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By

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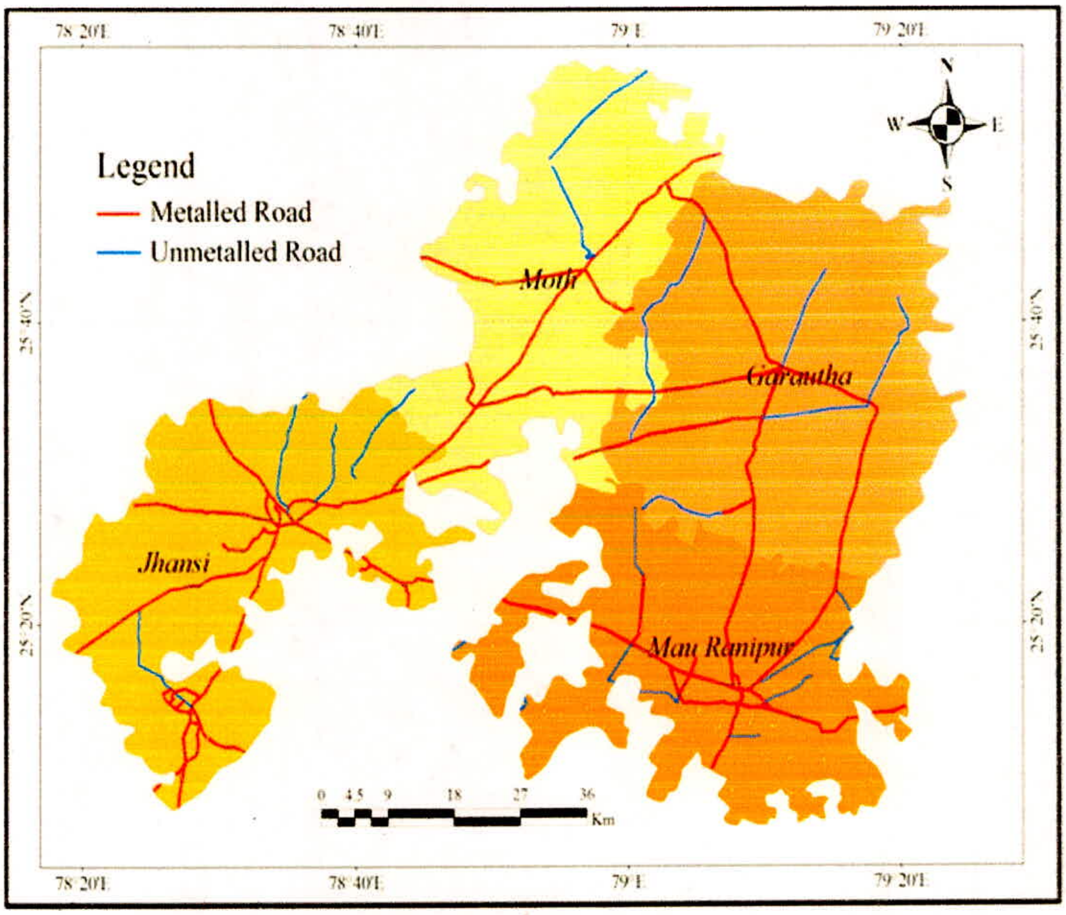
(Year 2015-16)

Report

On

Infiltration study of Moth block in Jhansi distinct of Bundelkhand region



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1 INTRODUCTION

Infiltration is the process by which water on the ground surface enters the soil. Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation. It is measured in inches per hour or centimeters per hour or millimeters per hour. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier. It is related to the saturated hydraulic conductivity of the near-surface soil. The rate of infiltration can be measured using an infiltrometer.

Infiltration is caused by two forces: gravity and capillary action. While smaller pores offer greater resistance to gravity, very small pores pull water through capillary action in addition to and even against the force of gravity. The rate of infiltration is determined by soil characteristics including ease of entry, storage capacity, and transmission rate through the soil. The soil texture and structure, vegetation types and cover, water content of the soil, soil temperature, and rainfall intensity all play a role in controlling infiltration rate and capacity. For example, coarse-grained sandy soils have large spaces between each grain and allow water to infiltrate quickly. Vegetation creates more porous soils by both protecting the soil from raindrop impact, which can close natural gaps between soil particles, and loosening soil through root action. This is why forested areas have the highest infiltration rates of any vegetative types.

In dry soil, water infiltrates rapidly. This is called the initial infiltration rate. As more water replaces the air in the pores, the water from the soil surface infiltrates more slowly and eventually reaches a steady rate. The infiltration rate decreases to a steady or quasi-steady state as the soil becomes saturated. Therefore, the filtration rate curve shows a sharp decline with time. The constant rate approached after a sufficiently large time is referred as the steady-infiltration rate. Some water that infiltrates will remain in the shallow soil layer, where it will gradually move vertically and horizontally through the soil and subsurface material. Some of the water may infiltrate deeper, recharging groundwater aquifers.

Infiltration rate is an important component of the hydrologic cycle. It helps determine how rainfall is divided between recharging the groundwater and running off over the surface as sheetwash and in streams. Infiltration process is responsible for modifying precipitation and converting it to runoff and additions to soil moisture storage. The infiltration and other processes are interrelated through a common dependence on soil moisture conditions. In general the lower the infiltration rate, the greater the surface run off and thus the greater the potential for soil erosion. A high infiltration rate lets most of the rain water soak into the soil and make its way downward to the aquifer.

The top layer of leaf litter that is not decomposed protects the soil from the pounding action of rain; without this the soil can become far less permeable. In chaparral vegetated areas, the hydrophobic oils in the succulent leaves can be spread over the soil surface with fire, creating large areas of hydrophobic soil. Other conditions that can lower infiltration rates or block them include dry plant litter that resists re-wetting, or frost. If soil is saturated at the time of an intense freezing period, the soil can become a concrete frost on which almost no infiltration would occur. Over an entire watershed, there are likely to be gaps in the concrete frost or hygroscopic soil where water can infiltrate. Once water has infiltrated the soil it remains in the soil, percolates down to the ground water table, or becomes part of the subsurface runoff process.

Saturated hydraulic conductivity is one of the most important soil hydrophysical characteristics. Its determination is needed for many different applications and it is a key parameter for solutions in soil physics, hydrogeology, environmental protection, soil and groundwater protection against pollution, soil reclamation, irrigation and drainage for agricultural and non-agricultural purposes, landfill foundation, sport surfaces ,etc. It is also one of the main input parameters for models simulating transport of water and solutes through the soil profile.

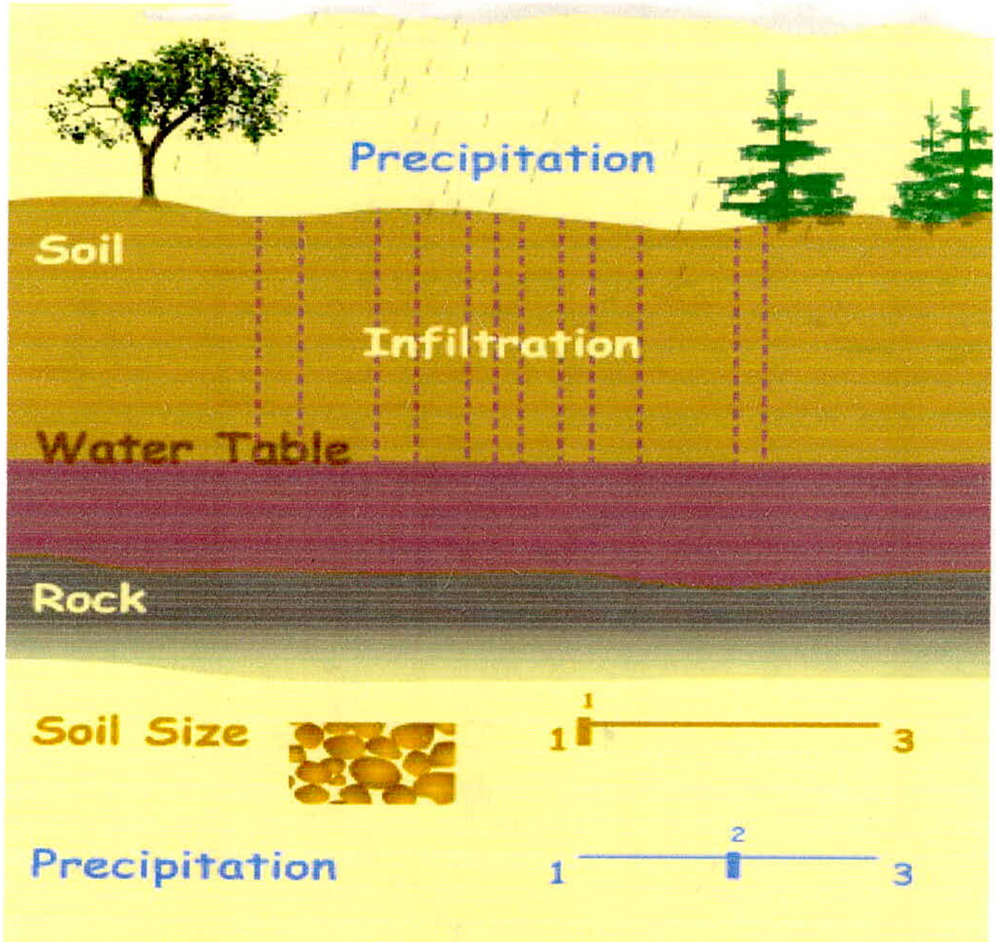

Figure 1: Infiltration Process

1.1 Infiltration Process

The process of infiltration can continue only if there is room available for additional water at the soil surface. The available volume for additional water in the soil depends on the porosity of the soil and the rate at which previously infiltrated water can move away from the surface through the soil.

The maximum rate that water can enter a soil in a given condition is the infiltration capacity. If the arrival of the water at the soil surface is less than the infiltration capacity, it is sometimes analyzed using hydrology transport models, mathematical models that consider infiltration, runoff and channel flow to predict river flow rates and stream water quality.

Water can be absorbed by the soil and may stay in the soil for long time until it gradually gets evaporated. If there is a lot of vegetative cover (green plants) the infiltrated water can also be absorbed by plant roots and later transpired. Infiltration occurs at the upper layers of the ground but may also continue further downwards into the water table.

The rate of infiltration depends on factors such as the amount of precipitation, the type of soils, the amount of vegetative cover over the area, pre-saturation levels, the topography of the land as well as the levels of evapotranspiration in that region.

2 STUDYAREA

2.1 About Bundelkhand Region

Bundelkhand region in central plains in India is situated between longitude 78o20'N and 81o40'N and latitude 23o20'E and 26o20'E and comprises of 13 districts covering 7.08 Million Hectares (Mha), out of which six districts comprising of 4.12 Mha are in Madhya Pradesh and seven districts comprising of 2.94 Mha are in Uttar Pradesh. The districts in Madhya Pradesh are Sagar, Damoh, Datia, Panna, Chattarpur, and Tikamgarh and in Uttar Pradesh are Jhansi, Lalitpur, Jalaun, Hamirpur, Banda, Mahoba and Chitrakoot. The area is bounded by Vindhyan Plateau in south to river Yamuna in north, river Ken in east and rivers Betwa, Sindh and Pahuj in west. Plate-I shows the administrative districts of the Bundelkhand region in the two states.

While the geographical area of Bundelkhand region in Madhya Pradesh is 39% more than that in Uttar Pradesh, population in Bundelkhand region of Madhya Pradesh is around 28 % lesser than that in Uttar Pradesh. Despite the fact that normal rainfall in Madhya Pradesh portion is 17 % more than that in Uttar Pradesh and rainfall pattern being more drought prone in Uttar Pradesh as compared to Madhya Pradesh, higher percentage of population in Uttar Pradesh is attributed to age old and higher level of development of irrigation in Uttar Pradesh. About 82% of the population is dependent on agriculture in both the States.

While the Yamuna flows from west to east, its first order tributaries viz., Betwa, Ken, Sindh, Pahuj, Gharara, Bagain and Paisuni flow from south to north. Second order tributaries of the Yamuna namely, Dhasan, Jamuni, Birma, Sonar, Patna, Bewas, Kopra etc., also drain the area. The entire drainage forms a part of Ganga basin. The region generally slopes from south to north. The elevations in the area range from 600 m above mean sea level (amsl) in southern part to 150 m amsl near the Yamuna. The area in Madhya Pradesh is conspicuous of undulating rocky ravine topography coupled with level plains, while the area in Uttar Pradesh gradually slopes from mild ravines to level plains near the Yamuna. Almost entire region of Bundelkhand (UP and MP) is prominently of Vindhyan rocks in southern part and Granites of different kinds at different depths with alluvium soils on top mixed with rocky and boulder outcrops here and there. The geology, hydro-geology, hydrology, soils and the climatic distribution are directly responsible to the agricultural growth and consequently to the livelihood of people in Bundelkhand (both UP and MP). Plate-II shows the physiography and the drainage systems prevailing in the Bundelkhand region in two States.

Low agricultural productivity because of inappropriate agricultural practices that make it anunviable profession. Still mono-cropping is practiced by most of the farmers that causes adverse impact on the soil fertility. Due to increase in population, land holding per person has become very low that renders low yield and therefore poor income from the land. The production is largely concentrated into the hands of a few landlords.

Lack of alternate livelihood options: Livelihood from other sources, like forest and traditional crafts and occupation is also edging. With only 3-4 months of agricultural labour being available and no alternate livelihood of option. So a large number of labourers are forced to migrate to other regions of the country, the estimated migration rate being around 39% for the region.

Degeneration of Natural Resources base: Being home to a succession of enlightened kingdoms through the millennia, the kings of the Bundela dynasty built and maintained innumerable rainwater harvesting structures, which ensured abundant supplies of water throughout the year. The water bodies were mostly tanks (small, medium and large) which got filled up during the rainy season and which in turn charged the groundwater. Thus, the wells in the village had plenty of water throughout the year. Even in the years when the monsoon was below normal, there was no shortage of drinking water for humans and animals. All this changed in the last 50 years when indiscriminate cutting of trees without any serious replanting, led to the disappearance of most of the forests. With rapid increase in the human and animal population during this period the pasturelands also disappeared and water bodies started drying up. Today, the lush bamboo and teak forests that covered large tracts of this terrain and nurtured some of the best biodiversity, wildlife (including tigers and leopards) and other forest wealth in the country are all gone. Depletion in ground water table and lack of avenues for storing the rain water has posed havoc on water availability both for drinking and irrigation. The recharging of ground water resources through collecting the rain water in traditional ponds is not taking place due to degradation of such ponds, encroachment of forest lands, cutting of forests and blocking the catchments areas of watershed regions. The result is that wells being used for drinking water and irrigation are not providing enough water to serve the purpose for the whole year.[2] Most agriculture is single-crop and rain fed with supplementary water from open wells. Thus, large numbers of farmers are highly dependent on the monsoon rains to recharge these wells. Poverty is rampant in Bundelkhand region. Low productivity in agriculture and industrial backwardness, together with the dying traditional household/cottage industries have kept the region as one of the most poverty stricken. Employment and income generation programmes run by government, hardly reach the poor in the feudal set up of the society, widely prevalent in the area. Migration to other states doesn't always solve the problem of everybody, when the population living below poverty line is very large.

Given the background of Bundelkhand Region and the key concerns mentioned above, it is important that economic activities are revived in the region with a key focus on management of natural resources, especially water. The water management approach has to be built around the issue of sustainability in terms of both source creation and its management (quality and quantity), and building of institutional systems at various levels (village, block, district levels) for community based management of water and sanitation challenges. An integrated approach to water and waste water management has to be undertaken.

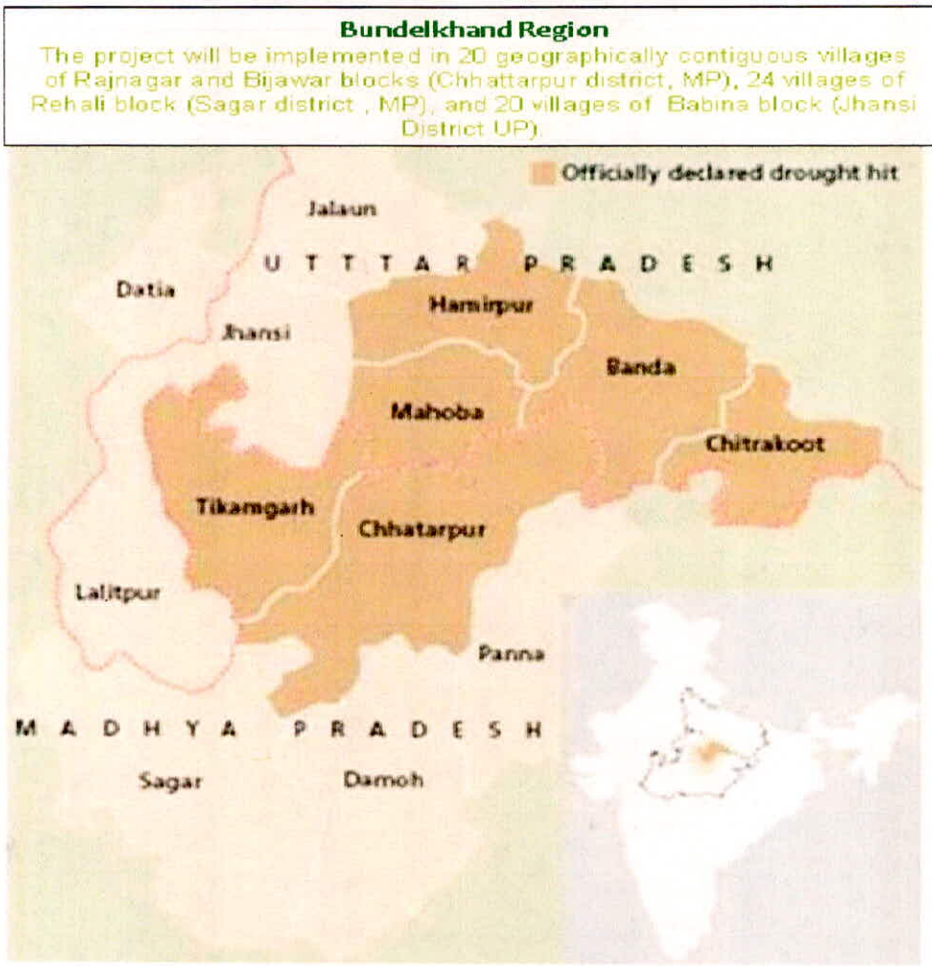

Figure 2: Bundelkhand Region

2.2 Geology of Bundelkhand Region

Central Ground Water Board (CGWB) has carried out extensive geological and hydro-geological surveys in the Bundelkhand region. As quoted from their report 'Hydrogeology in the Bundelkhand Region' the geological formations in this region are from Archaeans to recent origin. The crystalline rocks of Achaeans consist of granite, gneiss and quartz reefs. The Vindhyan are represented by sand stone, lime stone and shale. The rocks are dominant in the region while the unconsolidated formations of recent (Quaternary) consisting of sand, silt and clay occupy northern parts of the region along the river Yamuna in the districts of Jalaun, Hamirpur, Banda, Panna and parts of Chitrakoot. The underlying Archaeans is mostly composed of basal crystalline, mostly granites, popularly known as 'Bundelkhand Granite' and metamorphic, mostly gneisses. These are fractured jointed and weathered. The thickness of weathered zone depends upon the topography, drainage & vegetation cover. The granites are pink to grey coloured and are coarse to fine grained. The Granites are normally sloping northerly towards the Yamuna.

The Vindhyan, are represented by a pile of Precambrian sedimentary rock, consisting of sub-horizontal and weakly folded beds of sand stone, shale and limestone. These sediments, attaining thickness of more than 4000 m are laid over Achaean rocks. The Vindhyan are exposed in Damoh and parts of Panna district in Madhya Pradesh and Banda district of Uttar Pradesh. In Chitrakoot granite hillocks are capped by lower Vindhyan rocks and Kaimur sandstone. The limestones extending towards the Yamuna are highly cavernous. Large size of cavities also occurs in limestones in Panna district of Madhya Pradesh.

Alluviums on the other hand comprise mainly of clays, silt and sand stone mixed with gravel and kankar. These formations have a thickness of about 130 to 150 m over the eroded base of Bundelkhand Granite. The alluvium deposits are mostly found in Hamirpur, Jalaun and parts of Jhansi district near the Yamuna and northern parts of Datia and Panna districts in Madhya Pradesh.

2.3 Hydrogeology of Bundelkhand Region

As per the report of the CGWB, the nature and the extent of the aquifer bodies and their hydro-geological properties in relation to the ground water flow characteristics, the formations can be broadly classified in two regions of Bundelkhand, Consolidated and Unconsolidated.

The Consolidated Formations, composed of granite, gneisses and quartz reef etc. These are hard rocks and compact with negligible porosity resulting into poor aquifers. The porosity of these rocks varies from 0 to 0.3%, and, therefore, these formations are incapable of holding and transmitting water. However, along the planes of weakness and fractures, joints, and shear planes, the weathering and decomposition provides appreciable porosity to up to 30 to 50%. Generally dug wells in these zones have a depth of 5 to 30 m with water levels between 3 to 15 m below ground level (bgl). The yield of such wells can range from 40 to 135 m3 per day.

***The Vindhyan* formations** on the other hand are composed of sand stones, shale and limestones. The sandstones and shale are hard and compact hence form poor aquifer. The ground water occurs in these formations under water table conditions in fine interstice of the weathered zones and joint planes. Deeper sandstone zones are compact and impervious and generally do not bear water and are thus unsuitable for ground water development. The cavernous zones and cavities in limestones on the other hand are generally potential repositories of ground water and provide copious discharge when tapped. Wells in limestones can yield up to 100 to 500 m3/day. Unless tapped, both these formations leak water which flows fast towards the Yamuna.

The Unconsolidated Formations occur south of the Yamuna in Jalaun, Hamirpur, Banda and parts of Chitrakoot district in Uttar Pradesh. Unconsolidated formations are characterised by generally north-east sloping planes formed by the drainage system of Yamuna river. The sediments mainly comprise clay-kankar-silt with intercalation of sand and gravel lenses of varying thickness and inter-granular porosity. Thickness of these deposits is about 50-150 m. Ground water in these strata generally occurs in the upper zones of about 40 m. and under semi-unconfined conditions at deeper level below 40 m. Wells between 30 to 40 m of granular aquifer can yield 50-65 litres per second (lps) (4000 to 5000 m3/day). Hydro-geology of the Bundelkhand region is shown in Plate-III. The patterns of depth to water levels in a good year like 1998-99 in the pre monsoon and post monsoon periods are sketched in Plates-IV & V respectively.

2.4 Soils types of Bundelkhand Region

The soil found in the area may be classified into four group on the basis of colour and topography i.e. red (upland soils) and black (low land soils). On the basis of texture, the red soil is further divided into 'Rakar' and 'Parwa' and the black soil group into 'Kabar' and 'Mar'. Broadly there are four types of soils in the region namely.

(i) Red sandy soils

(ii) Shallow black soils

(iii) Mixed red and black sand

(iv) Alluvial soils.

Red sandy soils, commonly known as Rakar soils contains quartz, orthoclase, microcline etc and exists in districts of Jhansi and Lalitpur in Uttar Pradesh and Datia, Tikamgarh, Chattarpur and parts of Panna in Madhya Pradesh. These soils are shallow, gravelly and extremely porous with low organic matter and have poor water holding capacity and are thus not much suitable for main stream agricultural activities.

Shallow black soil, also locally known as Parwa soils, which are coarse grained clayey in nature and mostly grey to grayish brown in colour, usually occurs in low lying areas of the district Jalaun, Hamirpur and Banda. The particle size of this soil varies from fine to medium and has high water retaining capacity and is thus suitable for plant growth and crop cultivation. Mixed red & black soils also called Kabar soils in Tikamgarh, Chattarpur & Panna districts in Madhya Pradesh consists of quartz, orthoclase, microcline etc.

The alluvial or Mar soil occurs in northern parts of region in the districts of Jalaun and Hamirpur in Uttar Pradesh and parts of Panna in Madhya Pradesh. The soil is brown in colour with medium depth. This soil is generally less rich in organic matter. Plate-VI shows gradually changing behaviour of the soil pattern and has an important bearing on hydrology, hydro-geology, and agronomy resulting into a typical livelihood pattern of the people.

Due to lower moisture carrying capacities, agricultural practices mainly depend on soil types and therefore, future strategic options would require detailed investigations of soils and underground geological mappings of the Bundelkhand area.

Table 1.Soil Classification Table Based On Values of Saturated Hydraulic Conductivity *K*

Soil (according the relative permeability)	**Approximate range of saturated hydraulic conductivity (m s-1)**	**Examples of soil types**
Highly impermeable	$< 10^{-10}$	clays with low and medium plasticity, clays with high and extremely high plasticity
Impermeable	from 10^{-8} to 10^{-10}	gravel loams, gravel clays and sandy clays, loams with low and medium plasticity
Lowly (poorly)	from 10^{-6} to 10^{-8}	sandy loams, loamy sands and clayey sands, loamy gravels and clayey gravels
Permeable	from 10^{-4} to 10^{-6}	sands and gravels , containing fine-grained fraction (5 – 15 %)
Highly permeable	$> 10^{-4}$	sands and gravels without or with very low fine grained fraction (<5%)

2.5 About Moth Area

The present scheme has covered the area of Moth Development Blocks of District Jhansi, Uttar Pradesh. It is sanctioned in the year 2015-16. The geographical extent of latitude and longitude of the project is 25° 36' 4.0932" - 25° 45' 38.3184" N and 78° 45' 9.1692" - 78° 59' 21.966" E. Jhansi district in the southwestern part of the Uttar Pradesh lies between 25^{0}07” and 25^{0}57” north latitude and 78^{0}10” and 79^{0}25” east longitudes. The area is comprised of Bundelkhand gneissic complex of archean age and alluvium of recent age. Physiographically, the area can be divided into two units i.e. Southern Bundelkhand Pediplane Province and Northern Highly Eroding Composite Plain Province.

Demographic Characterstics: According to the Survey of India, the area of the present Jhansi district is 5024 sq km. It has 5 tehsils, 8 blocks (shown in map-3), 21 urban centers and 760 inhabited villages. The relief of the district varies roughly from 150m-450m above the mean sea level. The population of the district is 17,44,931 (2011 Census) with 28.06% and 0.06% of the population being of Scheduled Caste and Scheduled Tribe respectively. The sex ratio for Jhansi district as per 2001 Census is 871 (against state's sex ratio of 898). Jhansi also has witnessed incidences of female infanticide causing the skewed sex ratio.

Jhansi being one of the major cities in the region, about 40.79% of total population of the district lives in urban areas and the rest 59.2% in rural areas. Jhansi district has 760 inhabited villages that support a population of 10,33,171. The Jhansi tehsil, in which the Jhansi town is located alone houses approximately 7.9 lakh people and has a population density of 262 persons per square kilometer (as against the district statistic of 217).

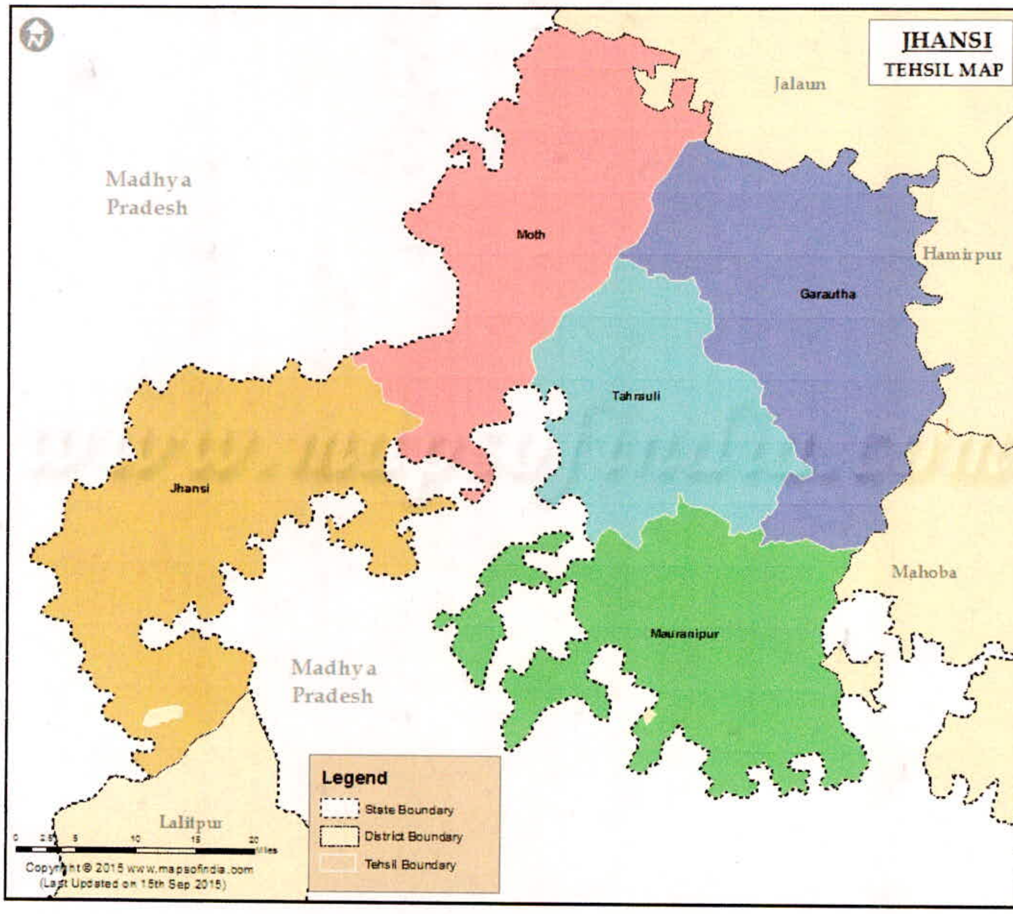

Figure 3: Tehsil Map of Jhansi District

The Jhansi district, although low on social indicators overall, is relatively better than other districts in Uttar Pradesh. As per 2011 census, the infant mortality rate for Jhansi district is 78 per 1000 births (IMR for UP state is 83/100 births). Major reason cited for this is availability of better health care facility in Jhansi district in comparison to most other districts. The lower Total Fertility Rate (TFR) for Jhansi district combined with a lower Crude Birth Rate (29.1 per 1000 population against the state CBR of 32.4 per 1000 population) has meant that the district has witnessed a lower (17.5 %) growth in population in the period 1991-2001. This is much lower than the state figure (28.43%) and even the national average (21.34%).The percentage of population living below poverty line in Jhansi district is 18.3%. The per capita income of Jhansi district is not available, but that of the state of Uttar Pradesh is Rs. 10817 (2003 – 04). The Jhansi district has also lately been experiencing large migration of people to other areas.

The area is chiefly drained by the river Betwa and minor rivers like Dhasan and Pahuj. The Betwa and Pahuj rivers are tributaries of Yamuna and Dhasan is tributary of Betwa. The major tributaries of Dhasan are the Lakheri, Sukhnai, Kurera etc which are mainly ephemeral. All three main rivers are perennial.

Jhansi district is situated at an elevation of 150-450 m above the mean sea level. Geologically, it is comparatively level; a low lying and fertile tract. It has the general appearance of a plain dotted with isolated low and rocky hills. The district has two physically distinct portions.

North Eastern Plains: This plain covers the Mauranipur, Garutha and part of Moth tehsils. It comprises small hillocks spread out across the plain. It is drained by river Dhasan and its tributaries Lakheri and Chainch, rivers. It has a slope towards the north-east.

The South Western Plateau: This plateau covers the southern portion of Jhansi tehsil and south western part of Mauranipur tehsil. This is a plateau in the South Western direction and is adorned with tall hills here and there. The land is undulating with several ravines. The general slope is towards the north. Geologically, Jhansi has an assemblage of Granite rocks known as Bundelkhand Granitic Complex. The district is dotted with granite and gneiss along with quartz reefs and igneous rocks.

2.6 Drainage and River System

Main source of irrigation in the district is through ground water and canal. Total length of canal is 1236 km by which 75235 hectare area is irrigated. There are 89 no. of government tubewells through which 3806 hectare area is irrigated. Irrigation by private tubewell is 8678 hectare. Hence 54% area is irrigated by ground water. Net sown area is 326767 hectare and net irrigated area is 196078 ha. The ratio of net irrigated area to net sown area is 60%. For drinking water supply pipe line schemes and India Mark II hand pump exist in the district. There are 739 India Mark II hand pumps for providing water to 863342 persons. The area is chiefly drained by the river Betwa and minor river like Dhasan and Pahuj. The Betwa and Pahuj rivers are tributaries of Yamuna and Dhasan is tributary of Betwa. The major tributaries of Dhasan are the Lakheri, Sukhnai, Kurera etc which are mainly ephemeral. All three main rivers are perennial.

The slope of the district is towards the north and the north east. The district has almost 5 major basins, enunciated as follows:

Betwa basin: This river touches the boundary of the district at Badora village and flows along the boundary of the district for almost 14 kms before flowing into the Tikamgarh district and re-entering Jhansi tehsil at Banguan village. In the district, this river has been dammed at Dhukuwa and Parischa.

Tributaries of Betwa: Besides Dhasan, some minor streams flowing from the hills of Moth, Jhansi and Maharanipur tehsils form the tributaries of the Betwa river. An important stream is the Barwa which has bee dammed to form Barwa Sagar lake in the district.

Dhasan: Arising from Madhya Pradesh, this river enters the district through the Mauranipur tehsil and forms its boundary with Mahoba and Hamirpur districts. The river has a rocky bed and its course is flanked by ravines, which grow highly complex as it approaches Betwa. The river has been dammed at Lahchura and Pahari and is used to divert water to irrigation canals.

Tributaries of Dhasan: Important tributaries of the Dhasan are the Ur, the Sukhnai, the Lakheri and the Chainch. These are primarily monsoon rivers that cause floods during the monsoons but are usually completely dried up after the winters.

Pahuj: This river enters Jhansi tehsil from Gwalior district and forms the boundary with the district of Datia. The Pahuj river, although flowing mostly through rugged country, does not have a deep bed. It has been dammed near village Simartha and is currently used to supply water to the Jhansi town.

2.7 Climate and Rainfall

The annual rainfall of the Bundelkhand region varies from 800 to 1300 mm, about 90% of which is received during South-West monsoon period. The major part of the rainfall is received during the month of July and August. The length of growing season in Bundelkhand ranges between 90 to 150 days depending upon rainfall and temperature regimes. The winter rains are erratic, occasional, meager and uncertain. The total rainy days/year vary from 30-45 in the region with an average of 37.

The distribution of rainfall is very erratic and low rainfall, drought are common features inn the area. Long dry spells during rainy season are also experienced often, which adversely affect the crops. It has been observed that in a cycle of 5 years, 2 are normal, 2 drought years and 1 is excessive rainfall year.

The climate of Jhansi is characterized by a hot dry summer and cold winter and is marked for high variability of rainfall year to year. There are primarily four seasons: – Dry Summer season – from March to May i.e. before advent of monsoon, moist summer season – from June to September (Monsoon) transition period - in October and November, which is the post monsoon period, and winter season – from December to February. The coldest months in the year are December and January. Average monthly rainfall and temperature is given in Table 2.5.

Agro-climatic characterization of IWMP-X Micro-watershed

The agro-climate of the water shed is characterized by dry and hot summer, warm and moist rainy season and cool winter with occasional rain showers. Mean annual temperature ranges from 24 to 25°C.The mean summer (April-May-June) temperature is 34°C which may rise to a maximum of 46 to 49°C during the month of May and June. The diurnal variation in temperature is quite high. The early rise in temperature during March-April accompanied with westerly winds reduces the humidity and causes damage to the Rabi crops, resulting in poor development.

Table 2: Jhansi District Average Annual Precipitation

Block	Average Rainfall(mm)	Area(Sq Km)	Volume water(m/cm)
Moth	850.00	644.24	547.60
Chirgaon	850.00	507.42	431.31
Bamaur	850.00	805.46	684.64
Gursarai	850.00	715.48	608.16
Bangra	850.00	524.53	445.85
Mauranipur	850.00	592.69	503.79
Babina	850.00	551.47	468.75
Badagaon	850.00	422.26	358.92
District Total		4270	

Table 3: Average Monthly Rainfall and Temperature of the Last Seven Years

Month	Rainfall in mm.								Temperature c	
	2009	2010	2011	2012	2013	2014	2015	Average	Max.	Min.
January	11.1	4.8	0	0.7	0	8.8	3.2	4.09	16.5	6.5
February	0	0.4	0	31.4	0	0.8	23.6	8.03	21.2	8.4
March	0	13	30.1	17.5	0	0	0	8.66	32.8	21.6
April	10.4	1.8	0	0.1	2.8	2.7	1.8	2.8	38.4	29.7
May	4.6	6.4	22.4	13.9	18.2	12	1.4	11.27	45.4	34.2
June	95.3	39.4	50.9	69.5	583.2	8	26.8	124.73	47.2	35.1
July	135.9	196.4	170.1	82.3	244	189.7	214.6	176.14	46.4	33.6
August	286.6	127.8	80.9	99.9	206.8	181.9	142.6	160.93	42.3	31.7
September	57	106.2	27.5	36.5	90.3	70.5	155.7	77.67	37.4	29.2
October	47.8	0	6.8	0	0	57.6	0.1	16.04	34.7	28.5
November	0	0	0	0	24.3	10.3	30	9.23	31.4	19.8
December	0	1.4	0.1	0.8	0	3.5	2.2	1.14	20.4	9.3
Total	648.7	497.6	388.8	352.6	1169.6	545.8	602	600.73		

The important minerals found in this region are building stone and road material, ceramic pegmatite and pyrophyllite and diaspore. The coldest months in the year are December and January in which the temperature goes as down as 10^0 C. This is due to the cold waves caused by the western disturbances moving across north India. From March onwards, the temperature begins to rise progressively and peaks in May in which temperature goes up to 45^0 C, which is accompanied by dusty storms. Thunderstorms occur during the pre-monsoon months while fog is common during winters.

The district gets maximum part of its rains in the Monsoon season, during which the south westerly winds as well the winds from Bay of Bengal bring the rain clouds along with them. The average rainfall of the Jhansi district as reported in the District Gazetteer (1965) is 880 mm. Inspite of the fairly decent average rainfall of the districts, its uncertainty and erratic behaviour leads to dry spells causing droughts and also floods in the Monsoon. The uncertainty in the rainfall is the main reason of poor agriculture yield. Rain is also received in a very small amount during November to May, but this rain is very important for agriculture in this region. This rain is called "Mahawat" in the vernacular language.

Agricultural: Jhansi has less than half of its area as agricultural, including both Kharif and Rabi crops. The hill topography of the district does not permit large-scale farming and cultivation of land under the so-called improved agricultural practices. The soil quality in the district has also been a major factor in the use of land for agriculture and the consequent demand for irrigation. In the regions of black soils in tehsil Moth, Garautha and Mauranipur, artificial irrigation has not been absolutely necessary because of the water retaining capacity of the soil. In the red soils, however, irrigation is necessary because the soils are incapable of retaining moisture. Similar to the Tikamgarh district, the main Kharif crops in the district are paddy, jowar, bajra, maize, pulses etc. while the main Rabi crops are wheat, gram, mustard, oilseeds etc. The maximum water requirement in the district is for irrigating the tilhan and the wheat crops mainly because they account for a bulk of the total sown area. .

The open pan evaporation varied in the range of 0.7 to 23 mm/day during the year with average of about 6 mm/day. Average relative humidity varied in the range of 25 to 98 per cent; however the range of wind speed varies between is 0.9 to 16 kmph

Groundwater Resources: As per the Groundwater Board, Jhansi, the Net Annual water availability from groundwater in the Jhansi district is approximately 1093.1 mcm. Out of this, the groundwater draft for all uses in the district is approximately 407.29 mcm; 37.29% of the groundwater potential. There are however, other estimates also that show Annual Replenishable Groundwater to be 896 mcm and groundwater development to be around 90%. Depth water in any area is of great significance in deciding drilling depths, selection of pumping devices, crops to be grown and deciding areas for ground water storage / artificial recharge. The indiscriminate exploitation of groundwater in the district has led to depletion of storage and lowering of water levels in many parts on one hand and fall in water levels to critical limits on the other hand. In many parts of the district, the groundwater levels have gone down to more than 30 metres below ground level (mbgl). In 6 villages, the water levels is above 60 mbgl.

Surface Reservoirs: Jhansi district is famous for its numerous huge water reservoirs built during the rule of Chandela and later Bundela kings. There are a large number of such structures which have utilized the slope of the land, the plateau and existing hillocks. In addition to these, there are also several dams built at various locations on the Betwa, the Dhasan, the Pahuj and the Saprar rivers.

Table 4: Jhansi District – Major Lakes And Reservoirs

Name	Storage Capacity (mcm)	Current Status
Lakes		
Kachneo Lake	44.7	Old lake, in the past canals were taken out from
		this lake
Arjar Lake	17.4	Highly silted; canals taken out Used for
Barwar Lake	33.4	drinking water supply and irrigation
Barwasagar Lake	10.3	Dammed by a 1.21 km long embankment;
		supplies water for irrigation through canals
Magarpur Lake	2.44	Supplies water for irrigation through canals
Siaori Lake	10	Opened for irrigation; receives water from Kamala
		Sagar that has increased its irrigation capacity
Magarwara Lake	1.65	Used for irrigation
Pachwara Lake	5.88	Used for irrigation
Dams		
Pahuj Dam	18.27	Used to supply drinking water to Jhansi town
Dongri Dam	9.92	Supplements the Pahuj dam in drinking water
		supply to Jhansi town and for irrigation
Paricha Dam	78.22	Used for irrigation to Jhansi, Jalaun and Hamirpur
		districts
Dhukuwan Dam	57.79	Used for irrigation through canals
Pahari Dam	47.76	Used for irrigation in Hamirpur district
Saprar Dam	76.20	Used for irrigation in Jhansi district through Ranipur
		canals and capacity enhancement of Siaori Lake
Lahchura Dam	10.57	Used for irrigation
Khaprar Dam	3.51	Used for irrigation
Total	428.01	
Capacity		

Urban Drinking Water Supply: In the Jhansi town, raw water is brought from Matatila dam to Babeena based settling and purification system from where it is distributed to the Jhansi city. This water supply is further supplemented by supply from the Pahunj dam and several handpumps, open wells and tubewells.

The water supply scheme for the town is designed and implemented by the Jal Sansthan. Once it is complete, it is handed over to the municipal authority which is responsible for its operation and maintenance. Since full cost of the supply system is not recovered, it becomes difficult to take comprehensive and annual maintenance of the supply pipelines. As a result, maintenance is mostly undertaken only when there is a burst or a leakage.

As per the information provided by the Jal Sansthan, Jhansi Division, currently the Jhansi town is being reconstituted into 16 zones by the U.P. Jal Nigam. At present, the town does not have adequate drinking water storage facilities and the pipelines system is also undersized. In addition, there are no pipelines in certain areas of the town where is supplied mainly through handpumps and water tankers. As can be seen from Table 6, the total requirement in the town is 77.55 million litres per day (m.l.d) whereas the supply system only caters to 58 mlpd . There is therefore a shortage of 20 million litres per day in the town itself.

Rural Drinking Water Supply: As per the District Statistical Handbook, 2005 of the Jhansi district, all the 760 inhabited villages are covered under the water supply schemes, through one source or the other. As a result of the continuous efforts by the State Government, the supply situation in the villages is improving, but at a very slow pace. One of the reasons for this is that a lot of the villages at the tail-end of the supply system do not get water at all on account of inadequate electricity supply. There is therefore, still a very high dependence on handpumps, which form the bulk of the means by which water is accessed by the rural population.

The Irrigation Water Situation: The low water table and the hilly topograph of the district have always been an obstacle to the expansion of irrigation. The district was abundant in masonry wells which were employed for irrigating the fields before canals were introduced in the same areas for revenue benefits. As already mentioned, Jhansi has many lakes, ponds and reservoirs from where canals have been taken out for irrigation. Embankment (Bandhan-system) was also popular here, as in other districts of Bundelkhand. The Rajghat canal project, mentioned earlier, is now a major source of irrigation water for the district. Besides providing water directly, which is lifted using pumps and taken through unlined channels, it has also recharged most of the wells in the command areas.

At present the conventional method of applying water through minor irrigation channels, distributaries and water courses is being followed in the district. However, sometimes electric/diesel pump sets are also used to lift water from the wells. The conditions of existing irrigation channels in the command are generally satisfactory except in some reaches where proper maintenance is required. Most of the channels are unlined, hence susceptible to loss of water through seepage.

Table 5: Jhansi District Urban Water Supply Sources And Demand

Urban Centre	Source of water	Water Requirement (M.L.D)	Water Available(M.L.D)
Jhansi	Matatila Dam, Pahunj Dam	63.338	48.500
	Tubewel l-12, HP-2098		
Mauranipur	Saprar Dam, HP-71	3.562	1.820
Samthar	Tubewel l-02, HP-64	1.415	1.300
Barwasagar	Dam, Tubewel ls, HP 140	1.545	0.920
Erich	Tubewel l-02, HP-155	0.596	0.380
Moth	Saprar Dam, HP-222	0.919	0.640
Ranipur	Tubewel l-01, HP-75	1.262	0.730
Gursarai	Barwar Lake, HP-65	1.609	0.730
Chirgaon	Tubewel ls, HP-59	0.987	0.950
Garautha	Tubewel ls, HP-59	0.611	0.430
Badagaon	Tubewel ls, HP-63	0.562	0.410
Katera	Tubewel l-04, HP-32	0.447	0.410
Todi	Tubewel l-04, HP-66	0.706	0.680
Fatehpur			
Total		77.559	57.90

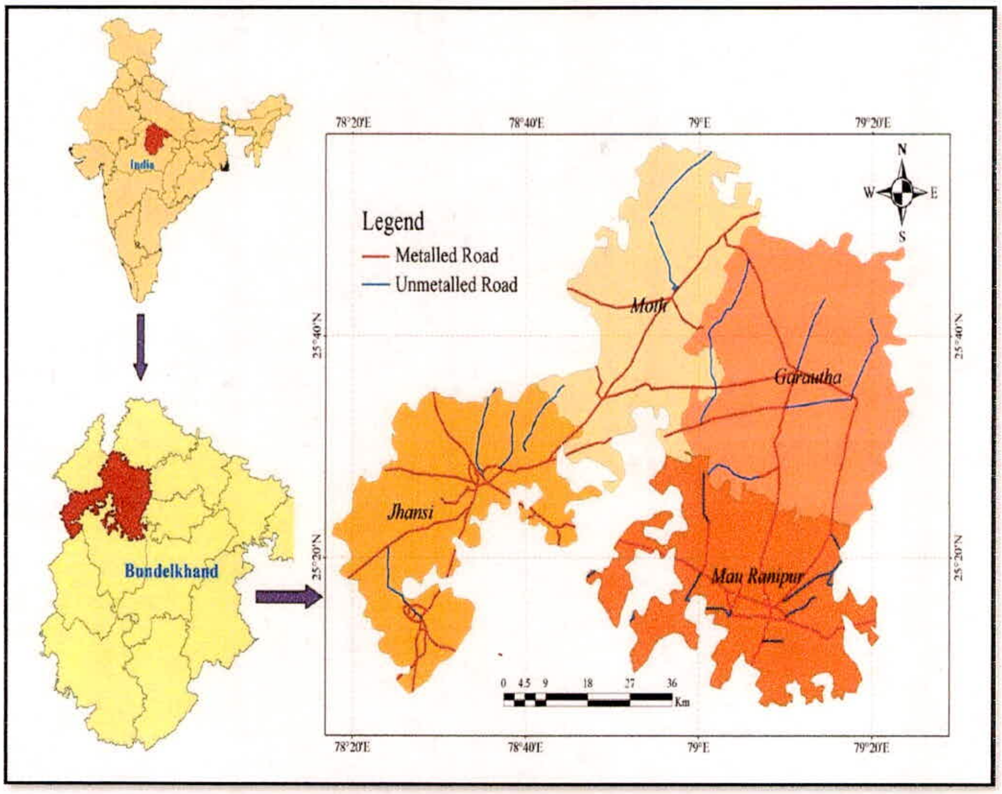

Figure 4: Location Map of Jhansi Districts

3 GEOMORPHOLOGICAL SET-UP

The remote sensing technique has been used to delineate the Geo morphological set-up of the study area. Remote Sensing (RS) data are essential input for the appraisal of natural environments as it provides valuable information for the interpreting the landscape. This technology has already demonstrated to provide information on natural resources such as land use land cover, soil, vegetation and crop patterns on periodic basis. Geographic Information System (GIS) is the latest tool available to capturing, storing, querying, analyzing, and displaying geospatial data. Thus it plays an important role in evolving alternate scenarios for natural resources management. Combination of RS and GIS provide multi-dimensional information for mapping of an area.

The scope of work in the present study includes rectification and geo referencing of satellite images pertaining to years 2006, preparation of maps for the area including land use land cover, major streams and tributaries etc. using satellite imageries and topographic maps, marking the location of water resources projects, their area of influence and other features in the Jhansi District.

3.1 Use of Survey of India Toposheet

The topographic map 54/K and 54/O (1:250,000 scale) were used as base map. It was converted to digital mode using scanning. The topographic map was georeferenced with longitude and latitudes using the ArcGIS software and spatial analyst tools and demarcated the boundary of study area.

3.2 Use of Satellite Data

Landsat ETM^+ images have been used for the study. Landsat ETM^+ data was downloaded for the year 2006 to study land use and land cover pattern. The Enhanced Thematic Mapper Plus (ETM+) instrument is a fixed "whisk-broom", eight-band, multispectral scanning radiometer capable of providing high-resolution imaging information of the Earth's surface. It detects spectrally-filtered radiation in VNIR, SWIR, LWIR and panchromatic bands from the sun-lit Earth in a 183 km wide swath when orbiting at an altitude of 705 km. The primary new features on Landsat 7 are a panchromatic band with 15 m spatial resolution, an on-board full aperture solar calibrator, 5% absolute radiometric calibration and a thermal IR channel with a four-fold improvement in spatial resolution over TM. The Enhanced Thematic Mapper Plus (ETM+) satellite data from 19 November 2006 was downloaded from Global Land Cover Facility (GLCF).

3.3 Preparation of DEM

DEM of the study area has been generated using ASTER data. ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer sensor) is an imaging instrument that is flying on the TERRA satellite launched in December 1999 as part of NASA's Earth Observing System (EOS). ASTER provides images with high resolution. There are 14 spectral bands all together spanning the visible and infrared spectra. Since sensor operates in visible and NIR bands, cloud cover pose problem in view of the earth and availability of the data. Because of its off-nadir sensor pointing capability, ASTER can collect the stereo pairs necessary to generate high resolution DEM (using bands 3N and 3B). The ASTER onboard the Terra satellite has produced 30 m resolution elevation data. There is a fairly complete coverage of world at this high resolution and data are free. Japan's Ministry of Economy, Trade and industry (METI) and NASA announced the release of the ASTER Global Digital Elevation Model (GDEM) in June 2009. The GDEM was created by stereo-correlating of the 1.3 million scenes from ASTER VNIR archive, covering the Earth's land surface between 83N and 83S latitudes. The GDEM is produced with 30 meter postings, and is formatted in 1 x 1 degree tiles as GeoTIFF files. The GDEM is referenced to the WGS84/EGM96 geoid. The GDEM's pre-production accuracy estimates were 20 meters at 95% confidence for vertical data, and 30 meters at 95% confidence for horizontal data. The digital elevation model of the study area is shown in Figure 5. Elevation ranges from 93 m to 410 m in the study area.

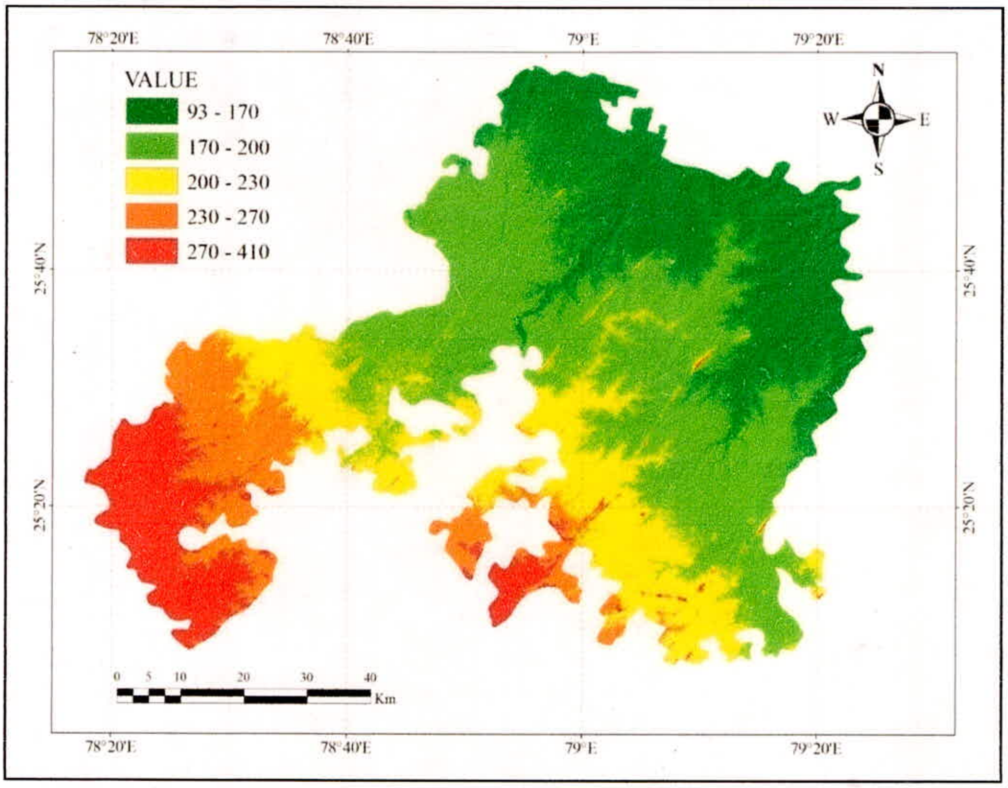

Figure 5: Digital Elevation Model of Jhansi District

(In Meters)

3.4 Preparation of Drainage map

Drainage ma has been prepared using the aster dem. The drainages in topographic maps, of years 1965 to 1975, were in general matching with those prepared using astem dem data. The drainages network map is show in figure 6.

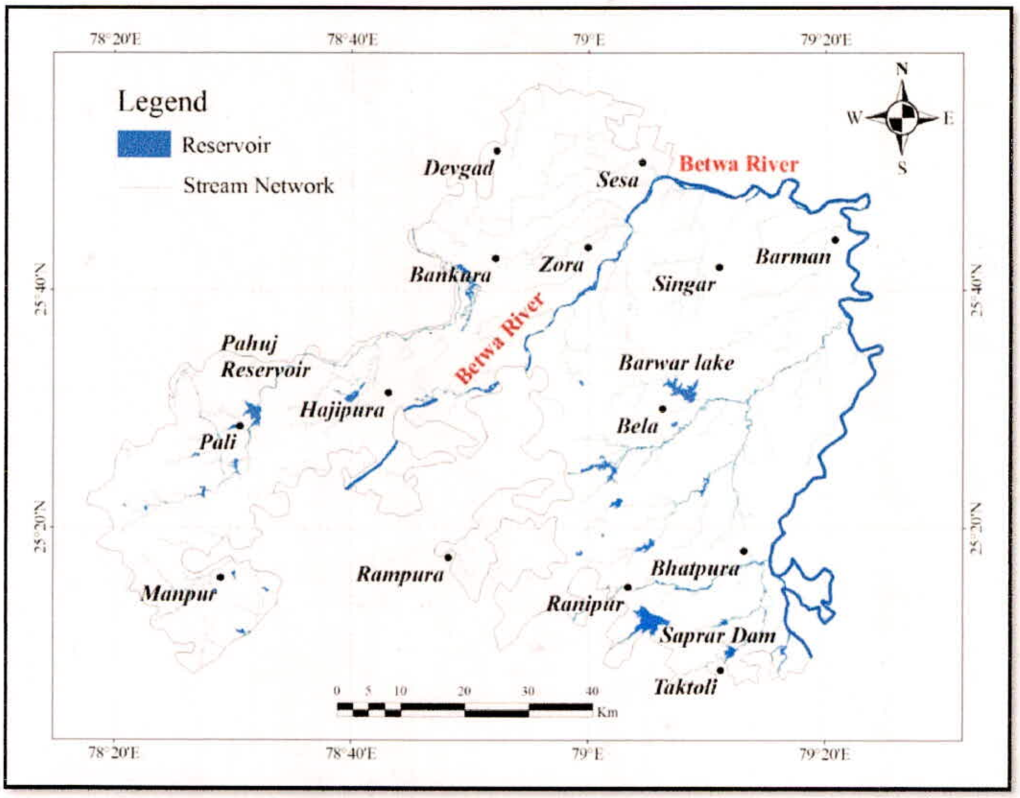

Figure 6: Drainage Network of Jhansi District

3.5 Preparation of Land use Land cover map

Land use land cover study has been carried out using Landsat ETM^{+} images of 19-11-2006. Area of Jhansi district is 5024 Sq. Km., unsupervised classification technique was used for land-cover map generation. In the technique, spectral clusters are automatically generated using distance measure in a multidimensional space. Pixels belonging to a particular cluster are, therefore, spectrally similar. Clustering is a popular technique for image classification. False Color Composite (FCC) map of of Jhansi District was also prepared using this satellite data (Fig. 7).

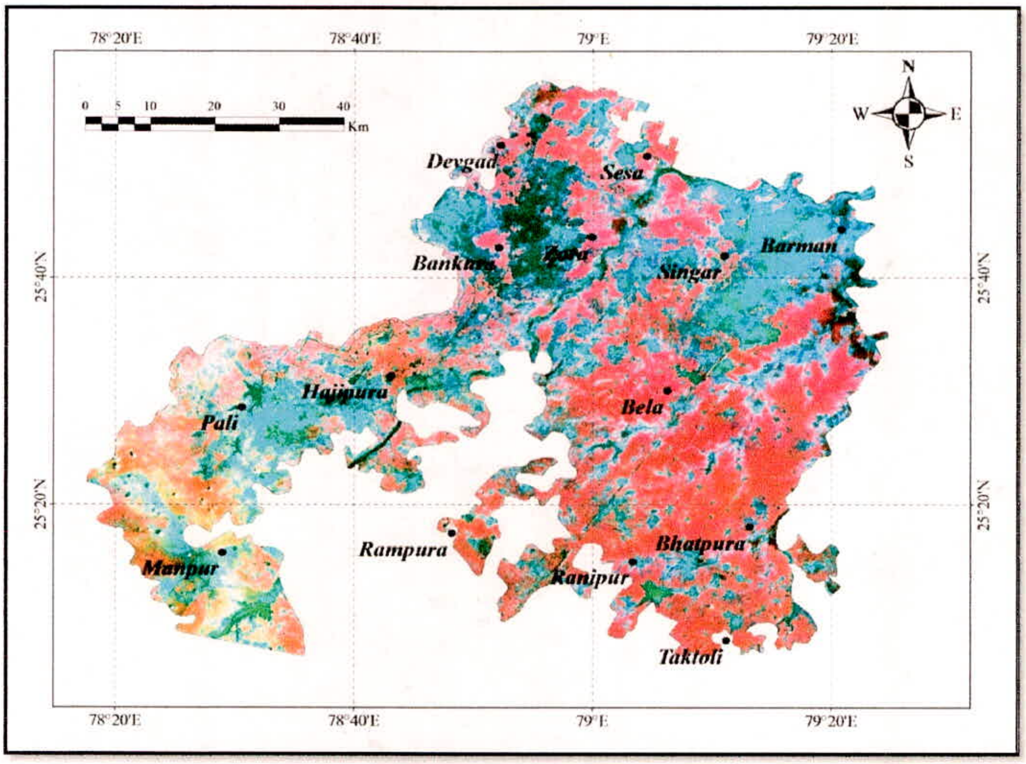

Figure 7: False Color Composite Map of Jhansi District

The satellite data was enhanced before classification using histogram equalization in ERDAS Imagine 8.5 to improve the image quality. Area was classified in to five categories, namely water body, agricultural land, settlement, forest cover, hilly/ barren land and river bed (Fig. 7). The area covered by different landuse classes are shown in table no 6:

Table 6: Land Use Classification of Jhansi District

Land use Classes	Area Sq.km	Percentage
Water body	122.76	2.43
Forest	87.85	1.74
Agricultural Land	4476.12	88.64
Settlement	48.11	0.95
Hilly/Barren Land	304.42	6.03
River Bed	10.44	0.21

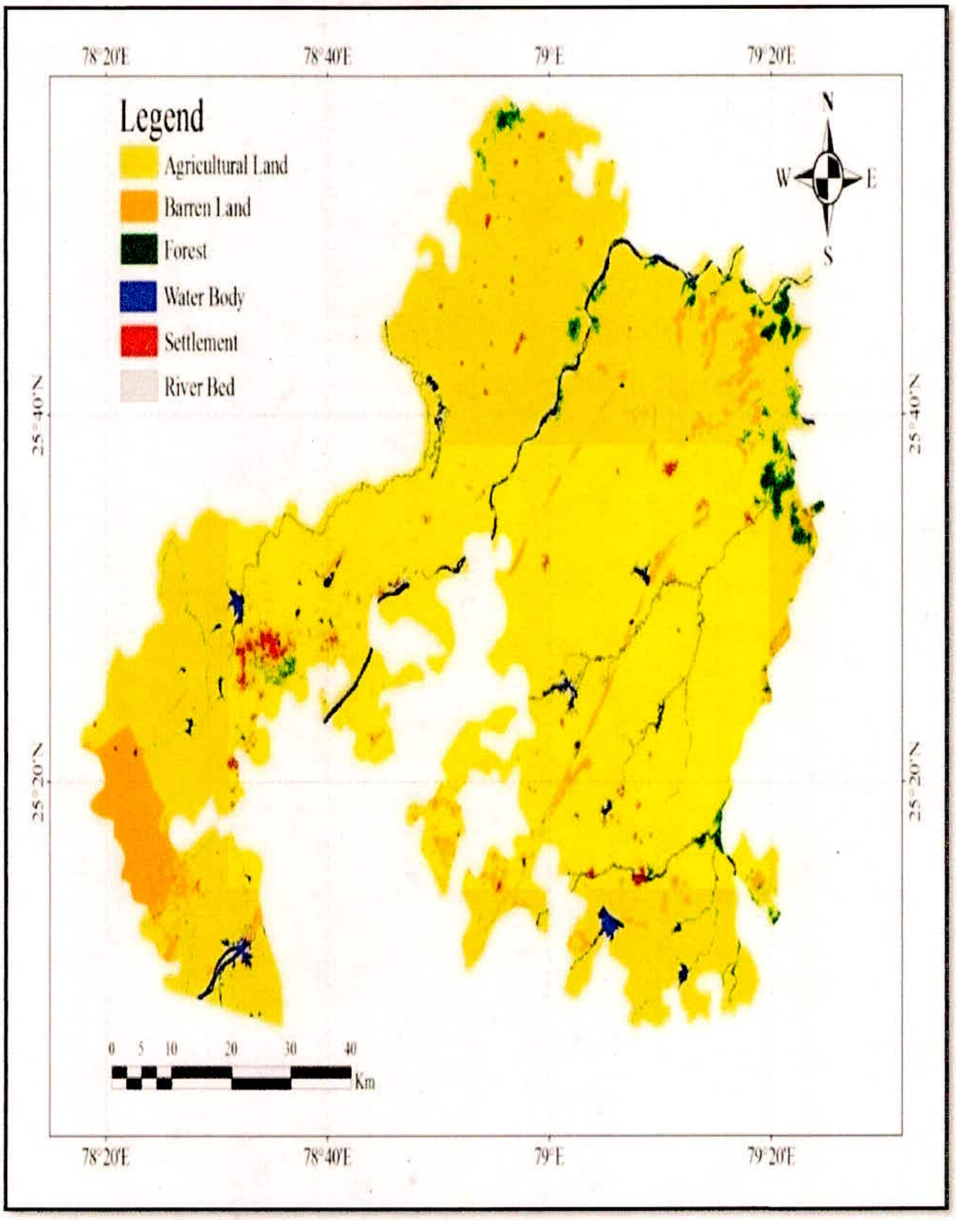

Figure 8: Landuse Map of Jhansi District

3. FACTORS AFFECTING INFILTRATION PROCESS

The process of infiltration is affected by many different factors. Important factors are discussed below:

i) Soil Properties

The type of soil and soil texture (sandy, silty, clay) can control the rate of infiltration. Soils that have stable strong aggregates as granular or blocky soil structure have a higher infiltration rate than soils that have weak, massive, or plate like structure. Soils that have a smaller structural size have higher infiltration rates than soils that have a larger structural size. Generally speaking, the wider the range of pore sizes, more gradual is the change in the infiltration rate.

Amount and type of clay minerals in the soil profile are also controlling the infiltration rate. Many clayey soils develop shrinkage cracks as they dry, creating a direct conduit for water to enter the soil. These soils have high infiltration capacities as water moves in to the shrinkage cracks, although at other times, when cracks are not present, their infiltration rate is characteristically low.

Even if the subsoil has excellent under drainage but at the surface soil pores are sealed due to turbid water or by in wash of fine soil particles it may prevent entry of water into the soil and infiltration rate will be low.

ii) Initial Moisture Content

The content or amount of water in the soil affects the infiltration rate of the soil. The infiltration rate is generally higher when the soil is initially dry and decreases as the soil becomes wet. As soil become wet, the infiltration rate slows down to the rate of permeability of the most restrictive layer. For saturated soils, the infiltration falls to the saturated hydraulic conductivity almost instantaneously.

iii) Organic Matter

Infiltration is affected by crop and land management practices that affect surface crusting, compaction, and soil organic matter. An increased amount of plant material, dead or alive, generally assists the process of infiltration. Organic matter increases the entry of water by protecting the soil aggregates from breaking down during the impact of raindrops. Particles broken from aggregates can clog pores and seal the surface and decrease infiltration during a rainfall event.

iv) Soil Temperature

If saturated soil mass gets frozen due to severe low temperature it becomes nearly impermeable. It affects the infiltration

v) Human Activities on Soil Surface

If the soil surface gets compacted due to construction of roads, operation of tractors and other farm implements and machinery the porosity of the soil is decreased. As a result bigger pores are almost eliminated making soil impermeable. It reduces the infiltration rates appreciably.

4. VARIATION OF INFITRATION RATE

Soils with low infiltration can be responsible for runoff and flooding and can become saturated during rain events. This, in turn, decreases soil strength and increases erosion potential. It can also cause nutrient deficiencies in plants and generate anaerobic conditions. Soils that have reduced infiltration have an increase in the overall amount of runoff water. This excess water can contribute to local and regional flooding of streams and rivers or results in accelerated soil erosion of fields or stream banks.

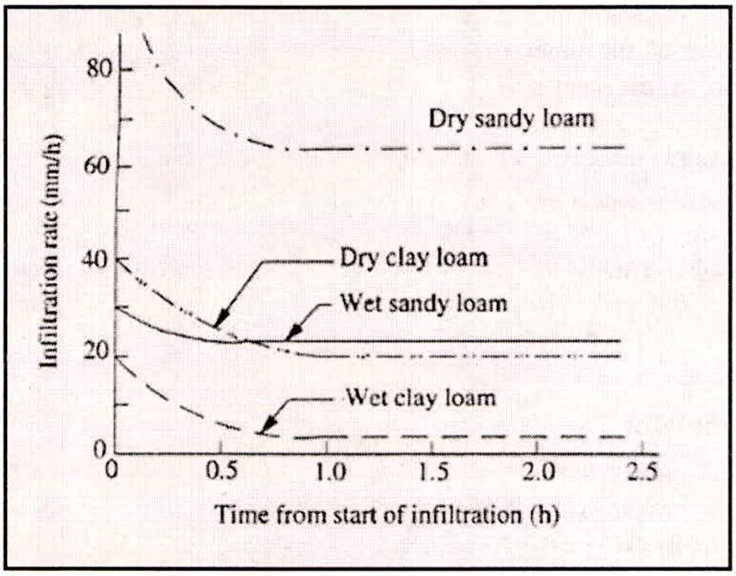

Figure 10 : Field Set Up of Double Ring Infiltrometer

6. INFILTRATION CHATACTERISTICS OF THE STUDY AREA

In the present study infiltration characteristics are being studied for (Moth) Jhansi district at total 30 grid points. The results for all infiltration test locations are presented in this section.

Figure 24 to 55 present the infiltration characteristics of the different locations in the study area. A brief description of the location is provided in the corresponding tables (table 11-42).

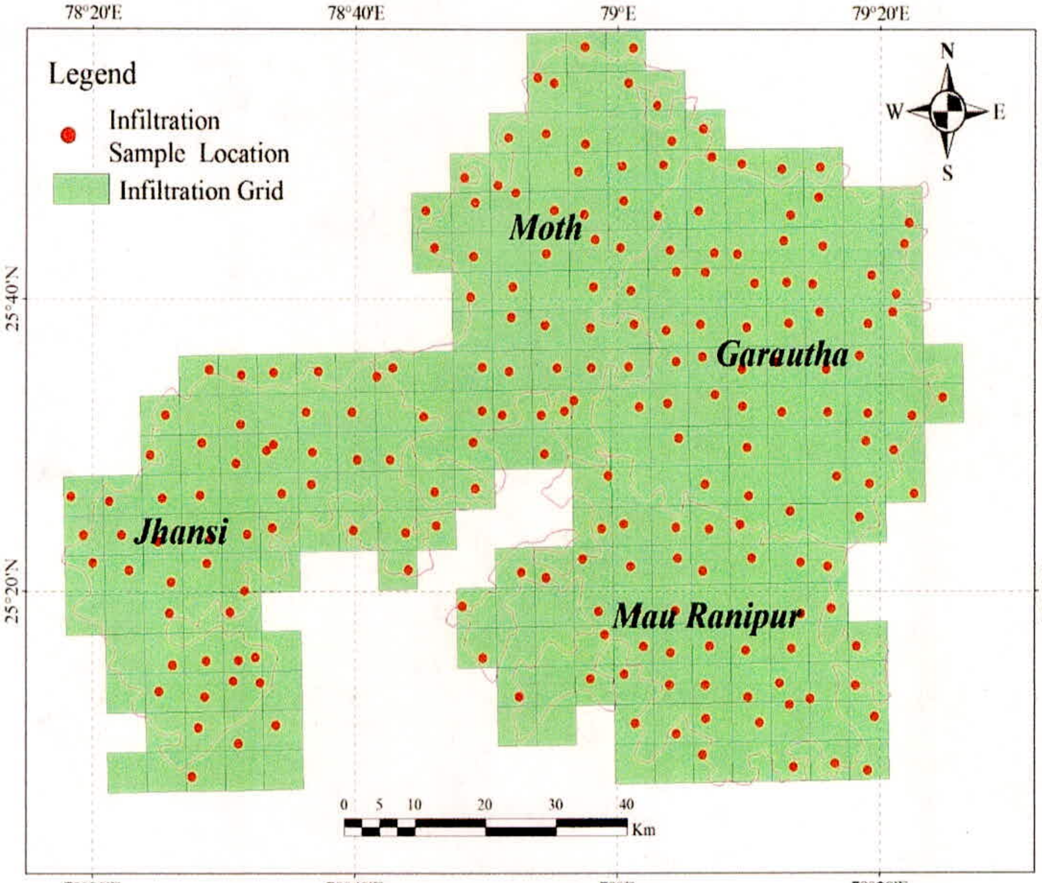

Figure 11: Sample Location Map for Infiltration Test Locations of Jhansi District.

Table 7: List of Infiltration Test Location of Jhansi District

S.No.	Grid No.	Location/Village	Latitude	Longitude
1	1	Dhaurka/Bhandana	25.92	78.90
2	2	Salliyan Buzurg	25.95	78.96
3	3	Kalaiya Buzurg	25.95	79.02
4	4	Chhewta	25.91	78.92
5	6	Karai	25.91	79.01
6	7	Kamtari	25.89	79.05
7	8	Bahaderpur	25.85	78.86

8. TECHNIQUE OF INFILTRATION METHOD

There are two technique of infiltration method.

i. Double Infiltrometer Method

ii. Minidisc Infiltrometer Method

8.1 Double Infiltrometer Method

Infiltrometer is a device used to measure the rate of water infiltration into soil or other porous media. Commonly used infiltrometers are single ring or double ring infiltrometer, and also disc permeameter.

Double ring infiltrometer requires two rings: an inner and outer ring. The purpose is to create a one-dimensional flow of water from the inner ring, as the analysis of data is simplified. If water is flowing in one-dimension at steady state condition, and a unit gradient is present in the underlying soil, the infiltration rate is approximately equal to the saturated hydraulic conductivity. An inner ring is driven into the ground and a second bigger ring around that to help control the flow of water through the first ring. Water is supplied either with a constant or falling head condition, and the operator records how much water infiltrates from the inner ring into the soil over a given time period.

There are three main problems related to the use of infiltrometers:

1. The pounding of the infiltrometer into the ground deforms the soil causing cracks and increasing the measured infiltration capacity.

2. Natural rainfall reaches terminal velocity. Also natural droplet sizes differ with different types of storms. Pouring water from a measuring cup however loses this momentum and variance.

3. With single ring infiltrometers, water spreads laterally as well as vertically and the analysis is more difficult.

The double ring infiltrometer is a widely used method of infiltration test used in many applications; i.e. ,design of land drainage pipes, design of sports surfaces, golf courses, isolation layers of the communal waste, etc. The infiltrometer consists of two concentric metal rings (see Figure2.) which are driven into the soil, and of a perforated metal plate.

Figure 12: Double Ring Infiltrometer

8.1.1 Installation

1. Place the inner ring with the cutting edge facing down on the ground. Remove small obstacles such as stones or twigs. When measuring below the ground surface, a profiled pit should be made.

2. Put the driving plate on top of the inner ring. Depending on its diameter the ring will fit over, between or within the pins located on the bottom side of the driving plate.

3. Use the impact-absorbing hammer to insert the infiltration ring about 5 cm vertically into the soil. Make sure to disturb the soil as little as possible. In stiff soils have someone stand on the driving plate while another person drives it in. Remove the driving plate from the inserted infiltration ring. Keep the depth of placement as limited as possible so as not to disturb the top layer. Insert the rings in any case to below a particular top layer, such as a disturbed or crusted top layer or layer with macro-pores.

- ✓ In the case you should encounter any play between the ring and the ground, push the ring back in its place. A disturbed crust can be healed using bentonite or other soil material.

4. Place the outer ring with the cutting edge facing down around the inner ring and put the driving plate on top of it.

5. Repeat step 3. (see figure). The shape of the driving plate will ensure a depth identical to that of the inner ring.

6. The standard double ring infiltrometer set allows simultaneous measuring in threefold. Place the rings 2 - 10 m apart, depending on the field situation, and repeat steps 1 to 5.

- ✓ Place all rings at a similar depth to allow comparison of the results. Differing ring diameters are not supposed to produce differing results.

Figure 13: Process of Double Ring Infiltrometer

7. Place the measuring bridge with measuring rod and float on the inner ring. Remove, without disturbing the soil structure, any vegetation that may hamper free movement of the float or affect the measuring.

8. Fill the outer ring with water, then the inner ring, to approximately 5 - 10 cm. Start measuring immediately to determine the infiltration curve .

- ✓ The water level within the infiltration rings should be as low as possible to ensure vertical infiltration. The rings should not go dry. It is recommended to fill to 5 - 10 cm.
- ✓ To protect the ground surface when pouring the water, use plastic foil, a jute cloth, sponge or a 1-2 cm layer of sand or gravel. It is also possible to pour the water via your hand on the ground.
- ✓ Make sure to have sufficient water at hand. Filling one set of rings requires approx. 25 litre.

SOME REMARKS:

To measure only the infiltration capacity of saturated soil it will suffice to saturate the soil (by pouring water in thep rings) without measuring. To obtain optimal results in determining the infiltration capacity, use water of a similar quality and temperature top that of the real system you are examining.

8.1.2 Equipment

The double ring infiltrometer, wooden piece or something similar in order to drive the rings into the soil, hammer, bucket, measuring jug, scissors, knife, stopwatch, equipment for writing records, measuring tape, washcloth, and water.

8.1.3 Measurement Procedure

The measurement is taken in the inner cylinder; the outer cylinder is used only as a tool to ensure that water from the inner cylinder will flow downwards and not laterally. The soil surface in the inner cylinder is covered by a perforated metal plate which is used in order to dissipate the force of the applied water, to distribute water uniformly inside the ring and to prevent disturbance of the soil.

Two nail points of different lengths are fixed to the metal plate. These nail points are used for observation of decreasing water level during the infiltration. Both (inner and outer) cylinders are driven into the soil (to a depth of about 10-20 cm).

It is recommended that the turf around the rings' periphery is cut with a knife, the soil is then less disturbed by driving the rings into it. The metal plate is placed on the soil surface in the inner cylinder, and water is poured into both cylinders (the water level in the inner cylinder should reach the upper nail point).

At this moment the stopwatch is started and the time needed for the water level to drop from the upper nail point to the lower nail point is measured and recorded. After this elapsed time, a certain amount of water was infiltrated. When the water level reaches the lower nail point, the time is recorded and the same amount of water is poured back from a prepared graduated bottle. The water level in the outer cylinder is kept at the same level as the water level in the inner cylinder.

Results from the double ring infiltrometer measurements can be taken only as directory information; however they can be considered as accurate enough for many applications.

1. Start the measuring by noting the time and the water level in the inner ring (reference level) as indicated on the measuring rod. Use columns A and B on the field list. When carrying out synchronic measuring, use several field lists.

   Always use copies of the field list; use the original only for reproduction.

Figure14: Field Measurement of Infiltration Using Double Ring Infiltrometer.

2. Determine the drop in the water level in the inner ring during a certain interval. Note the time and the water level in column A and B on the field list. Start with short intervals (for instance 1-2 min) and conclude measuring with a longer interval (20 - 30 min, depending on the type of soil).

✓ Make sure the infiltration rings do not go dry during measuring. Add water when only a few centimeter of water are left in the rings. Write the new levels in column B of the list.

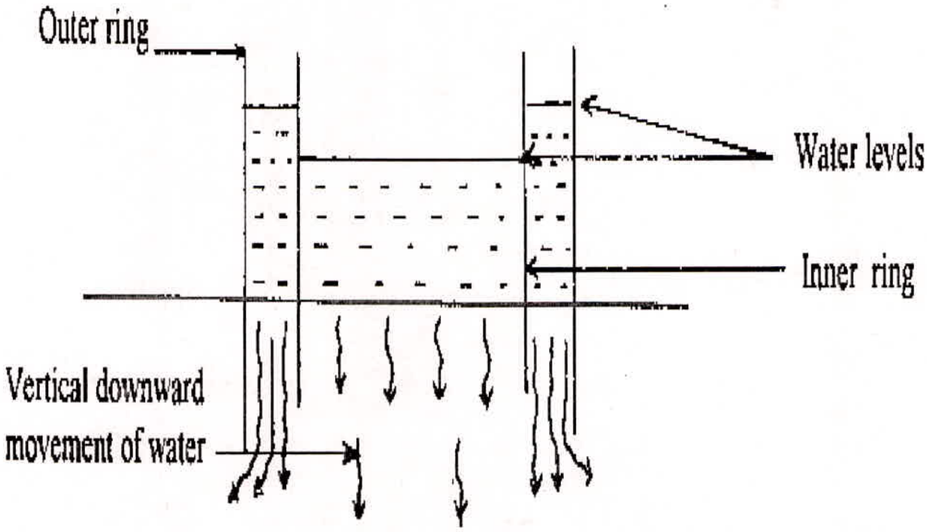

Figure 15: Infiltration Process Caused At Different Water Levels Through Inner And Outer Rings.

- ✓ Keep the water in the inner and outer ring at a similar level. A higher water level in the outer ring will lead to a decreasing infiltration rate in the inner ring. A lower water level in the inner ring will cause the buffering against lateral spreading to decrease.

3. Stop measuring only if the infiltration rate has reached a constant value. A change of < 10% in a certain phase is often considered as constant. Depending on the type of soil this may occur within 1 or 2 hours, in exceptional cases only after a day.

4. Remove the rings using the pull-out hooks.

5. Rinse the rings make sure no earth sticks and sets to the rings. Proper maintenance will prevent unnecessary disturbance of the soil upon installation.

8.1.4 Data Record and Calculation from the Double Ring Infiltrometer Experiment

The measured data are recorded to a Data record form, like that on the right-hand side. This form includes the necessary parameters for our double-ring infiltrometer demonstrated in the photos. However, these parameters can be different for other double ring infiltrometers.

1. Calculate the cumulative time and time steps in columns C and D using the data in columns A and B. Determine the infiltration in column E by calculating the water level differences between intervals in column B.

2. Calculate the infiltration capacity (cm) in column F by dividing for each interval the infiltration (column E) by the time step (column D). If necessary, convert the infiltration capacity to e.g. [mm] in column G.

3. The tabulated data can be used to determine the infiltration curve. Plot out the calculated infiltration capacity (column I) on the y-axis of a graph and the cumulative time (column D) on the x-axis.

4. The near-saturated hydraulic conductivity equals the more or less constant infiltration capacity established toward conclusion of the measuring. Use multiple measurements to calculate a reliable mean value for a certain type of soil or landscape unit.

5. Determine, if necessary, the cumulative infiltration for a certain period. The cumulative infiltration is the total amount of water infiltrating over a certain period of time (L, for instance mm). Fill in column H of the field list by adding the total infiltration (column E) for each interval from the starting of measuring on.

Table 8: Format of Data Record And Computation Using Double Ring Infiltrometer

A	B	C	D	E	F	G	H	I
S.No.	Time (min)	Time (Sec)	Cumulative Time (min)	Vol (cm^3)	cm	Cumulative (mm)	Infil. Rate cm/sec	Infil. Rate mm/hr

8.1.5 Applications

The double ring infiltrometer is suitable for almost any type of soil with the exception of clogging soils, stony soils or the soil of steep slopes. The outer ring causes almost vertical infiltration of water from the inner ring. A number of soilhydrological features can be determined (per soil layer): Infiltration capacity.

- ✓ Near-saturated hydraulic conductivity.
- ✓ Infiltration curve.
- ✓ Cumulative infiltration over a certain period.

The double ring infiltrometer is applied, among other things, in determining the infiltration capacity of flooded soils for:

- ✓ Surface irrigation and drainage projects.
- ✓ Infiltration or water purification basins.
- ✓ Seepage from watercourses, canals, basins or wastewater lagoons.
- ✓ Soil leaching at waste storage sites.
- ✓ Research into the effects of cultivation.
- ✓ Research into drainage effects.
- ✓ Research into badly permeable layers of sports fields.

8.1.6 Troubleshooting

- ✓ If horizontal insertion of the infiltration ring and the driving plate is not successful, a stone or a root might impedeρ the process. Choose another spot for measuring.
- ✓ If the infiltration rate proves not to be constant, continue measuring. A variance of less than 10% per interval is consideredρ as constant.
- ✓ Increased infiltration is established. This may result from:
- ✓ Macro pores. They tend to occur in soils susceptible to shrinkage (cracks and fissures resulting from drought), asρ a result of vegetation (rooting), soil fauna, or in strongly disturbed topsoil (ploughing). Insert the ring well into the soil, to below the disturbed top layer. Carry out measuring at several representative spots to obtain a reliable mean infiltration curve of the soil or landscape unit.

- ✓ Disturbance of the soil caused by installation of the ring. Bentonite or other types of clay may be used to healρ crusted or disturbed soils. Play between the infiltration ring and the ground can be fixed by applying soil.
- ✓ If the water level in the inner ring exceeds the level in the outer ring, buffering against lateral spreading is insufficient.ρ Make sure the water in both rings has the same level.
- ✓ In well-layered soils, water will tend to strain off sideways, despite the use of the double ring. If necessary, determineρ the infiltration curve of the underlying layers separately in a pit.

- ✓ Too high a water level in the infiltration rings will cause the water to spread laterally. The maximum water levelρ should be 5 -10 cm.
- ✓ Sustained measuring will increase lateral spreading.ρ
- ✓ Infiltration is below expectation. Several factors may be the cause:ρ
- ✓ The soil is crusted. First, establish the infiltration curve of the undisturbed (crusted) soil, then remove the crust andρ measure again. A large difference in infiltration indicates the occurrence of a crust. Usually the crust will measure less than 1 centimeter (Bouwer, 1986).
- ✓ If the water level in the outer ring exceeds the level in the inner ring, water from the inner ring will hardly infiltrateρ and may become negative. Make sure the water has the same level in both rings.
- ✓ The water poured into the rings has disturbed the soil structure. Protect the soil and use plastic foil, a jute cloth,ρ sponge, or a 1-2 cm layer of sand or gravel. It is also possible to pour the water on the ground via your hand.
- ✓ Water used for measuring, containing sediments or other suspending agents may cause a low-permeable layer. Useρ water of a similar quality and temperature to that of the soil of which you are measuring the infiltration capacity.

9. MINIDISC INFILTROMETER METHOD

The Mini Disk Infiltrometer is a very handy, manually operated device to measure unsaturated hydraulic conductivity at tensions between -0.5 cm and -6 cm. It consists of two chambers, which are filled with water (see Fig16). The upper chamber (bubbling chamber) controls the suctions. Water for infiltration is stored in the lower chamber.

There is a porous, sintered, stainless steel disk at the bottom of the lower chamber. The disk is 0.3 cm thick and has a diameter of 4.5 cm. In the field a disk with such a small parameter is relatively easy to set up on the soil surface, which needs to be smooth and leveled.

However, only a small part of the soil is measured, which does not full fill the requirements of the representative volume of water.

The amount of water, which can be infiltrate is 135 cm3. The time interval for manual readings needs to be determined according to the soil type being tested, and the tension. The recommended interval in the User's manual for sand is 2 to 5 s, for silt loam 30 s and for tight clay 30 to 60 minutes.

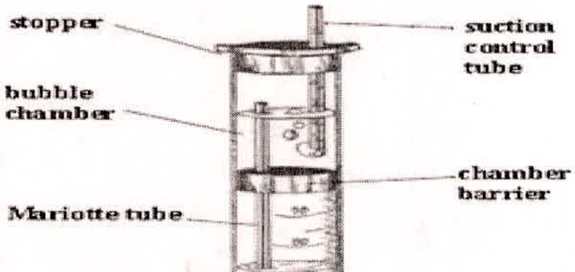

Figure 16: Minidisc Infiltrometer

9.1 Measurement Procedure

A special care needs to be taken to the preparation of the soil surface. Good hydraulic contact between the infiltrometer disk and the infiltration surface is essential for correct measurement. If the surface is not smooth, a thin layer of silica sand can be used as a contact material. When filling the infiltrometer with water, start with the bubbling chamber and then fill also the water reservoir tube. Make sure that water is not leaking from anyplace around the disk. Set the suction rate (depending on the soil). According to the User's manual, a suction rate of 2 cm should be adequate for most soils. To start the experiment, record the initial water level in the reservoir tube, place the infiltrometer on the surface, and start the stopwatch. The water level needs to be recorded at regular time intervals.

Figure 17: Minidisc Infiltrometer

9.2 About the Infiltrometer

The Mini Disk Infiltrometer is ideal for field measurements; due to its compact size, the water needed to operate it can easily be carried in a personal water bottle. It is also practical for lab and classroom use, in demonstrating basic concepts of unsaturated soil hydraulic conductivity.

9.3 Specifications

Total Length: 32.7 cm

Diameter of tube: 3.1 cm

Sintered stainless steel disc: 4.5 cm diameter, 0.3 mm thick

Length of suction regulation tube: 10.2 cm

Suction range: 0.5 to 7 cm of suction

Length of water reservoir: 21.2 cm

Length of mariotte tube: 28 cm

Volume of water required to operate: 135 ml

9.4 Hydraulic Conductivity

The knowledge of hydraulic conductivity benefits scientists, land managers, and growers, by indicating how quickly water infiltrates when applied to a given field or soil type. Infiltration is also relevant in contaminant transport, ground water recharge and ecosystem sustainability. The hydraulic conductivity of the soil is the rate at which water can move through the soil under certain conditions and hydraulic gradients. Water movement through soil typically happens under saturated and unsaturated conditions.

Because the Mini Disk Infiltrometer is a tension Infiltrometer, it measures the unsaturated hydraulic conductivity of the medium it is placed on at different applied tensions. Flow through an unsaturated soil is more complicated than flow through continuously saturated pore spaces. Macropores generally fill with air, leaving only the finer pores to accommodate water movement. Therefore, the hydraulic conductivity of the soil is strongly dependent on the detailed pore geometry, water content, and differences in matric potential. (Rose,1966; Brady and Weil, 1999).

The Mini Disk Infiltrometer measures the hydraulic conductivity of the medium it is placed upon. Because the Infiltrometer has an adjustable suction (0.5 to 7 cm) you can get additional information about the soil by eliminating macropores with an air entry value smaller than the suction of the Infiltrometer. This is done by controlling the infiltration with a small negative pressure or suction. When the water is under tension or suction, it does not enter macro pores such as cracks or wormholes, but goes further into and through the soil as determined by the hydraulic forces in the soil.

Saturated conductivity occurs when all the pores, including the large ones (such as cracks or wormholes), are filled. Macro pores flow, however, is extremely variable from place to place, and therefore difficult to quantify.Infiltrating water under a tension prevents the filling of the macro pores and gives a hydraulic conductivity characteristic of the soil matrix, and is less spatially variable.

Unsaturated soil hydraulic conductivity is a function of water potential and water content of the soil. The decrease in conductivity as the soil dries is due primarily to the movement of air into the soil to replace the water. As the air moves in, the pathways for water flow between soil particles becomes smaller and more tortuous, and flow becomes more difficult

9.5 Preparation

To prepare the Infiltrometer for measurement, do the following:

1. Fill the bubble chamber three quarters full by running water down the suction control tube or removing the upper stopper.

Note: Do not use distilled water. Soil water has solutes and clays have salts on the exchange sites. Using distilled water changes the ionic balance and may flocculate or disperse the clay in the soil

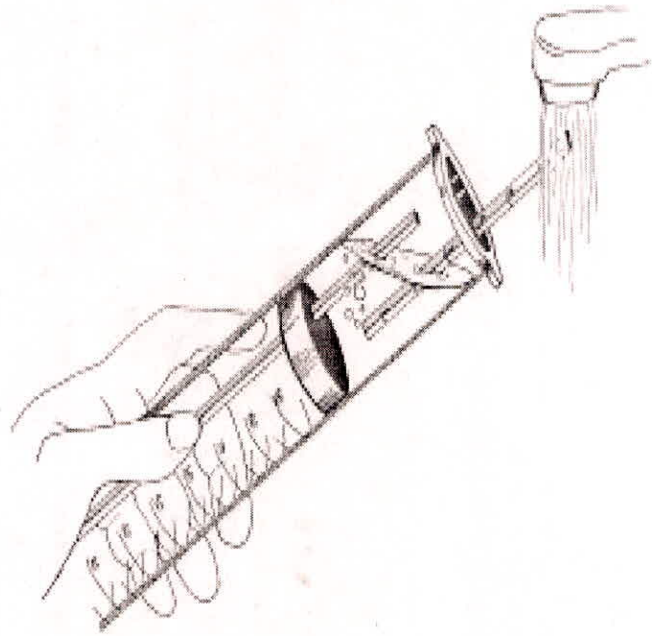

Figure 18: Filling Bubble Chamber

2. Once the upper chamber is full, slide the suction control tube all the way down, invert the Infiltrometer, remove the bottom elastomer with the porous disk, and fill the water reservoir.

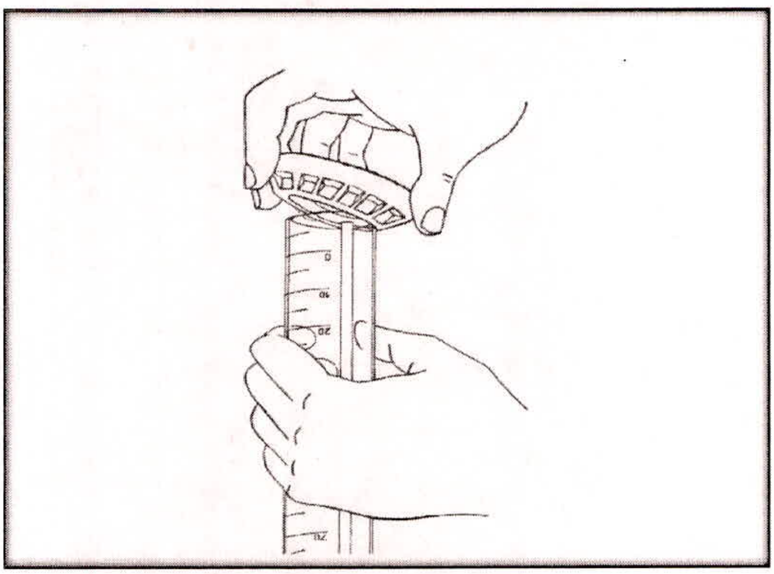

Figure 19: Removing Bottom Elastomer

3. We carefully set the position of the end of the mariotte tube with respect to the porous disk to ensure a zero suction offset while the tube bubbles. If this dimension is changed accidentally, the end of the mariotte tube should be reset to 6 mm from the end of the plastic water reservoir tube.

4. Replace the bottom elastomer, making sure the porous disk is firmly in place.

5. If the Infiltrometer is held vertically, no water should leak out.

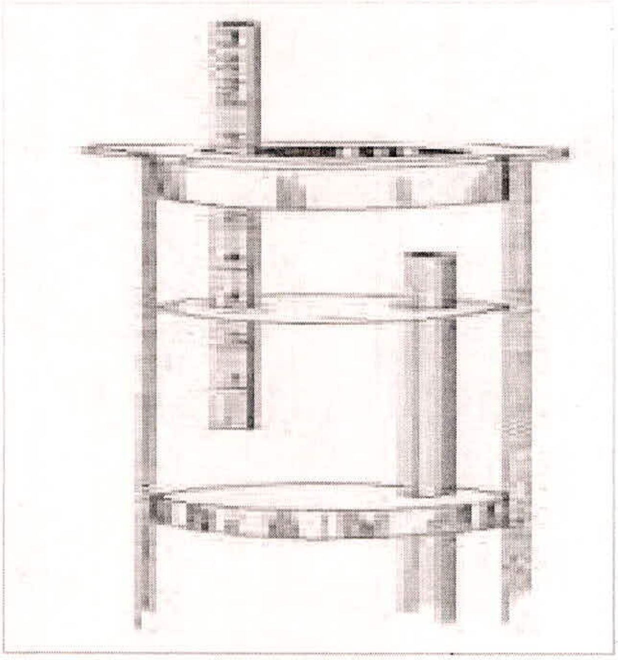

Figure 20: Upper Chamber and Suction Tube

9.6 Choosing the Suction Rate

Since different soil types infiltrate water at different rates, measuring the change of volume vs. time can often be difficult, particularly in a sandy soil where the water infiltrates rapidly. Therefore, you can adjust the suction rate to better accommodate measuring infiltration for the type of soil you are measuring. (See Figure 5) For most soils, a suction rate of 2 cm should be adequate. In sandy soils where in- filtration occurs very quickly, an adjustment to 6 cm may be helpful, and we recommend a suction rate of 0.5 for more compact soil with slower infiltration.

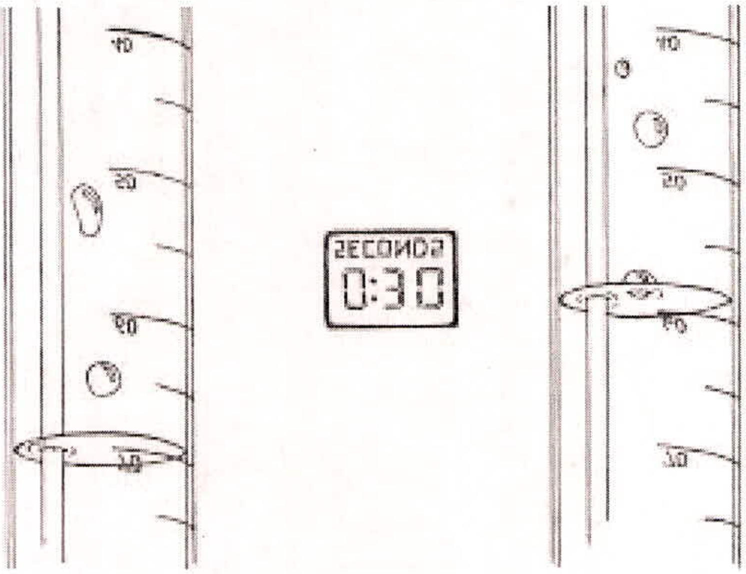

Figure 21: Suction Rate

However, we generally recommend that adjusting the suction to rates other than 2 cm should be reserved for more advanced users who are comfortable with the instrument and theory of operation.To adjust the suction rate, move the suction tube up or down so the water level is even with the desired suction rate marked on the side of the tube. If the suction tube is difficult to move, apply a small amount of vacuum grease on the tube to ease movement.

9.7 Placement

The Infiltrometer should be applied to a smooth spot on the soil surface. If the surface is not smooth, a thin layer of fine silica sand or diatomaceous earth can be applied to the area directly underneath the Infiltrometer stainless steel disk. This ensures good contact between the soil and the Infiltrometer. When possible, we also recommend using a ring stand and clamp to hold the Infiltrometer in place.

9.8 Data Collection

To make the hydroulic conductivity measurement, make sure you have first prepared the instrument as described in Section 4. Then do the following:

1. Record the starting water volume.

2. At time zero, place the Infiltrometer on the surface, assuring that is makes solid contact with the soil surface.

3. Record volume at regular time intervals as the water infiltrates. The time interval you choose is based on both the suction rate you select and the soil type being measured. For example, sand typically require two to five seconds between readings, a silt loam every 30 seconds, and a tight clay 30 to 60 minutes. A typical data set looks like the first and third columns of Table 9.

4. For the calculation of hydraulic conductivity to be accurate at least 15 to 20 mL of water needs to be infiltrated into the soil during each measurement.

Table 9: Sample Infiltrometer Data

Time (s)	sqrt (t)	Volume (mL)	Infiltration (cm)
0	0.00	95	0.00
30	5.48	89	0.39
60	7.75	86	0.58
90	9.49	83	0.77
120	10.95	80	0.97
150	12.25	77	1.16
180	13.42	75	1.29
210	14.49	73	1.42
240	15.49	71	1.55
270	16.43	69	1.68

9.9 Use the Spreadsheet Macro

Decagon has created a basic Microsoft Excelr spreadsheet to help calculate the slope of the curve of the cumulative infiltration versus the square root of time based on the data gathered in the above steps. You can download the spreadsheet at http:/www.decagon.com/macro. Follow steps 1 through 3 to use this spreadsheet. Input the volume levels you recorded into the corresponding volume column, and correlated with the time column on the left. You may need to extend the columns depending on how much data you have recorded. The square root of time column and infiltration column changes automatically based on your data, and the graph on the right of the table updates to reflect the changes. Save the data as a new spreadsheet on your hard drive.

9.10 Calculate Infiltration

A number of methods are available for determining soil hydraulic conductivity from these data. The method proposed by Zhang (1997) is quite simple, and works well for measurements of infiltration into dry soil. The method requires measuring cumulative infiltration versus time and fitting the results with the function.

Table 10: Van Genuchten Parameters For 12 Soil Texture Classes and Values For A 2.25 Cm Disk Radius And Suction Values From 0.5 To 6 Cm

			h_o						
			-0.5	-1	-2	-3	-4	-5	-6
Texture			A						
Sand	0.145	2.68	2.84	2.40	1.73	1.24	0.89	0.64	0.46
Loamy Sand	0.124	2.28	2.99	2.79	2.43	2.12	1.84	1.61	1.40
Sandy Loam	0.075	1.89	3.88	3.89	3.91	3.93	3.95	3.98	4.00
Loam	0.036	1.56	5.46	5.72	6.27	6.87	7.53	8.25	9.05
Silt	0.016	1.37	7.92	8.18	8.71	9.29	9.90	10.55	11.24
Silt Loam	0.020	1.41	7.10	7.37	7.93	8.53	9.19	9.89	10.64
Sandy Clay Loam	0.059	1.48	3.21	3.52	4.24	5.11	6.15	7.41	8.92
Clay Loam	0.019	1.31	5.86	6.11	6.64	7.23	7.86	8.55	9.30
Silty Clay Loam	0.010	1.23	7.89	8.09	8.51	8.95	9.41	9.90	10.41
Sandy Clay	0.027	1.23	3.34	3.57	4.09	4.68	5.36	6.14	7.04
Silty Clay	0.005	1.09	6.08	6.17	6.36	6.56	6.76	6.97	7.18
Clay	0.008	1.09	4.00	4.10	4.30	4.51	4.74	4.98	5.22

A quadratic equation is included in the Excel spreadsheet. Columns 2 and 4 from the table are used to produce an XY (scatter) plot to the right of the table. This is used to calculate C_1, which is the slope of this line, denoted as \y" The following graph gives an example.

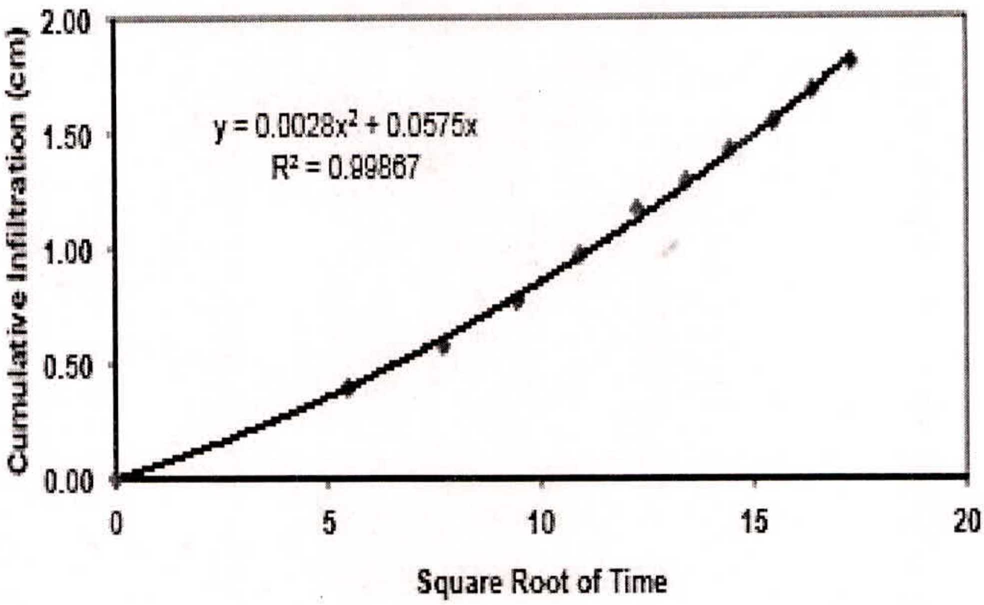

Figure 22: Quadratic Equation Graph

Occasionally Infiltrometer data gives a negative C1 value. Negative hydraulic conductivity is a physical impossibility, so such valves indicate a problem with the data set. Usually such data comes from shallow flow restricting layers or jiggling the Infiltrometer during the measurement. A much more extensive discussion of tension Infiltrometer measurement and analysis is given in Dane and Topp (2002) p. 888-896. If you are measuring hydraulic conductivity on a soil with a $n<1.35$, changes to the Zhang (1997) equation proposed by Dohnal et al. (2010) have improved estimates of K as compared to the previous equation.

9.11 Water Repellency Index

Lichner, et al. (2007) proposed an index of soil water repellency, R, can be determined from the sorptivities of 95% ethanol and water. The Mini Disk Infiltrometer can be used for these measurements. To do this, make sure you have rest prepared the instrument as described in Section 4. Please note that the water reservoir has to be filled with ethanol to make the ethanol sorptivity measurements, and with fresh or tap water to make the water sorptivity measurements. The bubble chamber is filled with fresh or tap water in both cases, and the suction rate of 2 cm is selected (Section 4). Then follow steps 1 through 5.

1. Record the starting ethanol volume.

2. At time zero, place the Infiltrometer on the surface, ensuring that it makes solid contact with the soil surface.

3. Record volume at regular time intervals as the ethanol infiltrates. The time interval necessary for different soil types is presented in Section 5. Use the Microsoft Excel spreadsheet (www.decagon.com/macro) to calculate the cumulative in infiltration I (cm) and square root of time t (s) based on the data gathered in the above steps. Use the Excel spreadsheet to estimate the slope (S_e) of the cumulative in infiltration versus square root of time relationship:

4. Repeat steps 13 for water instead of ethanol, making sure to place the Infiltrometer far enough away from the wetted zone of the previous measurement. The time intervals used for the water infilltration should be the same as for the ethanol in infiltration. Again, use the linear approximation to estimate the slope (S_w) of the cumulative infiltration versus the square root of the time relationship.

5. The repellency index R is computed from $R=1.95^{Se}$. It should be mentioned that ethanol can damage the numbering on the water/ethanol reservoir so care must be taken to avoid spillage. Note: Only the In Infiltrometers with polycarbonate water reservoirs (produced after 2005) should be filled with ethanol.

9.12 Maintenance

9.12.1 Cleaning

All of the Infiltrometer parts can be cleaned using mild soap and water. The stainless steel disk can be cleaned with a brush or even run in a dishwasher. Since it is stainless steel, it does not rust, cleans easily, and should not snag or tear on rags when washing.

9.12.2 Suction Tube

If the suction regulation tube is difficult to move, use a small amount of vacuum grease to allow it to move more freely.

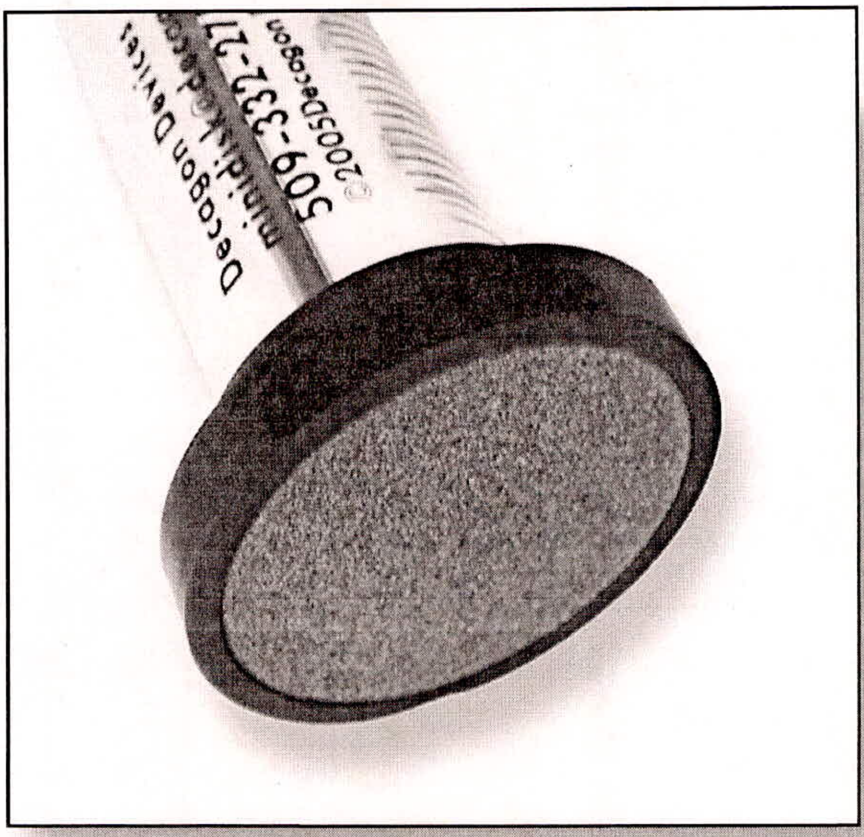

Figure 23: Suction Tube

Table 11: List of Infiltration Test Location of (Moth) Jhansi

S.no.	Grid no.	Location/village	Latitude	Longitude
1	2	Kailia	25.955073	78.957885
2	3	Pepri kala	25.949888	78.992469
3	4	Jhakauli	25.922121	78.893496
4	6	Jhakalia	25.898968	78.956138
5	7	Karai	25.915376	79.010444
6	8	Bepta	25.898285	79.068400
7	9	Bahadurpur	25.850924	78.859027
8	12	Gayari	25.848521	79.021722
9	13	Sesa	25.840822	79.069976
10	14	Ingukalan	25.861410	79.106984
11	15	Dhanoti	25.826790	78.856590
12	16	Angthari	25.819862	78.917416
13	17	Mahluba	25.819777	78.972860
14	18	Bitguna	25.816880	79.009616
15	19	Poonchh	25.820506	79.045625
16	20	Kyolori	25.772461	78.779956
17	21	Paharpura	25.761955	78.805180
18	22	Shahjapur	25.766387	78.829742
19	23	Jera	25.778199	78.855232
20	24	Puliya	25.776567	78.911084
21	25	Gulpura	25.767298	78.958532
22	26	Kabulpur	25.721263	78.754995
23	27	Talaua	25.715135	78.815102

S.no.	Grid no.	Location/village	Latitude	Longitude
24	28	Bakun bujur	25.712490	78.872719
25	29	Reb	25.720062	78.920439
26	30	Moth rural	25.735234	78.960761
27	31	Kiriyan	25.670604	78.811798
28	32	Pawai	25.679744	78.868270
29	33	Bichhondana	25.629738	78.801207
30	34	Baral	25.624547	78.857946

9 INFILTRATION CHATACTERISTICS OF THE STUDY AREA

In the present study infiltration characteristics are being studied for (Moth) Jhansi district at total 30 grid points. The results for all infiltration test locations are presented in this section.

Figure 24 to 55 present the infiltration characteristics of the different locations in the study area. A brief description of the location is provided in the corresponding tables (table 11-42)

Table 12: Brief Description of Site No. 2

Test location:	Agriculture land	Site number:	2
Village/site name:	Kailia	District name:	Jhansi
Latitude:	25.955073	Longitude:	78.957885
Date of test:	11/01/2016	Landmark/landowner:	Near byroad

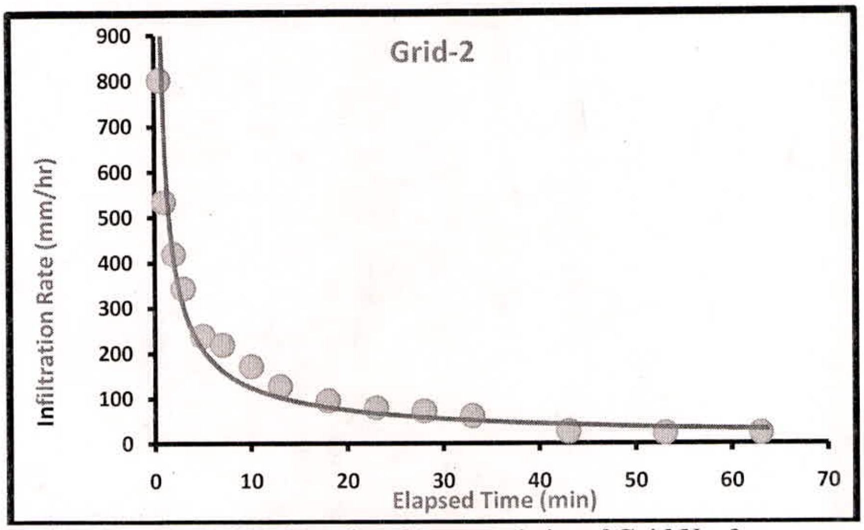

Figure 24: Infiltration Characteristics of Grid No. 2

Table 13: Brief Description of Site No. 3

Test location:	Baren. Land	Site number:	3
Village/site name:	Pepri kala	District name:	Jhansi
Latitude:	25.949888	Longitude:	78.992469
Date of test:	11/01/2016	Landmark/landowner:	Near byroad

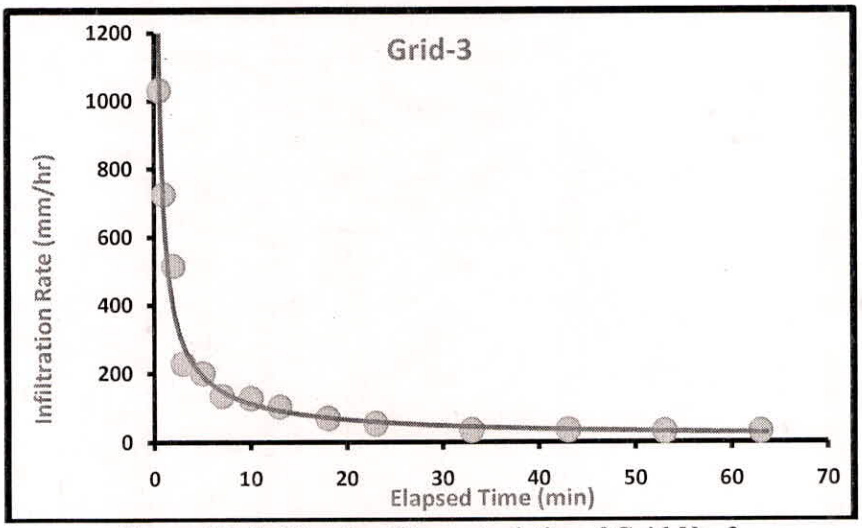

Figure 25: Infiltration Characteristics of Grid No. 3

Table 14: Brief Description of Site No. 4

Test location:	Agriculture land	Site number:	4
Village/site name:	Jhakauli	District name:	Jhansi
Latitude:	25.922121	Longitude:	78.893496
Date of test:	11/01/2016	Landmark/ landowner:	Near byroad

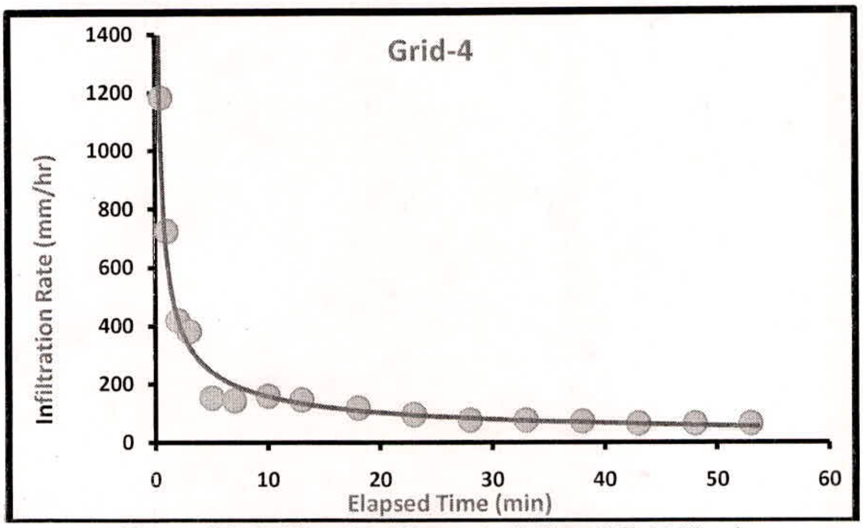

Figure 26: Infiltration Characteristics of Grid No. 4

Table 15: Brief Description of Site No. 5

Test location:	Baren. Land	Site number:	5
Village/site name:	Tigarganespura	District name:	Jhansi
Latitude:	25.897851	Longitude:	78.910967
Date of test:	11/01/2016	Landmark/landowner:	Near byroad

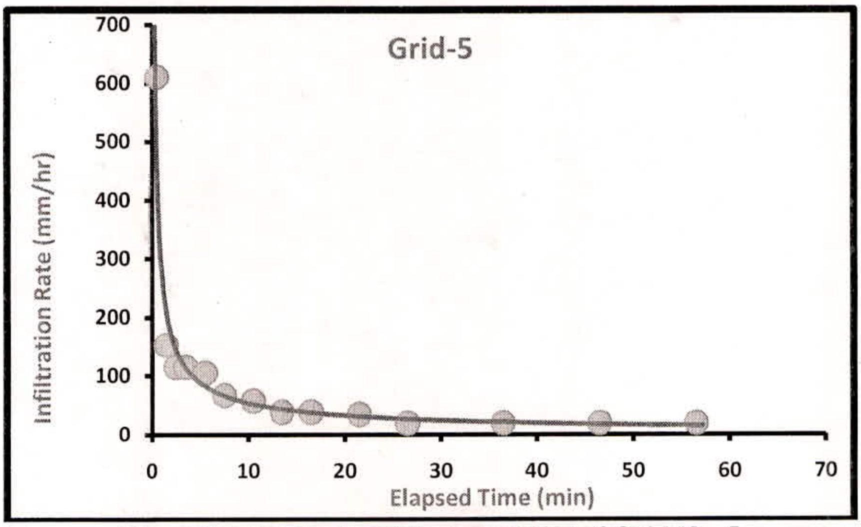

Figure 27: Infiltration Characteristics of Grid No. 5

Table 16: Brief Description of Site No. 6

Test location:	**Agriculture land**	**Site number:**	**6**
Village/site name:	**Jhakalia**	**District name:**	**Jhansi**
Latitude:	**25.898968**	**Longitude:**	**78.956138**
Date of test:	**12/01/2016**	**Landmark/landowner:**	**Near byroad**

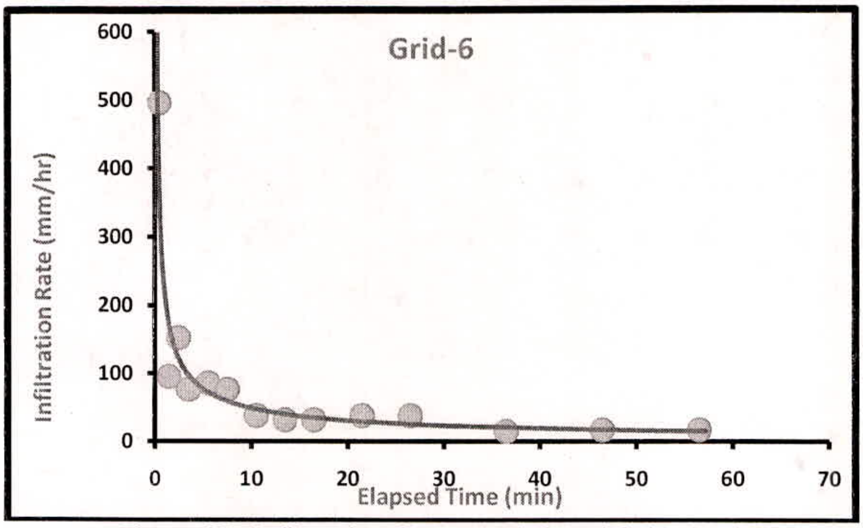

Figure 28: Infiltration Characteristics of Grid No. 6

Table 17: Brief Description of Site No. 7

Test location:	**Baren. Land**	**Site number:**	**7**
Village/site name:	**Karai**	**District name:**	**Jhansi**
Latitude:	**25.915376**	**Longitude:**	**79.010444**
Date of test:	**12/01/2016**	**Landmark/landowner:**	**Near byroad**

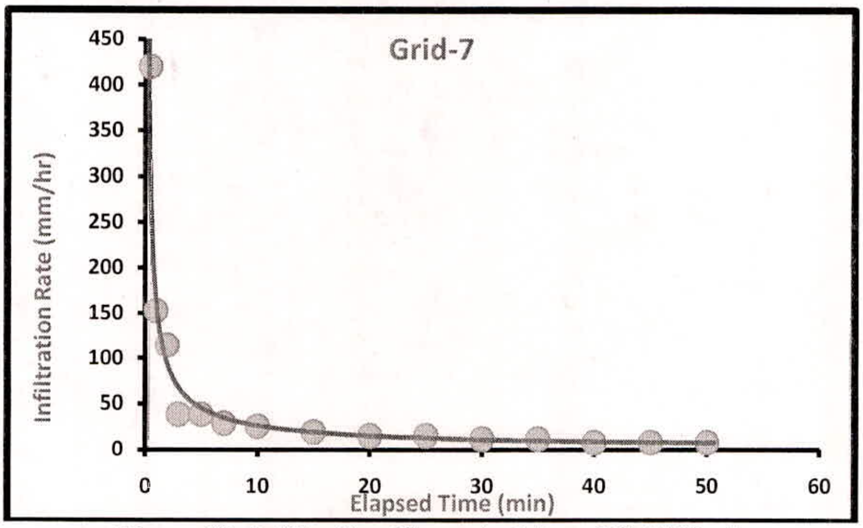

Figure 29: Infiltration Characteristics of Grid No. 7

Table 18: Brief Description of Site No. 8

Test location:	Baren. Land	Site number:	8
Village/site name:	Bepta	District name:	Jhansi
Latitude:	25.898285	Longitude:	79.068400
Date of test:	12/01/2016	Land mark/lanowner:	Nearbyroad

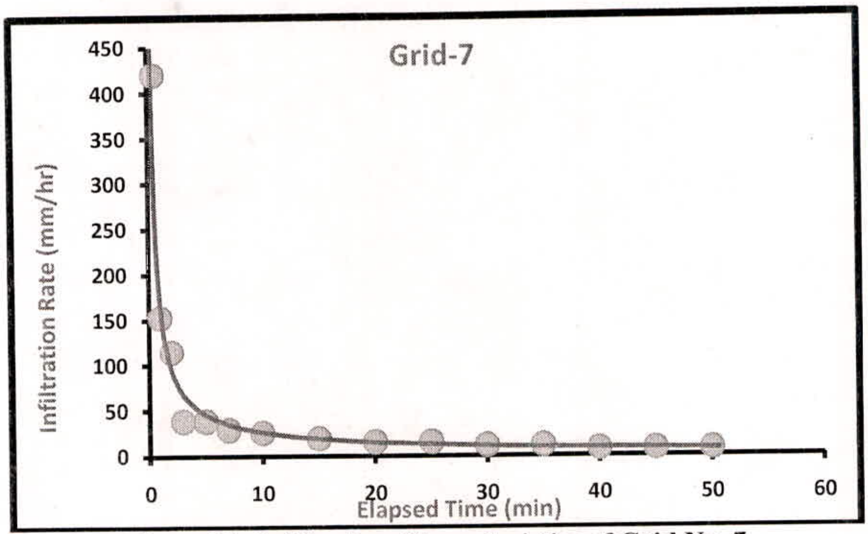

Figure 30: Infiltration Characteristics of Grid No. 7

Table 19: Brief Description of Site No. 9

Test location:	Agriculture land	Site number:	9
Village/site name:	Bahadurpur	District name:	Jhansi
Latitude:	25.850924	Longitude:	78.859027
Date of test:	12/01/2016	Land mark/land owner:	Nearby road

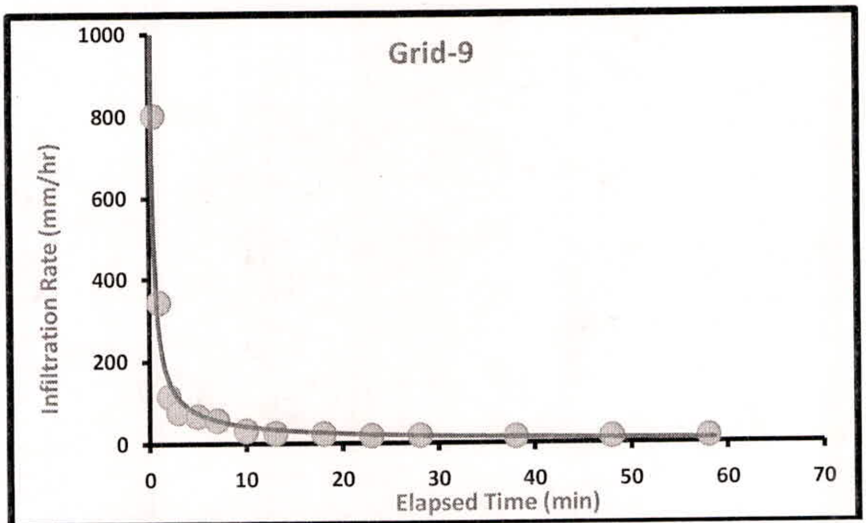

Figure 31: Infiltration Characteristics of Grid No. 9

Table 20: Brief Description of Site No. 11

Test location:	Agriculture land	Site number:	11
Village/site name:	Bangari	District name:	Jhansi
Latitude:	25.838121	Longitude:	78.953745
Date of test:	13/01/2016	Land mark/land owner:	Nearby road

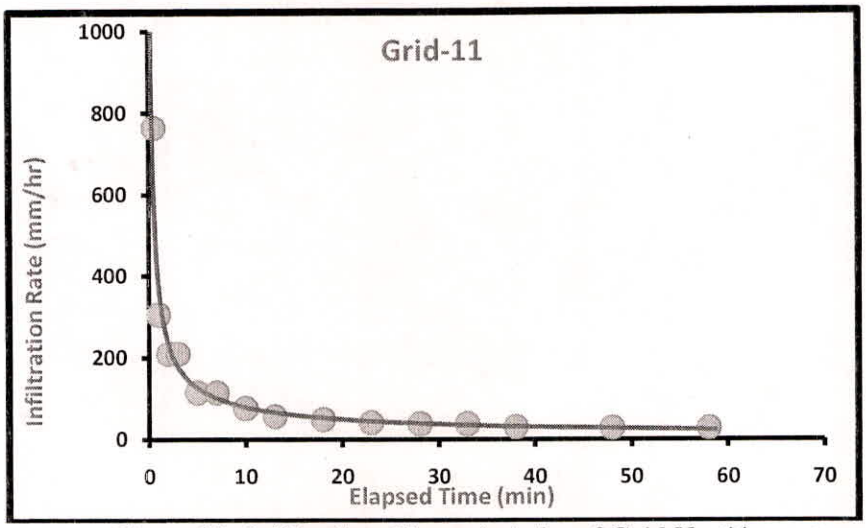

Figure 32: Infiltration Characteristics of Grid No. 11

Table 21: Brief Description of Site No. 12

Test location:	Agriculture land	Site number:	12
Village/site name:	Gayari	District name:	Jhansi
Latitude:	25.848521	Longitude:	79.021722
Date of test:	13/01/2016	Land mark/land owner:	Nearby road

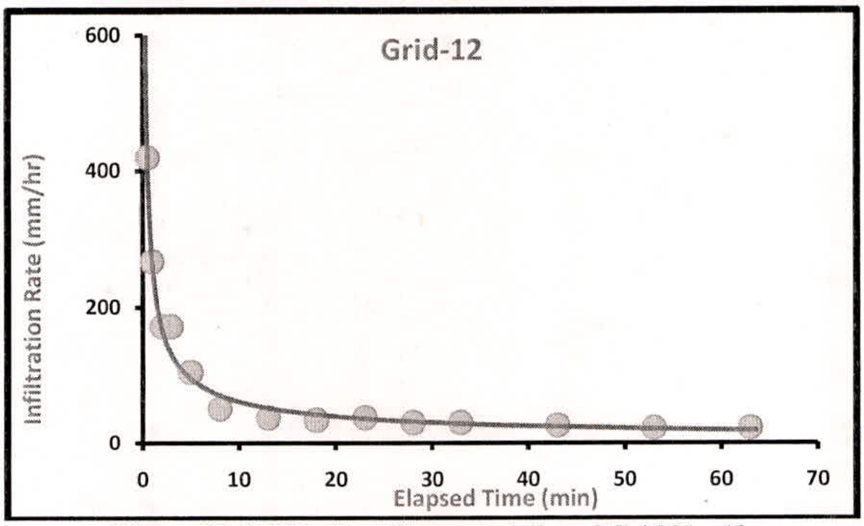

Figure 33: Infiltration Characteristics of Grid No. 12

Table 22: Brief Description of Site No. 13

Test location:	Baren. Land	Site number:	13
Village/site name:	Sesa	District name:	Jhansi
Latitude:	25.840822	Longitude:	79.069976
Date of test:	13/01/2016	Land mark/land owner:	Nearby road

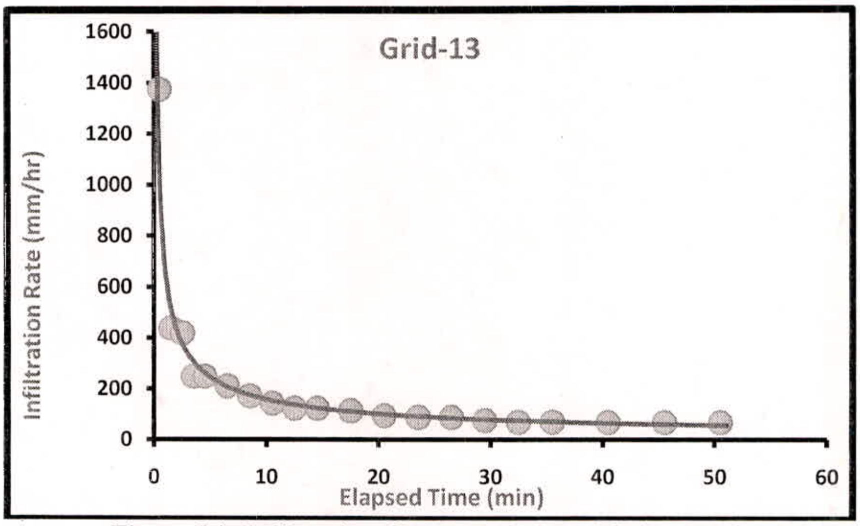

Figure 34: Infiltration Characteristics of Grid No. 13

Table 23: Brief Description of Site No. 14

Test location:	Agriculture land	Site number:	14
Village/site name:	Ingukalan	District name:	Jhansi
Latitude:	25.861410	Longitude:	79.106984
Date of test:	13/01/2016	Land mark/land owner:	Nearby road

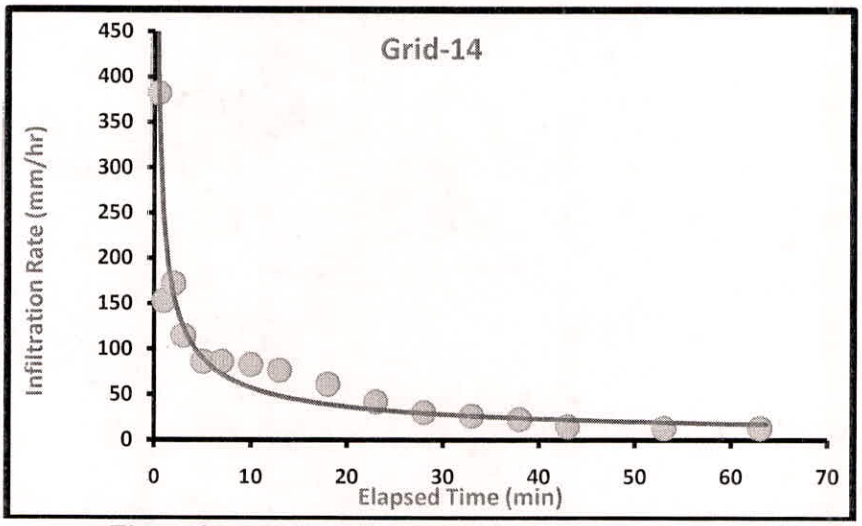

Figure 35: Infiltration Characteristics of Grid No. 14

Table 24: Brief Description of Site No. 15

Test location:	Baren. Land	Site number:	15
Village/site name:	Dhanoti	District name:	Jhansi
Latitude:	25.826790	Longitude:	78.856590
Date of test:	14/01/2016	Land mark/land owner:	Nearby road

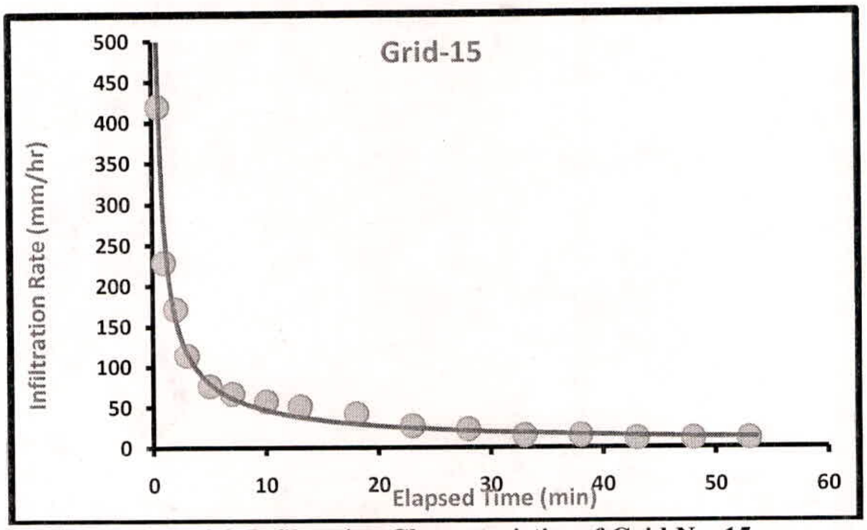

Figure 36: Infiltration Characteristics of Grid No. 15

Table 25: Brief Description of Site No. 16

Test location:	Baren. Land	Site number:	16
Village/site name:	Angthari	District name:	Jhansi
Latitude:	25.819862	Longitude:	78.917416
Date of test:	14/01/2016	Land mark/land owner:	Nearby road

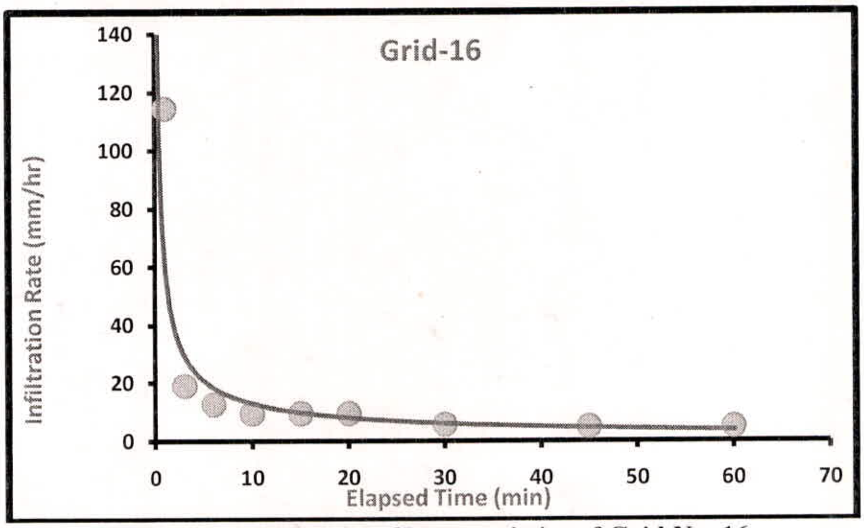

Figure 37: Infiltration Characteristics of Grid No. 16

Table 26: Brief Description of Site No. 17

Test location:	Agriculture land	Site number:	17
Village/site name:	Mahluba	District name:	Jhansi
Latitude:	25.819777	Longitude:	78.972860
Date of test:	14/01/2016	Land mark/land owner:	Nearby road

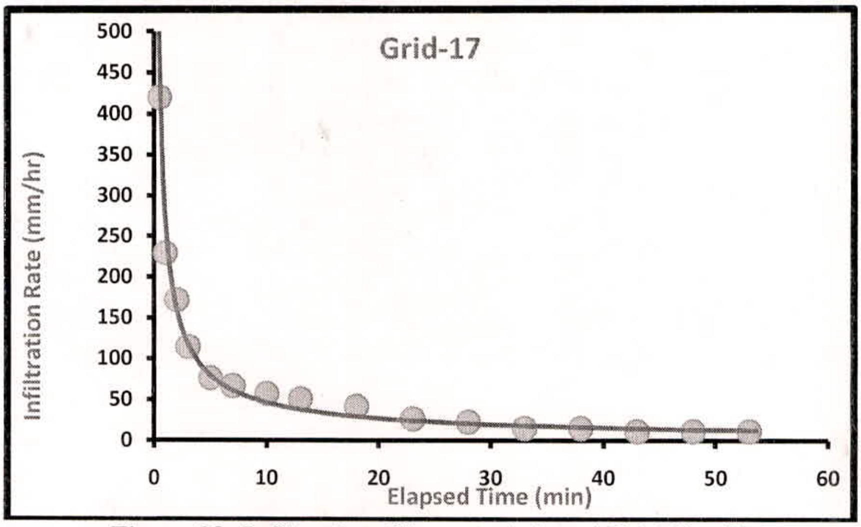

Figure 38: Infiltration Characteristics of Grid No. 17

Table 27: Brief Description of Site No. 18

Test location:	Baren. Land	Site number:	18
Village/site name:	Bitguna	District name:	Jhansi
Latitude:	25.816880	Longitude:	79.009616
Date of test:	15/01/2016	Land mark/land owner:	Nearby road

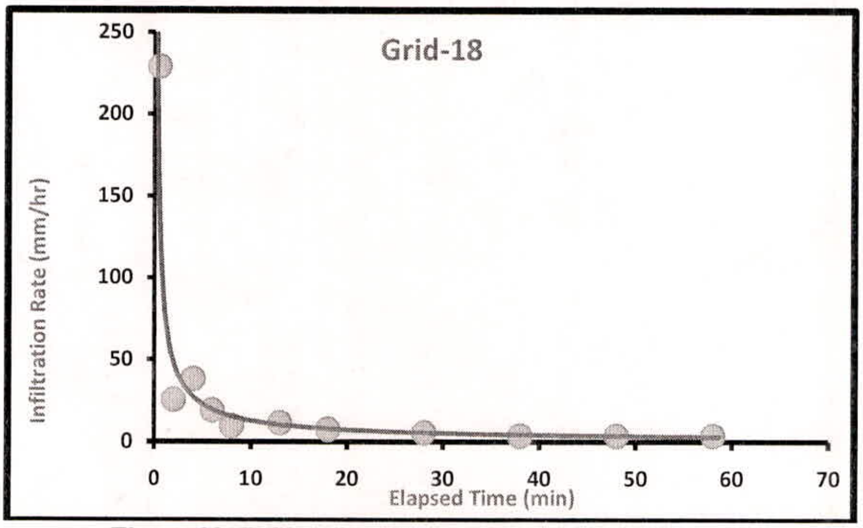

Figure 39: Infiltration Characteristics of Grid No. 18

Table 28: Brief Description of Site No. 19

Test location:	Agriculture land	Site number:	19
Village/site name:	Poonchh	District name:	Jhansi
Latitude:	25.820506	Longitude:	79.045625
Date of test:	15/01/2016	Land mark/land owner:	Nearby road

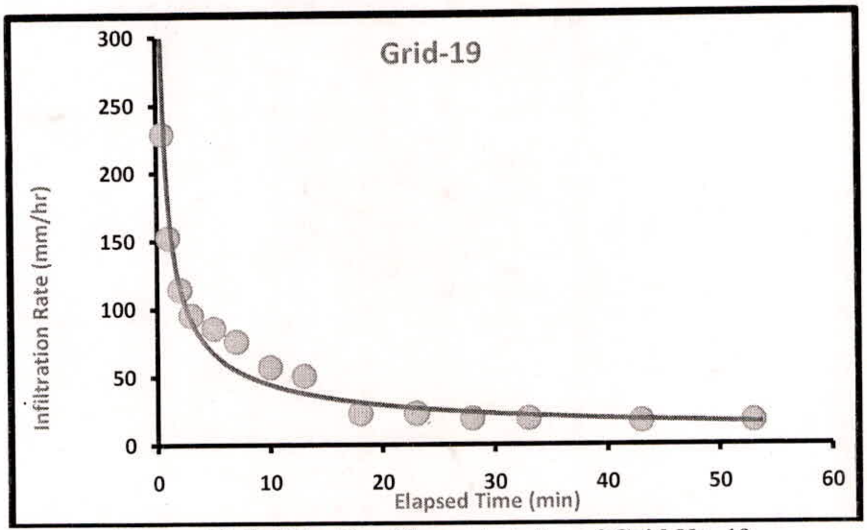

Figure 40: Infiltration Characteristics of Grid No. 19

Table 29: Brief Description of Site No. 20

Test location:	Baren. Land	Site number:	20
Village/site name:	Kyolori	District name:	Jhansi
Latitude:	25.772461	Longitude:	78.779956
Date of test:	15/01/2016	Land mark/land owner:	Nearby road

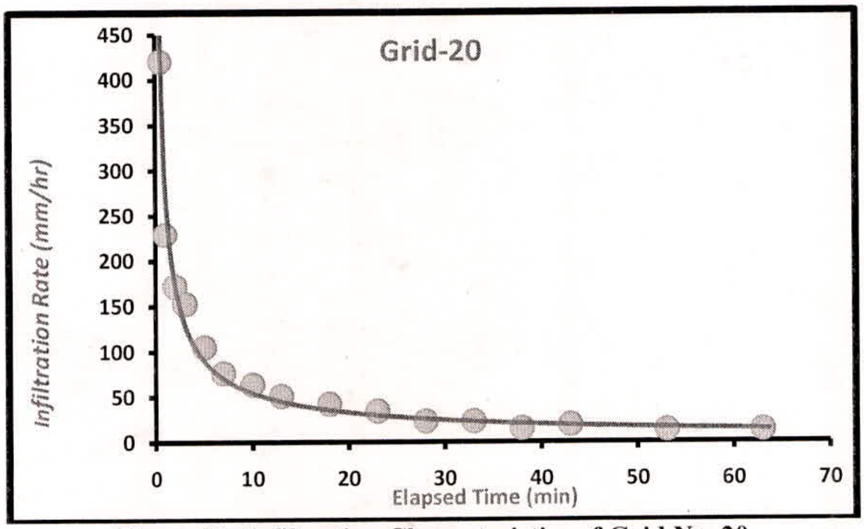

Figure 41: Infiltration Characteristics of Grid No. 20

Table 30: Brief Description of Site No. 21

Test location:	Baren. Land	Site number:	21
Village/site name:	Paharpura	District name:	Jhansi
Latitude:	25.761955	Longitude:	78.805180
Date of test:	15/01/2016	Land mark/land owner:	Nearby road

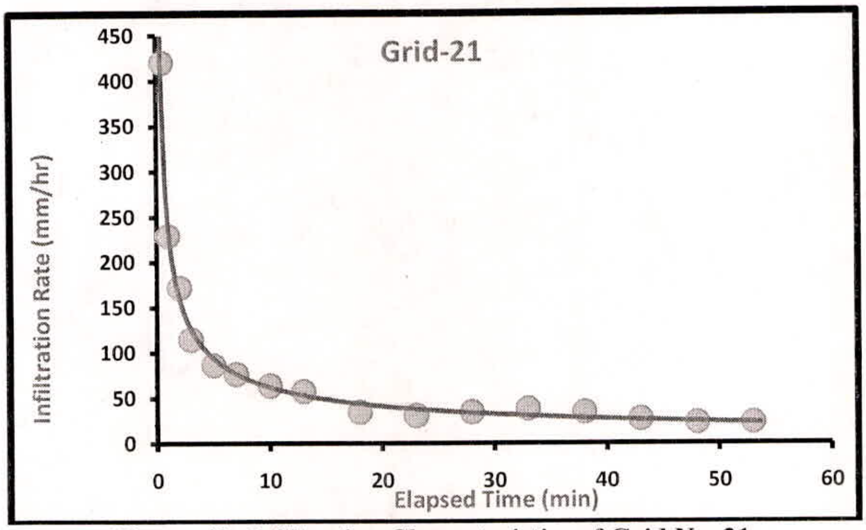

Figure 42: Infiltration Characteristics of Grid No. 21

Table 31: Brief Description of Site No. 22

Test location:	Agriculture land	Site number:	22
Village/site name:	Shahjapur	District name:	Jhansi
Latitude:	25.766387	Longitude:	78.829742
Date of test:	15/01/2016	Land mark/land owner:	Nearby road

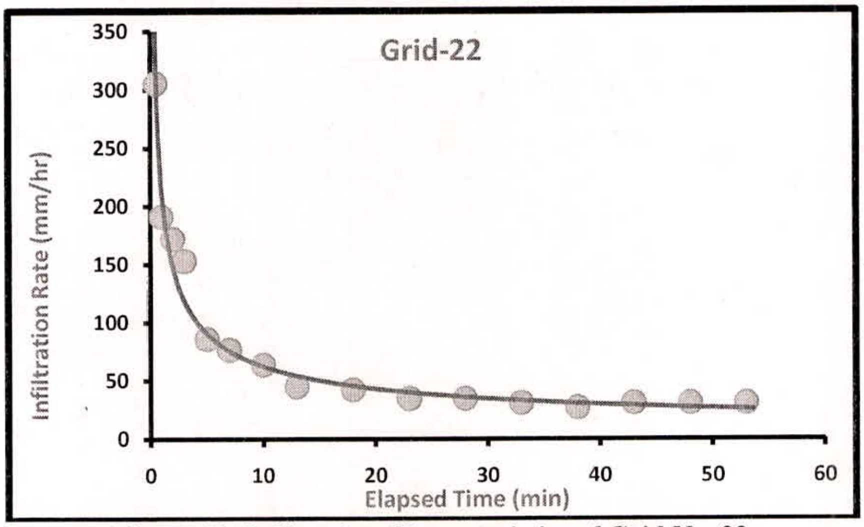

Figure 43: Infiltration Characteristics of Grid No. 22

Table 32: Brief Description of Site No. 23

Test location:	Baren. Land	Site number:	23
Village/site name:	Jera	District name:	Jhansi
Latitude:	25.778199	Longitude:	78.855232
Date of test:	17/01/2016	Land mark/land owner:	Nearby road

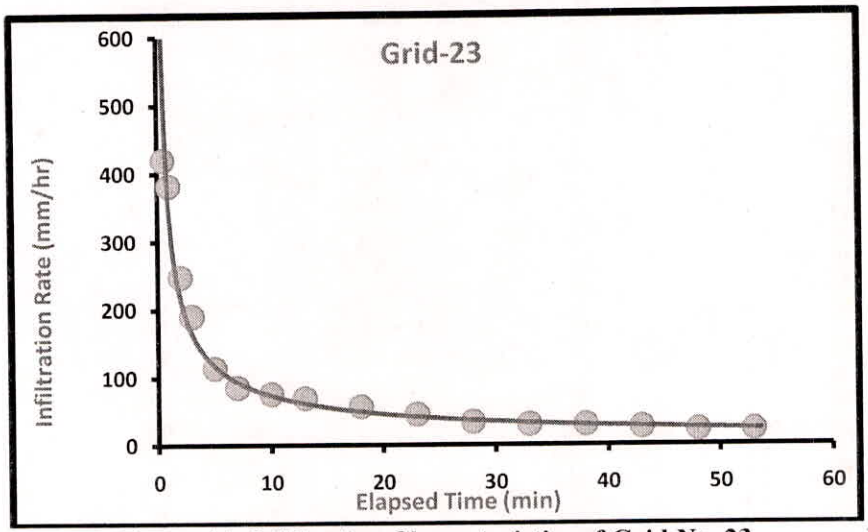

Figure 44: Infiltration Characteristics of Grid No. 23

Table 33: Brief Description of Site No. 24

Test location:	Baren. Land	Site number:	24
Village/site name:	Puliya	District name:	Jhansi
Latitude:	25.776567	Longitude:	78.911084
Date of test:	17/01/2016	Land mark/land owner:	Nearby road

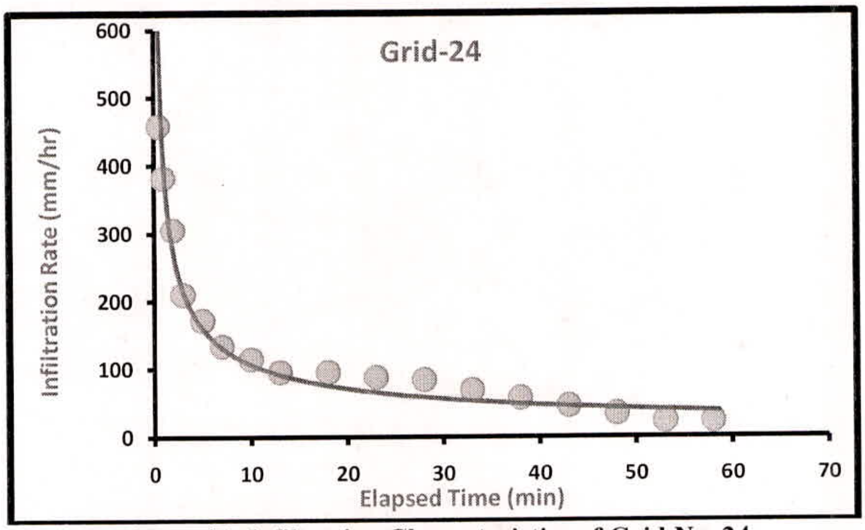

Figure 45: Infiltration Characteristics of Grid No. 24

Table 34: Brief Description of Site No. 25

Test location:	Baren. Land	Site number:	25
Village/site name:	Gulpura	District name:	Jhansi
Latitude:	25.767298	Longitude:	78.958532
Date of test:	17/01/2016	Land mark/land owner:	Nearby road

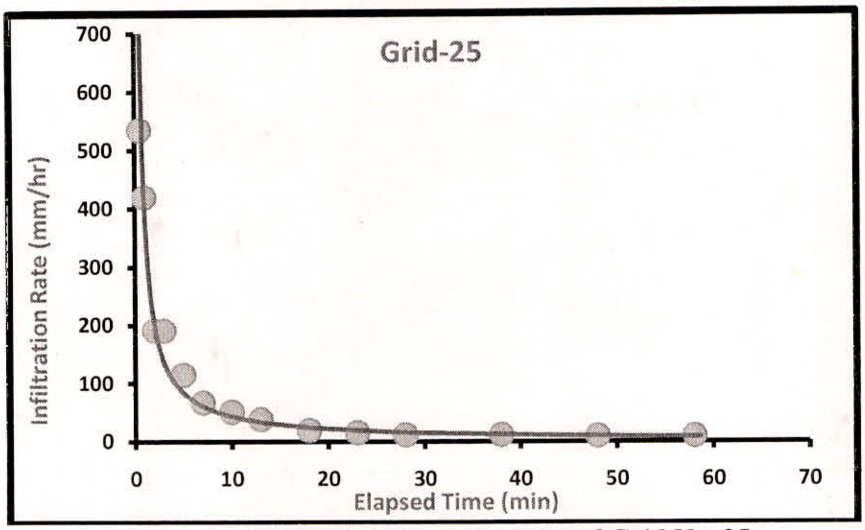

Figure 46: Infiltration Characteristics of Grid No. 25

Table 35: Brief Description of Site No. 26

Test location:	Baren. Land	Site number:	26
Village/site name:	Kabulpur	District name:	Jhansi
Latitude:	25.721263	Longitude:	78.754995
Date of test:	17/01/2016	Land mark/land owner:	Nearby road

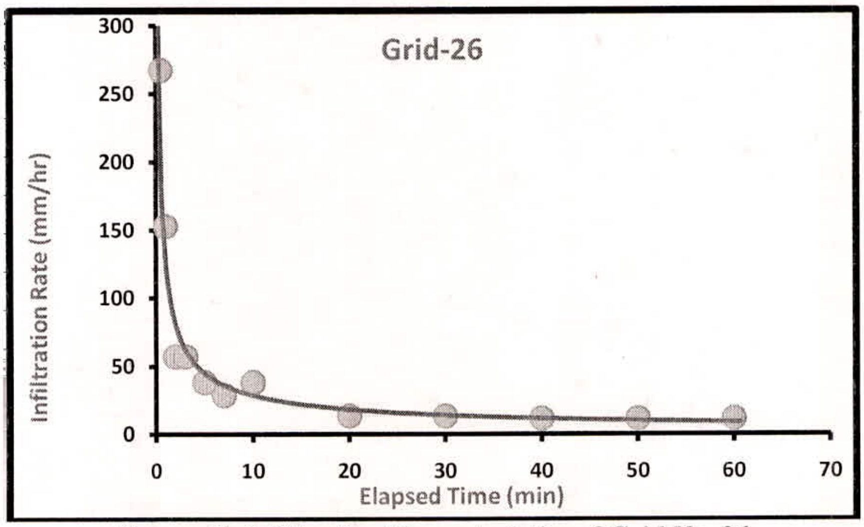

Figure 47: Infiltration Characteristics of Grid No. 26

Table 36: Brief Description of Site No. 27

Test location:	Agriculture land	Site number:	27
Village/site name:	Talaua	District name:	Jhansi
Latitude:	25.715135	Longitude:	78.815102
Date of test:	17/01/2016	Land mark/land owner:	Nearby road

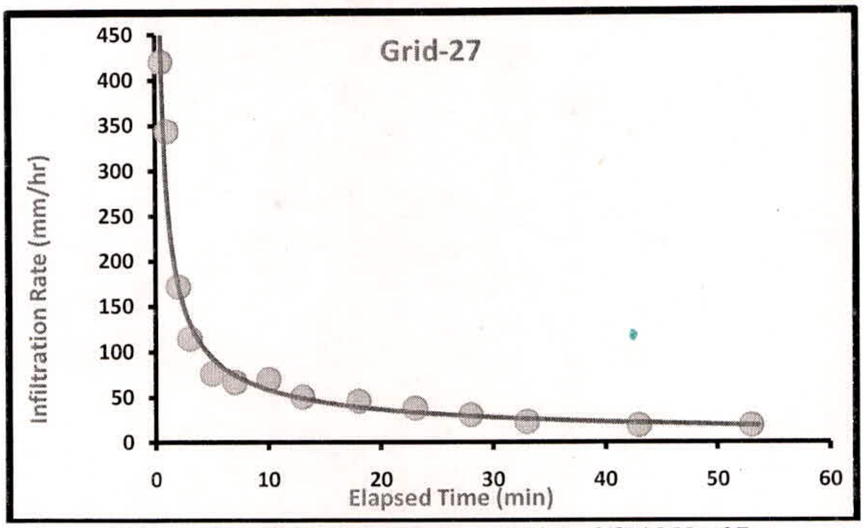

Figure 48: Infiltration Characteristics of Grid No. 27

Table 37: Brief Description of Site No. 28

Test location:	Baren. Land	Site number:	28
Village/site name:	Bakun bujur	District name:	Jhansi
Latitude:	25.712490	Longitude:	78.872719
Date of test:	19/01/2016	Land mark/land owner:	Nearby road

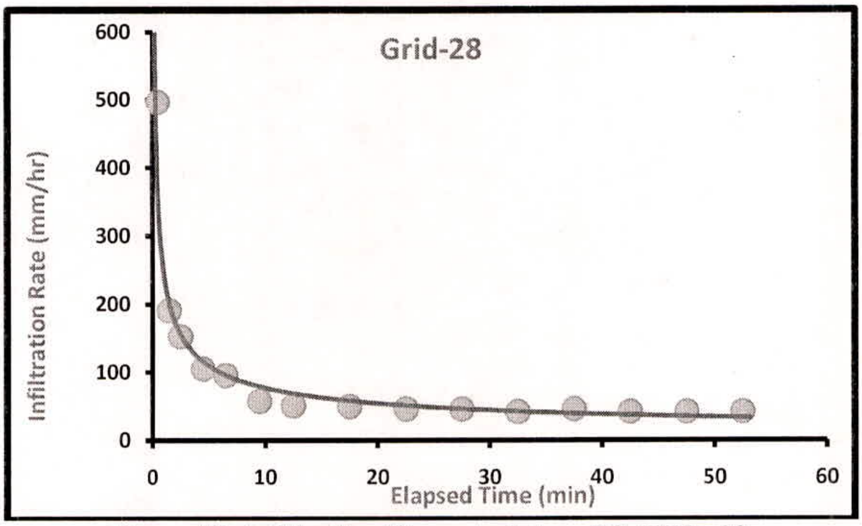

Figure 49: Infiltration Characteristics of Grid No. 28

Table 38: Brief Description of Site No. 29

Test location:	Agriculture land	Site number:	29
Village/site name:	Reb	District name:	Jhansi
Latitude:	25.720062	Longitude:	78.920439
Date of test:	19/01/2016	Land mark/land owner:	Nearby road

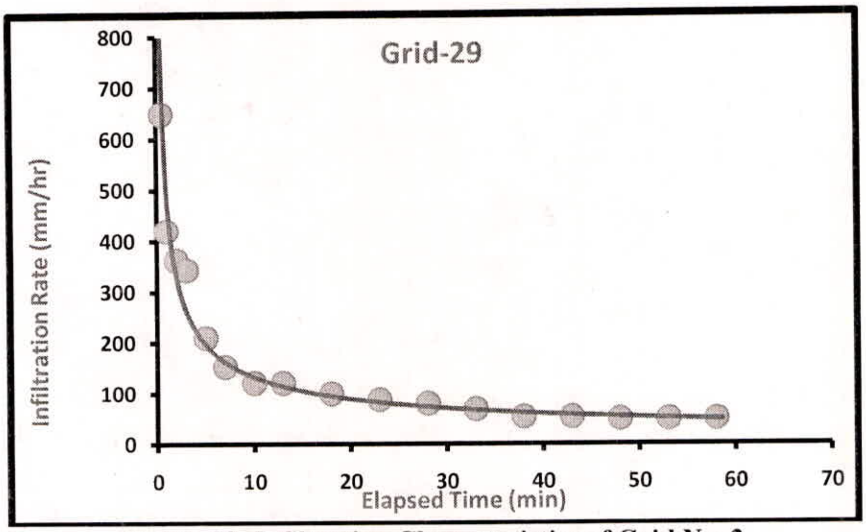

Figure 50: Infiltration Characteristics of Grid No. 2

Table 39: Brief Description of Site No. 30

Test location:	Baren. Land	Site number:	30
Village/site name:	Moth rural	District name:	Jhansi
Latitude:	25.735234	Longitude:	78.960761
Date of test:	19/01/2016	Land mark/land owner:	Nearby betwa river

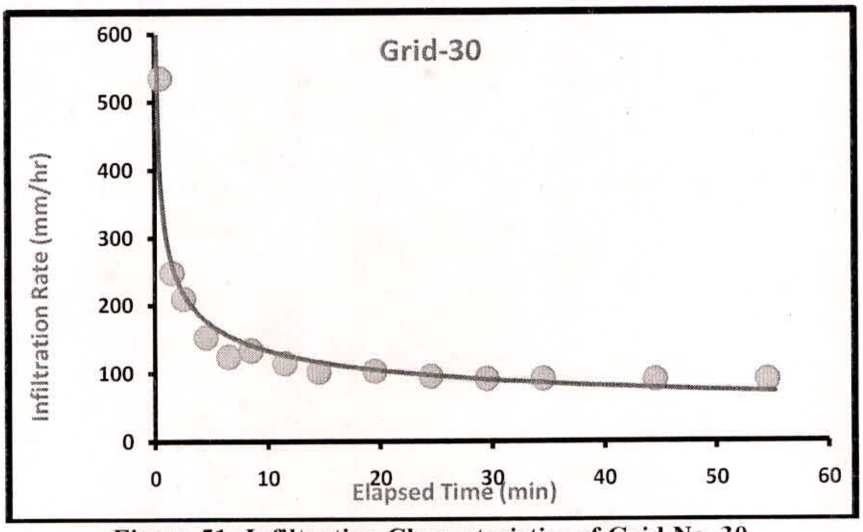

Figure 51: Infiltration Characteristics of Grid No. 30

Table 40: Brief Description of Site No. 31

Test location:	Agriculture land	Site number:	31
Village/site name:	Kiriyan	District name:	Jhansi
Latitude:	25.670604	Longitude:	78.811798
Date of test:	19/01/2016	Land mark/land owner:	Nearby road

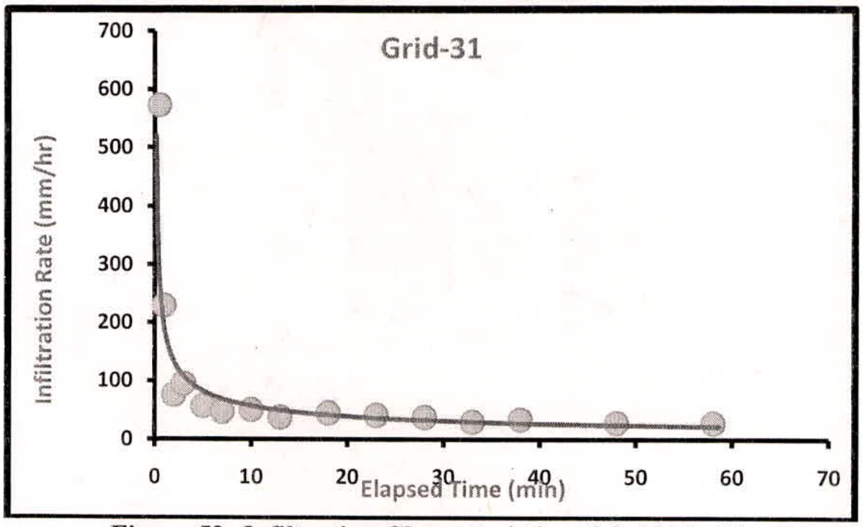

Figure 52: Infiltration Characteristics of Grid No. 31

Table 41: Brief Description of Site No. 32

Test location:	Baren. Land	Site number:	32
Village/site name:	Pawai	District name:	Jhansi
Latitude:	25.679744	Longitude:	78.868270
Date of test:	19/01/2016	Land mark/land owner:	Nearby road

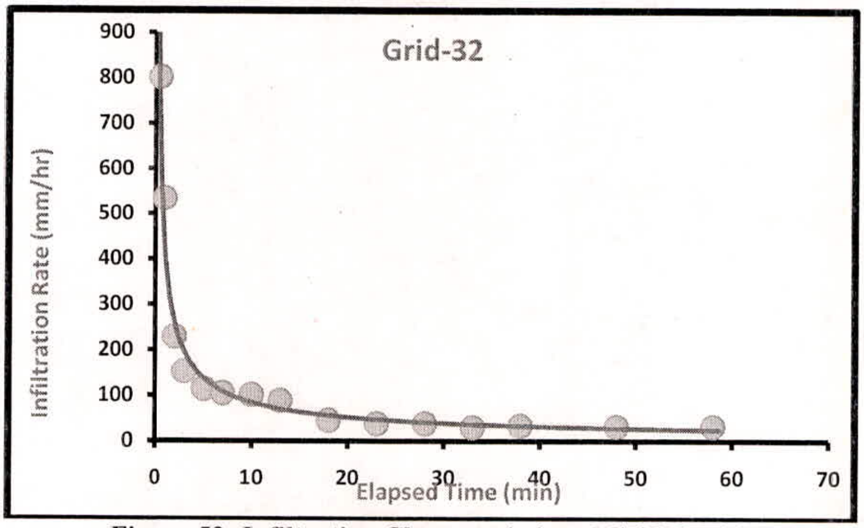

Figure 53: Infiltration Characteristics of Grid No. 32

Table 42: Brief Description of Site No. 33

Test location:	Baren. Land	Site number:	33
Village/site name:	Bichhondana	District name:	Jhansi
Latitude:	25.629738	Longitude:	78.801207
Date of test:	19/01/2016	Land mark/land owner:	Nearby road

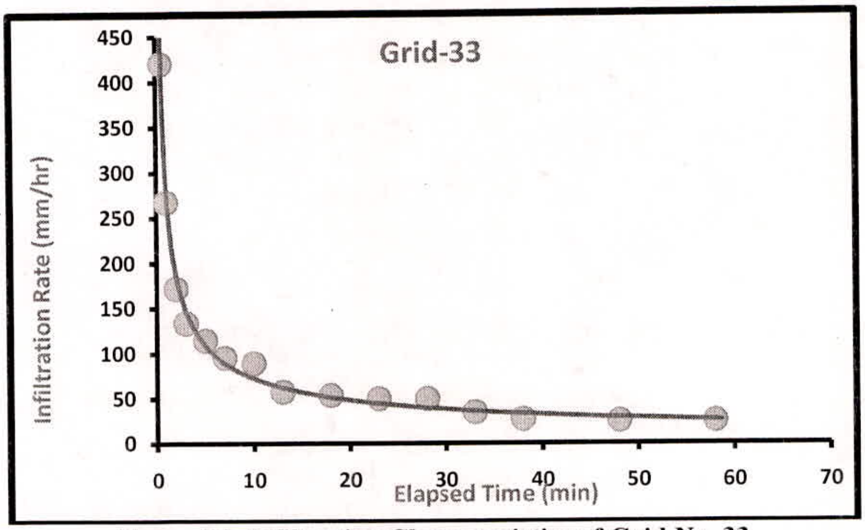

Figure 54: Infiltration Characteristics of Grid No. 33

Table 43: Brief Description of Site No. 34

Test location:	Agriculture land	Site number:	34
Village/site name:	Baral	District name:	Jhansi
Latitude:	25.624547	Longitude:	78.857946
Date of test:	19/01/2016	Land mark/land owner:	Nearby road

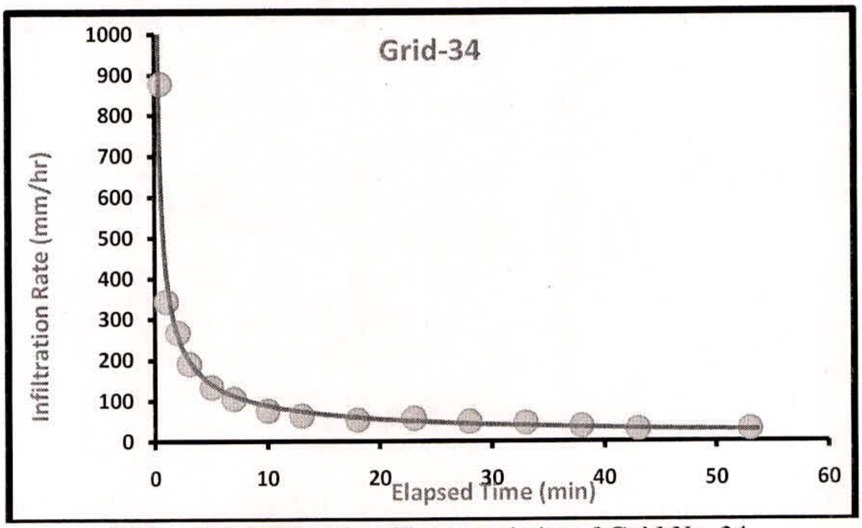

Figure 55: Infiltration Characteristics of Grid No. 34

Table 44: Steady Infiltration Rates of The Various Locations

S.no.	Grid	Location	Initial infiltration rate	Steady infiltration rate
	2	Kailia	801.8	22.9
	3	Pepri kala	1030.9	30.9
	4	Jhakauli	1183.6	64.9
	6	Jhakalia	496.4	17.2
	7	Karai	420	7.6
	8	Bepta	1680	21
	9	Bahadurpur	801.8	15.3
	12	Gayari	420	22.9
	13	Sesa	1374.5	68.7
	14	Ingukalan	381.8	13.4
	15	Dhanoti	420	11.5
	16	Angthari	114.5	5.09
	17	Mahluba	420	11.5
	18	Bitguna	229.1	3.8
	19	Poonchh	229.1	17.2
	20	Kyolori	420	13.4
	21	Paharpura	420	22.9
	22	Shahjapur	305.5	30.5
	23	Jera	420	22.9
	24	Puliya	458.2	22.9
	25	Gulpura	534.5	9.5
	26	Kabulpur	267.3	11.5
	27	Talaua	420	19.1
	28	Bakun bujur	496.4	42
	29	Reb	649.1	49.6
	30	Moth rural	534.4	90.7
	31	Kiriyan	572.7	28.6
	32	Pawai	801.8	32.5
	33	Bichhondana	420	24.8
	34	Baral	878.2	30.5

The distribution of infiltration rate in different parts of moth block of jhansi district are graphically presented in the contour map shown in figure 30.

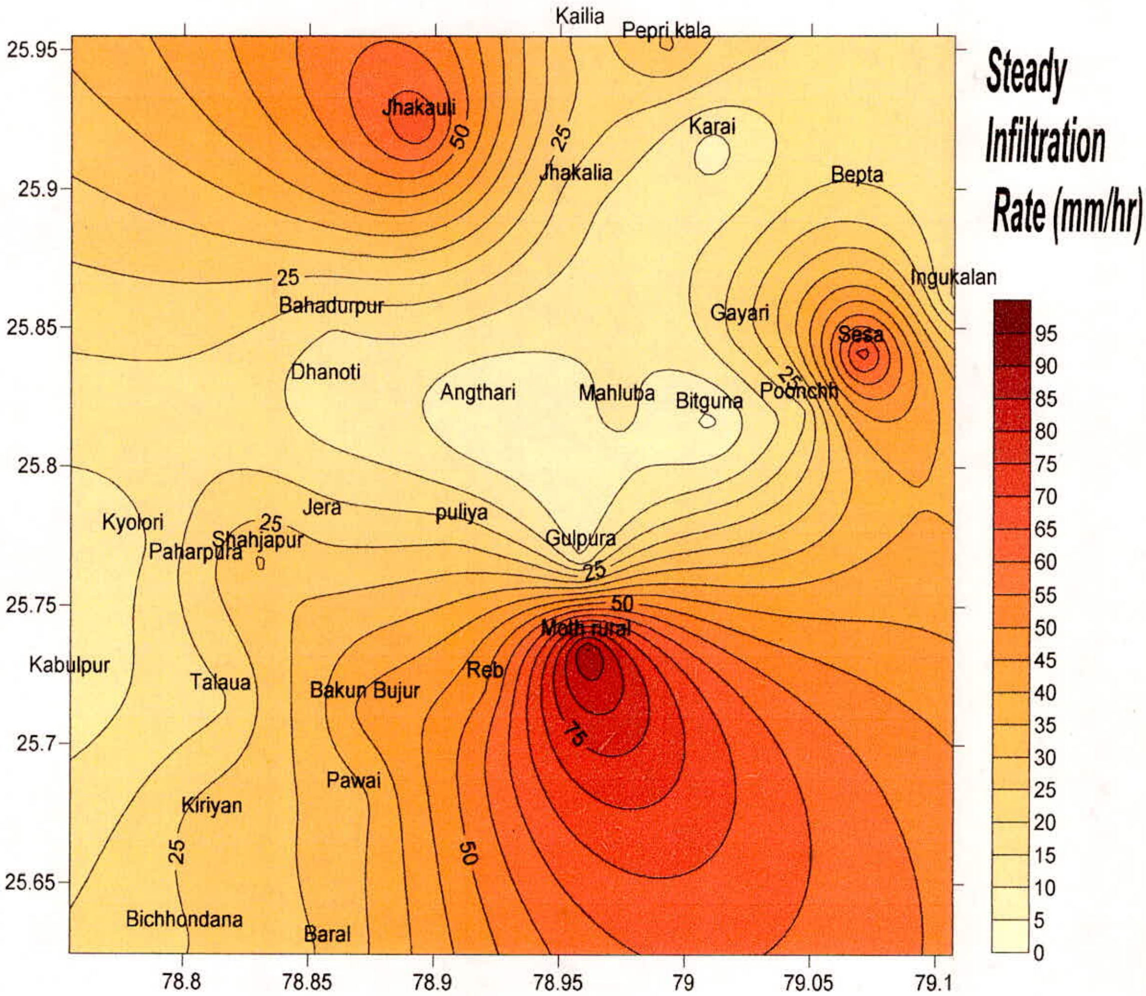

Figure 56: Steady Infiltration Rate at Various Location of Jhansi District

CONCLUDING OBSERVATIONS

Infiltration characteristics have been studied for moth block of Jhansi district of Bundelkhand region at total 30 grid points using the double ring infiltrometer. Results obtained (table 22 and fig. 32) indicates that the infiltration characteristics vary significantly in different parts of the district. Infiltration rates in the district vary within a range of 3.8 mm/hr to 90.7 mm/hr. In general it is seen that higher infiltration rates are observed in western and southern parts of the district while moderate to lower rates are generally observed in the eastern, middle and northern parts of the district. Lowest infiltration rate of 3.8 mm/hr was observed for Bitguna (grid no. 18) while highest rate of 95.7 mm/hr was observed for near moth rural (grid no. 30). Major part of the block is observed to have moderate to low rates of infiltration. The average infiltration rate of the moth blocks of Jhansi districts, based on the data of all the grids, comes out to be 26.18 mm/hr.

Further analysis brings out that although the infiltration rate varies from 3.8 to 95.7, of the total 30 sites (grid points), only 3 sites show rates of more than 65 mm/hr. 6 sites show a range between 65- 30 mm/hr and 17 sites show a range between 30-10 mm/hr. Thus, only 3 sites have a rate of more 60 mm/hr and only 2 sites of the total have a rate of 40 mm/hr and above. Similarly the lower range of below 10 mm/hr is exhibited by only 4 sites. Most of the other sites (25 of the total 30) have infiltration rates between 10-80 mm/hr, of which 9 sites have a range of 11-20 mm/hr, 11 sites have a range between 21-40 mm/hr and 4 sites show a range of 41-80 mm/hr. The average infiltration rates of these 25 sites (with a range between 10-80 mm) come out to be 26.2 mm/hr.

The mostly observed range of infiltration rates (10-80 mm/hr) have indicative of clay loam to sandy loam soils. As far as moth block is considered, the majority soil type in the district are either a brownish grey soil (a variety of red soil) which is locally called parwa or purva which consists of loam to sandy clay loam texture and, black cotton soil locally called mar which has high clay content. Soils with higher rates of infiltration (above 80 mm/hr) are generally the ones which have high degree of stones and kankar, although they are mostly loamy and, alluvial soils. They are called rankar (with a varity called moth ranker) which are found in some parts of the district.

Soils with very low rates of infiltration (clayey soils) are expected to have a high rate of runoff and good soil moisture holding capacity while those with very high rates of infiltration (generally more than 80 mm/hr) which is generally observed in ranker soils that have very little soil moisture holding capacities. Thus, less water is stored in these soils for plant growth, and plant production decreases, resulting in less organic matter in the soil and weakened soil structure. This is one of the reasons why ranker soils are known for less productivity.