig 3) have been classified into five classes, such as 'very low' (< 700 mm.), 'low' (700 mm – 950 mm), 'moderate' (950 mm – 1050 mm), 'normal' (1050 mm – 1,450 mm) and 'high' (> 1,450mm). Southern central parts of the study area falls under high rainfall zone and it contributes 15% of the total area, 32% of the study area falls under normal rainfall zone, 44% of the area falls under moderate rainfall zone, 7% falls low rainfall zone and 2% of the area receives very low rainfall zone. The mean annual average rainfall stations map and the spatial variation maps are shown in Fig. 2 and Fig. 3 respectively.

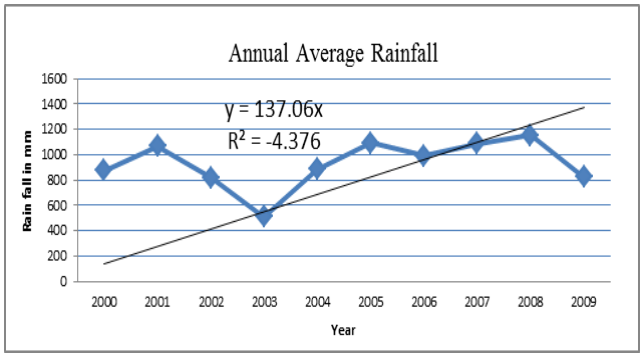

Figure.2 Annual average rainfall map

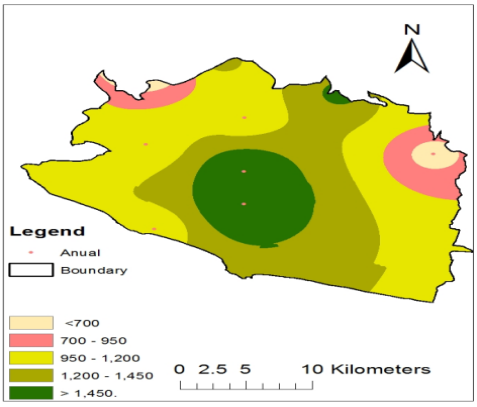

Figure.3 Spatial rainfall variation map

Monthly Variation Rainfall

The variation of monthly rainfall of the Kodayar sub basin (Fig.4) explains that a homogeneous pattern of rainfall variation is found in all the rain gauge stations the intensity gradually increases from January to April, and suddenly drops from July to August. The maximum amount of rainfall is shown in the month of October and again decreases in December. This trend is observed the entire rain gauge stations located in the study area.

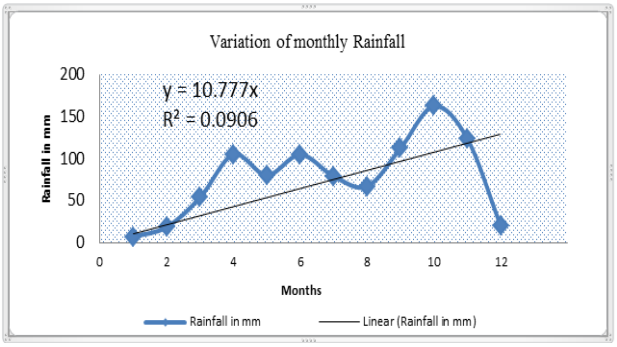

Figure.4 Monthly average map(2000-2009)

Seasonal Variation of Rainfall

The seasons in the study area has been classified as pre monsoon (March-May), SW monsoon (June-September), NE monsoon (October –December) and Post monsoon (January-February). The Seasonal Variation of Rainfall pattern recorded for the period of ten years (2000-2009) has been analysed for 19 rain gauge station in the study area (Fig.5). The percentage of seasonal rainfall contribution during each station has also been computed (Table.1). The contribution among the seasons are: the southwest monsoon of 38.8% (364mm) ,northeast monsoon of 33.5% (307mm) ,Pre monsoon of 25.5% (239mm) and the post monsoon of 3% (27mm) of the total mean annual rainfall. During South west monsoon period, the station Surulacode recorded the maximum average rainfall (Fig. 6) of 694mm and Bhoothapandi recorded the minimum of 207mm. The contribution of southwest monsoon is more in Kaliyal, Keeriparai, Kuzhithurai, Meekodu, Mulagumoodu, Pechiparai, Surulacode and Nagercoil when compared to the northeast monsoon seasonal rainfall. The seasonal variation of this period shows, most part of the central area falls under the rainfall range of 340mm-425mm,which covers 425km^2(67%) of the total area. In the northeast monsoon period, the maximum rainfall recorded was in Thukkalai 506mm and the minimum in Bhoothapandi 207mm. The rainfall is increasing gradually towards west, southern west and southern east of the study area, more than 80% of the area received normal rain during this season. Pre monsoon contributes 25.5% (239mm) of the annual rainfall and the maximum average amount of rainfall received in Thukkalai of 362mm and minimum in Bhoothapandi of 133mm.

TABLE .1 Seasonal and Percentage of Rainfall observed from Various Rain Gauge Stations

Sl.No	Rain gauge Station	Post-monsoon (mm)	% of contribution	Pre-monsoon (mm)	% of contribution	SW monsoon (mm)	% of contribution	NE monsoon (mm)	% of contribution
1	Arumanai	9.60	1.05	227.44	24.79	339.47	37.00	340.94	37.16
2	Bhoothapandi	21.48	3.97	133.10	24.61	206.61	38.20	179.62	33.21
3	Colachel	7.58	0.86	209.09	23.77	310.39	35.28	352.65	40.09
4	Eraniel	28.58	2.39	354.99	29.66	393.19	32.85	428.15	35.77
5	Kaliyal	18.42	3.14	134.80	22.97	230.35	39.26	203.23	34.63
6	Kanyakumari	44.20	6.77	188.62	28.91	216.38	33.16	244.04	37.40
7	Keeriparai	26.40	3.07	177.63	20.64	349.37	40.59	307.29	35.70
8	Kulasekaram	17.57	2.31	212.19	27.91	259.18	34.09	271.45	35.70
9	Kuzhithurai	10.72	1.24	201.85	23.36	387.11	44.79	256.33	29.66
10	Meekodu	11.78	1.49	175.86	22.31	317.67	40.31	282.78	35.88
11	Mulagumoodu	33.89	2.77	320.27	26.22	485.22	39.73	382.08	31.28
12	Nagercoil	43.72	3.78	336.75	29.13	387.78	33.55	384.50	33.26
13	Pechiparai	25.46	2.79	241.78	26.48	377.46	41.34	268.38	29.39
14	Surulacode	72.95	5.81	321.33	25.58	694.40	55.27	202.31	16.10
15	Thukkalai	27.05	1.94	362.37	25.99	505.47	36.25	505.77	36.27

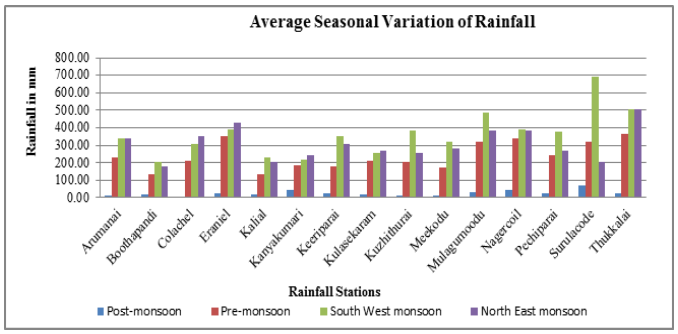

Figure .5 Average seasonal variation map (2000-2009)

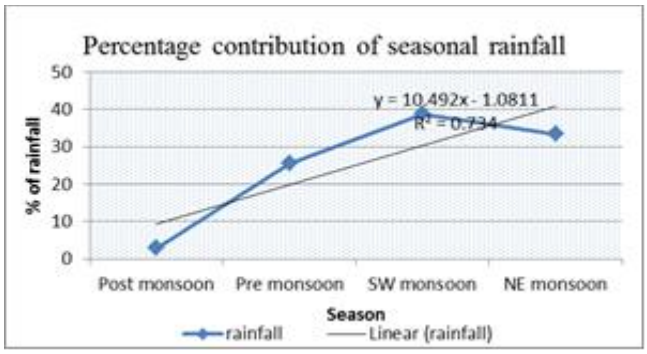

Figure .6 percentage of seasonal contribution of the study area

Spatial variation rainfall map

The spatial variation of seasonal rain fall distribution of post monsoon, pre monsoon, SW monsoon and NE monsoon is shown in figure 7 (a, b, c & d) respectively. From the post monsoon map it is noted that the south eastern side covers around 335Km^2(52.4%) of study area received the rainfall, in the range of 26mm to 39mm and the south western side covers 254km2 (40%) of the area received around 13mm to 26mm of rainfall. During the pre-monsoon period, central portion of area which includes Thukkalai, Mulagumoodu, and Eraniel covers 275km^2(43%) of total study area in the range of maximum of more than 270mm. Southwest monsoon map shows 425km^2 (67%) of the study area covers the range of rainfall between 340mm to 430mm.

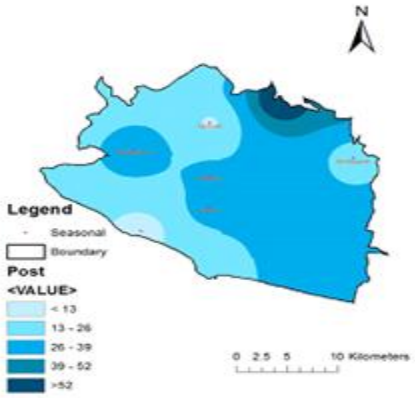

Fig 7 (a) Post monsoon

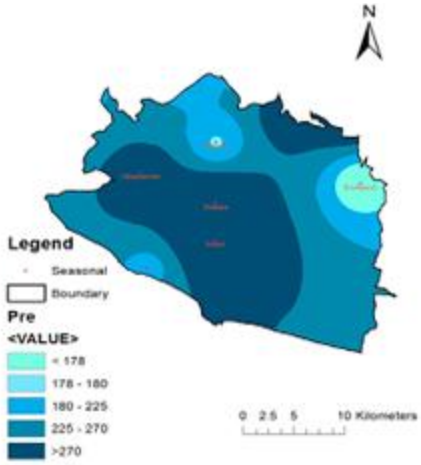

Fig 7 (b) Pre monsoon

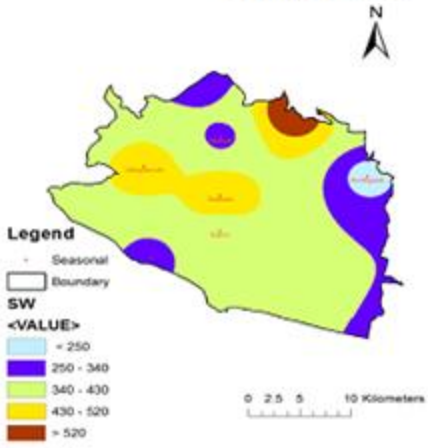

Fig 7 (c) South West monsoon

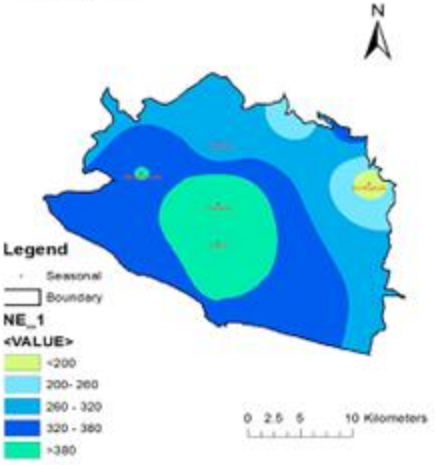

Fig 7 (d) North East monsoon

Figure .7(a, b,c.&d) Spatial variation of seasonal rainfall map

Average water level and its fluctuation in different seasons

The seasonal groundwater fluctuation map (Fig.8) prepared from the selected observation wells in the study area inferred that most of the wells have sufficient water level in all the four seasons. The spatial seasonal variation map of the study area is shown in figure 9 (a, b, c, &d). In which some wells show variation with respect to rainfall and the land use conditions. Thus indicating that these areas are of runoff zones and the recharge rate is lesser than other places, where Colachel (Fig.10), Nagercoil and Bhoothapandi were identified to have higher rate of fluctuation with respect to rainfall. Geogically these above stations fall under hard rock regions. The water holding capacity of the soil in the study area is good thereby the groundwater remains stable no matter how the intensity of the rainfall is. Hence the Spatial Variation of water level Fluctuations map for the all the four seasons are almost similar (Fig.9).

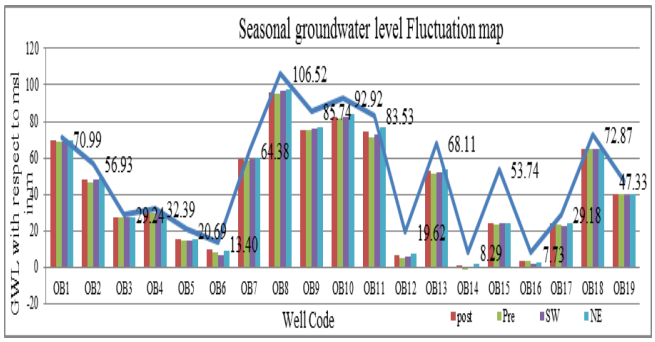

Figure.8 Seasonal variation of groundwater fluctuation with respect to mean sea level

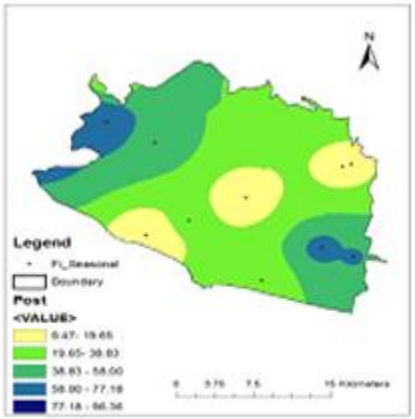

Fig 9(a) Post monsoon GW level

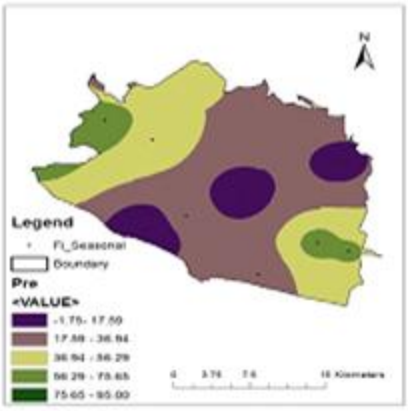

Fig 9(b) Pre monsoon GW level

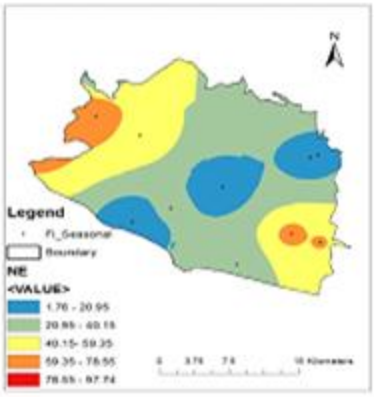

Fig 9(c) NE monsoon GW level

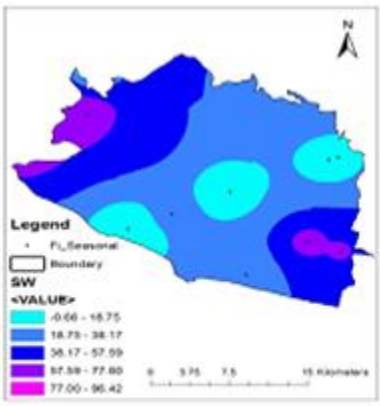

Fig 9(b) SW monsoon GW level

Figure. 9 (a, b, c & d) Spatial Variation of water level Fluctuations map

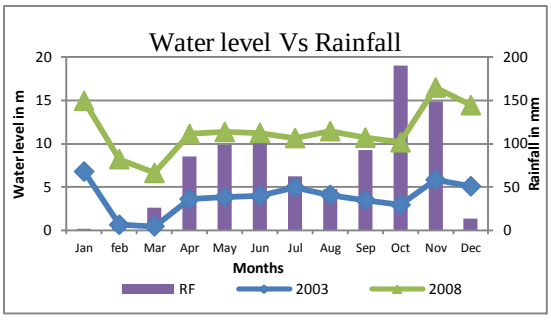

Figure.10 Rainfall Vs Groundwater level map

Around 60 % of the area is contributed to agriculture which includes cultivation of crops like paddy, coconut, plantains & various pulses involving irrigation which uses the available surface water bodies. Having many number of surface water bodies in these regions adds a good source for recharge the groundwater.

CONCLUSION

It is observed that by the month of January the water level starts lowering and by the month of May, the water level declined to 10m. Although there is substantial amount of rainfall in the south eastern region where the water level is near surface conditions during August, the average depth to water level also deepens by the month of May. This may be due to the hard rock terrain in the region which does not allow water to infiltrate into the deeper aquifer zones, and hence most of the water escapes as runoff and partially gets absorbed into the ground to sustain shallow aquifers. The entire study area can be divided into five groups based on their average annual rainfall distribution. The study of various data series viz., annual, monthly and seasonal indicated that northern part of the state receives higher annual, monsoon and July month rainfall. However, during December, the eastern and the western part of the state receive higher rainfall.

Monthly rainfall analysis shows that maximum rain showers are recorded during the month of October and the lowest rainfall intensity is usually recorded during January at all the rain gauge stations located in the study area. From the analysis of seasonal rainfall, it is found that the percentage contributions of rainfall during various monsoon periods are in the following order: SW monsoon (38.87%) > NE monsoon (33.5%) > Pre-monsoon (25.5%) > Post-monsoon (2.2%) spatial distribution pattern of rainfall indicates that the magnitude of rainfall increases towards central portion of study area during all the four monsoon (NE monsoon, pre-monsoon and post-monsoon) seasons. However, the magnitude decreases towards north easterly direction during SW monsoon period. Though the contribution of post-monsoon is too minimum, the rainfall intensity is higher in the North portion. As the study area is a hard rock terrain, it is observed that some of the places have deeper water levels during pre-monsoon season. Groundwater starts to replenish

the shallow aquifers during SW monsoon season and reaches high during NE monsoon period when plants are dormant and evaporation rates are less. The groundwater levels remain stable for the entire season and a few locations there is a variation of levels due to rainfall variation during pre-monsoon season.

Acknowledgments

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