Studies on the Effects of Rainfall and Soil Infiltration on Groundwater in Yerekoppi-1 Micro-Watershed Haveri district of Karnataka

ABSTRACT

The amount of water infiltrating the soil surface directly affects the quantity of surface runoff and erosion, and the recharge of both soil and ground water. Groundwater recharge is an informative indicator of the water located beneath the ground surface. It has a direct impact on renewable supplies of groundwater. In the present study, infiltration rate was used for effect on the groundwater level of the Yerekoppi-1 micro watershed (Manakur sub-watershed) in Haveri district of Karnataka state. In Yerekoppi-1 micro- watershed, 38 borewells are there in the vicinity of major stream of the micro- watershed. The mean depth of ground water levels in the micro- watershed were monitored at a monthly frequency during January-2023 to March-2024. It was found that the maximum average depth of bore wells are about 17.6 mbgl and lowest average depth of borewell about 8.8 mbgl. Soil infiltration rate was measured at upper, middle and lower reaches of the watershed area in the year 2023 and 2024. The majority of the area contributed clay soil. Inall the areas, infiltration rate for clay soil is less than 5 mm/hr. Infiltration rates for all the areas were 4.78, 4.30, 4.08, 3.37 and 1.72 mm/hr. Soil infiltration during a rainstorm is closely related to a number of factors such as the intensity and kinetic energy of the rainfall, soil surface conditions and soil properties such as those related to aggregate stability. The groundwater recharge may be improved by growing plantation crop for increasing infiltration rate, construction of percolation tanks and farm ponds in the lower most of the agricultural land.

Keywords**:** Infiltration rate, Drainage, Groundwater level, Rainfall and Soil texture

1. INTRODUCTION

The dynamic changes of climate and human activities have altered the natural flow of rivers [1] and in some arid and semiarid regions, flow of many rivers continue to decrease, even appeared zero flow in dry season. For survival of vegetation, typical water deficiency and ecological river system has brought a great impact to the ecology and social development [2]. The amount of water infiltrating into the soil surface directly affects the quantity of surface runoff and the recharge of both soil and ground water [3] which are the main sources of river flow. So, the river flow, especially the ecological basic flow which maintained by groundwater during periods of low or no rainfall is affected directly by rainfall infiltration. Correctly estimating the infiltration process over time is of importance in hydrologic budget determinations, watershed management and irrigation system design [4]. Soil infiltration during a rainstorm is closely related to a number of factors such as the intensity and kinetic energy of the rainfall, soil surface conditions and soil properties such as those related to aggregate stability, soil texture, structure, the mineral composition and soil moisture in the soil profile [3].

There is a need for rainfall intensity which has effects on groundwater recharge. Recharge results from effective precipitation (ie., precipitation minus losses from evapotranspiration) which infiltrate into the subsurface from where hydraulic gradients are downward [5]. In many environments, natural groundwater discharge sustains base flow to rivers, lakes and wetlands during periods of low or no rainfall, so increased attention should be given to the effect of rainfall on groundwater recharge - there is a need for more detailed investigations of rainfall intensity effects on groundwater recharge. An increase in soil moisture diminishes the hydraulic gradient, thus decreasing the driving force responsible for water infiltration into the soil [3]. The dynamics of soil water infiltration are governed by both energy and mass transport processes and initial soil moisture plays an important role in producing the mass and energy gradients. The power law functions between the infiltration capacity and the aboveground biomass increased in water-limited ecosystems, whereas vegetation biomass was not significantly related to infiltration capacity in humid regions [6].This paper combined to estimate the effects of rainfall intensities on groundwater regime and it could provide a thought for infiltration, ecological basic flow and watershed management of the study area.

2. METHODOLOGY

2.1 Study Area

Yerekoppi-1 micro-watershed (Manakur sub-watershed, Ranebennur taluk, Haveri district) is located in between 14^{0}32’45”-14^{0}35’37” North latitudes and 75^{0}37’49”-75^{0}39’14” East longitudes. The study area falls under the watershed codification of 4D4D2c08 with an area of 941.07 ha (Fig.1).

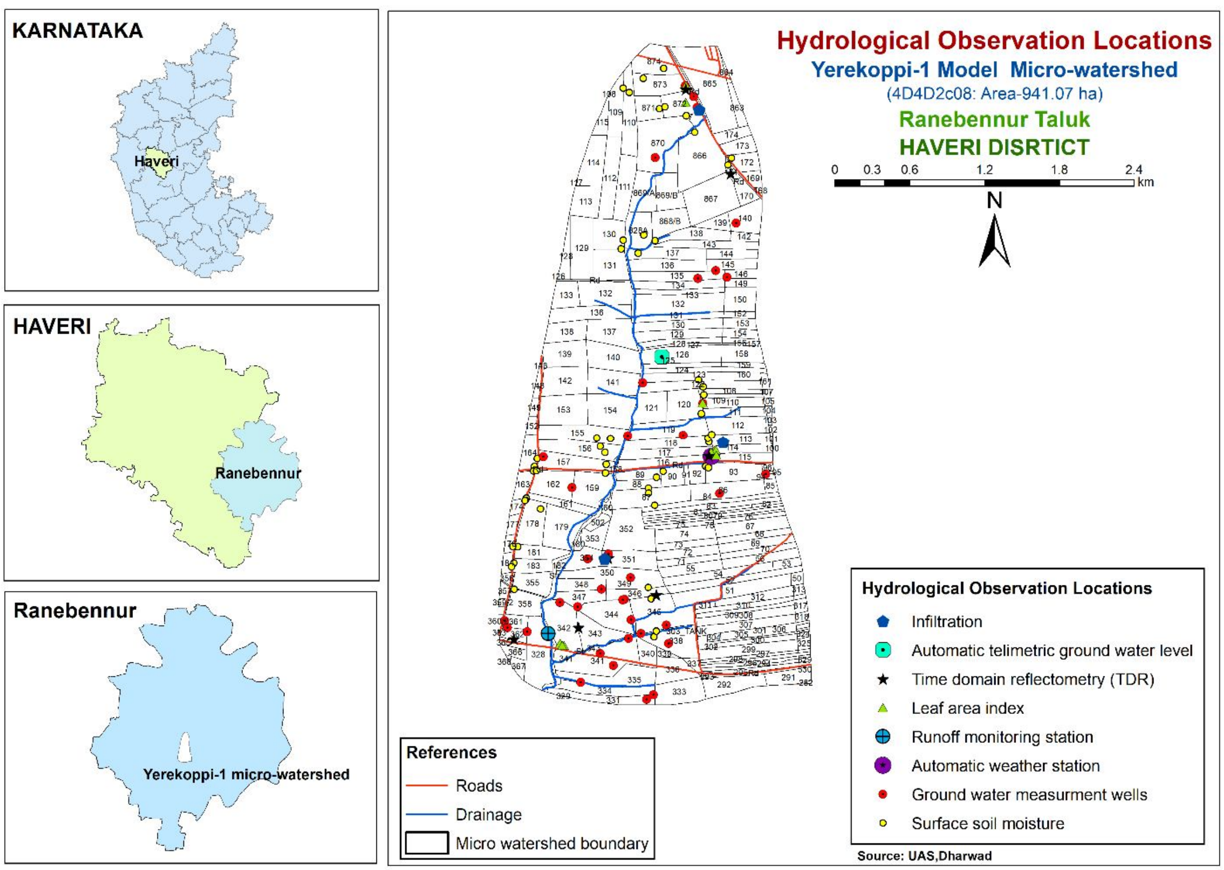

Fig. 1. Location of Yerekoppi-1 Model micro-watershed, Ranebennur taluk, Haveri district, Karnataka

2.2 Drainage, Rainfall and Natural Vegetation of the Micro-watershed

The micro-watershed has only few small tanks which are not able to store the water flowing during the rainy season. This is reflected in the failure of many bore wells in the villages. If the available rain water is properly harnessed by constructing tanks and recharge structures at appropriate places in the villages, then the drinking and irrigation needs of the area can be met to great extent. In order to develop the rainfall indices of the Manakura sub-watershed, data from the Ranebennur rain gauge station in Ranebennur taluk of Haveri district was taken into account. The annual rainfall at Ranebennur station (Hobli H.Q.) is presented.The natural vegetation is sparse comprising few tree species, shrubs and herbs. The mounds, ridges and boulders occupy some area which is under thin to moderately thick forest vegetation. Still, there are some remnants of the past forest cover which can be seen in patches in some ridges and hillocks in the micro-watershed.

2.3 Infiltration, Groundwater and Climate

The infiltration rate was measured at different soil phases. A double-ring infiltrometer was installed 10 cm deep in soil; care was taken to maintain the same instructed depth in all the soil phases. Out of the two cylinders, one was used to form buffer pond in order to avoid the lateral movement of water. Water level in cylinder was recorded with help of point gauge and stop watch. The point gauge was used to record the water level at the cylinder. The water level in cylinder was brought to initial level often at regular intervals of one hour. The measurements were continuous until the flow rate remained constant and the steady-state infiltration capacity was measured. In total 38 bore wells are selected for monitoring groundwater depth. The ground water level was recorded once in a month using water level indicator and also station coordinates are noted using GPS. The ground water level was recorded after 5 to 8 hoursof pumping stopped. Rainfall, temperature, humidity and PET data were collected from Karnataka State Natural Disaster Monitoring Center, Govt. of Karnataka for the study.

2.4 Soil texture and soil depth

Texture is an expression to indicate the coarseness or fineness of the soil as determined by the relative proportion of primary particles of sand, silt and clay. The most productive lands with respect to surface soil texture are clayey soils that have high potential for retention and availability of water and nutrients but, have more problems of drainage, infiltration, workability and other physical problems. The depth of the soil determines the effective rooting depth for plants and in accordance with soil texture, mineralogy and gravel content, capacity of the soil column to hold water and nutrient availability.

3. RESULTS AND DISCUSSION

3.1 Digital Elevation Model and Drainage System

Digital Elevation Model (DEM) obtained by processing the Cartosat-1 data at a spatial resolution of 30 m is available for entire India. The DEM for the study area is shown in Fig.2.The elevation shows a significant variation with the difference in minimum and maximum elevation being approximately 65 m. Drainage delineation analysis is an important application of DEM to demarcate the drainage basin. A drainage basin is the topographic region from which a stream receives runoff, through flow and groundwater flow. A number of factors like topography, soil type, bedrock nature, climate, vegetation cover, fracture pattern, etc. influence input, output and transport of sediment and water in a drainage basin. The absolute accuracy evaluation result shows in flat, hilly and mixed areas (flat and hilly), if the region of interest is on the flat region, the height accuracy is better than hilly areas. Hence it is inferred from the results that the elevations are found to be influenced by the ruggedness of the terrain [7].

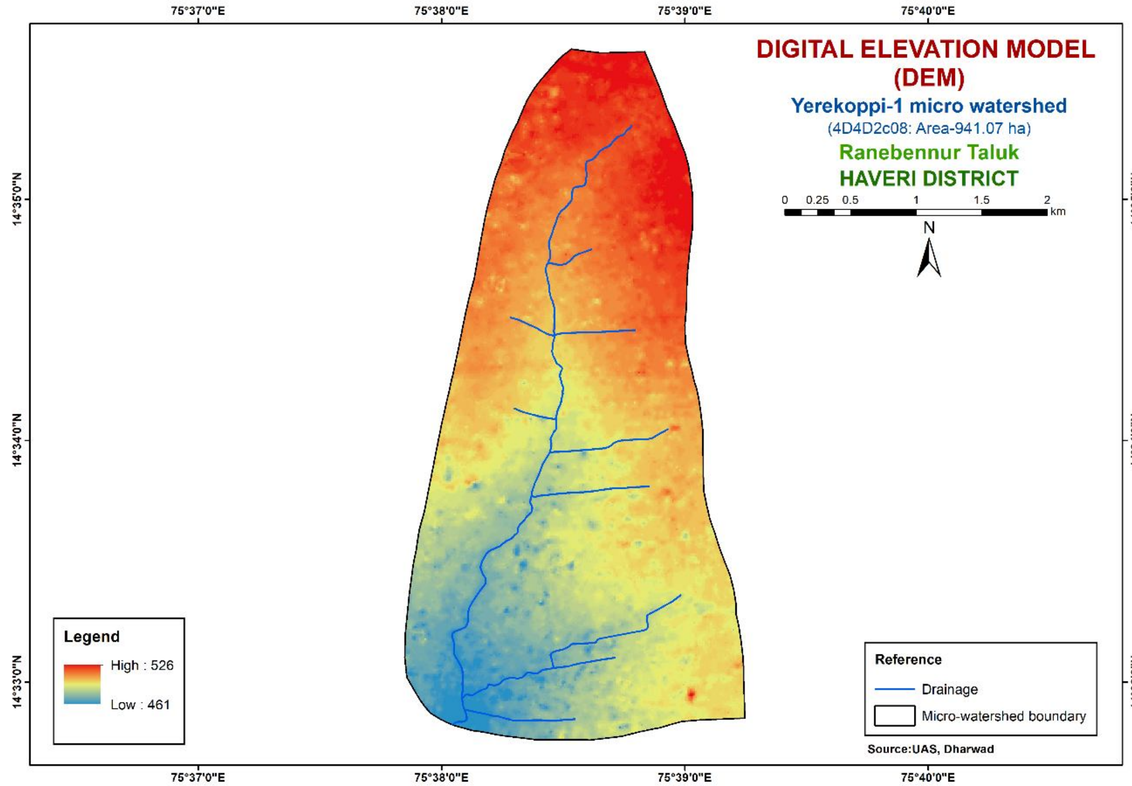

Fig.2. Digital Elevation Model (DEM) of Yerekoppi-1 micro-watershed, Karnataka

3.2 Natural Vegetation

The natural vegetation is sparse comprising few tree species, shrubs and herbs. The mounds, ridges and boulders occupy some area which is under thin to moderately thick forest vegetation. Still, there are some remnants of the past forest cover which can be seen in patches in some ridges and hillocks in the sub-watershed.Apart from the continuing deforestation, the presence of large population of goats, sheep and other cattle in the sub-watershed is causing vegetative degradation of whatever little vegetation left in the area. The uncontrolled grazing has left no time for the regeneration of the vegetative cover. This leads to the accelerated rate of erosion on the hill slopes, resulting in the formation of deep gullies in the foot slopes and eventually resulting in the heavy siltation of few tanks and reservoirs in the sub-watershed.There were some litters covered on soil surface, but almost no microbiotic soil crust and surface vegetation. According to the interactions between soil and vegetation in ecological succession, annual species usually growon the soil where soil texture wasloose and aeration conditions were better [8]. The soil surface beneath shrubs or trees is protected by the canopy from raindrops, reducing the formation of soil crusts and enhancing the soil infiltration capacity. The findings suggest that land conversion improves soil water retention and hydraulic conductivity, thus attenuating the generation of surface runoff [9].

3.3 Weather Parameters

The average annual rainfall (2014-2021) recorded at the Ranebennur (GP) was 700.7 mm in last 7 years (Table 1). The maximum precipitation of 376.3 mm is received during south–west monsoon period from June to September, north-east monsoon contributes about 162.1 mm and prevails from October to early December and the remaining 162.4 mm is received during the rest of the year. During the year 2015, 2016, and 2017, annual rainfall was deficient by 19.6%, 43% and 43%, respectively, During 2014, 2019 and 2021, annual rainfall was excess by 43% , 37% and 43 %, respectively as compared to average annual rainfall (Fig.3). The winter season is from December to February. During April and May, the temperatures reach up to 36.9°C and in December and January, the temperatures will go down to 17.8°C.

Table 1 Mean monthly rainfall, PET, 0.5 PET at RanebennurTaluk, Haveri District

Month	Rainfall (mm)	Temp Max (°C)	Temp Min (°C)	Max RH (%)	Min RH (%)	PET (mm)	0.5 PET (mm)
January	7.5	31.1	17.2	85.4	33.1	109	54.5
February	4.6	33.3	18.6	78.4	24.6	124	61.8
March	8.8	35.9	21.2	81.9	22.4	181	90.6
April	41.9	36.9	23.1	87.4	25.8	154	77.0
May	99.6	35.1	23.4	89.8	40.2	151	75.4
June	91.8	31.7	22.9	92.3	55.7	126	63.2
July	104.5	29.1	22.2	93.5	66.0	130	64.8
August	104.3	29.0	21.9	94.7	68.6	130	65.2
September	75.7	30.4	21.6	97.7	65.0	109	54.7
October	126.4	31.0	21.1	99.1	59.6	129	64.5
November	34.0	31.0	19.4	95.3	49.6	98	49.0
December	1.7	31.0	17.8	92.3	42.3	101	50.4
Total	**700.7**					**1541.8**	**770.9**

Rainfall distribution, Potential Evapotranspiration and 0.5 PET is shown in Fig.4. The average monthly Potential Evapotranspiration (PET) is 128.5 mm and varies from a low of 98 mm in November to 181 mm in the month of March. The PET is higher than precipitation in all the months. Generally, length of growing period in Guddadanveri sub-watershed ranged from 180 to 190 days. The length of growing period begins at 17^{th} week (which is April 4^{th} week) and ends at 43^{rd} week (which is October 4^{th} week). While 26^{th} standard week in the growing season may be critical for moisture which means that May 4^{th} week and partly July 1^{st} week could be meteorologically drought period, during which precipitation is not sufficient enough to meet the minimum PET demand of the crops/ vegetation in the region. Dry spells/weeks are not found continuous and growth of crops may not be markedly affected if the recommended drought management practices for a given crop/crops are adopted. One protective or life - saving irrigation based on the critical stage of the crop would be of great advantage [10]. Based on the observation, farmers can schedule sowing and other agronomic practices for short duration and long duration crops.The major crops in the micro watershed were maize, cotton, arecanut, soybean, onion, rabi sorghum, sunflower and chilli.

Water consumption by crops varies substantially, reflecting differences in cropping density, crop choice, soil characteristics, irrigation availability and agricultural management as well as climatic drivers of evapotranspiration. The choice of suitable crop likely to contribute substantially towards water saving without affecting food production, where water resources are scarce [11].

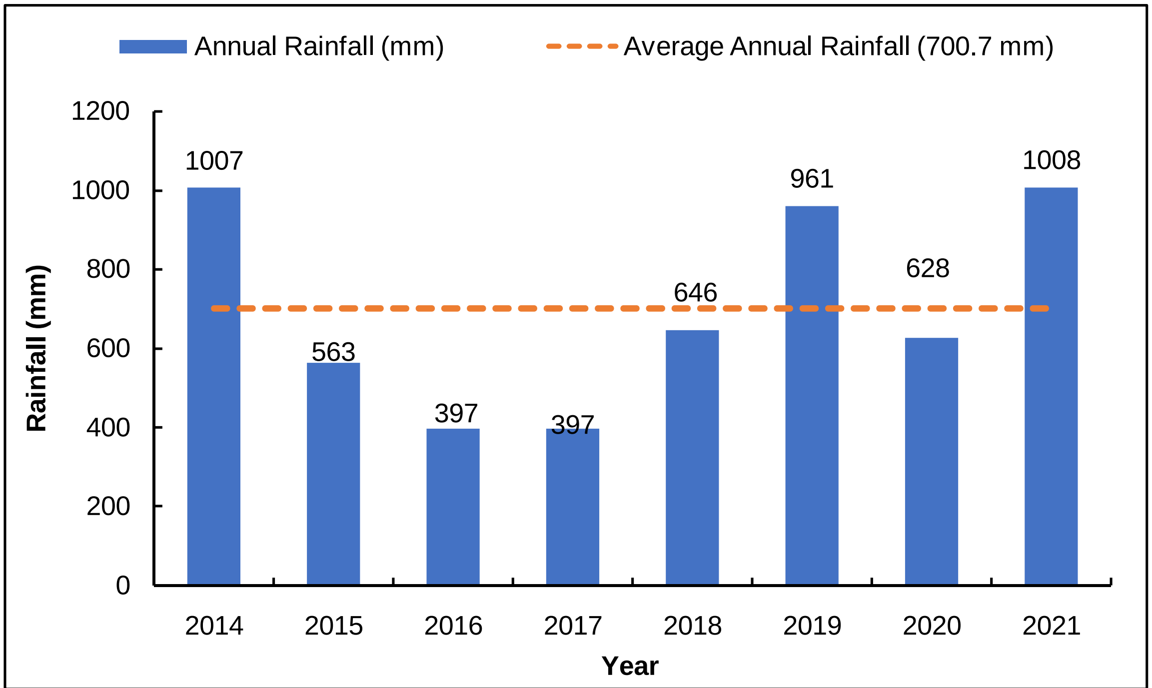

Fig.3. Average annual rainfall ofRanebennur Taluk, Haveri District

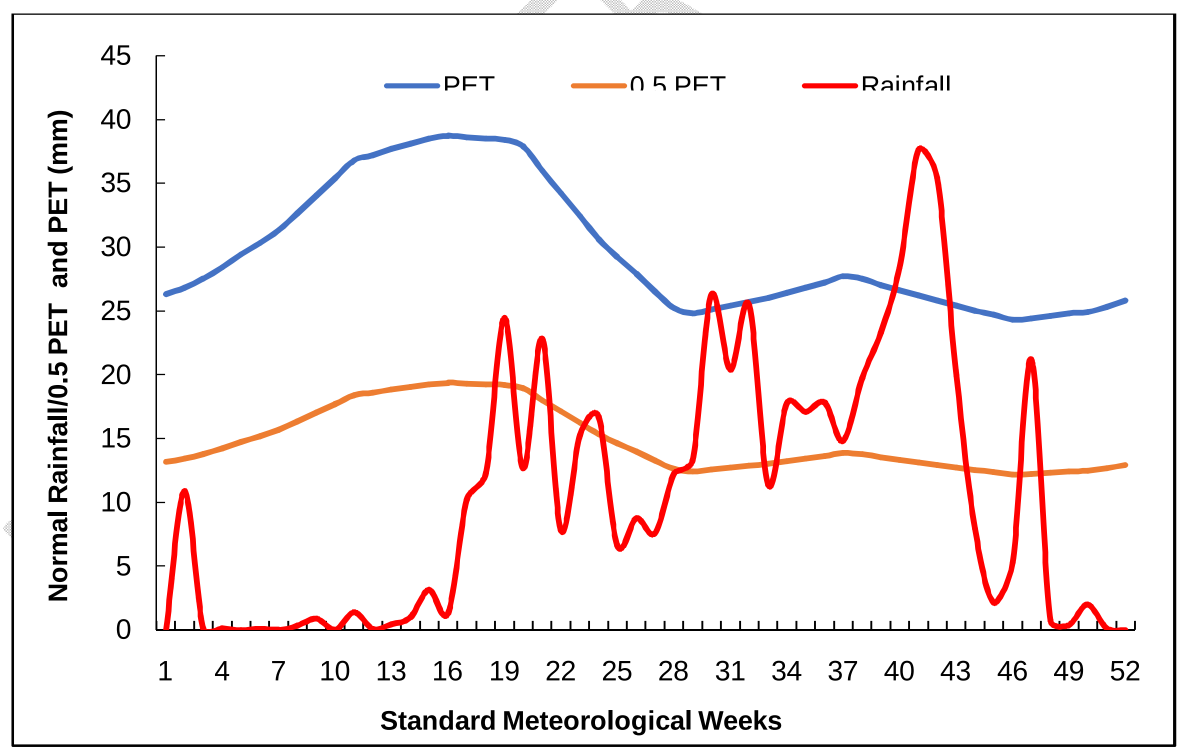

Fig. 4. Mean weekly rainfall, PET and 0.5 PET at Ranebennur Taluk, Haveri District

3.4 Infiltration rate

Soil infiltration rate was measured at upper, middle and lower part of the watershed area in the year 2023-24 and 2024-25. The majority of the watershed area is contributed by clay soil. For all treatments, the infiltration rate for clay soil isless than 5 mm/hr. Infiltration rates for all the areas were 4.78, 4.30, 4.08, 3.37 and 1.72 mm/hr and R^2 for the trend line reaches the value of 0.089, 0.961, 0.603, 0.695 and 0.0481, respectively (Fig. 5). The lowest part of the area had the numeric less infiltration rate than middle and upper part of the micro watershed. The reason was likely attributed to the differences in soil pores at the different slope positions induced by the differences in soil erosion and deposition processes. Due to the flat terrain and low area for runoff concentration at the upper area, the surface runoff had transported the silt particles and organic matter. In contrast, the decomposed aggregates or clods are prone to consolidate, which decreased infiltration rate via reducing soil pores [12,13].

Infiltration rates decrease linearly at R^2 =0.481 with the increase in soil strength. This indicates that the soil layer with high resistance to penetration controls the movement of infiltrated water to lower the infiltration rate. This condition is due to the soil condition at this area where the topsoil consists of compacted soil due to the past logging activities [14], which leads to less void space between space particles and reduces the availability of macro pores, which is an important pathway in the process of infiltration of water into the soil [15].

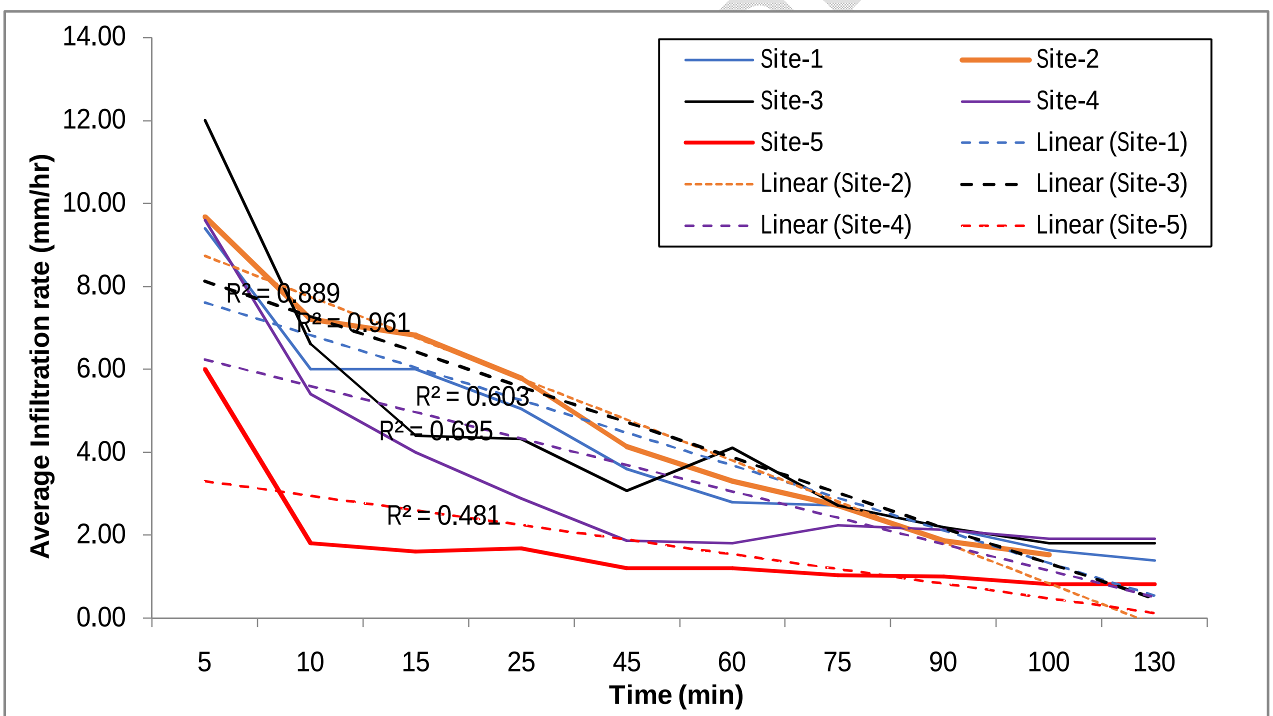

Fig.5. Infiltration rate at different sites of Yerekoppi-1 micro watershed, Karnataka (2023-24)

3.5 Groundwater Depth

Groundwater levels fluctuate naturally in response to a sequence of climatic events and to constraints imposed by hydrogeologic and topographic characteristics. The groundwater level influenced by borewell recharge, discharge, topography of land, soil texture etc. Trend analysis of water table depths indicates marked spatial variations of groundwater levels in Yerekoppi-1 micro-watershed of the study area. The depth to water table was recorded from April,2023. The deeper water table (17.6 mbgl) was recorded during March,2024 and the shallow water table depth of 8.8 mbgl was recorded during October,2023 (Fig.6). These data indicated marked spatial variability in the distribution of wells with distinct rates of change across the different geomorphic units visible [16]. Groundwater resource of a region is one of the building blocks for balanced economic development of the area. The water table represents the groundwater reservoir and changes in its level represent the changes in groundwater storage [17].

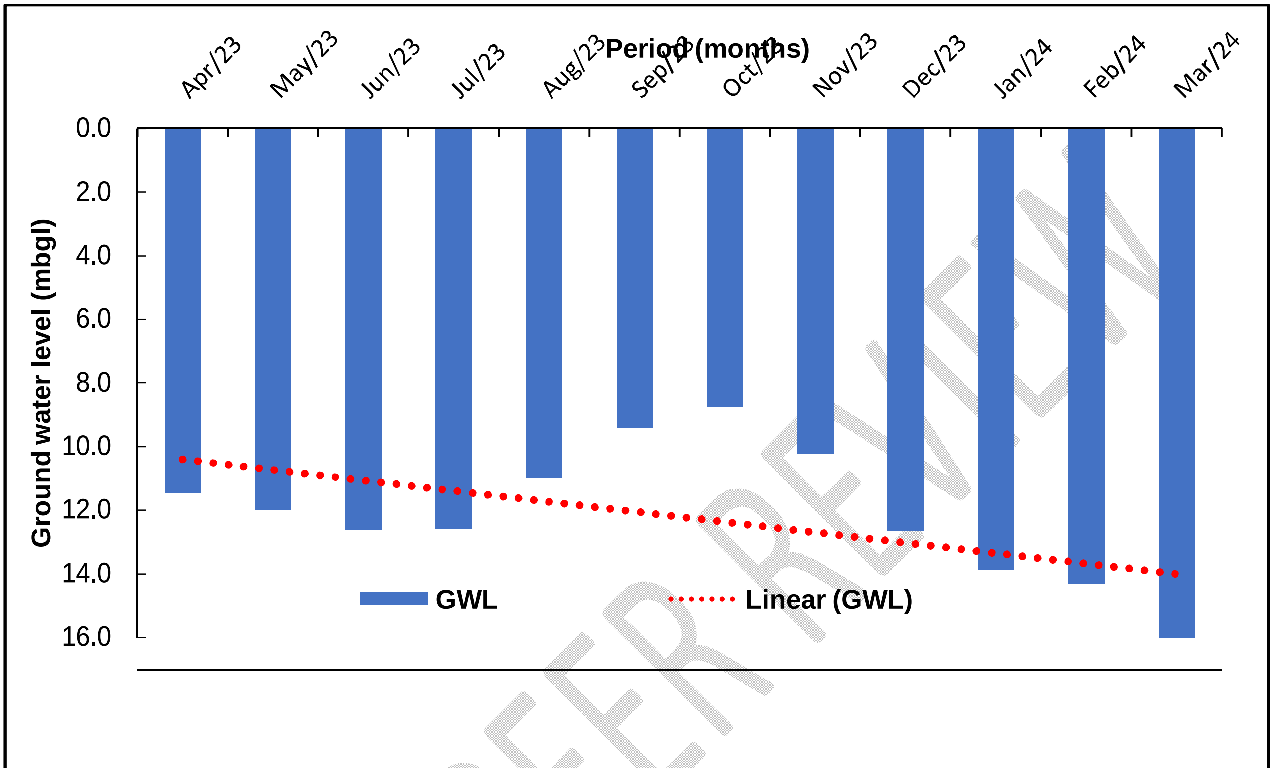

Fig.6. Ground water depth of Yerekoppi-1 micro-watershed, Karnataka

The groundwater levels during the summer, Kharif and Rabi for the year 2023 observed at 38 wells located in Yerekoppi-1 micro-watershed has been used to create point maps in GIS. The groundwater table in the Yerekoppi-1 micro-watershed has been recorded between 6.68 to >25.49 mbgl during summer, 6.38 to > 16.7 mbgl during kharif and 6.99 to >21.40 mbgl during Rabi season (Fig. 7a,b,c). During summer season, most of the watershed area has deeper water table and during rabi season has a medium groundwater table in the year 2023 (Fig.7a,b,c). The highest groundwater elevation occurred in north-eastern part to north of the study area and the lowest groundwater elevation obtained in the south-eastern to south parts of the study area. The groundwater elevation gradients are higher in northern part and gradually decrease towards the southern parts and the general flow occurs from north to south [18].

The groundwater table is deep on the upstream side and shallow on the mid and valley side. This is possibly due to the flux that the water drains down slope to bring the soil moisture to the field capacity [19]. In addition, the soil depth on the upslope is shallow, which means it dries out faster than the deep soils due to evaporation; therefore, the quantity of water flowing toward the well is declining faster as compared with well in the deep soil [20].

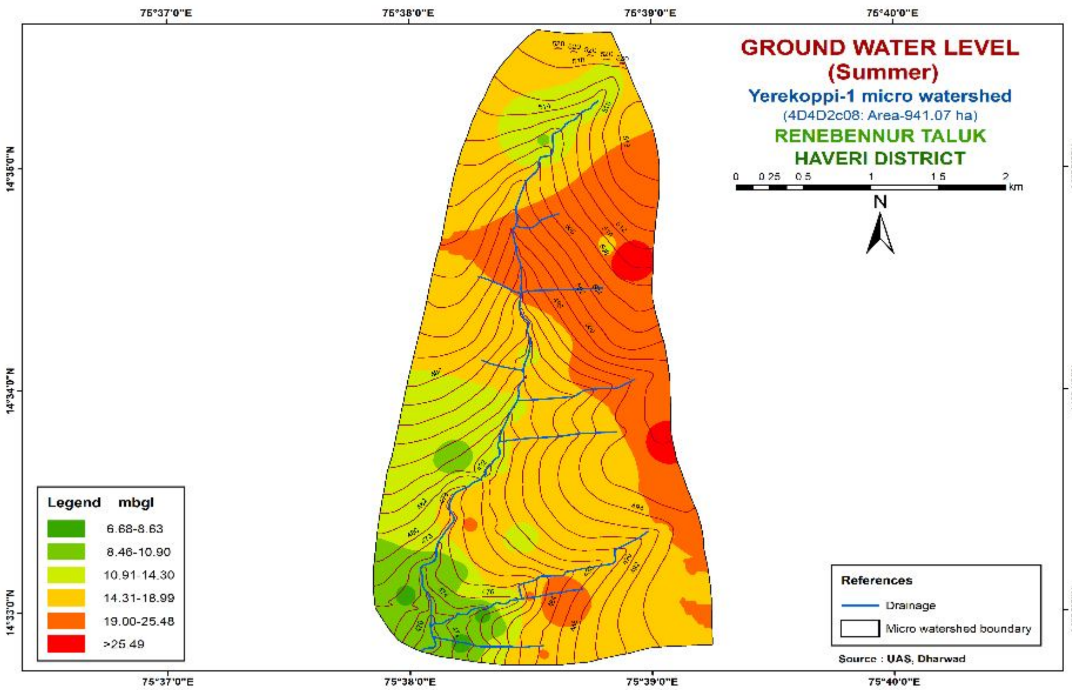

Fig.7a. Ground water depth at Yerekoppi-1 micro-watershed during summer

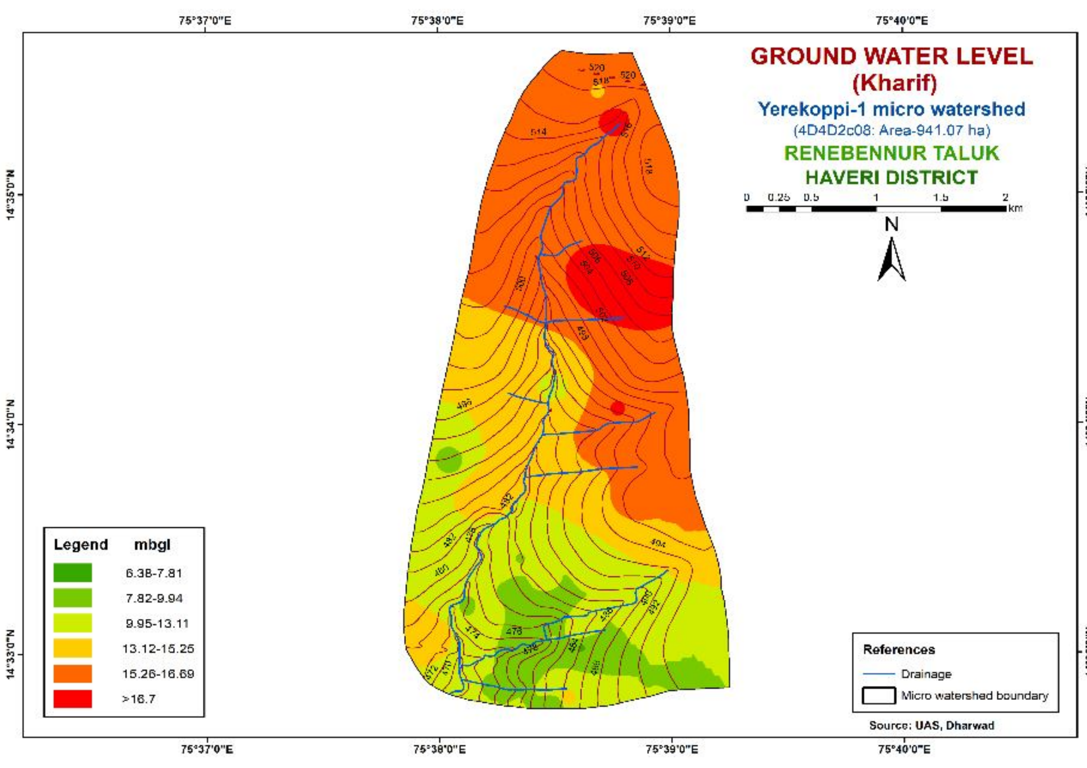

Fig.7b. Ground water depth at Yerekoppi-1 micro-watershed during kharif

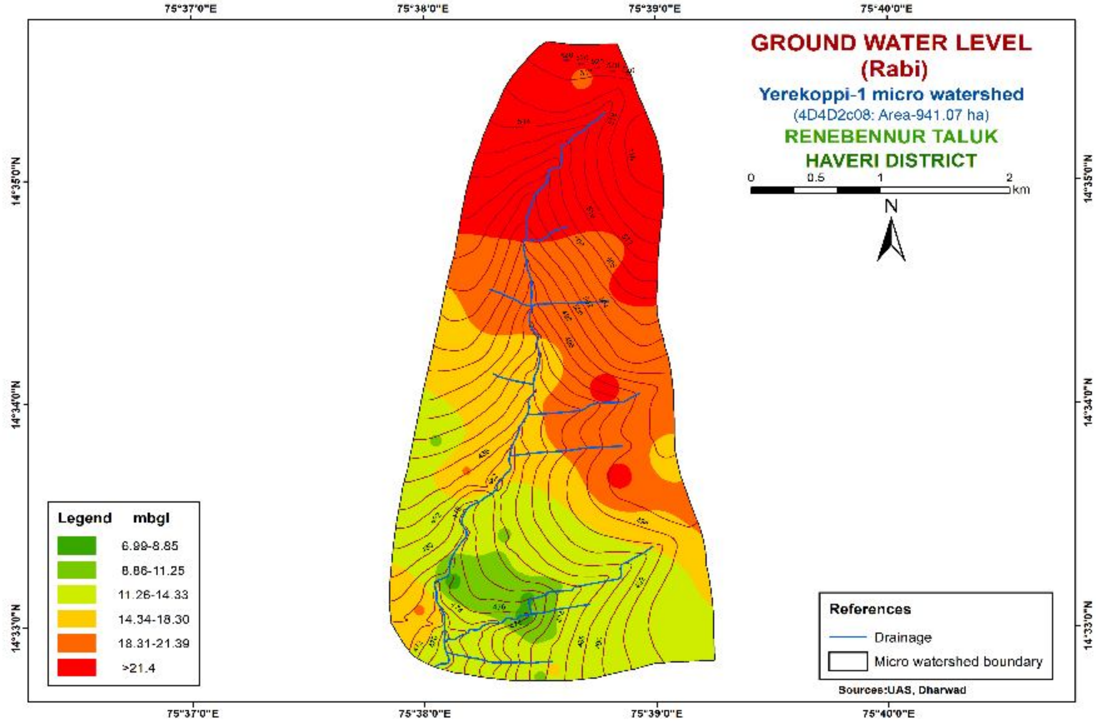

Fig.7c. Ground water depth at Yerekoppi-1 micro-watershed during Rabi.

3.6 Soil Texture and Soil Depth

Texture is an expression to indicate the coarseness or fineness of the soil as determined by the relative proportion of primary particles of sand, silt and clay. It has a direct bearing on the structure, porosity, water infiltration, adhesion and consistence. The surface layer of a soil to a depth of about 25 cm is the layer that is most used by crops and plants. The surface soil textural class provides a guide to understanding soil-water retention and availability, nutrient holding capacity, infiltration, workability, drainage, physical and chemical behaviour, microbial activity and crop suitability. An area of about 888 ha (94.32 %) has clay texture at the surface and 53 ha (5.68%) area has contributing settlement (Fig.8). The most productive lands with respect to surface soil texture are clayey soils that have high potential for retention and availability of water and nutrients but, have more problems of drainage, infiltration, workability and other physical problems.

The depth of the soil determines the effective rooting depth for plants and in accordance with soil texture, mineralogy and gravel content, the capacity of the soil column to hold water and nutrient availability. Soil depth is one of the most important soil characters that are used in differentiating soils into different soil series. The soil depth classes used in identifying soils in the field are shallow (25-50 cm), moderately deep (75-100 cm), deep (100-150 cm) and very deep (>150 cm). They were used to classify the soils into different depth classes and a soil depth map was generated (Fig.9).

Shallow (25-50 cm) soils cover an area of about 26 ha (2.8 %), moderately deep soils (75-100 cm) cover an area of about 127 ha (13.51 %), deep soils (100-150 cm) cover an area of about 50 ha (5.3 %) and very deep soils (>150 cm) cover an area of about 684 ha (72.7 %). The most productive lands with deep (100-150 cm) and very deep (>150 cm) soils cover about 734 ha (78.38 %) where all climatically adopted long duration crops be grown. The maximum clay content at any depth of the profile is one of the key factors controlling the movement further down the profile and thus, the final steady rate [21].

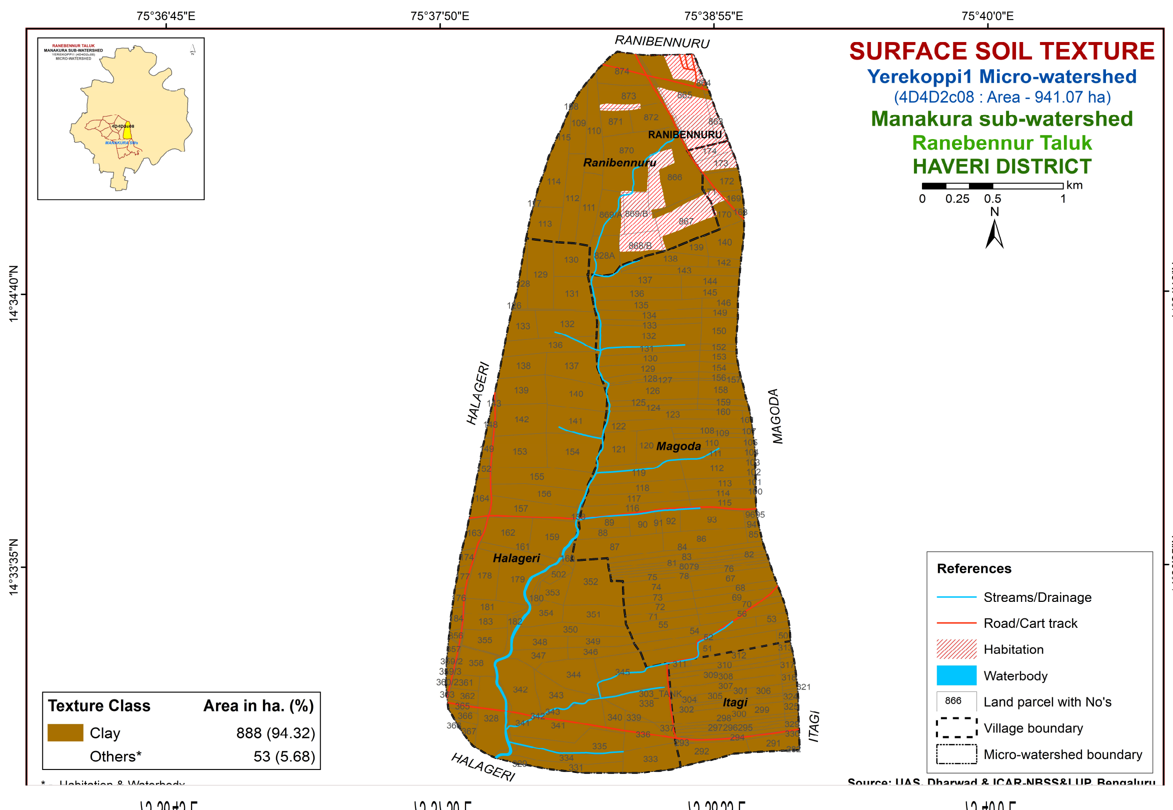

Fig.8 Soil texture of Yerekoppi-1 micro-watershed, Ranebennur Taluk, Haveri District

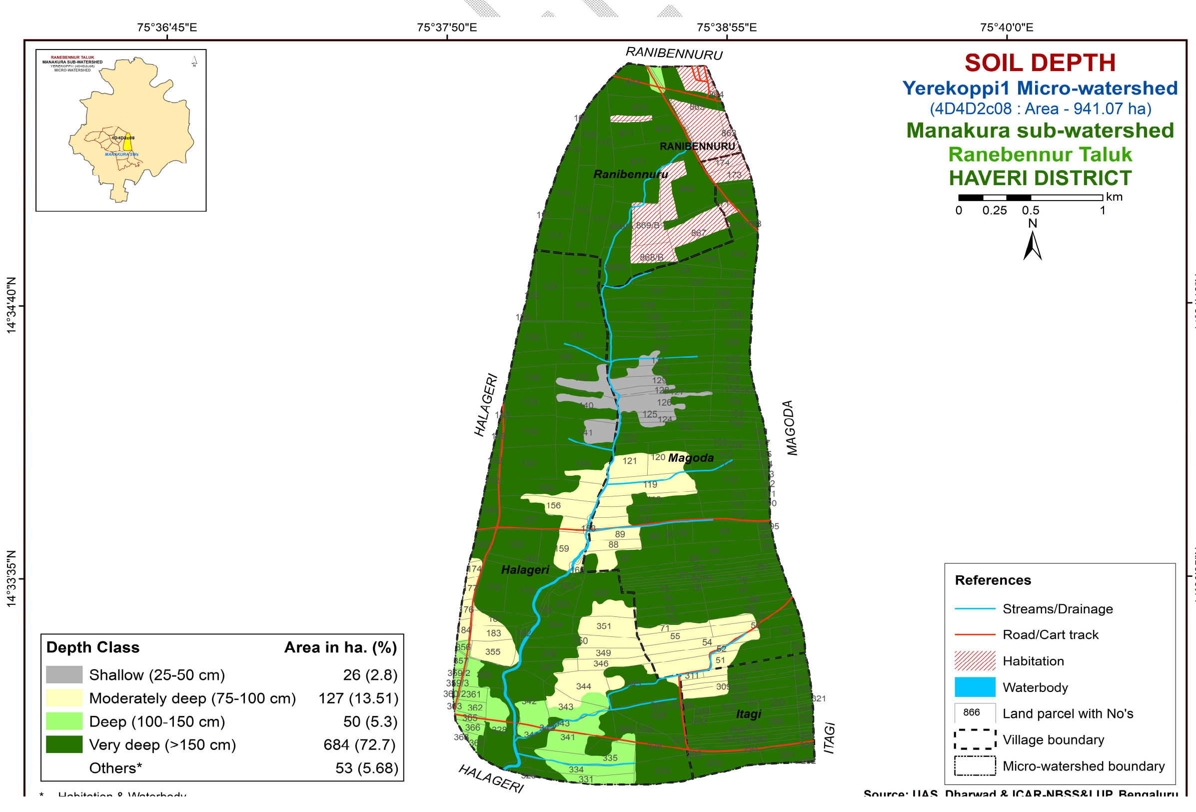

Fig.9 Soil depth of Yerekoppi-1 micro-watershed, Ranebennur Taluk, Haveri District

4. CONCLUSION

Infiltration rates were generally low in the entire study area, the penetration depth of rain events, which form the majority of the total precipitation in semi-arid conditions, is limited exposed to intense evapotranspiration and ultimately reduces the groundwater recharge potential. The areas with higher drainage density may have lower potential for groundwater recharge due to increased surface runoff and reduced infiltration. The groundwater map shows the natural topography and prevailing conditions in the watershed are favorable for declining water table. The point recharge and farm ponds may be constructed in the lower most corner of the agricultural fields to increase the natural recharge of rain water during the monsoon period.

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