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INTERACTION OF SOIL WITH GROUNDWATER REGIME IN SHALLOW UNCONFINED AQUIFER OF WRC-1 WATERSHED, CENTRAL INDIA

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ABSTRACT

Different soil types have their own distinct impact on the groundwater levels, seasonal water table fluctuations and yield of the open dug wells. The aim of this study was to evaluate the role of different soil types and their possible implications on groundwater regime in unconfined aquifers. This paper is concerned with the static groundwater levels, water table fluctuations and yield of the open dug wells in different types of soils. The results indicate: (A) Clayey soil represents 12.2 to 13.11 mbgl pre-monsoon SWL, 7.02 to 8.54 mbgl post-monsoon SWL, 4.57 to 5.18 meter water table fluctuation and yield of the dug wells between 36 m^3/day to 90 m^3/day in pre-monsoon respectively; (B) Fine Calcareous soil represent 7.02 to 16.16 mbgl pre-monsoon SWL, 3.66 to 9.6 mbgl post-monsoon SWL, 1.52 to 6.71 meter water table fluctuation and yield of the dug wells between 36 to 72.9 m^3/day in pre-monsoon respectively; (C) Loamy soil and clayey soils (mixed) with moderate erosion (mixed) represent 4 to 18.9 mbgl pre-monsoon SWL, 3 to 12.93 mbgl post-monsoon SWL, 3 to 12.5 meter water table fluctuation and yield of the dug wells between 9 to 97.2 m^3/day in pre-monsoon respectively; (D) Loamy soil represent 5.79 to 8.54 mbgl pre-monsoon SWL, 2.15 to 4.27 mbgl post-monsoon SWL, 1.52 to 6.39 meter water table fluctuation and yield of the dug wells between 33.75 to 67.5 m^3/day in pre-monsoon respectively. Thus out of four types of soil zones, C- soil zone (loamy + clayey soil) represent deeper groundwater levels, probably due to deeply weathered condition. The water table fluctuation (WTF) also indicates similar results where, C-soil zone has greater WTF values as compared to A, B and D soil zones. On the other hand yield of the open dug wells, tapping unconfined aquifers has higher values in B, C and D soil zones, which indicates negligible control of soil zone on yield of the dug wells. This deviation (higher yield values) may be due to other hydrogeological characteristics of the aquifer and not influenced by soil zones.

Keywords: Watershed, Soil, Static groundwater levels (SWL), Water table fluctuation (WTF) and Yield of the dug wells.

INTRODUCTION

Groundwater is the sub-surface water that occurs beneath the water table in the soils and geological formations that are fully saturated (Freeze, 1987). Soil hydrology determines the water–soil–plant interactions in the Earth's system, because porous medium acts as an interface within the atmosphere and lithosphere, regulates main processes such as runoff discharge, aquifer recharge, movement of water and solutes into the soil and ultimately, the amount of water retained and available for plants growth (Di Prima, et al., 2020). Soil hydrology can be strongly affected by land management (Di Prima, et al., 2020). Understanding the landscape-soil interaction through geomorphological analysis and mapping enables better land use planning, watershed management and landscape ecological planning (Fairbridge, 1968). Therefore, investigations of assessing the impact of land management changes on the soil hydrology are necessary, especially with a view to optimise water resources (Di Prima, et al., 2020). Understanding spatial patterns of soil attributes in similar climatic and geological terrain circumstances can be accomplished by analyzing the landform-soil interaction in conjunction with drainage and elevation factors (Bell et al., 1994; Gessler et al., 1995). Hydropedology focuses on the interface between the hydrosphere and the pedosphere and emphasizes flow and transport processes in field soils as they occur in the landscape (Ya-Sin Yang, et al., 2006). The consistency, depth, texture, structure, colour, formation of identifiable subsurface horizons and morpho-logical features of soils derived from various parent materials vary (Tamgadge and Ghosh, 1991). On the basaltic terrain, landscape configuration characteristics follow a fairly specific soil pattern, which affects soil morphology and physico-chemical properties (Pofali et al., 1979). Numerous studies on soil mapping using visual interpretation of remotely sensed data have been published (Venkataratnam, 1984; Prasad et al., 1990) and particularly the 1:50,000 scale has been proven to be quite effective for soil mapping at various levels (Ahuja, et al., 1992). Aim of the present study was to evaluate pre-monsoon and post-monsoon static ground water levels, water level fluctuations and yield with different soil zones.

STUDY AREA

The study area is a part of WRC-1 watershed, Chargarh river basin and covered under Survey of India topographic maps 55G/15, 55G/16, 55K/3 and 55K/4 and bounded by 77°45' - 78°05' E longitude and 21°0 - 21°25' N latitude, covering an area of 412.51 sq.km. (Fig.1). The Chargar river originates in the Satpura mountain range and flow from North-West to South-East direction through Khed, Udkhed and Ghatladki area and meet Wardha river near Bhambora village in Morshi tahsil of Amravati district, Maharashtra State, India.

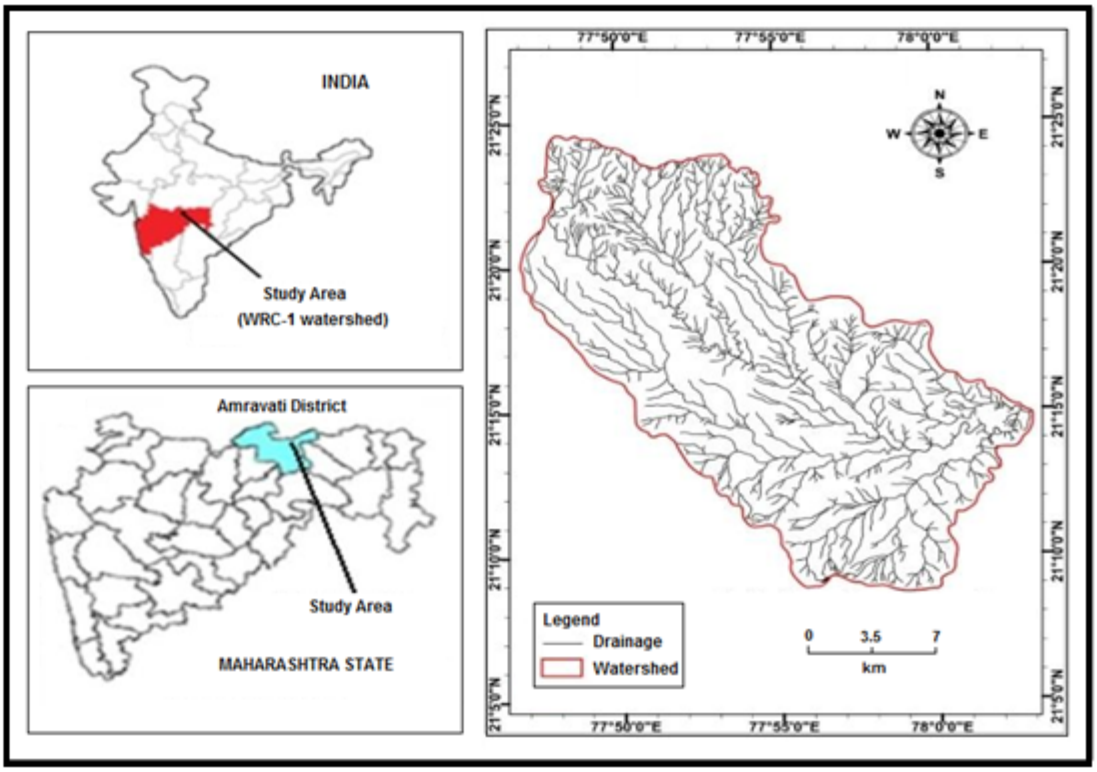

Fig. 1: Location map of the study area.

MATERIALS AND METHODS

The Survey of India topographic maps 55 G/15, 55G/16, 55 K/3 and 55K/4 (1:50,000 scale) are utilized to generate a base map of the study area. The WGS-1984,UTM-Zone-43N projection system was utilized to delineate geomorphological units from the digital elevation model (DEM) in Arcmap 10.2 software. For accurate results and to consider recent substantial changes in the drainage pattern, IRS-Resource Sat-II, LISS-III false colour composite (FCC) satellite imagery (Tile F43R15, F43R16, F43M03 and F44M04) was utilized. The image was obtained from Resource Sat-II (November 2017) with a spatial resolution of 23.5 metres and three spectral bands green, red, and near-infrared (NIR) were used to create the false color composite imagery. The Remote sensing applications were utilised to interpret geology, hydrology, geomorphology, soil and slope features of the area, by applying supervised and unsupervised classification and spatial enhancement techniques. During present study, Arc-Map 10.2 software has been utilized along with the spatial entities such as point data (bore well, dug well, village location etc.) and polygon data (natural tank, ponds, soil, geology, geomorphology etc.). All the spatial entities (spatial data) are linked with the related attribute data sets in contradictory data structure as hierarchical and relational database structure. The Arc-Map 0.2 GIS software is also utilized to prepare sub-surface hydrogeological maps and digital elevation models of the Chargarh river basin.

For the soil analysis, soil maps prepared by (EUDASM), National Bureau of Soil Surveys (NBSS), Joint research centre European Soil Data centre and Land use planning (LUP) were referred. To determine landform-soil relationship, geomorphological units were overlaid separately on the thematic maps of drainage, slope, soil, soil depth and erosion. Hydrologic soil groups and land cover/use are more important in determining the Curve

Number value (USDA 1986). According to the soil texture classification scheme of the United States Department of Agriculture (USDA), soil can be classified into 12 textures, ranging from sand to heavy clay. Four hydrologic soil groups are derived from these soil properties (Ziyue Zeng, 2017).

GEOMORPHOLOGY

The geomorphological features of the area are highly dissected plateau, moderately dissected plateau, residual hill, valley, strike ridge, scarp, pediment, pediplain, butte, alluvial plain, gullied land, valleys and water bodies of Chargarh river. Geomorphologically, the area can be classified into two major classes as highly dissected plateau (HDP) and moderately dissected plateau (MDP). The lineaments and geomorphological units indicate numerous long and short fractures which can be responsible for the infiltration of surface water into underground formations. The major part of the watershed is under MDP category, with thick soil cover and thick weathered mantle.

SOIL

Basaltic lava flows are covered by a thin soil cover, which extends up to 2 meter depth in the watershed area. These are predominantly black soils with a few calcareous particles. The soil is classified as loam based on the quantities of sand, silt and clay. It ranges from silty clay beneath the loam to 'clay loam' due East of the watershed, categories as 'silty clay' category. Natural infiltration is controlled by the soil profile and type. Due to heavy irrigation of the orange crop in the watershed area, soil moisture in the centre and southern parts of the watershed is extremely high (National Bureau of Soil Survey and land use planning, NBSS and LUP, 2023). Four types of soils are observed in the WRC-1 watershed with different hydrogeological characteristics. In the study area, there are stretches of fertile black soil in the South-Eastern part of Morshi and Southern part of Chandur Bazar tehsil of Amravati district. On the banks of the Wardha river, deep rich black soils make up the south-eastern part of Morshi tahsil and also medium to deep black soil and deep brown to red soil have been identified. Aim of this work is to identify the inter-relationship between soil, slope and hydrogeology of the area by adapting remote sensing and GIS technique. The different soils exposed in the area are derived from different rock types. The study of soil is important because variety of soil textures are responsible for the groundwater infiltration and water holding capacity for longer duration (Fuladi and deshmukh, 2025). The sand (0.06 mm to 2 mm diameter) helps in high infiltration of groundwater, silt (0.02 mm to 0.06 mm diameter) has medium infiltration rate and clay (< 0.02 mm diameter) has low infiltration rate. In the WRC-1 watershed, the different soil types are described as follows: (A) Clayey soil on gently sloping dissected lands with moderate erosion, (B) Fine Calcareous soil on very gently sloping plains and valleys with moderate erosion, (C) Loamy soil on gently sloping lower plateau with severe erosion; clayey soils with moderate erosion (mixed),(D) Loamy soil on gently sloping rolling lands with mesas and buttes with severe erosion; clayey soil with severe erosion.

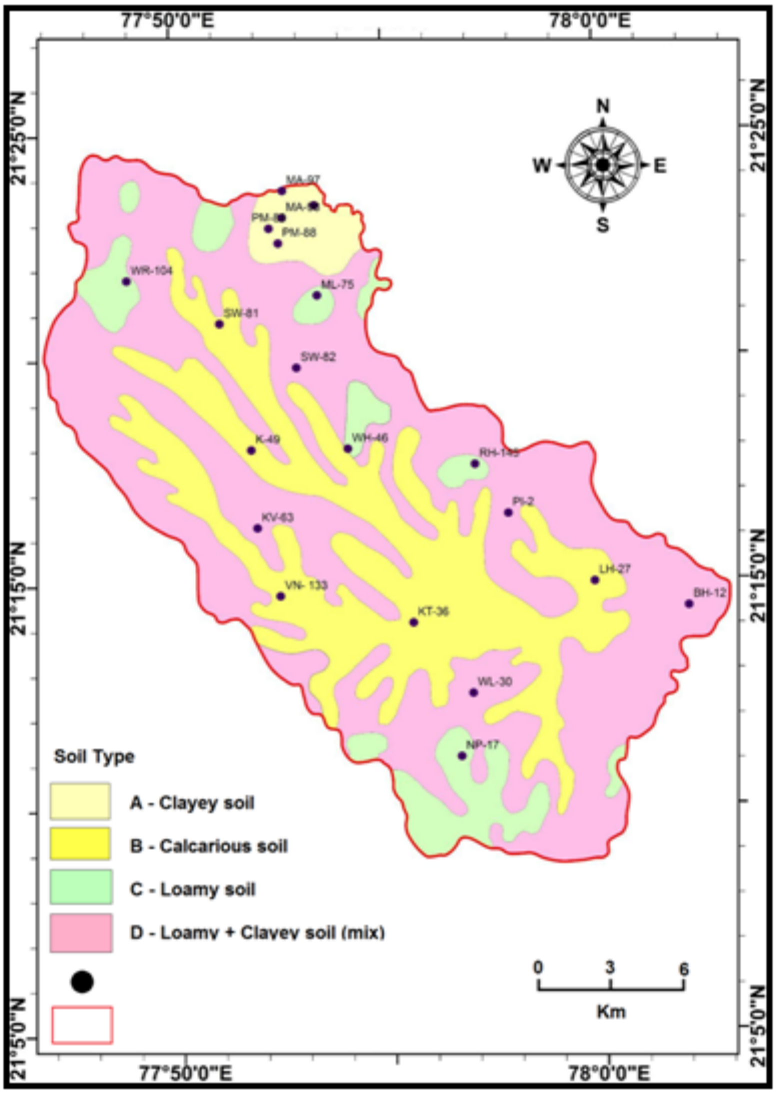

Figure 2: Different types of soils exposed in WRC-1 watershed, with open dug well locations.

RESULT AND DISCUSSION

HYDRO-PEDOLOGY

Different soil zones within WRC-1 watershed behave differently with respect to different hydrogeological conditions as, (A) Clayey soil represents 12.2 to 13.11 mbgl pre-monsoon SWL, 7.02 to 8.54 mbgl post-monsoon SWL, 4.57 to 5.18 meter water table fluctuation and yield of the dug wells between 36 m^3/day to 90 m^3/day in pre-monsoon respectively; (B) Fine Calcareous soil represent 7.02 to 16.16 mbgl pre-monsoon SWL, 3.66 to 9.6 mbgl post-monsoon SWL, 1.52 to 6.71 meter water table fluctuation and yield of the dug wells between 36 to 72.9 m^3/day in pre-monsoon respectively; (C) Loamy soil and clayey soils (mixed) with moderate erosion (mixed) represent 4 to 18.9 mbgl pre-monsoon SWL, 3 to 12.93 mbgl post-monsoon SWL, 3 to 12.5 meter water table fluctuation and yield of the dug wells between 9 to 97.2 m^3/day in pre-monsoon respectively; (D) Loamy soil represent 5.79 to 8.54 mbgl pre-monsoon SWL, 2.15 to 4.27 mbgl post-monsoon SWL, 1.52 to 6.39 meter water table fluctuation and yield of the dug wells between 33.75 to 67.5 m^3/day in pre-monsoonrespectively.

Table 1: Different soil types and corresponding pre-monsoon static water levels, seasonal water table fluctuation and yield of the open dug wells in WRC-1 watershed.

Sr. No.	Soil Type	Area in Sq. Km. (%)	Dug Well ID	Locality/ Village	Static Groundwater Level (SWL)		Seasonal Water Table Fluctuation	Yield of the dug wells in Pre-Monsoon Season (lit./day)	Yield of the dug wells in Post-Monsoon Season (lit./day)	Yield of the dug wells in Pre-Monsoon Season (m3./day)	Yield of the dug wells in Post-Monsoon Season (m3./day)	Lithology/Aquifer
					Pre-monsoon SWL	Post-monsoon SWL						
1.	(A) Clayey soil on gently sloping dissected lands with moderate erosion	12.95 (3.14)	MA-97	Maniardi	12.2	7.02	5.18	36000	108000	36	90	WR+SW+VB+MB
			MA-98	Maniardi	13.11	8.54	4.57	36000	108000	36	108	WR+SW+VB+MB
2.	(B) Fine Calcareous soil on very gently sloping plains and valleys with moderate erosion	123.08 (29.84)	LH-27	Lihida	7.02	4.44	2.58	112500	135000	72.9	145.8	Alluvium
			KT-36	Katpur	16.16	9.6	6.71	252000	630000	48.6	121.5	JB+SW+CMB
			K-49	Khed	10.21	8.69	1.52	67500	56250	67.5	56.25	LT+LM+VAB+MB
			SW-81	Saiwada	8.54	3.66	4.88	36000	216000	36	216	LS+WB+SB+MB
3.	**(C)** Loamy soil on gently sloping	37.58 (9.11)	NP-17	Ner Pinglai	10.98	2.44	8.54	36000	54000	36	144	WB+VB+CMB

	lower plateau with severe erosion; clayey soils with moderate erosion (mixed)		WH-46	Warha fata	17.68	5.18	12.5	33750	67500	33.75	67.5	LS+WB+AVB+MB
			ML-75	Ambada	4	1	3	135000	540000	97.2	243	WB+ SW+FJB+MB
			WR-104	Ghatladki	18.9	14.93	3.97	36000	216000	36	216	LS+WB+CMB+MB
			RH-145	Rohnal	7.8	4.8	3	18000	216000	9	36	WB+CMB+MB
4.	**(D)** Loamy soil on gently sloping rolling lands with mesas and buttes with severe erosion; clayey soil with severe erosion (mixed)	238.91 (57.92)	WL-30	Wagholi	8.54	2.15	6.39	394200	919800	33.75	67.5	LM+WB+MB
			KV-63	Kolvihir	5.79	4.27	**1.52**	112500	157500	67.5	135	Alluvium

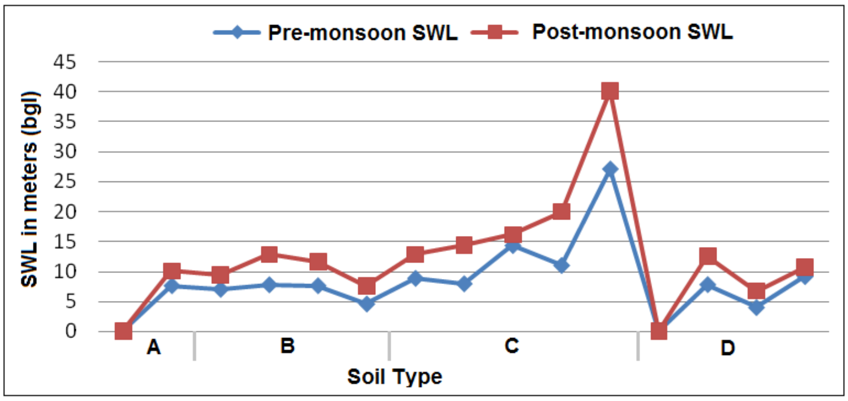

Figure 3: Pre-monsoon amd post-monsoon groundwater levels in different soil zones.

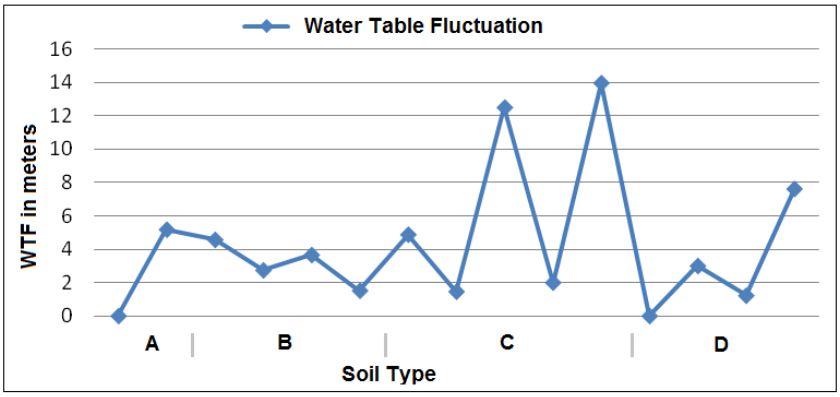

Figure 4: Water table fluctuation in different soil zones.

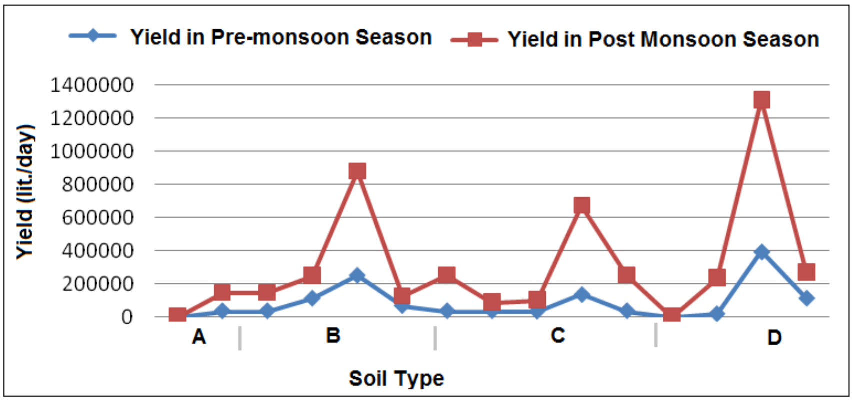

Figure 5: Pre-monsoon and post-monsoon yield in different soil zones.

The pre-monsoon static water levels, water table fluctuations and yield of the open wells are analyzed with respect to different soil types. The static groundwater level in WRC-1 watershed ranges between 4 to 18.9 m bgl (Table 1). The seasonal water level fluctuation ranges between 1.52 m bgl to 12.5 m bgl. The yield of the dug wells during the pre-monsoon season ranges between 9 m^3/day to 97.2 m^3/day (Table 1). The area of clayey soil on gently sloping dissected lands with moderate erosion covers an area of 12.95 sq.km. (Table 4) and loamy soil on gently sloping lower plateau with severe erosion covers 123.08 sq.km. area of the basin (Table 4). The area of Loamy soil on gently sloping of lower plateau with severe erosion, clayey soils with moderate erosion (mixed) covers 37.58 sq.km. area of the basin The area of Loamy soil on gently sloping rolling lands with mesas buttes with severe erosion, clayey soils with severe erosion (mixed) covers 238.91 sq.km. area, which is comparatively high as the other three soil types.

CONCLUSION

During this study an attempt has been made to decipher the influence of different types of soils on groundwater regime. It is observed that static groundwater levels in the pre-monsoon season vary widely. A and B - type of soil zones have shallow groundwater levels; dug wells In C- type soil zone have deeper groundwater levels and dug wells in D- type soil zone have shallow groundwater levels (Figure 3). Thus, out of four types of soil zones, C- soil zone (loamy + clayey soil) represent deeper groundwater levels, probably due to deeply weathered nature. The water table fluctuation (WTF) also indicates similar results where the C-soil zone has greater WTF value as compared to A,B and D soil zones (Figure 4). On the other hand yield of the open dug wells, tapping unconfined aquifers has higher values in B, C and D soil zones (Figure 5), which indicates negligible control of soil zone on yield of the dug wells. This deviation (higher yield values) may be due to other hydrogeological characteristics of the aquifer and which is not influenced by soil zones.

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