Determination of Infiltration Rate Capacity of Minor Irrigation (M. I) Tanks in Gangakatwa Stream Basin Over Lateritic, Basaltic and Granitic Formations in Parts of Vikarabad and Sangareddy District - Telagana State, India

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ABSTRACT:
The study focused on determining the infiltration rate capacity of three Minor Irrigation tanks in the Gangakatwa stream basin in Telangana State, India, which were located in areas with laterite, basalt, and granite formations. Geophysical Resistivity Surveys, (Vertical Electrical Sounding) were conducted parallel to the bund to determine the soil resistivity. Three locations were chosen based on the Resistivity of the soils to determine the infiltration rate capacity in each formation. The study utilized a double ring infiltrometer for the experimental analysis, and the infiltration rates were measured at intervals of 1, 2, 5, 10 and 20 minutes up to 123 minutes to assess the potential for soil structure restoration and the efficiency of the Minor Irrigation tanks. The results of this study could provide valuable insights into improving the efficiency of Minor Irrigation tanks and optimizing irrigation practices in the region.

KEY WORDS: Double Ring Infiltrometers, Basic Infiltration Rate, Minor Irrigation Tanks and Soil Resistivity.

1. INTRODUCTION

Infiltration refers to the process whereby T. J. Marshall (2002) water penetrates into the lower soil profile that becomes groundwater, which is critical for dividing water into two main hydrologic components surface runoff and subsurface recharge. Accurate determination of infiltration rate is essential for reliable prediction of surface runoff for planning. A high infiltration rate is typically desirable for plant growth and the environment.

The infiltration of water into soil has a significant impact on various land-based activities, including environmental sustainability, food security, biodiversity stability, and soil susceptibility to adverse environmental conditions.

Two factors can limit water availability for sustainable crops: a deep-water Table and Impervious Layers. If the water table is located too deep, it can hinder plant roots from accessing an adequate water supply, crops may struggle to access water, leading to water stress, reduced yields, and poor crop health. Impervious layers are soil layers or geological formations that restrict or prevent water movement through them, leading to poor drainage and increased water-logging. Excess water cannot percolate through the impervious layer, causing it to accumulate on the surface or in the root zone. Water-logging conditions can suffocate plant roots, impair nutrient uptake, and create anaerobic conditions, ultimately affecting crop growth and productivity. In both cases, the limited availability of water can have negative implications for sustainable crop production. It is crucial to manage these factors to ensure an adequate water supply for crops. Techniques such as soil modification, improved drainage systems, and water conservation practices.

Infiltration rates play an important role in various hydrological problems, Srinivasan. K and Poongothai S' (2013) such as estimating runoff, managing soil moisture, and planning for irrigation. A detailed study of infiltration helps evaluate peak rates and volumes of runoff for structures like culverts, bridges, and irrigation tanks. The infiltration rate helps in estimating groundwater recharge with respect to planning for watershed engineering irrigation and drainage systems.

2. THE STUDY AREA

The subject of the study is the drainage section of the Gangakatwa basin, a tributary of River Manjera, situated in parts of Vikarabad and Sangareddy Districts in Telangana State, India shown in Fig. 1.

LOCATION OF STUDY AREA

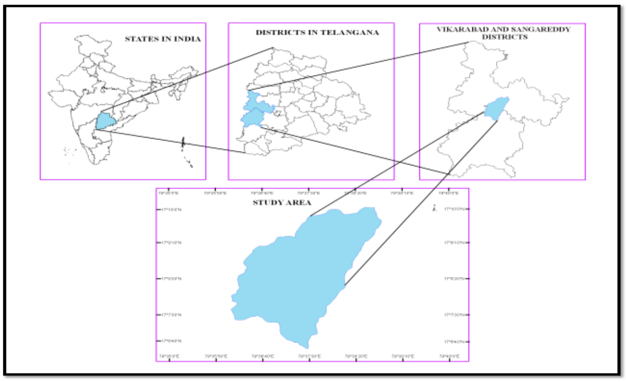

Fig.1. Location Map of Study Area

The study area is bounded by North Latitude170 6'40"-170 10'0" and East Longitude 790 35'50"-790 39'10", and it falls within Top sheet Nos. 56G/14 and 56G/15. The area covers approximately 318 Sq. Kms. Elevation ranges from 450m to 610m MSL. The average annual rainfall of the Sangareddy and Vikarabad Districts is 910 mm and 833 mm respectively. Water levels vary from 1.0 to 10.0 m during post monsoon season and 5 to 30 m in the pre-monsoon seasons. The average temperature of the study area varies from150 to 350 Degree Celsius

3. METHODOLOGY

Geophysical Surveys:

The Geophysical Resistivity method involves the generation of an artificial electric field within the Earth's subsurface using either a galvanic battery (DC) or a low-frequency AC generator. This electric current is introduced into the ground through two specific points referred to as the Current electrodes, denoted as 'A' and 'B.' Simultaneously, the potential in the area is measured using two additional grounded electrodes known as Potential electrodes, labelled as 'M' and 'N.' Electrical resistivity is a measure of the resistance encountered by a unit cube of material to the flow of current across its surface. If 'L' represents the length of the conductor and 'A' its cross-sectional area, the resistance (R) can be defined as:

$R = \rho * (L / A)$

resistivity (ρa) is calculated using the formula:

$\rho a = \rho * K * (\Delta V / I)$

In this equation, 'ΔV' denotes the potential difference, and 'I' represents the current.

$Ar = \rho\ L/A$

Schlumberger Array Description*:* The Schlumberger array employs four co-linear point electrodes for assessing the potential gradient at the midpoint. The Electrode Array is shown in Fig. 2. In this array, the spacing between the current electrodes and the potential electrodes follows a 1:5 ratio. The geometric factor 'K' for this specific array can be determined as:

K = {(AB/2)2 - (MN/2)2} / MN

Alternatively, K can be computed using the following formula:

K = (a2 - b2) / 2b

Here, 'a' represents half the spacing between the current electrodes, while 'b' signifies half the spacing between the potential electrodes. The apparent resistivity (ρa) can be calculated as:

$\rho a = \rho * K * (\Delta V / I)$

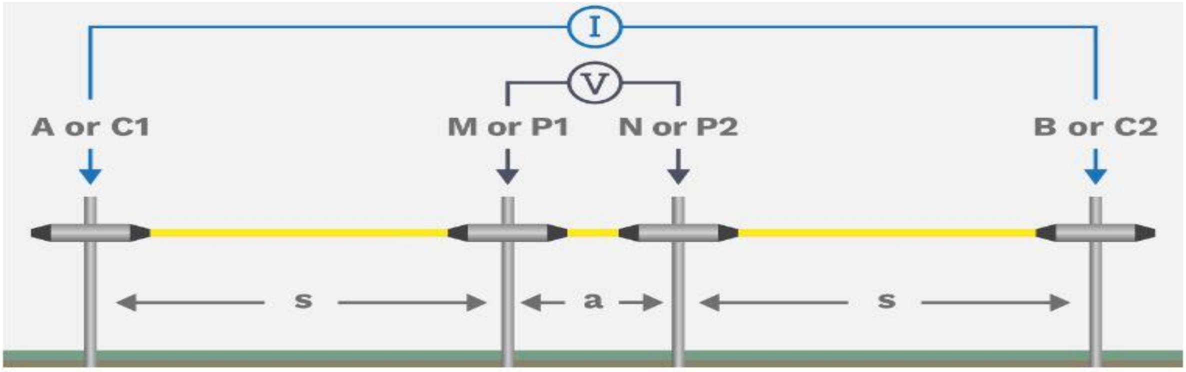

Fig.2. Schlumberger array

The Resistivity sounding with the Schlumberger array has been employed for the detection of soils properties. The survey was carried out parallel to the bund in three Minor Irrigation tank beds, in different Geological Formations, like Lateritic, Basalt and Granite. VES data was analyzed by using IPI2 Win Software, Mostly three /four layer cures were opted. The results are shown in Table 1.

Table. 1. Vertical Electrical Sounding Interpretation Results in Minor Irrigation Tank Beds of Study Area.

Vertical Electical Sounding Interpretation Results in (M.I Tank beds)															Analysis			
S.No	Name of the M.I Tank	VES NO	ρ1	h1	ρ2	h2	ρ3	h3	ρ4	h4	ρ5	h5	ρ6	H	Total Avarage Thickness in m)	Top soils Avarage Thickness in (m)	wethered soils Avarage Thickness in (m)	Geology
1	Panchalingala M.I Tank	1	126.0	1.0	9.4	8.0	24.3	23.3	195.0					32	34	1.4	32.6	clay loam Latritic soils /basalts
		6	10.6	1.5	53.0	3.1	6.8	15.0	2332.0	16.8	11.3			36				
		11	10.6	1.6	8.5	7.0	40.7	20.7	25.6	3.2				33				
2	Komsetypally M.I Tank	3	3.5	1.0	5.3	4.3	188.0	6.4	6.0	3.8	1.1			16	16	1.3	14.7	Clay soils /basalts
		6	2.8	1.8	5.7	1.2	2.3	1.8	67.7	1.1	247.0	10.0	531.0	16				
		16	2.2	1.2	5.4	2.9	20.4	7.1	53.1	6.0				17				
3	Munipally M.I Tank	1	8.4	1.6	5.0	3.4	202.0	16.0	9.0					21	24	2	22	clay Sandysoils /granites
		6	4.5	1.2	5.2	5.3	984.0	15.0	22.6					22				
		13	4.6	2.8	6.2	12.0	69.8	8.0	258.0	5.9	340.0			29				

Infiltration Tests

The infiltration tests were performed in three different locations across the study area shown in Figure 3a during non-rainy seasons after conducting Geophysical Resistivity Surveys (V.E.S) after data was interpreted and analyzed. Based on the interpreted results in Table 1, some locations were chosen for conducting infiltration tests. The Tests involved the use of a Double-Ring Infiltrometer, following the guidelines outlined in ASTM (2003).

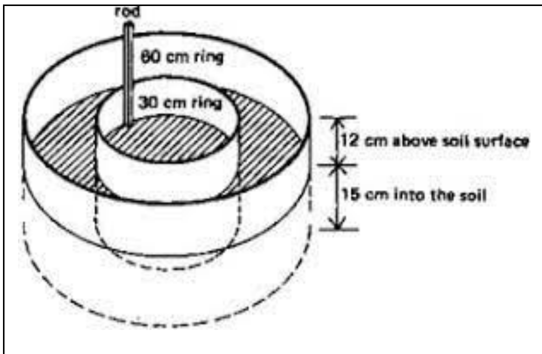

Fig. 3 Double-Ring Infiltrometer

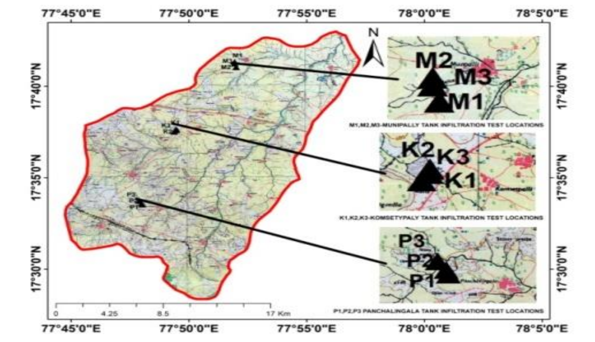

Fig. 3a Location of the study area

A double-ring infiltrometer shown in Fig. 3 consists of an outer ring with a diameter of 60 cm and an inner ring with a diameter of 30 cm. Both rings were carefully inserted into the soil to a depth of 15 cm, without tilting or excessively disturbing the soil.

To ensure accurate measurements, the bottoms of both rings were positioned at the same depth underground. Water was simultaneously poured into both rings until they were filled to the brim. The water levels in the inner and outer rings were carefully maintained at the same height throughout the experimentby allowing vertical downward movement of water from the inner ring, the lateral spread of water from the outer ring was minimized, reducing measurement errors.According to Vittala, G.R.C. Reddy, K.R. Sooryanarayana (2018), measurements were taken at specific time intervals using a stop timer.The water level drop in the inner ring was recorded at regular intervals, starting with 1-minute interval for the first 10 minutes. Subsequently, measurements were taken every 2 minutes from 10 to 20 minutes, every 5 minutes from 20 to 50 minutes, and every 10 minutes from 50 to 100 minutes. From there, measurements were taken at 20-minute intervals until it reached the steady state or Basic Infiltration Rate Fig. 4.

The stabilized infiltration rate was determined using a formula proposed by Horton (1933). This calculation involved the initial infiltration rate (Fo), the final constant infiltration rate (Fc), and a constant (k) that depends on soil and vegetation properties. By considering the infiltration rates at specific time points (F1 and F2) and the time interval (t2 - t1) between them, the stabilized infiltration rate was calculated. Infiltration rate curves were plotted to represent three distinct soils.

Results of Infiltation Rate obtained from the studies									
S.No	Site Name	Test No	Initial infiltation rate cm/h	Finnal Infiltation Rate cm/h	Cumulative Deptjh of Infiltation(cm)	Duration in(min)	Geomorphology	Aquifer
1	Panchalingala M.I Tank	L1	66	6.3	19.55	120	Valley Fill deep (Tank bed)	clay loam(Latritic) soils /basalts
		L2	72	6	17.2	120	Valley Fill deep (Tank bed)	clay loam(Latritic) soils /basalts
		L3	69	5.7	19	120	Valley Fill deep (Tank bed)	clay loam(Latritic) soils /basalts
2	Komsetypally M.I Tank	B1	0.9	0.75	3.55	124	Valley Fill Moderate (Tank bed)	Clay soils /basalts
		B2	0.9	0.9	3.38	121	Valley Fill Moderate (Tank bed)	Clay soils /basalts
		B3	0.9	0.75	3.3	123	Valley Fill Moderate (Tank bed)	Clay soils /basalts
3	Munipally M.I Tank	G1	27	2.1	7.3	120	Valley Fill shallow (Tank bed)	clay Sandysoils /granites
		G2	27	2.4	8	120	Valley Fill shallow (Tank bed)	clay Sandysoils /granites
		G3	30	2.7	9.8	120	Valley Fill shallow (Tank bed)	clay Sandysoils /granites

Table. 2. Results of Infiltration Rate Obtained in Minor Irrigation Tank beds in the Study area

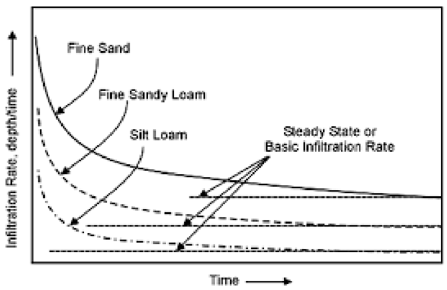

Fig. 4 - Graph showing steady state or Basic Infiltration Rate

The Basic Infiltration Rate:

The basic infiltration rate, is also known as the initial infiltration rate or infiltration capacity, it measures the rate at which water penetrates into the soil when it first comes into contact with the ground surface during a rainfall or when water is applied to the soil surface. Different soils types have different basic infiltration rates as depicted in Table 3 (Source: Food and Agriculture Organization - FAO.Org, America). It represents the maximum speed at which water can permeate the soil before factors such as surface sealing, saturation, or soil characteristics come into play, causing a slowdown in the infiltration process. Typically, this rate is expressed in units, inches per hour or millimeters per hour.

Table. 3. Basic Infiltration Rate for Various Soils Types

Soils Type	**Basic Infiltration Rate (mm/hours)**
Sand	Less Than 30
Sandy Loam	20-30
Loam	10-20
Clay Loam	5-10
Clay	1-5

In addition, the infiltration rate for different soil types is influenced by a range of rainfall characteristics. One of these factors is the size of raindrops, which can impact the force with which they strike the soil surface. Larger raindrops have the potential to disrupt the integrity of the soil surface, resulting in a reduction in infiltration rates. Furthermore, the type of soil itself plays a pivotal role in determining the rate of infiltration. As depicted in Graph 1, soils containing a substantial clay content and fine-grained structure tend to display diminished rates of infiltration. Shallow clay soils, in particular, typically exhibit infiltration rates ranging from moderate to low. Conversely, sandy loam soils, characterized by their porous structure, generally showcase higher rates of infiltration. Sandy clay soils typically possess a moderate capacity for infiltration. Soils composed of deep sands and well-drained, aggregated particles tend to exhibit notably high infiltration rates.

The field photograph and location map when conducting the infiltration test by using a double–ring Infiltrometer at the Minor Irrigation Tank, Komsetypally village is shown in Fig. 5 & 5a of the study area.

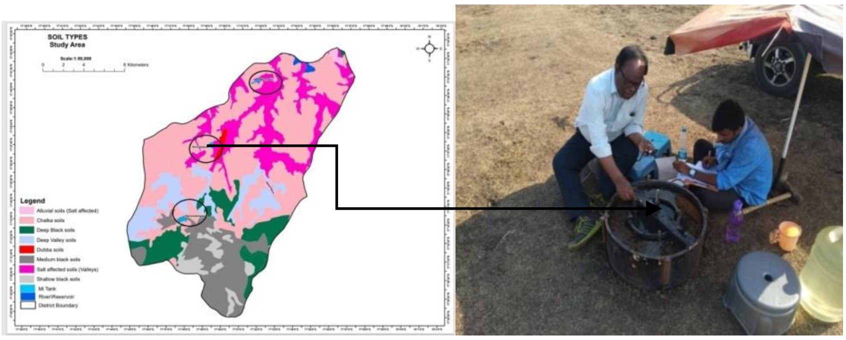

Fig. 5 & Fig. 5a - Infiltration test at Komsetpally village

Under the pounding condition, infiltration rate decreases exponentially, and it can be represented by Horton equation. [3] ... According Horton's equation,

$f = f c + (f 0 - f c) \times e - k t$. where,

Ft Infiltration rate cm/h at time ‘t’ in mines

Fo Initial rate of infiltration (cm/h)

Fc Final (constant) rate of filtration (cm/h)

K constant depending on soil and vegetation

K = Ln (F1 — Fc)— Ln (F2 — Fc)

t2 — t1

F F1 — Fc

e—kt1

F F F2 — Fc, e—kt2

Where

F1 Infiltration rate (cm/h) at time ‘t1’

F2 Infiltration rate (cm/h) at time ‘t2’

The Fig. 6 shows Infiltration rate curves with three representative soil characteristics initial infiltration rates, and final infiltration rates, cumulative depth of infiltration and duration of test obtained from the studies

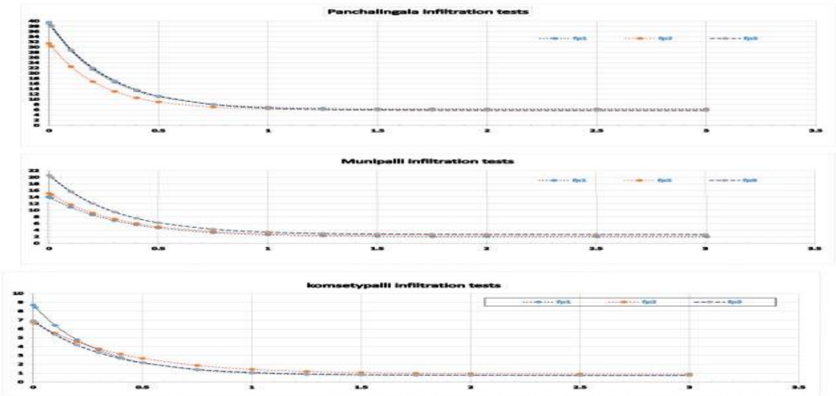

Fig. 6 - Graph showing Infiltation Rate Curves Showing Three Representative Soil Characteristics

4. RESULTS AND DISCUSSIONS

The aim of this study is to assess the subsurface hydraulic variability of complex Minor Irrigation tanks in a hard rock watershed and predict recharge in the watershed using double-Ring Infiltrometer,by Vittala, G.R.C. Reddy, K.R. Sooryanarayana (2018). Infiltration tests were conducted in various soil types as shown in Fig.4. The Soil type map was prepared by using Remote sensing and GIS to examine their infiltration characteristics. The results indicate spatial variation in infiltration rates given in Table.2. Comparatively Higher initial infiltration rates were observed at PanchalingalaMinor Irrigation tank in (lateritic soils/basaltic formations),clay loam 66 cm/h, 72 cm/h, and 69 cm/h, while lower initial infiltration rates were found at Komsetypally Minor Irrigation tank in Basaltic formation (black cotton)clay soils, 0.9 cm/h,0.9 cm/h,0.9cm/h. Moderate infiltration rates were also observed at Munipally Minor Irrigation tank in granitic soils, (Red soils) 27 cm/h, 27 cm/h. 30 cm/h

Moreover, the cumulative depth of infiltration was comparatively highest at Panchalinga, with values of 19.55 cm, 17.2 cm, and 19.0 cm in 120 minutes, respectively. At Munipally, the cumulative depths were 9.8 cm, 8.0 cm, and 7.35 cm in 120 minutes, and at Komsetypally it was 3.55 cm in 124 minutes and 3.8 cm in 121 minutes, 3.3cm in 123 minutes

Panchalingala (Gundam cheruvu): The top soils in Panchalingala are composed of Lateritic clay loam with resistivity values (ρa) ranging from 10.6 to 126 ohm-meters and a thickness of 1 to 1.6 meters. The average weathering depth is up to 36 meters (Table 1), suggesting comparatively high infiltration rates due to its weatheringand the nature of the soil. Lateritic soils are known for their good drainage properties, which contribute to higher infiltration rates in this area.

Komsetpally (Patta cheruvu or appakunta): In Komsetpally, the infiltration rates are lower compared to Panchalingala. The tank beds in Komsetpally contain clay and silt with top soil resistivity (ρa) values ranging from 2.2 to 3.5-ohm meters and a thickness of 1 to 1.8 meters. The average weathering depth is up to 15 meters by product of basalt rockindicating relatively low infiltration rates. Clay and silt soils have lower permeability, leading to reduced infiltration.

Munipally (Pedda Cheruvu): Munipally exhibits moderate infiltration rates. The soil in Munipally is clay loamy with resistivity values (ρa) ranging from 4.6 to 8.4 ohms and a thickness of 1.2 to 2.80 meters. The average weathering depth is up to 22 meters product of granites weathering suggestingmoderate infiltration rates. Clay loam soils generally have intermediate permeability, leading to moderate infiltration.

In summary, the study indicates that infiltration rates are comparatively higher in Panchalingala's Lateritic soils and moderate to low in the clay and loamy soils of Komsetpally and Munipally tank beds.

To ensure sustainable development in areas with over-exploited aquifers, D.Muralidharan (2009) recommends developing suitable strategies for artificial recharge studies. One such strategy is the removal of clay beds or the use of borehole injection methods in areas where necessary. These methods can help improve groundwater recharge and maintain water availability in the aquifers.

Overall, understanding the variations in infiltration rates and the properties of surface soil and geology is crucial for effectively managing and conserving water resources in these regions. Proper water management strategies can help mitigate the impacts of over-exploitation and ensure a sustainable water supply for the future.

5. CONCLUSIONS:

The Gangakatwa watershed, situated in Vikarabad and Sangaredy Districts of Telangana State, India, the region experiences inadequate rainfall and frequent drought conditions. The area is characterized by typical hard rock terrains commonly found in Southern India, predominantly consisting of basalts and granites. To assess the infiltration capacity within three minor irrigation tanks during non-rainy seasons, nine locations were selected, representing various soil types. The infiltration tests were performed using a double-ring infiltrometer.

The findings indicate that the tank bed of Komsetypally (Patta cheruvu or Appakunta) exhibited the lowest infiltration rates. To improve the infiltration rate in this area, it is suggested to remove the optimal silt layer, which could range from 1 to 1.8 meters. Alternatively, implementing a bore-hole injection structure could also aid in increasing the infiltration rate. On the other hand, Panchalinga (Gundam cheruvu) demonstrated comparatively higher infiltration rates within the study area, suggesting that there is no immediate need to remove the top deposited soils in this location. Interestingly, the results did not show significant variations across different rock types, particularly at the Munipally (Pedda Cheruvu) and Komsetypally (Patta cheruvu or Appakunta) tank beds.

6. ACKNOWLEDGEMENTS

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