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INFILTRATION STUDIES IN BELGAUM DISTRICT

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PREFACE

Belgaum district, unlike other north interior districts of Karnataka, receive well distributed and enough rainfall during southwest monsoon season. Major tributaries of River Krishna, (Malaprabha and Ghataprabha) flows through the district. Having enough water resources system, some parts of Belgaum district still faces severe drought situation. The ground water potential is also highly varying due to the wide distribution of Deccan trap. Therefore, to understand the runoff potential and infiltration capacity, infiltration tests were conducted in 9 taluks (except Athani taluk). Tests were conducted in two stages. In the first stage, studies were carried out in Malaprabha representative basin covering Belgaum and Khanapur taluks. In the second stage, remaining taluks under Belgaum district which falls in the command area of Malaprabha and Ghataprabha were studied for the determination of infiltration rate.

Rate of infiltration is the volume flux of water flowing into the soil profile per unit of soil surface area. The maximum rate at which the soil can absorb water through the soil surface is termed as infiltration capacity. This is a function of surficial characteristics, soil cover, texture, and structure, organic matter, clay minerals, land use, geology, precipitation characteristics, antecedent soil moisture condition etc.

Based on present study, a map was prepared showing spatial variation of infiltration rate. The relationship between infiltration classes and runoff potential are determined as per the specification given by All India Soil and Land use survey organisation under Ministry of Agriculture.

This work is carried out by Dr.B.K.Purandara, SRA, Sh.Chandra kumar, RA and Sh.Chandramohan, Sc 'B' of the Hard Rock Regional Centre , Belgaum. This is a part of the work programme, as the regional is planning for observing the infiltration rate for the whole hard rock region.

S.M. SETH
DIRECTOR

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1.Ø INFILTRATION STUDIES

1.1 Introduction

In our country, the ever thrusting population has resulted in more and more urbanization and industrialisation. However, due to these spontaneous developments, the demand for water resources increased beyond the limits of our available resources. It is estimated that 4ØØ M ha-m is the total precipitation over the country. Out of this, 37Ø M ha-m is supplied through rainfall (average rainfall, 115 cm) and 3Ø M ha-m is contributed through snow melt runoff. It has been estimated that 17.5% is lost through evaporation, 37.5% enters the soil and the rest (45%) is calculated as the run-off. Owing to the topographic, hydrologic and other constraints, it has been assessed that 7Ø M ha-m of surface water can be utilised by conventional methods of development. Major and medium irrigation projects have so far succeeded in tapping only 17 M ha-m in their reservoirs. Another 4 to 5 M ha.m is stored in tanks and small reservoirs. Of the 15Ø M ha-m which enter the soil, 11Ø M ha-m constitute soil moisture while 4Ø M ha-m percolate into the groundwater aquifers (Sharda et.al 1992).

Infiltration is one of the important phenomenon of the Hydrological cycle. Infiltration in general, may be defined as the movement of water into the soil through the soil surface. The phenomenon of infiltration deserves a special place in hydrologic study and understanding of the same enable us to estimate more effectively the amounts of run-off originating from precipitation, and the results thereof can be applied more confidently to the design problems.

Thousands of infiltration measurements have been made with a great variety of instruments, ranging from a simple ring infiltrometer, into which water is poured and its rate of disappearance measured to rainfall simulators, intricate in design, with which known amounts and intensities of water can be applied. Infiltration measurements have regularly show an initial high rate, at the beginning of the test, decreasing rapidly and then more slowly, until it approaches a constant rate in a period of 1/2 to 1 1/2 hr or longer. This typical trend is the response to a decreasing hydraulic gradient as the water moves deeper into the soil, in filling of pores with water, and change in the soil such as dispersion of aggregates, puddling of the surface layer by the impact of raindrops, and sealing of colloids and closing of soil cracks.

When turbid water is applied to the soil, non-capillary pores are quickly choked by the sediment that settles out and infiltration rate is sharply reduced. The same result is obtained when raindrops strike the unprotected soil, detaching soil particles which block the pores.

1.2 Effects of Infiltration

The process of infiltration has a tremendous impact over an area depending upon the rate of rainfall. If the intensity of rainfall, neglecting interception and evaporation losses is less than the rate of infiltration, all water will enter the soil profile. Conversely when the intensity by rainfall is greater than the rate of infiltration, it will result in surface run-off. Infiltration is thus responsible for:

(a) reducing the magnitude of floods and soil erosion.
(b) furnishing stream flow in periods of dry weather;
(c) providing water for the plants, and
(d) Recharging of groundwater reservoir.

1.3 Factors Influencing Infiltration

Infiltration characteristics of any land/terrain is strongly influenced by soil texture and structure, which govern non-capillary porosity, soil wetness, and the amount of protection from rainfall impact offered by vegetation.

1. Soil texture and structure:

Water may infiltrate into very coarse textured soils or well aggregated soils so readily that, none is lost in runoff in the heaviest downpour. By contrast, the surface layer of a bare clay soil may soak up the first moisture that falls, then it may swell and become a dense water proof layer that sheds the remainder of the water.

The structure of soils is mainly influenced by the aggregation of soil particles, the organic matter content helps to maintain a favourable structure by promoting soil aggregation. In some soils a compact dense layer of soil at shallow depth from the surface can greatly limit the rate of the downward movement of water. Under this condition the voids above the dense zone may be rather quickly filled and the infiltration rate thereafter reduced to a minimum. If, however, the lateral slope of the dense layer is favourable, substantial lateral movement of infiltered water may take place as subsurface flow in which case the rate of infiltration will be maintained at a fairly high rate. The moisture content of the soil is mainly responsible for influencing the infiltration. Obviously greater is the soil-moisture content, lesser is the rate of water intake by infiltration.

2. Rainfall Characteristics:

The infiltration rate is influenced by the rainfall duration and its intensity. The duration of sustained heavy rainfall results in a steady reduction in the infiltration capacity until the rate of infiltration attains a nearly constant value. When

the rainfall rate is smaller than the infiltration capacity, all rainfall will be infiltered as long as rainfalls. Intense rainfall has the effect of progressive reduction of the infiltration capacity because of increased supply of moisture to the surface layers of the soil, mechanical compaction of soil by raindrops impact and the inwash of fine material.

3. Human activities:

Cultivation of land, disturbing thereby soil aggregation besides destroying openings made by burrowing animals, insects and decayed roots. Over plowing under wet conditions destroy even the normal aggregation of the soil. Developing a grass cover or crop on normally bare ground results in an increase of the infiltration capacity. Where heavy pedestrian or vehicular traffic occurs on a soil, the surface is rendered relatively impervious.

4. Climatic Condition:

A change in the viscosity can influence the rate of infiltration. This is why infiltration capacity is somewhat lower in winter than in summer.

1.4 Importance of the Study

Infiltration characteristics of soil are very important for scientists, engineers and planners. Hydrologists mostly need infiltration data for the estimation of peak rates and volumes of runoff in the planning of dams, culverts and bridges etc. It is also useful for minimising the erosional hazards. Most important use of infiltration is to the agriculturists and ecologists who are concerned with the availability of soil moisture in the root zone of crops and plants.

2.Ø STUDY AREA

Belgaum district lies in the northern part of Karnataka bordering Maharashtra (Fig 1). There are ten talukas in the district namely Athani, Bailahongal, Belgaum, Gokak, Hukeri, Khanapur, Raibag, Ramdurg, Chikodi and Saundatti. The elevation of the hills extends to more than 1ØØØ m above sea level. Of the total geographical area of 1346348 ha , 192776 ha is under forest, and 627328 ha which is nearly 5Ø% of the geographical area is normally under crops.

Climate in the district is semi-arid in parts of Athani, Raibag, Gokak, Bailahongal, Ramdurg and saundatti taluks. In other parts it ranges from sub-humid to humid.

Nearly 95% of the annual rainfall is received during the period June to October, because of south west monsoon . Most of the remaining rainfall is received during November and December under the influence of Northeast monsoon.

The district has two major river systems Ghataprabha and Malaprabha which are tributaries of river Krishna (Fig 2). There are two dams one across Ghataprabha at Hidkal and the other across Malaprabha at Naviluteerth Locations are marked in figure 2.

2.1 Geology

Geologically Belgaum district may be divided into 4 regions (Fig 3). (a)Basal crystallines, which are mainly distributed in parts of Khanapur taluk, (b)Meta sedimentaries and Meta volcanics, observed in Bailahongal and Saundatti taluks, (c)Pre-cambrian sedimentaries, distributed over Hidkal, Gokak and Ramdurg taluks, and (d)Basalt with intertrappeans, found in Belgaum, Chikkodi, Raibag and Athani taluks.

2.2 Soils

Introduction of irrigation in an area must be proceeded by detailed field and laboratory investigations aimed at the classification of soils of the area for crop husbandry and to assess their suitability for irrigation . Detailed soil survey of the entire district has not been done systematically. From the data contained in various publications of the State Agriculture Department, there are mainly four types of soils in the district (Fig 4).

(i) Shallow medium black soils
(ii) Red sandy loam soils
(iii) Deep black soils
(iv) Red fine loamy soils

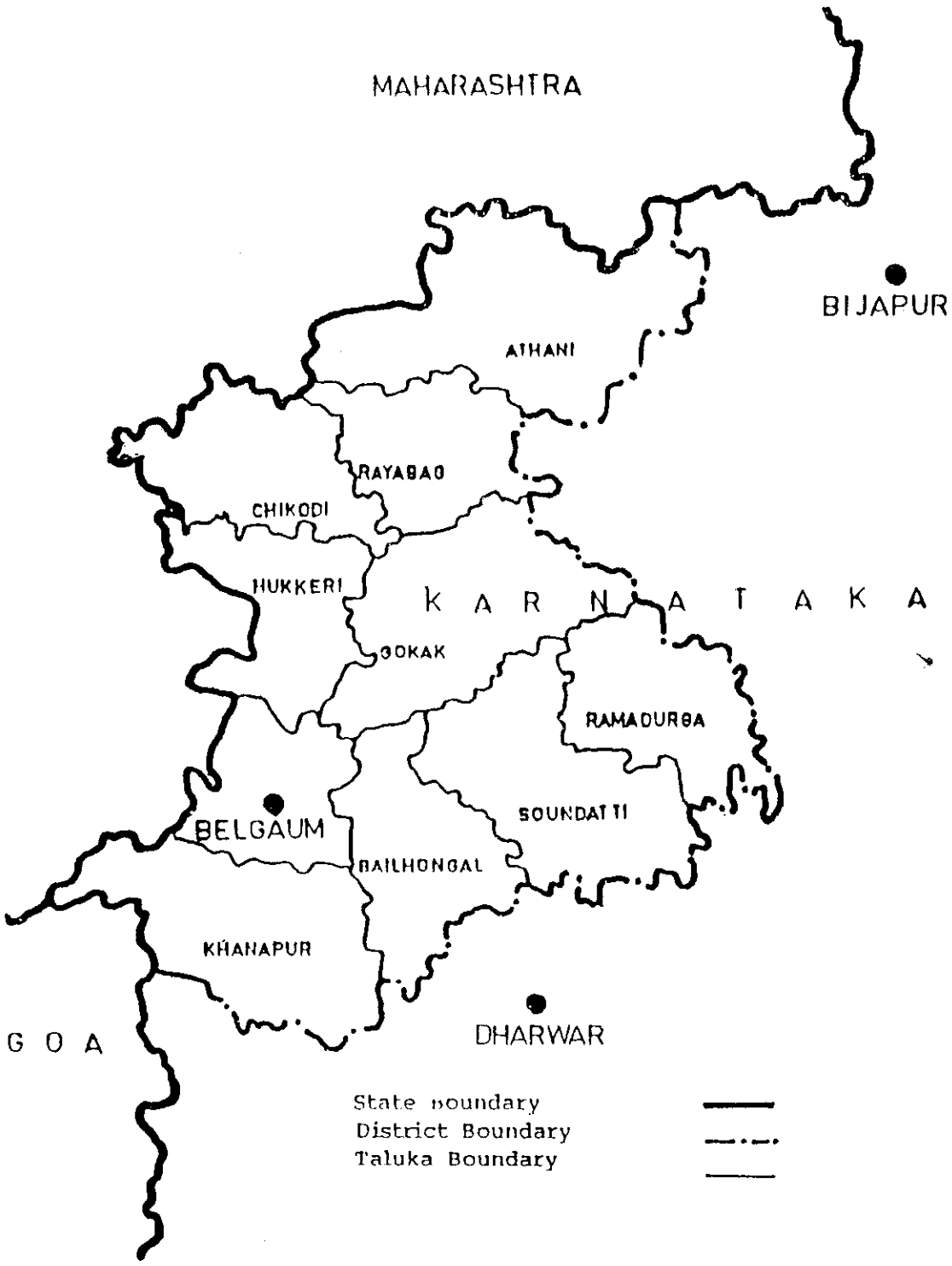

FIG.1: INDEX MAP OF BELGAUM DISTRICT

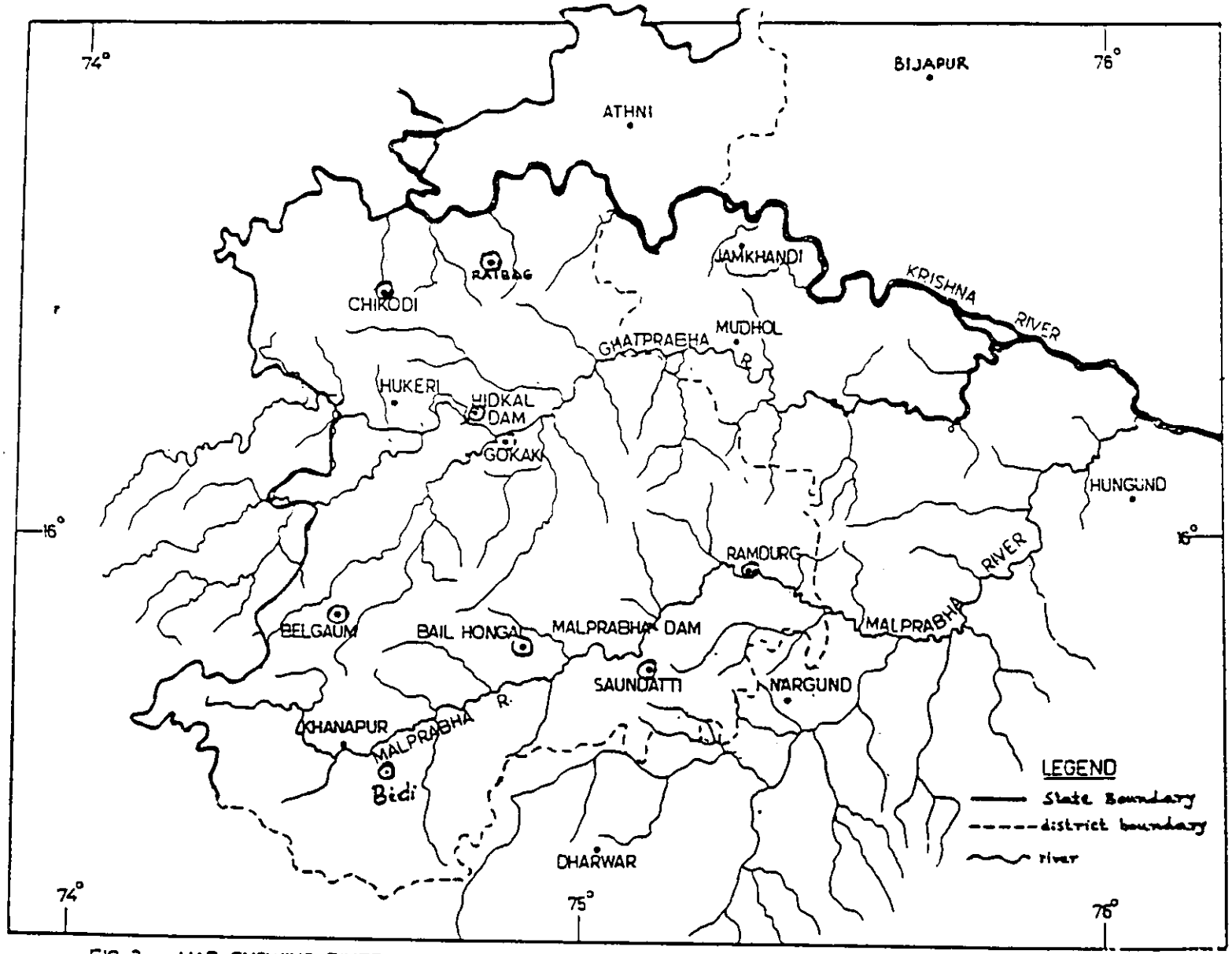

FIG. 2 - MAP SHOWING RIVER SYSTEMS IN BELGAUM DISTRICT

⊙ INFILTRATION LOCATIONS.

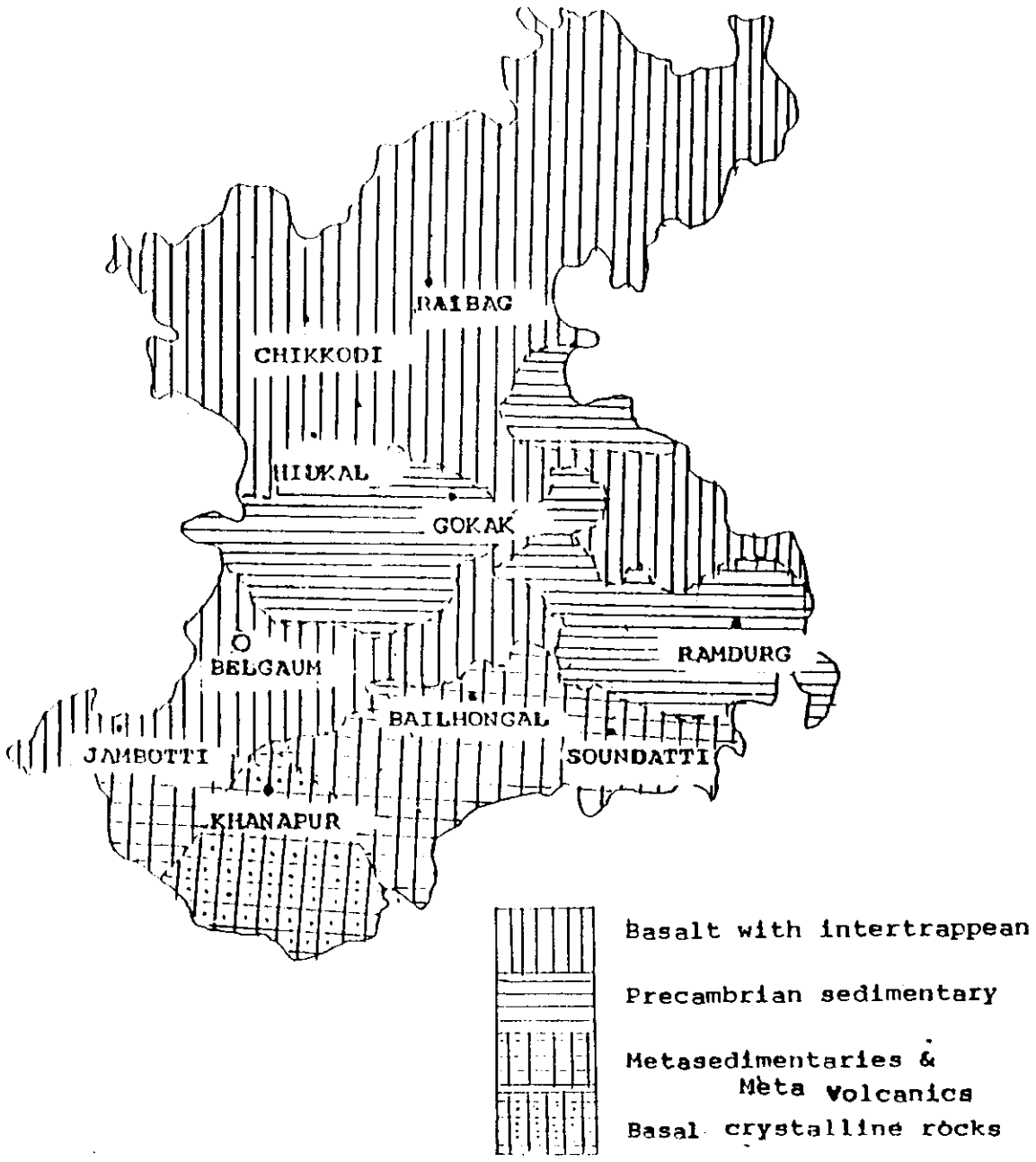

Fig. 3: Geological Map of Belgaum District.

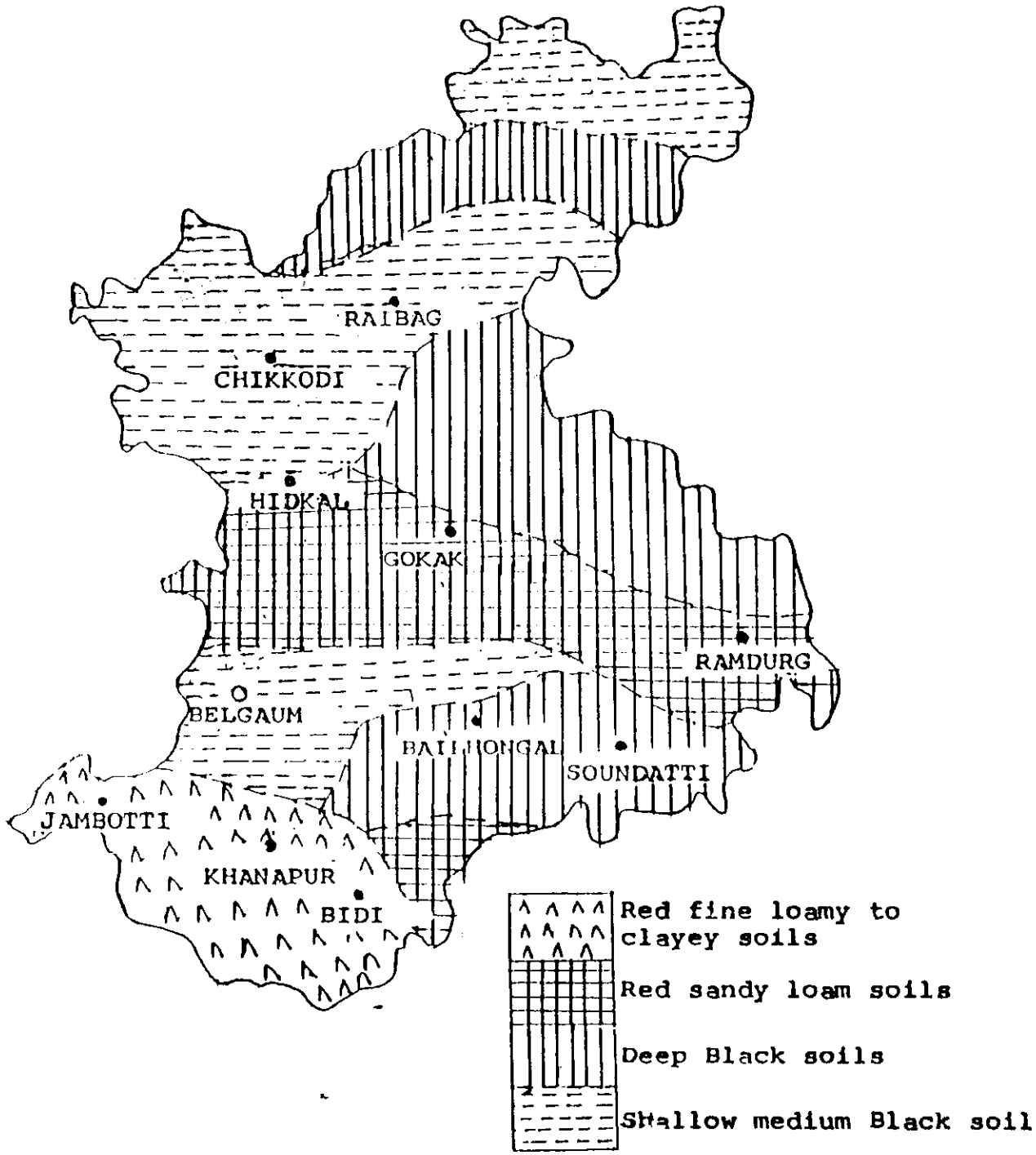

Fig. 4: Soil Map of Belgaum District.

(i) Shallow medium black soils: Distributed in parts of Belgaum, Hukkeri, Chikkodi and Raibag taluks of Belgaum district. These soils are moderately deep to deep, dark to very dark, grayish brown, dark reddish brown or black in colour, usually calcareous cracking and clayey. These soils usually occur on very gently sloping mid-lands. They are highly retentive , neutral tc alkaline in reaction and are well supplied with bases. These soils are fertile and produce good yields, when moisture is not the limiting factor. The crops grown on these soils under rainfed condition are Jowar,wheat, millet, cotton, sunflower, groundnut , linseed, chillies, gram and other pulses.

(ii)Red sandy loam soils: Parts of Hukkeri, Gokak and Ramdurg taluks are covered by Red sandy loam soils. These soils are deep to very deep, reddish brown to dark reddish brown, loamy sand to san y loam on the surface . They are neutral to acidic in nature and low to medium in cation exchange capacity and base saturation with medium to high water yielding capacity. Soils are well drained with moderate permeability. They respond well to irrigation, manuring and other water and land management practices.

(iii)Deep black soils: These soils generally occur on very gently sloping to nearly level or flat topography in low lands of Deccan trap and lime stone regions, in parts of Hukkeri, Gokak, Ramdurg, Bailahongal and saundatti taluks. Deep black soils are also found occurring on sedimentary rocks of mixed origin including transported soils occurring in the basins of major river valleys and depressions. These soils are very deep, dark brown, dark grayish brown to very dark gray or black in colour. These are highly retentive and fertile and are moderately well drained to imperfectly drained with slow to very slow permeability.

(iv) Red fine loamy soil: These are found in Belgaum and Khanapur taluks on hilly to undulating land on granites, granitic gneisses and Dharwar schists. Soils are very deep, dark brown to dark red, sandy loam to clay loam on the surface and loam to clay loam and at places gravelly sandy clay in the sub-surface horizon with distinct argillitic horizon. Soils are well drained with moderate permeability. Crops like wheat, jowar, millets, groundnut and pulses are grown under rainfed cultivation. Under irrigation, crops like paddy, sugarcane, chillies, sweet potatoes, vegetables and plantains are grown.

2.3 Land use pattern

In Belgaum district various types of land use pattern are followed. A major part of Khanapur taluk and parts of Belgaum taluk are covered by forest and shrubs. Agriculture land also occupies a good proportion of the Malaprabha catchment. However, in most of the other taluks forest area is quite negligible, with relatively higher percentage of barren land. More than 50% of the region is covered by agriculture in these taluks. A general land use pattern is given in figure 5.

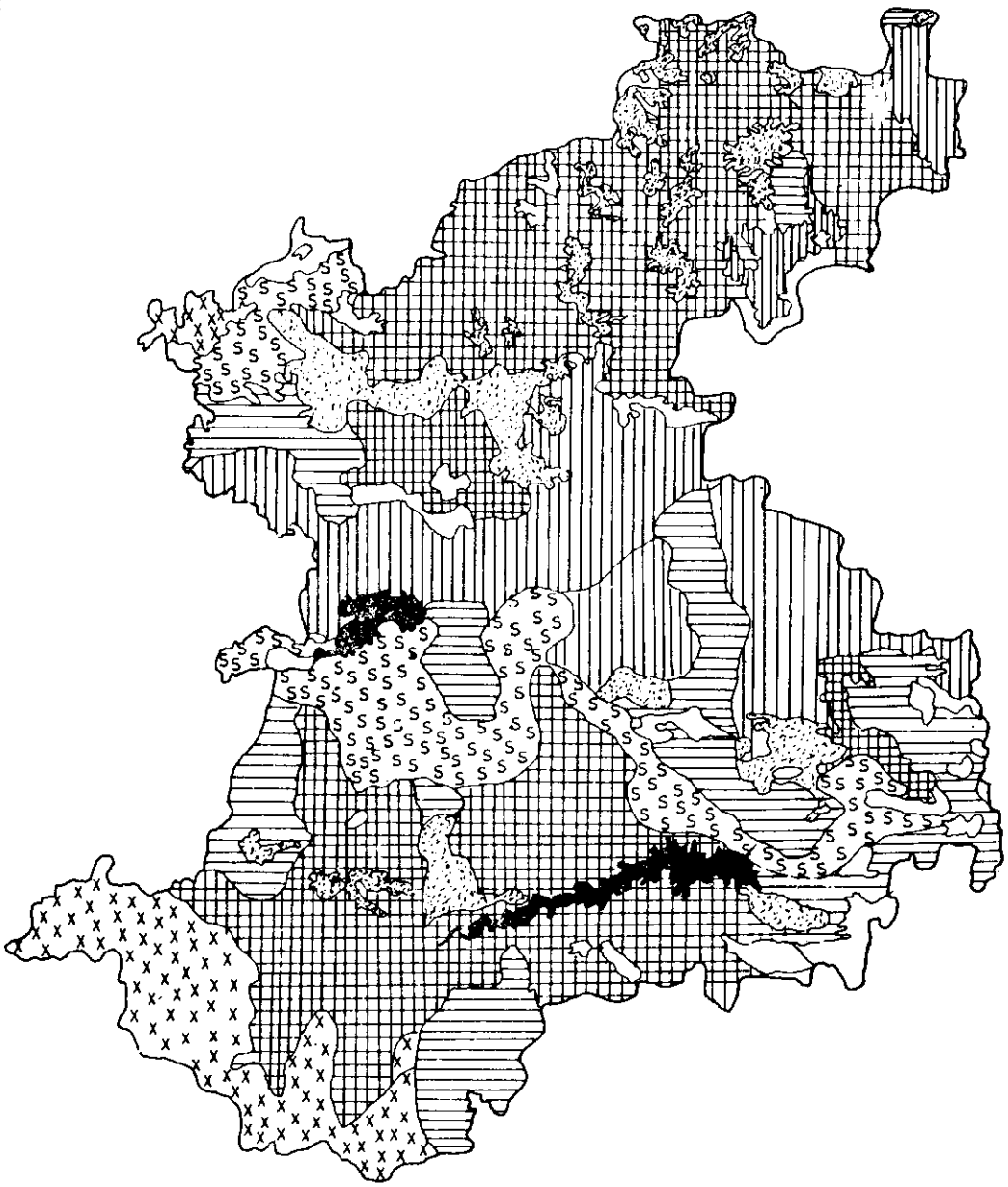

FIG-5 : LAND USE PATTERN OF BELGAUM DISTRICT

AGRICULTURE (KHARIF)

AGRICULTURE (RABI)

DOUBLE CROP

BARREN LAND

SCRUBS

FOREST

3.Ø STRATEGIES FOR INFILTRATION STUDY

Belgaum district has complex geological, pedological and land use pattern. Therefore, stratified sampling technique was adopted to select sites for conducting the infiltration test. An ideal site should represent certain environmental parameters. Under a complex environment, i.e. having different rock types, soil and land use pattern etc., the sampling based on only one geographical parameter, say rock type or soil type, cannot be an ideal choice. Hence, multistage stratification of the study area by using different geographical maps is needed to minimise the variations in order to obtain the homogeneous regions.

Based on available geology and soil maps the whole district may be divided into four micro hydrological regimes. These are as follows:-

1.Basalts with intertrappean with shallow medium black soils found mainly in Belgaum, Chikkodi and Raibag

2.Precambrian sedimentaries with red sandy loam soils found in Hidkal, Gokak and Ramdurg areas.

3.Meta-sedimentaries and Meta-volcanics with deep to very deep black soils distributed over Bailahongal and Saundatti taluks.

4.Basal crystallines with red fine loamy to clayey soil observed in Khanapur taluk.

In each of the above said regions, three tests were conducted depending upon the land use pattern, i.e., forests, shrubs, plantation , agriculture, barren or fallow lands.

After the selection of the site field investigation were carried out to note the following field parameters.

3.1 Field Parameters

As discussed earlier, infiltration characteristics of any region is primarily dependent upon number of factors such as topography, soil, and land use pattern. Infiltration of water into soil influences profoundly the soil water regime and in turn, its availability to plants, evaporation and transpiration and ground water recharge. Hence, it is the soil which plays a major role in the hydrological cycle. It is dependent on initial soil water content of the profile, physico-chemical properties of the soils and surface conditions. In general it is essential to have thorough knowledge of the field where we conduct the experiments. For this purpose, few field analysis may be carried out on the site.

(a) Soil Horizons:

Soil is one of the primary component which influences the infiltration rate. Parent material of soil is usually a weathered rock which contains decayed organic matter. Parent material may also be loose material, river gravel or sheet wash material. In these deposits, differential deposits, differential weathering, movement of water, and the growth and decay of vegetation at the soil surface, result in the soil developing a layered appearance. These layers are called soil horizons (Fig 6). A cross sectional study of the soil horizon is required to understand the thickness of soil cover and underlying material.

(b) Soil Texture:

Textural analysis of soil is a protracted and quite complicated laboratory procedure, however, there is a thumb method for classifying soil in the field.

Pick up a small amount of soil, moist it and try to roll it. If rolling is impossible, it may be classified as sand and if it just begins to form rolls, it is sandy loam soil. During rolling, if it continues to break, it is light loam soil. If roll is breaking while turning it to a ring, it is a medium soil. Heavy loam soils are those which forms a ring but breaks in between. Clay soils form continuous rings.

In addition to that, morphological feature such as stoniness, soil structure, fissure and abundance of roots etc. may be observed in the field.

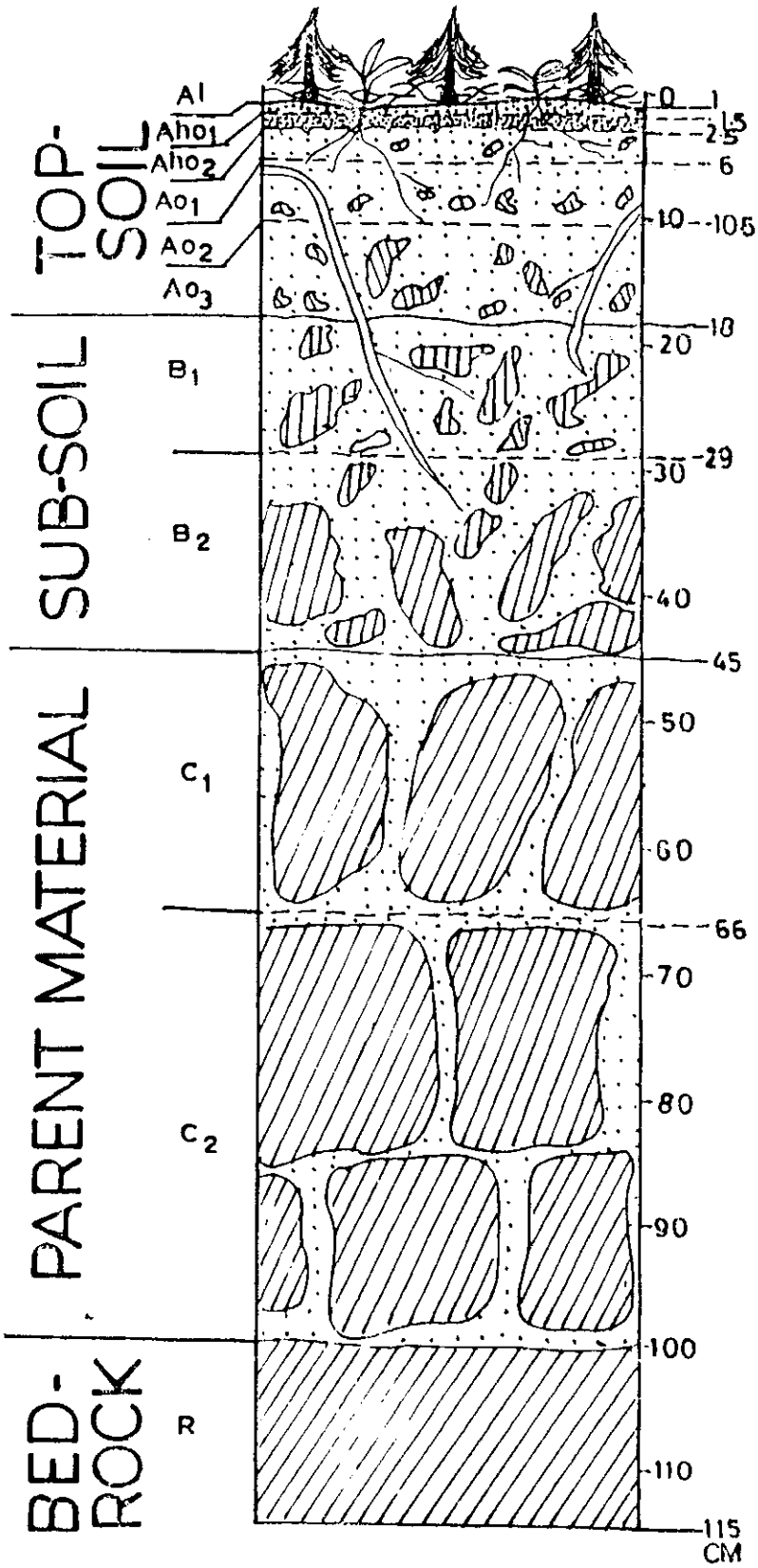

Fig. 6: Different horizons of soil.

4.Ø EXPERIMENTAL PROCEDURE

Owing to the complexity of the infiltration phenomenon, and the fact that many factors affect the process, the measurement of infiltration rates and volumes should be accomplished under field conditions. Two methods are there in common use for the purpose. (a) infiltrometers and (b) hydrograph analysis, where the hydrograph of the observed runoff resulting from periods of natural rainfall on a watershed is analysed.

Infiltration rates in soils and rocks can be determined in several ways. Laboratory determination involve placing soil or rock cores in suitable containers and allowing water to percolate through known soil cross sections. Unless soils are equigranular and loose laboratory values may differ from values obtained in the field Field determination under continuous soil saturation conditions are made by impounding water in experimental plots or allowing water to drain into pans or lysimeters placed below the soil surface. Sprinklers of various designs are used to create artificial rainfall experimental plots and infiltration rates for specified duration are deduced from the rate of rainfall and runoff. From a drainage basin, the rate of infiltration can be approximated if duration, amount and intensity of precipitation as well as interception, depression storage, evaporation and surface run-off are known.

Single ring infiltrometers are also used, but they are apt to give erroneously large values of infiltration rates due to the sponging effect of the soil material outside the cylindrical section of the soil below the ring. Turbulence of water should be avoided as otherwise finer particles in the soil may get suspended and subsequently settle down in a thin veneer and reduce the infiltration rate. To overcome these problems double ring infiltrometers are designed.

4.1 Double ring infiltrometers

In recent years, for the determination of infiltration rate, double ring infiltrometers are widely used. Infiltration characteristics of soils may be determined by ponding water in a set of two metallic rings installed on the field surface and observing the rate at which water level is lowered in the inner ring. In the single ring infiltrometer, a wide variation of data are observed. The variability could be due to the uncontrolled lateral movement of water from the ring after the wetting front reach the bottom of the ring. In the double ring infiltrometer these problems are solved. The experimental set-up is shown in figure 7. This consists of two concentric rings, (45 cm and 3Ø cm in diameter or 42.5 cm and 27.5 cm in diameter) of mild steel plates, and a couple of tanks with the same diameter as that of the rings to feed water to maintain constant head of water. A constant depth of water can be maintained by suitably adjusting

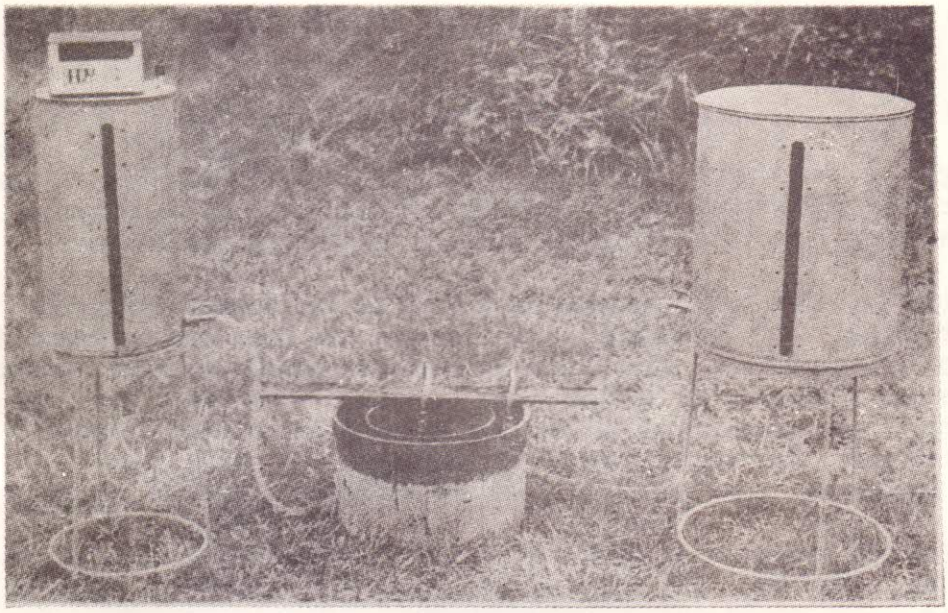

Figure 7 : Field setup : Double ring infiltrometer

the position of the nozzle of the tube which is connected to the water container. The experimental part involves the following steps:

(1)Selection of the site - site selection should be based on the rock type, soil, vegetation and rainfall intensity.

(2)Once the suitable site is selected, instruments will be set up as shown in the figure. Initially two rings of about 40 cm height (thickness 2-3 mm) and of suitable diameter should be selected.

(3)The rings must be driven inside the ground for about 20 cm.

(4)Two constant head devices with a marking of maximum water level will be lowered in to both the rings (inner and outer) through a flexible pipe and inturn this should be connected to the graduated container. Constant head device (float) will aid in maintaining the water level and to note the readings.

(5)In the next stage water will be supplied from the container tube. The minimum water level in the rings should be upto a depth of 10 cm. The fall of water level in the tanks corresponds to a depth of water infiltrated. However, use of containers can be dispensed with the measurements of depth of water infiltrated and water replenished in the ring upto a predetermined level by use of scale or by graduating the rings.

(6)The readings may be taken at definite intervals (0, 10, 10, 20, 20, 30, 30, 30, 60 in minutes) till we get a constant reading.

(7)Finally, a graph may be drawn with time on X-axis and infiltration rate on Y- axis.

Precautions to be taken while using double ring infiltrometer.

(1)Diameters of the containers and rings should be same.

(2)Distance between the rings should be maintained equally on all sides.

(3)Disturbance in soil layers should be minimum.

(4)Water level in the inner cylinder and the buffer pond should be equal.

5.Ø SITE DESCRIPTIONS AND INFILTRATION CURVES

Considering geology, geomorphology, soil and land use pattern, 9 sites were selected for the present study. Field exercises were carried out to know the soil type, and texture, topography, land use pattern etc.

A brief description of each infiltration sites where the tests were conducted, along with the infiltration curves are given below.

5.1 Bidi (Site nos. 1, 2 & 3)

The site is located at about 5Ø km south west of Belgaum in Khanapur taluk. Malaprabha river flows through Khanapur and the infiltration site is about 15 km from Khanapur. A minor irrigation tank is constructed for the irrigation purpose. Infiltration test was conducted on the natural terrace at an elevation of about 655 m. The region is covered by deep reddish loamy soils with medium loam texture. Soil layer is very thin and gravels and pebbles are more in this region. Pulses are grown on the agricultural where the test was conducted. Initial rate of infiltration is quite high (48.6 cm/hr) and final rate is 2Ø.4 cm/hr (Fig 8). This high value is attributed to the stony nature of the site.

Second test was conducted on the Barren land close to the Bidi tank. Land is very hard and is covered by a small thickness of soil. Rate of infiltration is low, i.e. initial rate is 6 cm/hr and final rate is 1.8 cm/hr (Fig 9).

The experiment was repeated on a land of Nilgiri plantation. The rate of infiltration is 3.6 cm/hr and the initial rate is 9 cm/hr (Fig 1Ø). Field observation shows that the soil moisture retention capacity is good. A bore well is dug here for a depth of 24Ø ft and it supplies enough water for the plantation. Soil is medium loam and black in colour.

5.2 Bailahongal (Site nos. 4, 5 & 6)

This region comes under the Malaprabha command area and is about 5Ø km East of Belgaum at an altitude of 667 m. Infiltration tests were conducted on three sites, i.e. Agriculture land, fallow land, and scrubby land.

First test was conducted on an agriculture land. Soil is black cotton and cotton is grown on this site. Texturally soil is heavy loam which are medium to fine grain in size. The initial rate of infiltration is 45.6 cm/hr and it falls to 6.6 cm/hr (Fig 11). High initial rate of infiltration shows that, soil absorbs high quantity of water and for saturation it takes 1 hr.

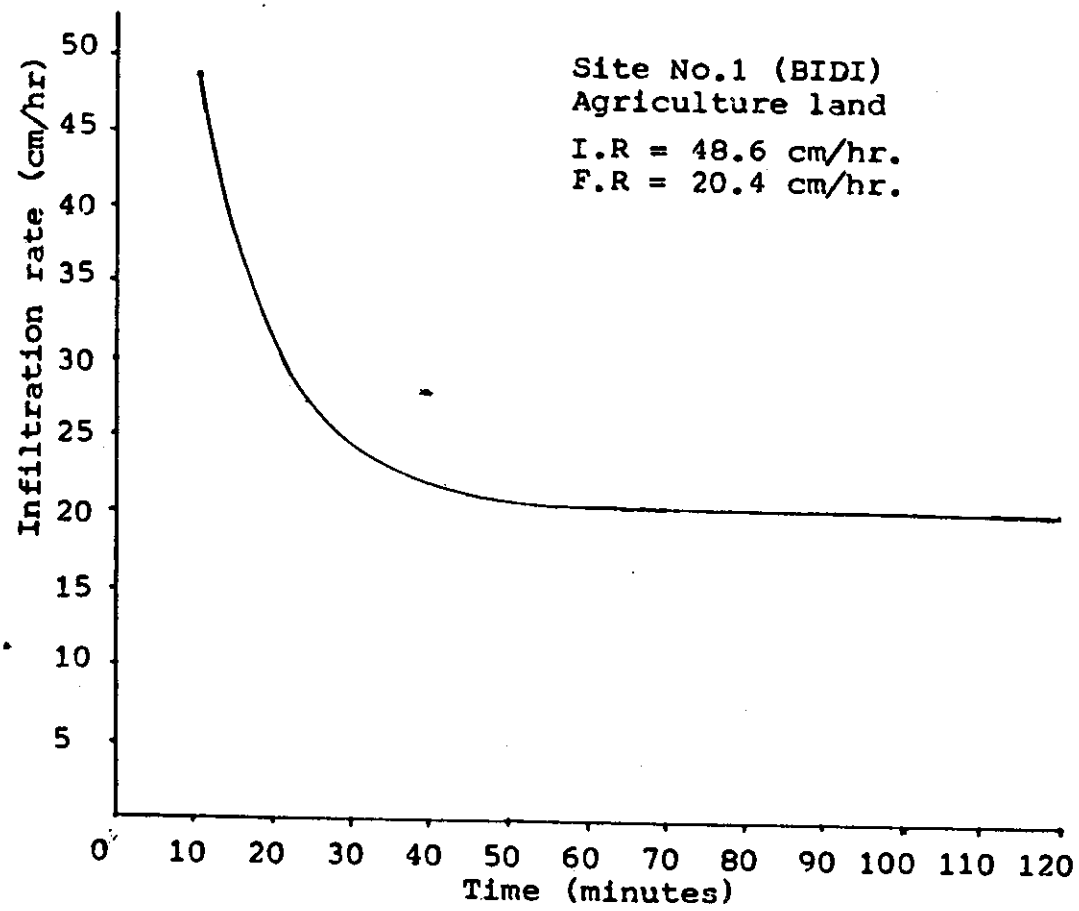

Figure 8 Infiltration curve at Bidi on Agriculture land

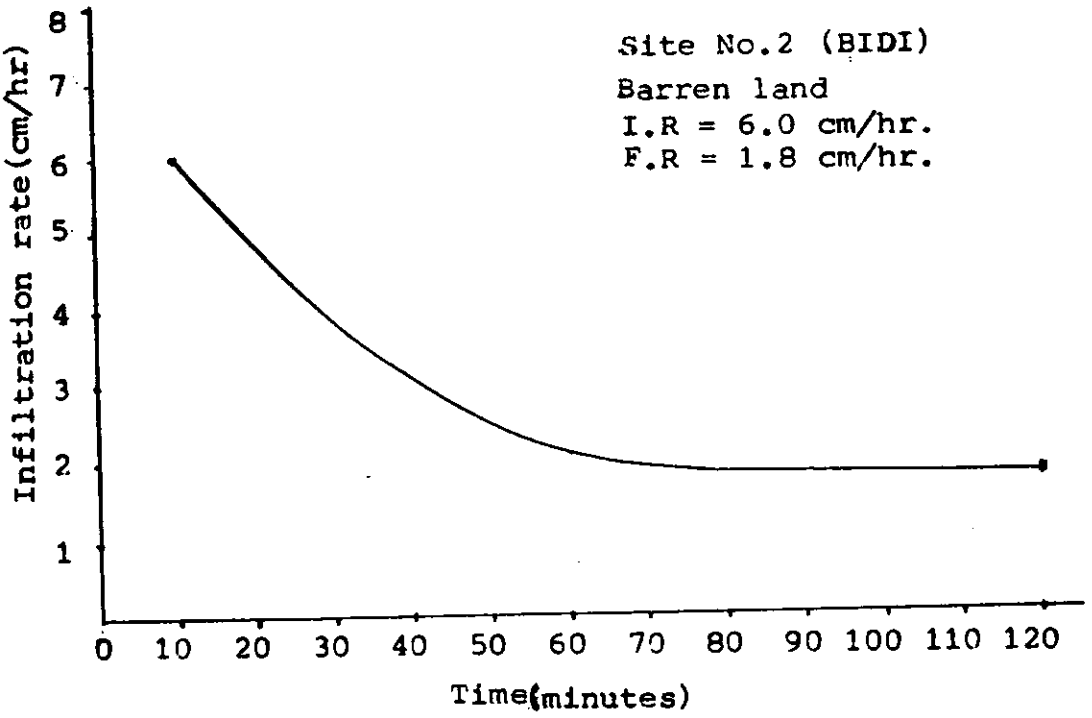

Figure 9 Infiltration curve at Bidi on Barren land

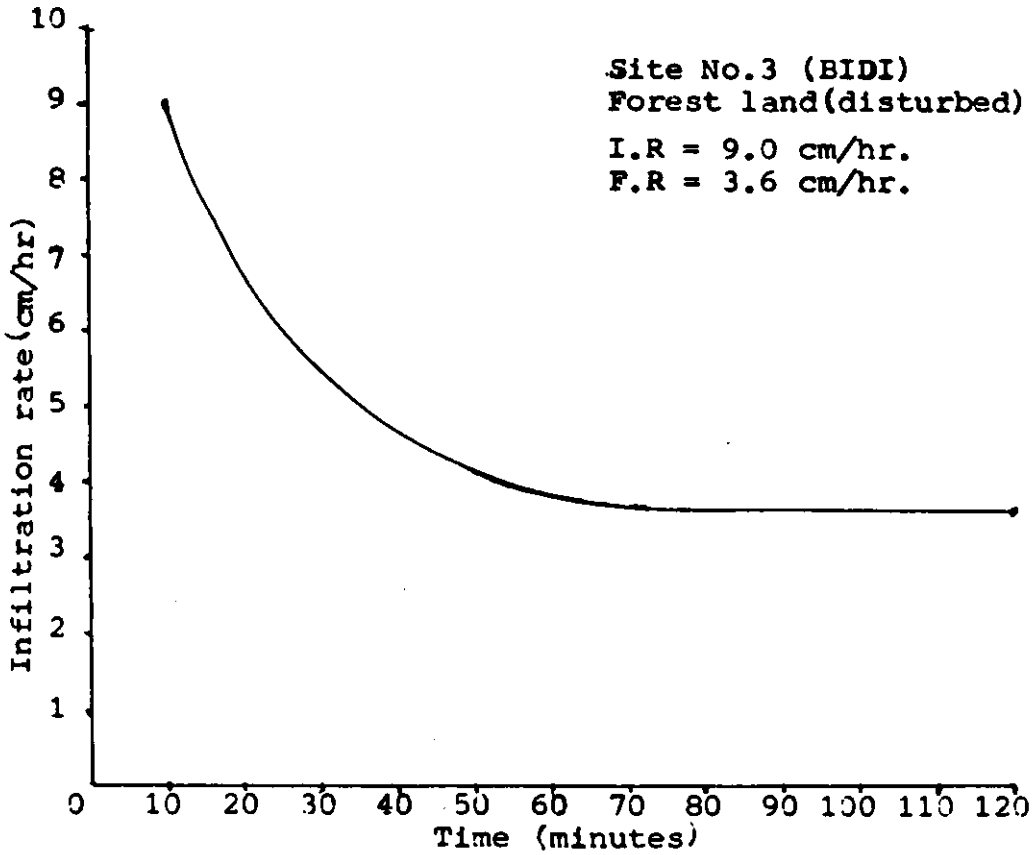

Figure 10 Infiltration curve at Bidi on Forestland (Disturbed)

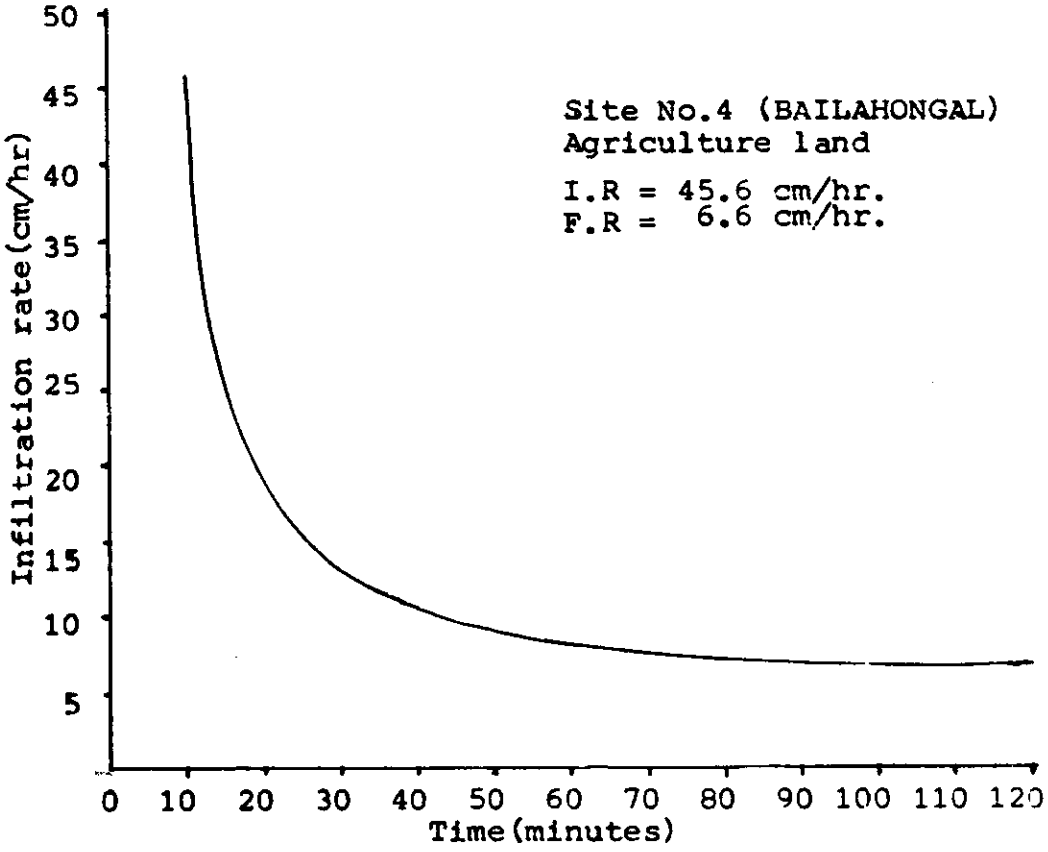

Figure 11 Infiltration curve at Bailahongal on Agriculture Land

Experiment was repeated on a fallow land where a school building is situated. Land is covered by black cotton soil with heavy loam texture. Initial rate of infiltration is 34.8 cm/hr and it comes to 4.2 cm/hr (Fig 12). For reaching the steady state it took 1 hr 10 minutes.

Infiltration rate on a scrubby land which is located at slightly higher elevation and with higher relief shows comparatively low rate of infiltration (initial rate is 21.6 cm/hr and final rate is 1.2 cm/hr) as shown in figure 13. Texture of the soil is heavy loam and shows slightly reddish colour.

5.3 Saundatti (Site nos. 7, 8 & 9)

Saundatti is located at about 90 km East of Belgaum. The elevation is 658 m and the region is undulating to nearly plain. A dam is constructed across the river at Naviluteerth in Saundatti taluk and this part of the study area falls under the Malaprabha command area.

Cotton is planted on the agriculture land where the test was conducted. Pebbles and gravels are common. Soil is light reddish in colour and texture is medium loam. Initial rate of infiltration is 33.6 cm/hr and the final rate is 13.8cm/hr (Fig 14).

Rate of infiltration in barren land also shows the same trend as in the agriculture land. Initial rate is 36.6 cm/hr and final rate is 14.8 cm/hr (Fig 15). Soil is light coloured and light loam in texture.

Infiltration rate was determined on a land where various types of plants are grown. This location is very near to the river (about 50 m). Light coloured soil with heavy loam texture are distributed over this region. Initial infiltration rate is 18 cm/hr and final rate is 5.4 cm/hr (Fig 16).

5.4 Ramdurg (Site nos. 10, 11 & 12)

Ramdurg is situated at about 100 km East of Belgaum at an altitude of 557 m. This region comes under the Malaprabha command area. Black to red soil is distributed over this taluk.

Test conducted on the agriculture land revealed that the soil is having high soil moisture retention capacity. Infiltration rate varied between 7.8 cm/hr to a negligible value which indicates that the region is waterlogged (Fig 17). Soil is black in colour and heavy loam in texture. Coconut plants and maize are grown on this part of the land.

To verify the results, a test was conducted on a fallow land. Here the infiltration rate varied from 5.4 cm/hr to 20.4 cm/hr (initial rate) as shown in figure 18. Saturation point is

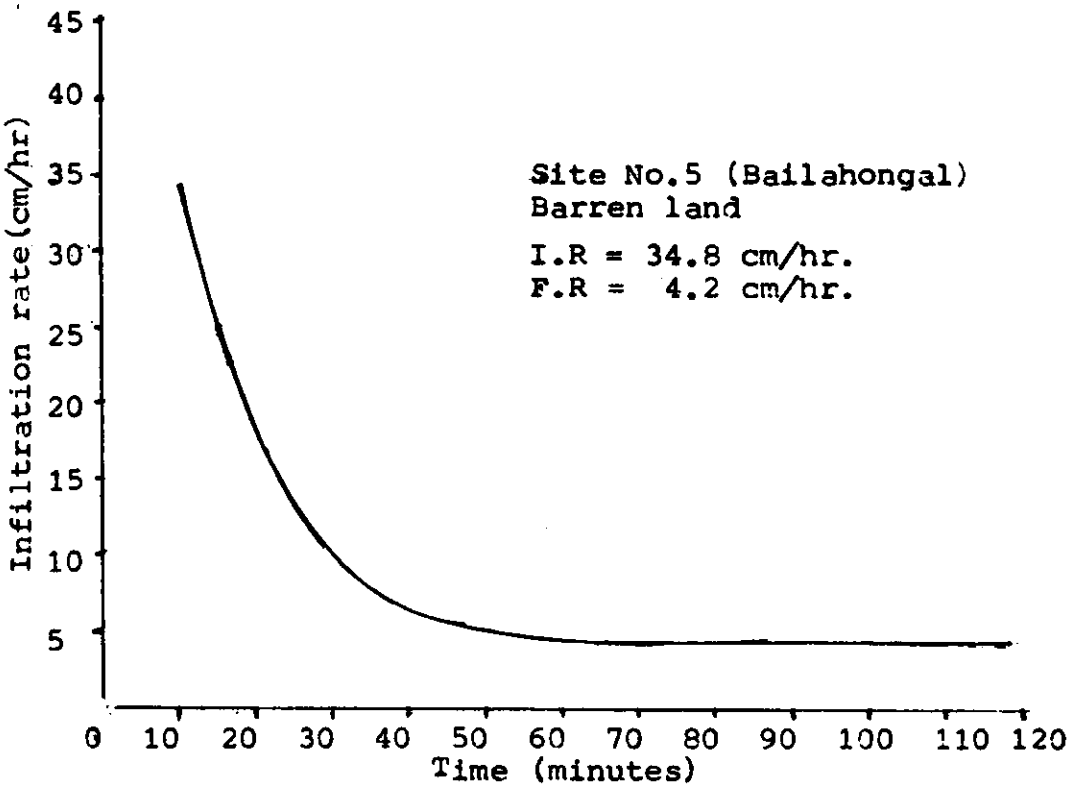

Figure 12 Infiltration curve at Bailahongal on Barren land

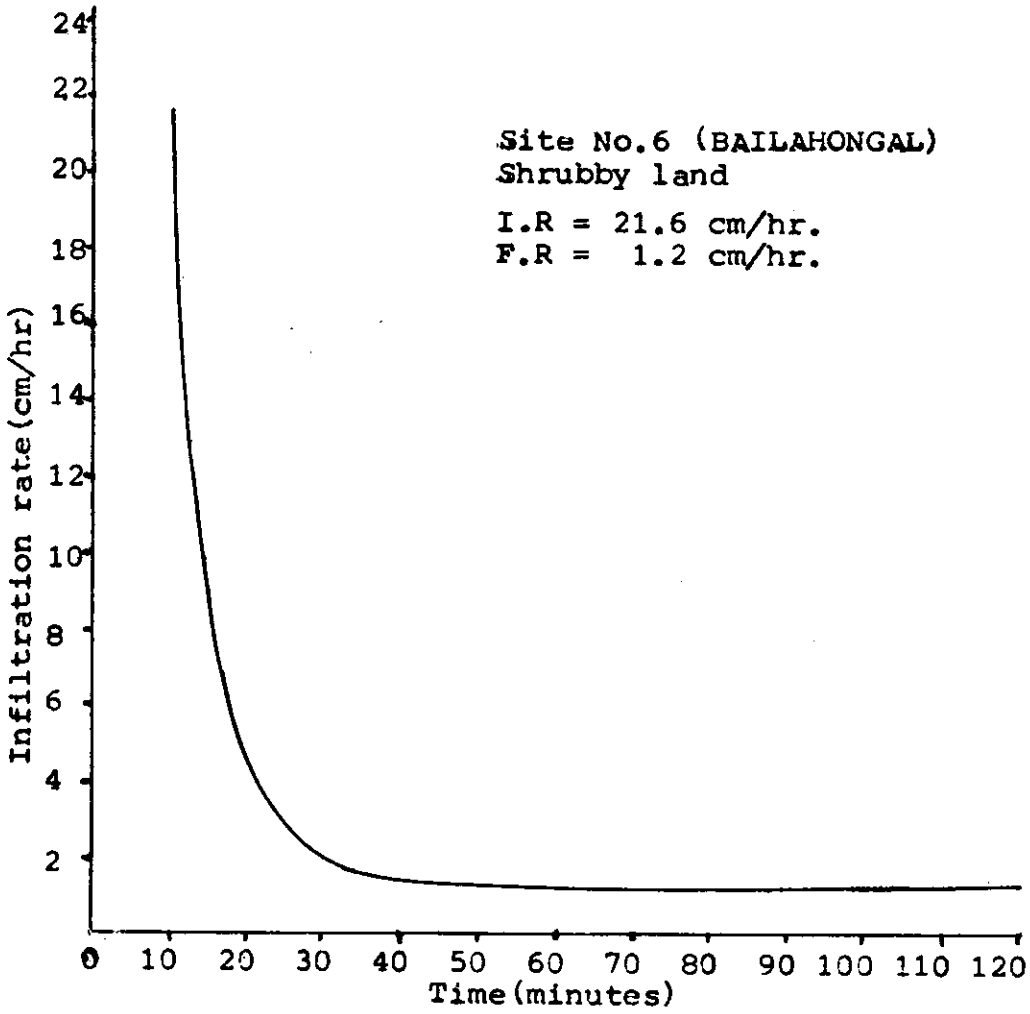

Figure 13 Infiltration curve at Bailahongal on Shrubby Land

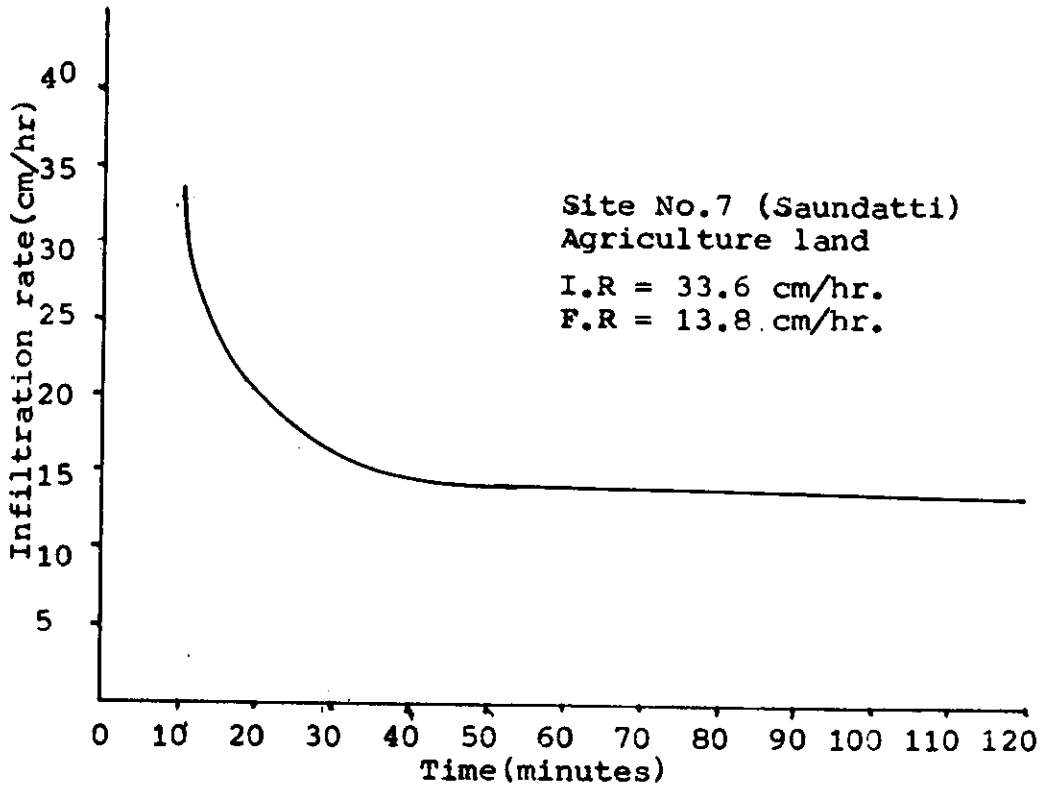

Figure 14 Infiltration curve at Saundatti on Agriculture Land

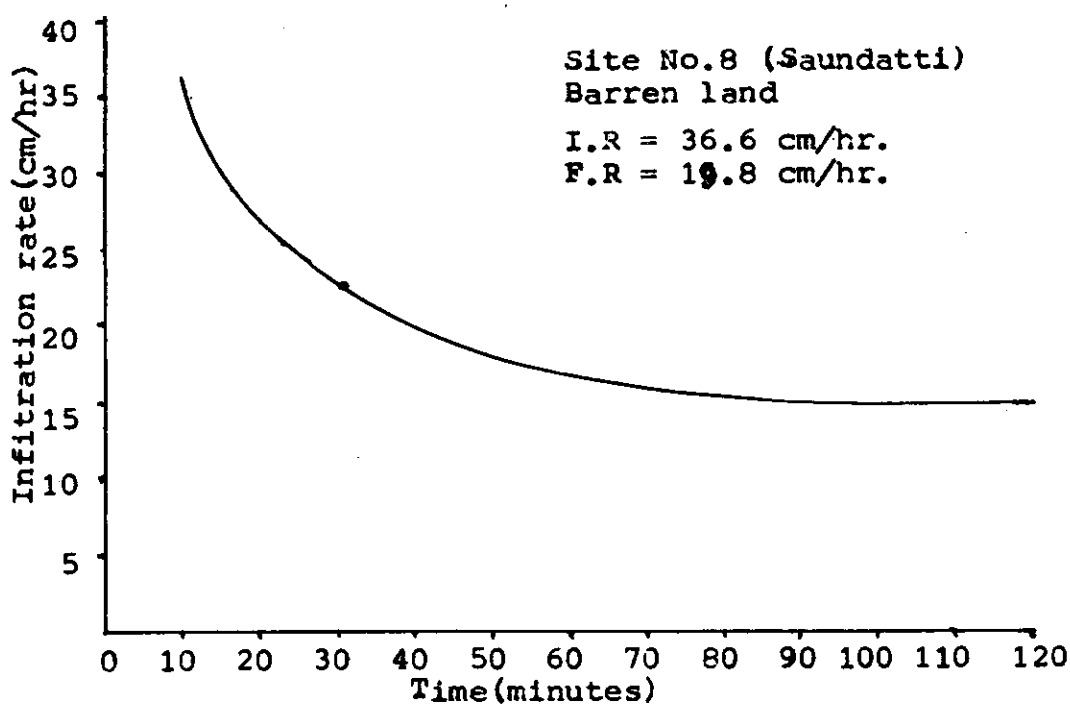

Figure 15 Infiltration curve at Saundatti on Barren Land

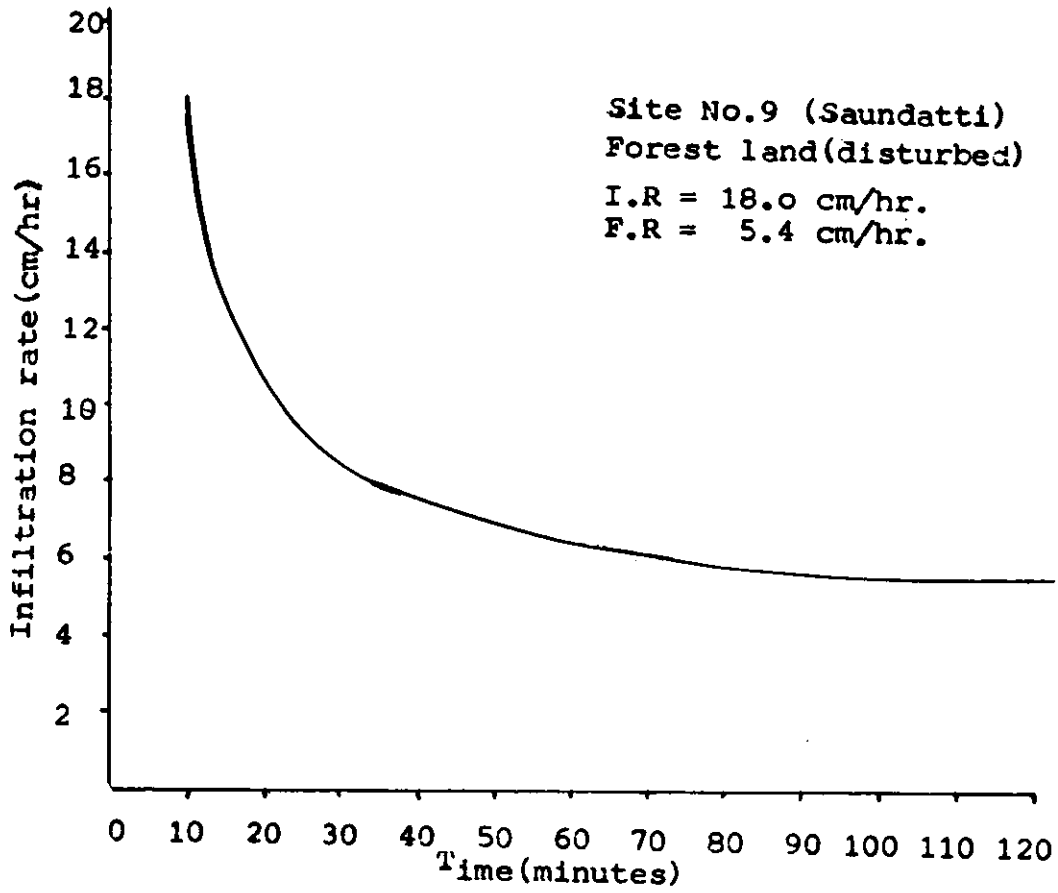

Figure 16 Infiltration curve at Saundatti on Forest Land

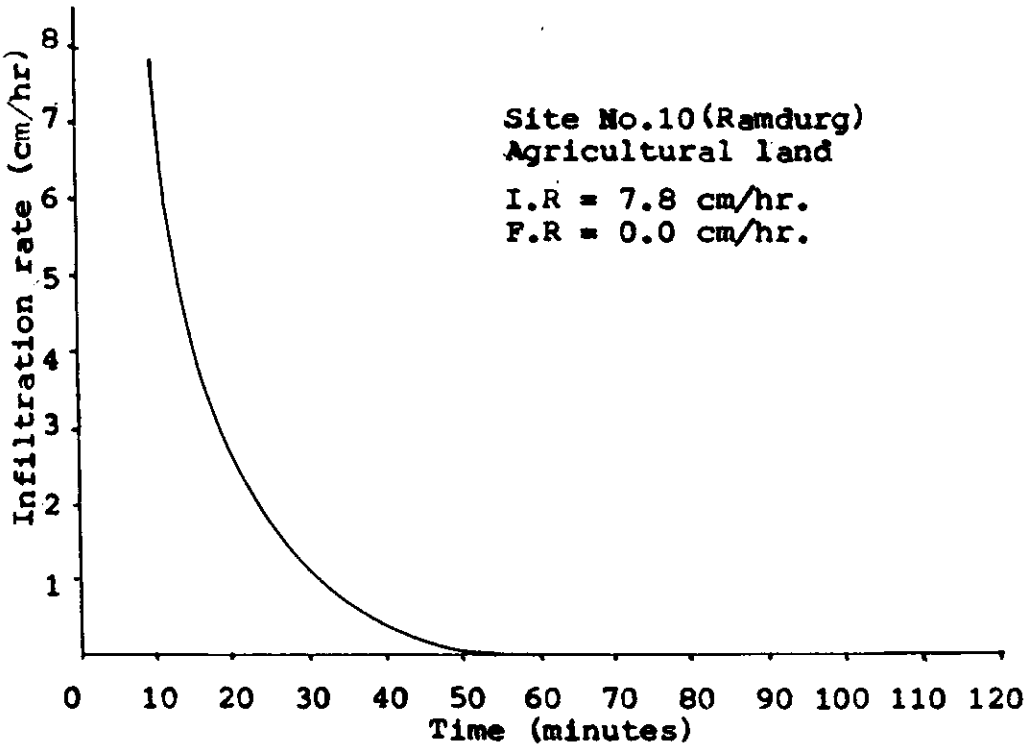

Figure 17 Infiltration curve at Ramdurg on Agriculture Land

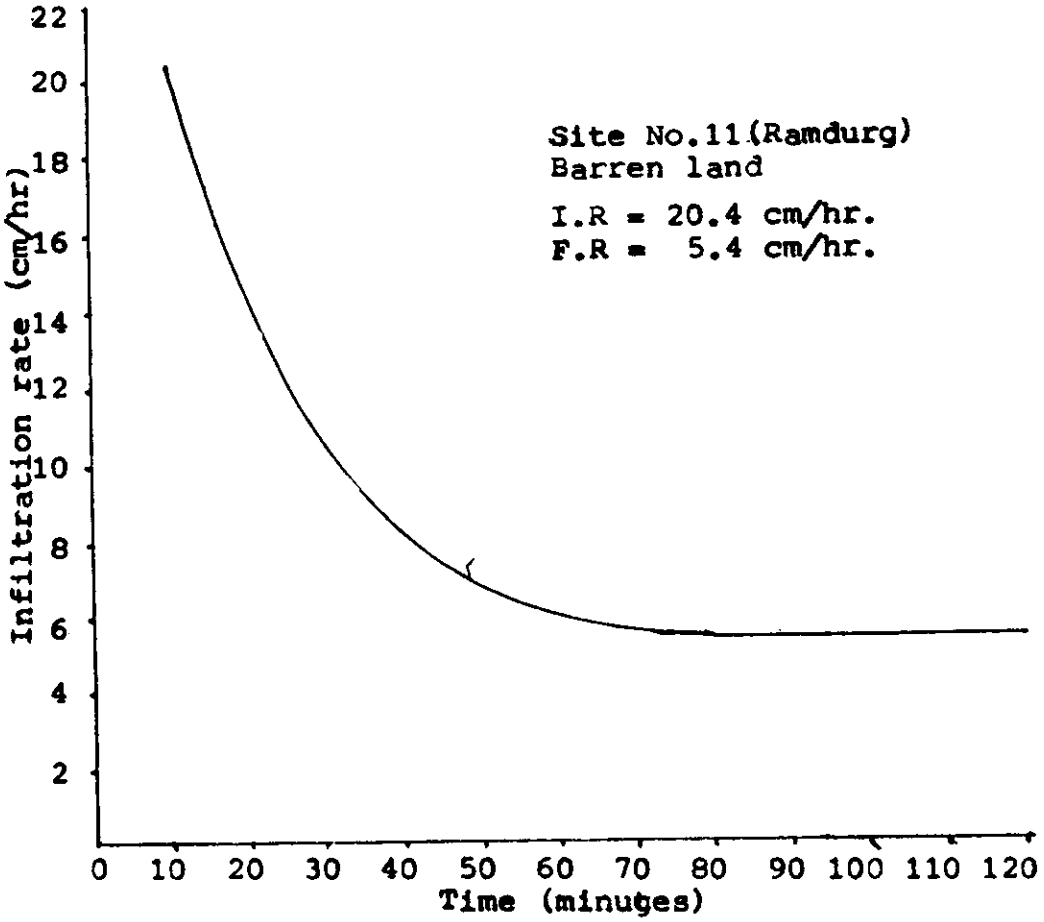

Figure 18 Infiltration curve at Ramdurg on Barren Land

reached after 1 and half hours. Soil is medium loam and slightly reddish in colour.

Infiltration rate observed on the plantation area is 4.8 cm/hr (Fig 19). Soil is light coloured and the texture is medium loam.

5.5 Belgaum (Site nos. 13 & 14)

Infiltration test was conducted in Belgaum taluk, Belgaum. Site is about 13 km from Belgaum city lying in NH-17A. Hidkal reservoir extends up to Belgaum taluk. Elevation above mean sea level is more than 7ØØ m. Experiment was conducted on an agriculture land (presently without cultivation). Land shows plain terraced structure and is covered by black soil. Texture is heavy loam. Initial rate of infiltration is 16.2 cm/hr and the final rate is 1.8 cm/hr (Fig 2Ø). Soil is black in colour and medium loam texture.

The test was repeated on a fallow land lying in a basin like structure, which shows comparatively high rate of infiltration (initial rate is 42.6 cm/hr and the final rate is 4.8 cm/hr) as shown in figure 21. Soil is black in colour and the texture is medium loam.

5.6 Hidkal (Site nos. 15)

Hidkal is 45 km from Belgaum, at an altitude of 625 m above mean sea level in Hukkeri taluk of Belgaum district. Infiltration site is located very close to the reservoir. Land is covered by horticultural and coconut plantation. Soil is light loam with light reddish colour. Infiltration rate varies from 3 cm/hr (final rate) to 12 cm/hr (initial rate) as shown in figure 22. For saturation, it took only 2Ø minutes. The tests were not carried out for other areas under different land uses as the near by areas are quite hard to drive the rings.

5.7 Gokak (Site nos. 16 & 17)

Gokak is 6Ø km north east of Belgaum at an altitude of 556 m above mean sea level and falls under the Ghataprabha command area.

Infiltration test was conducted on an agricultural land. Sugar cane is grown over this area. Ghataprabha river flows through this region. Topographic variations are prominent. Soil is black in colour and shows medium loam texture. Soil is salty as per the information received by the local farmers. Initial rate of infiltration observed is 12 cm/hr and it falls to Ø.6 cm/hr (Fig 23). Soil attains saturation within half an hour. Low infiltration rate could be due to the water logging problem.

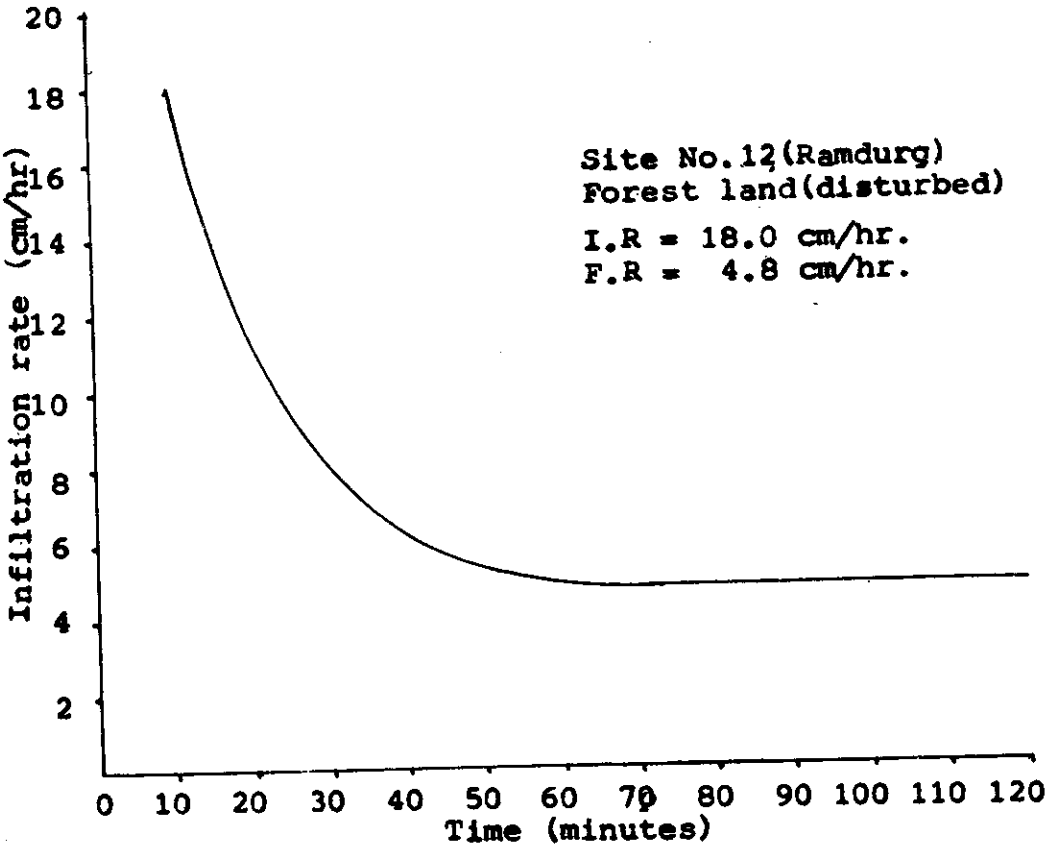

Figure 19 Infiltration curve at Ramdurg on Forest Land (Disturbed)

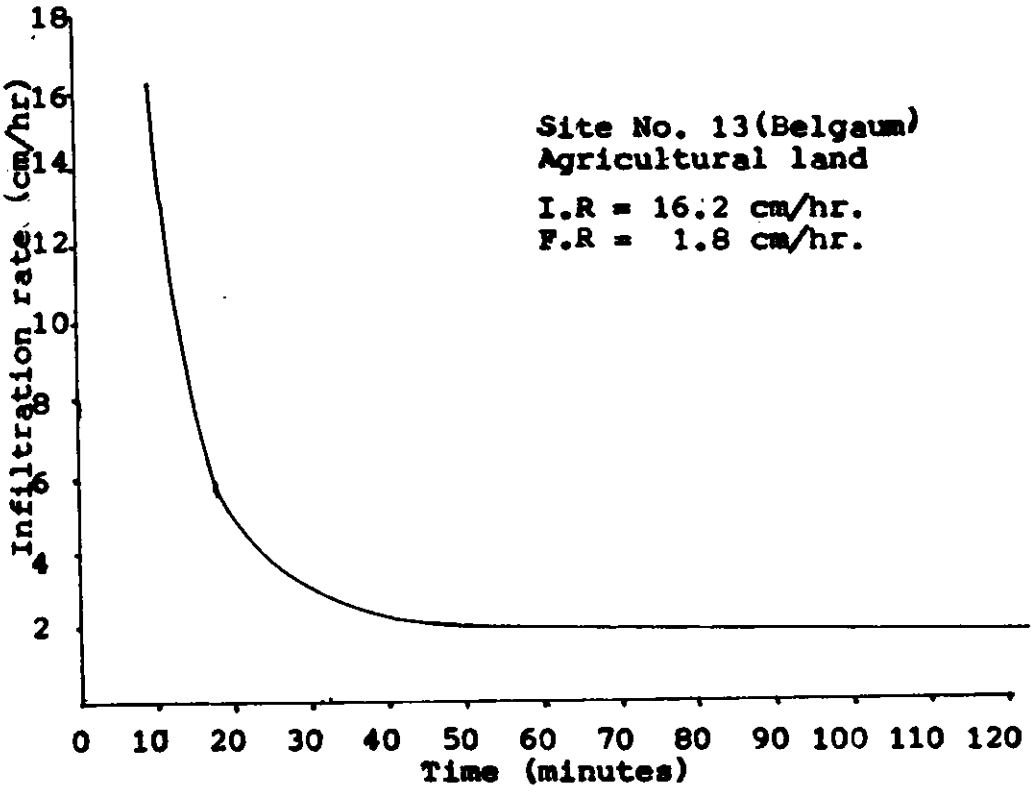

Figure 20 Infiltration curve at Belgaum on Agriculture Land

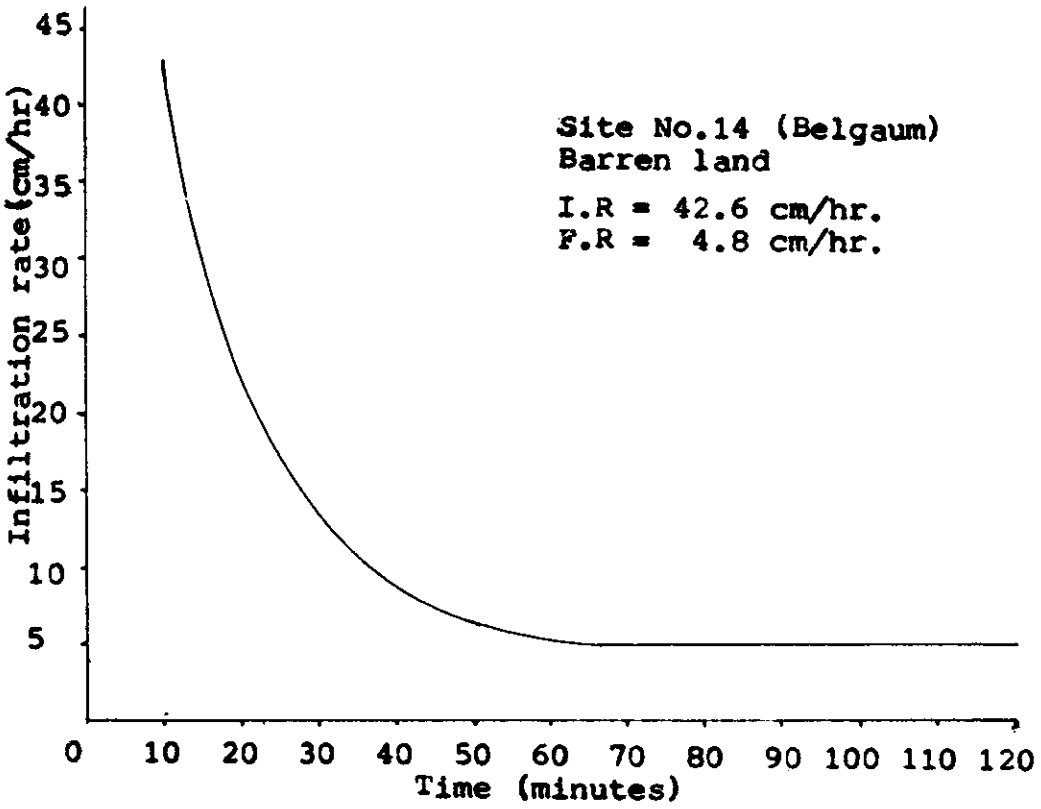

Figure 21 Infiltration curve at Belgaum on barren land

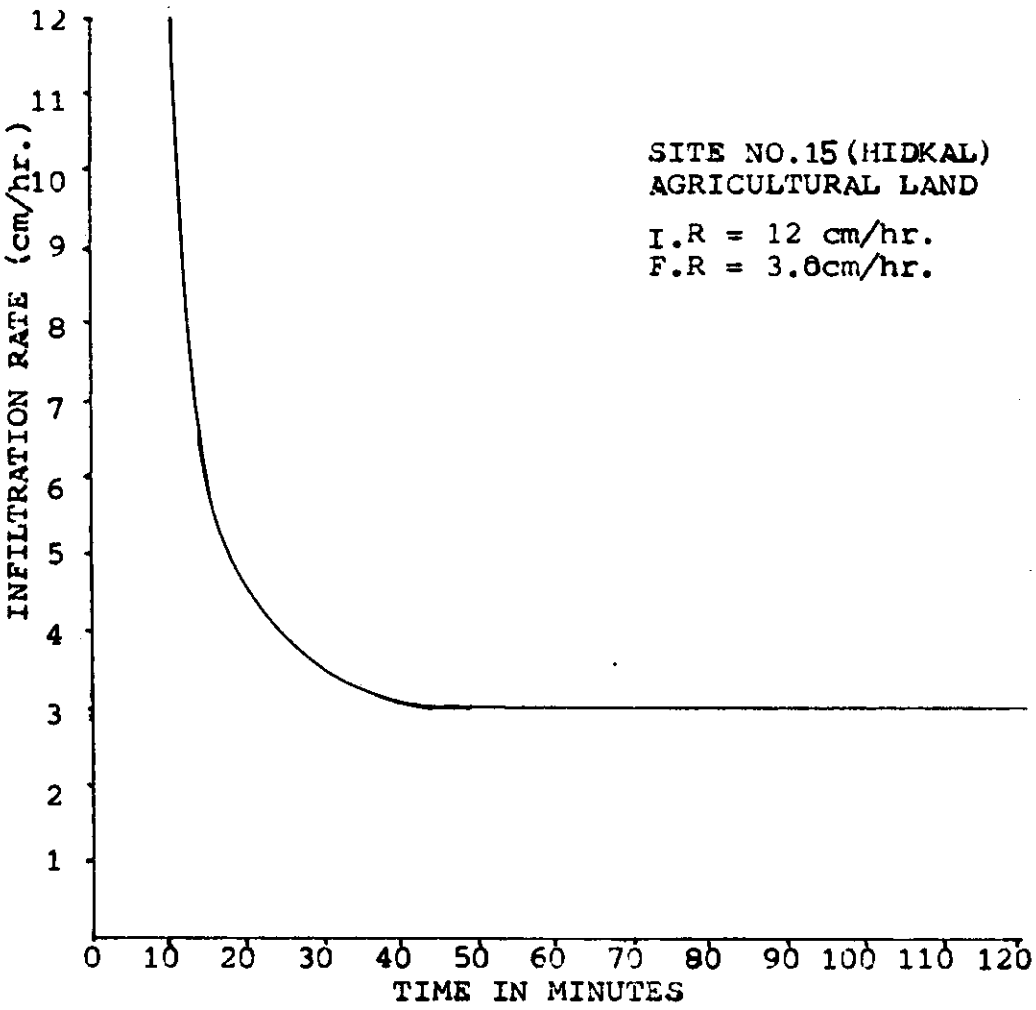

Figure 22 Infiltration curve at Hidkal on Agriculture land

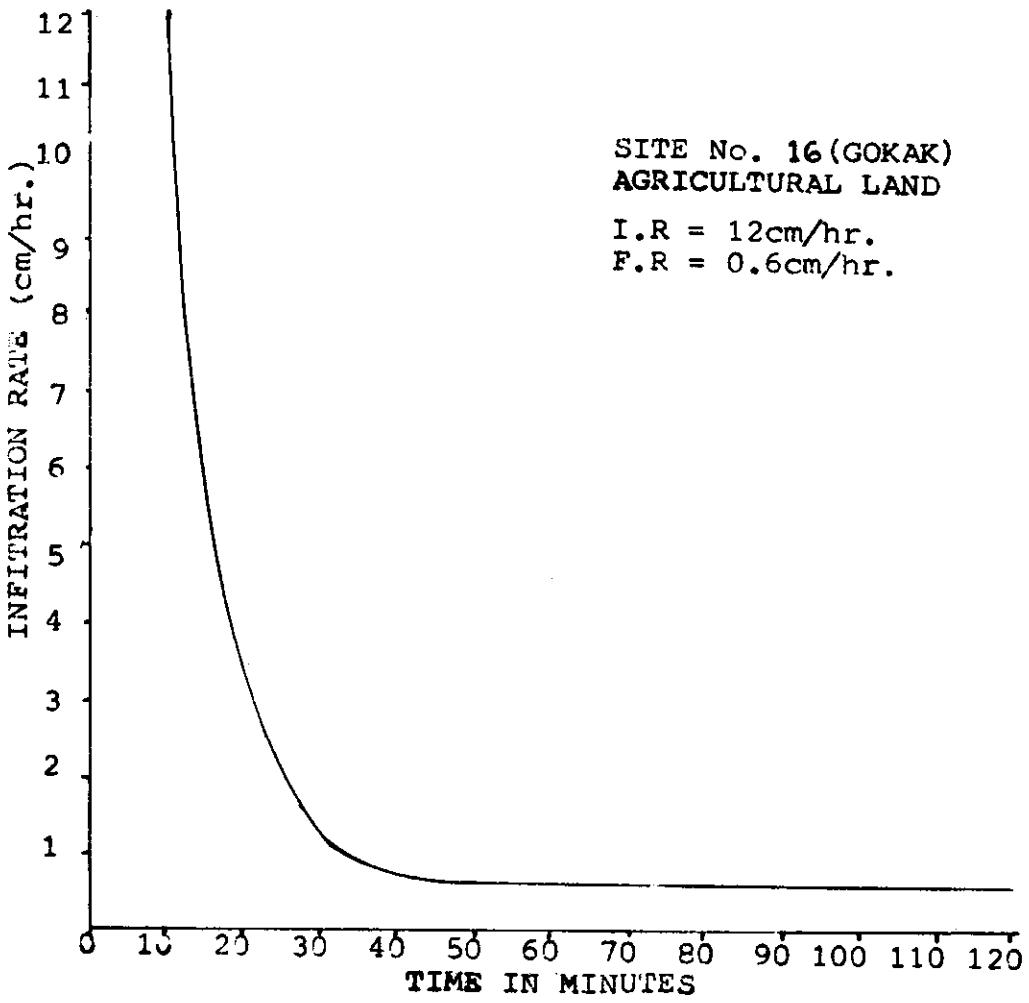

Figure 23 Infiltration curve at Gokak on Agriculture Land

Second test was conducted on a fallow land adjacent to the first site. Colour and texture of the soil are same. The initial rate of infiltration is 54 cm/hr and final rate is 13.2 cm/hr (Fig 24).

5.8 Chikodi (Site nos. 18, 19 & 2Ø)

Chikodi is 85 km north of Belgaum . The elevation of the region is 6Ø7 m above m.s.l. Parts of Chikodi taluk comes under Ghataprabha command area.

Agriculture land comprises of light coloured soil with medium loam texture. The initial rate of infiltration is 32.4 cm/hr and reaches constant rate of 8.4 cm/hr after 5Ø minutes (Fig 25)

Rate of infiltration on a barren land is 9 cm/hr and the initial rate observed was 18 cm/hr (Fig 26). For saturation of soil cover it took 7Ø minutes. Soil is light coloured and light loam in texture.

Experiment was repeated on a disturbed forest land having light coloured soil and heavy loam texture. Rate of infiltration is low when compared to the other regions and it varies between 14.4 cm/hr (initial rate) and 4.2 cm/hr (final rate) as shown in figure 27.

5.9 Raibag (Site nos. 22, 23 & 24)

Raibag is situated 12Ø km NE of Belgaum at an elevation more than 6ØØ m above mean sea level. Ghataprabha left bank canal passes through this part of the region.

Test was conducted on an agricultural land showing natural terraced structure. Soil is light coloured and having light loam texture. The infiltration rate observed initially is 24 cm/hr and the final rate is 5.4 cm/hr (Fig 28).

Second test was conducted on a fallow land adjacent to the agriculture land. Here the infiltration rate is quite less and it varies from Ø.9 cm/hr (final rate) to 4.2 cm/hr (initial rate) as shown in figure 29. Soil is as black cotton with heavy loam texture.

Third test was conducted on a disturbed scrubby land where the Nilgiris are planted. The layer of soil is light coloured with light loam texture. Soil cover is about one and half meters and is intercalated with white clays. Rate of infiltration is comparatively very high. Initial rate is 39 cm/hr and the final rate is 12.6 cm/hr (Fig 3Ø).

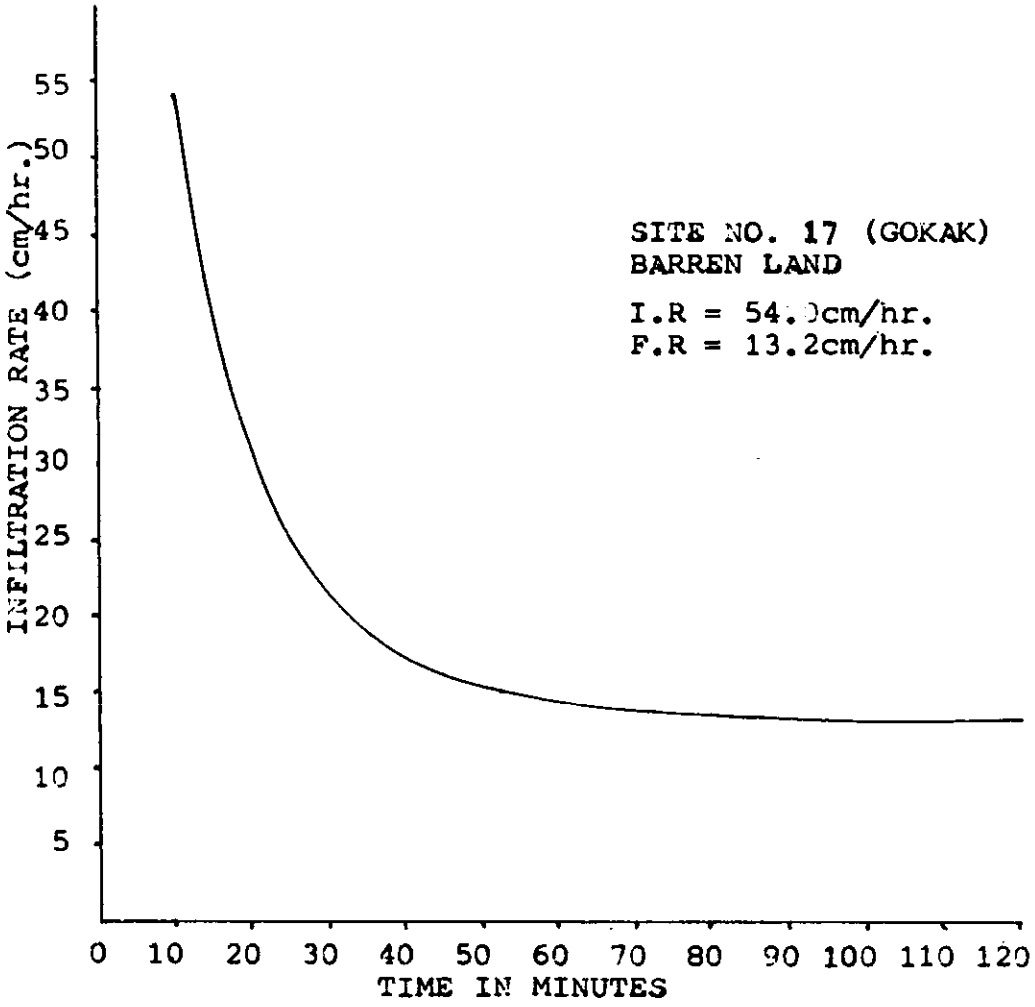

Figure 24 Infiltration curve at Gokak on Barren Land

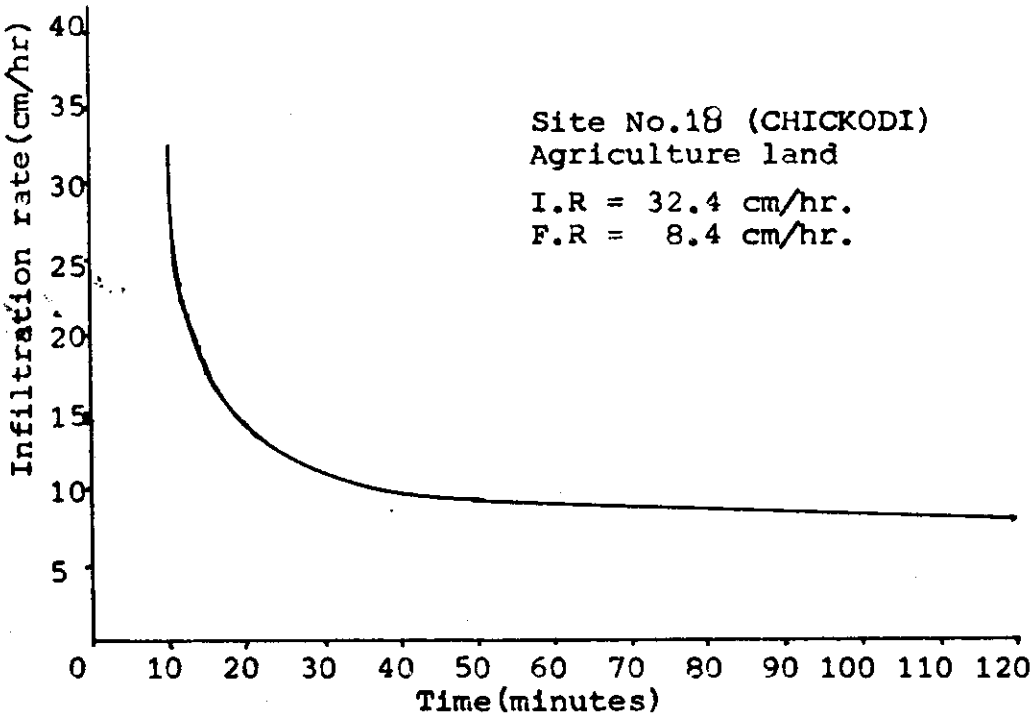

Figure 25 Infiltration curve at Chikkodi on Agriculture Land

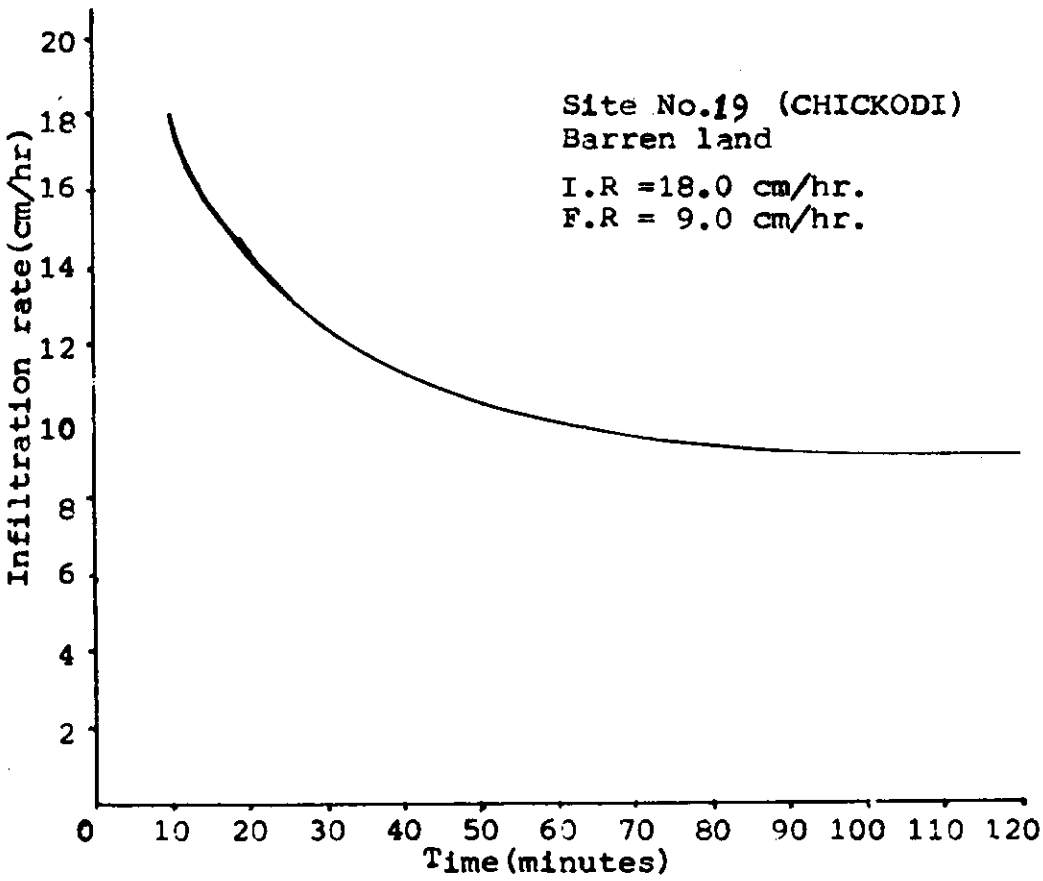

Figure 26 Infiltration curve at Chickodi on Barren Land

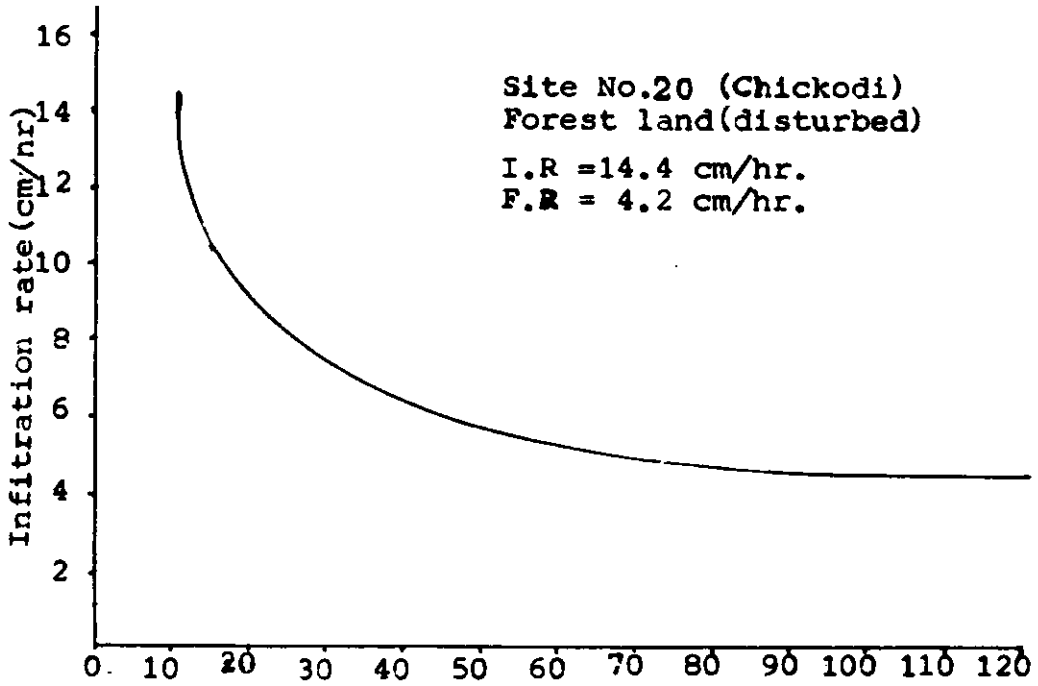

Figure 27 Infiltration curve at Chickodi on forest land(disturbed)

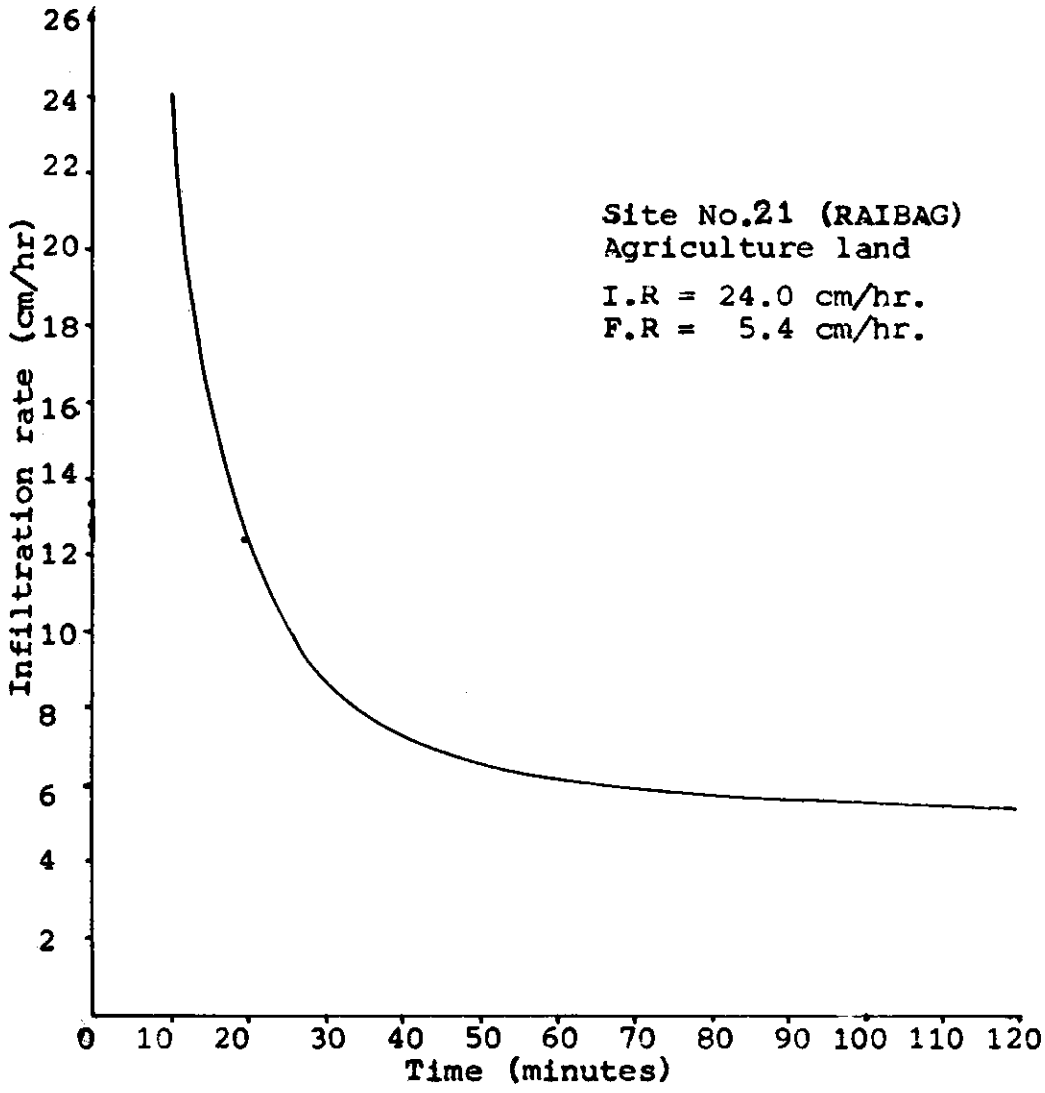

Figure 28 Infiltration curve at Raimbag on Agriculture Land

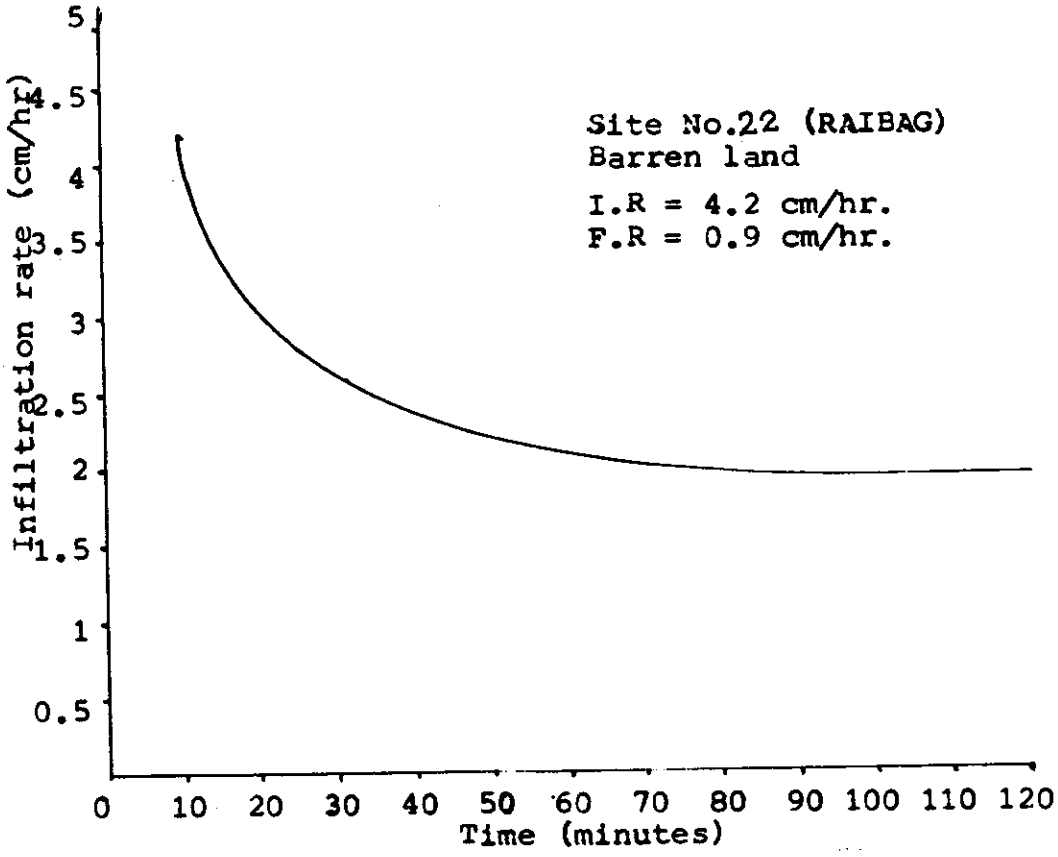

Figure 29 Infiltration curve at Raibag on arren Land

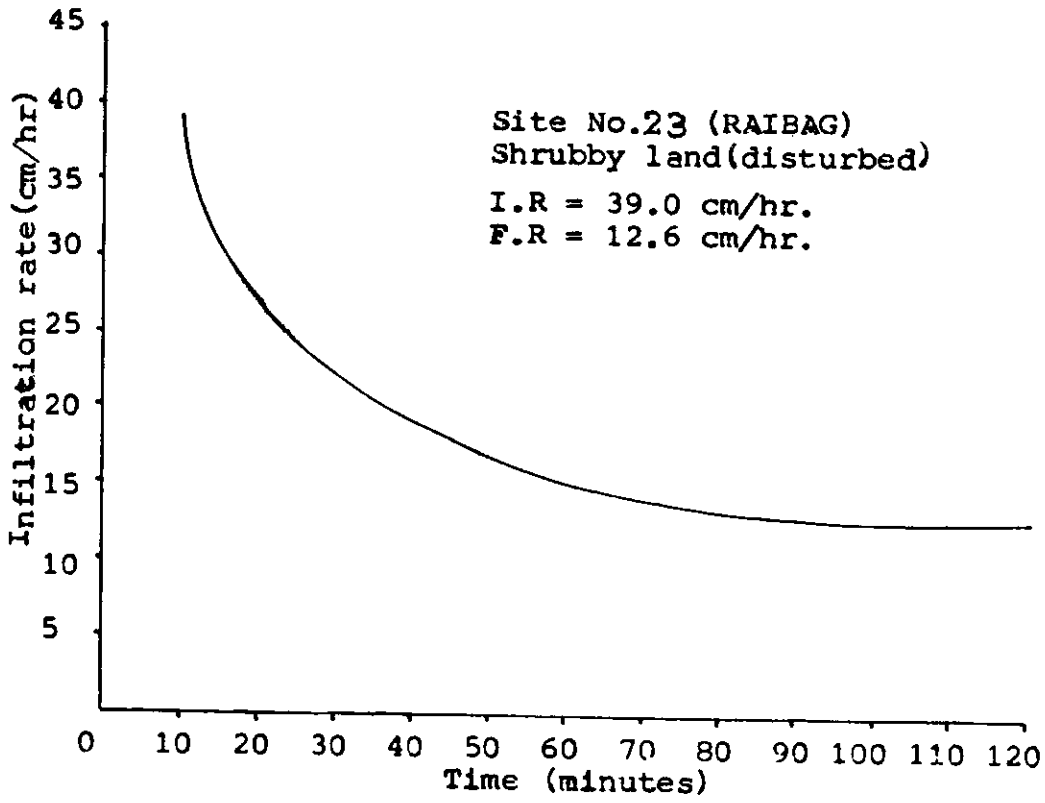

Figure 30 Infiltration curve at Raibag on Shrubby Land (Disturbed)

6.Ø ANALYSIS OF TEST RESULTS

6.1 Soil and Infiltration

Infiltration test in Belgaum district was conducted in two stages. In the first stage the tests were conducted in the upstream region of Malaprabha sub-basin covering Khanapur and Belgaum taluks. In the second stage, infiltration tests were carried out in 7 taluks which falls under the command areas of Malaprabha and Ghataprabha sub-basins in Belgaum district.

In the district, texturally four types of soils are observed, viz. light loam , medium loam, heavy loam and clays. Clays are mainly found in few sites at Belgaum and Khanapur taluks.

(i) Light loam soil: Average rate of infiltration in light loam soil is 6 cm/hr. It varies between 1.8 cm/hr (in Agriculture land at Belgaum) to 12.6 cm/hr at Raibag in a plantation. Infiltration rate observed for Malaprabha representative basin, which lies in Belgaum and Khanapur taluk is 3.8 cm/hr (upstream of Malaprabha sub-basin) and the rate observed in command areas of Malaprabha and Ghataprabha are 7.5 cm/hr and 8.3 cm/hr respectively.

(ii) Medium loam soil: This also exhibits approximately the same rate of infiltration as observed in light loam soil (6 cm/hr). The values observed for the upstream area is 2.3 cm/hr (Belgaum and Khanapur taluks), whereas in the taluks covered under the command area show high rate of infiltration (9.6Ø cm/hr in Malaprabha and 1Ø.3 cm/hr for Ghataprabha). A minimum of 1.2 cm/hr is observed at Asoga in Agriculture land and maximum of 2Ø.4 cm/hr is observed at Bidi in a barren land both are in Khanapur taluks.

(iii) Heavy loam soil : Average rate of infiltration is 2.5 cm/hr which varies between Ø.9 cm/hr in an agriculture land at Bomanvadi in Belgaum taluk and 6.6 cm/hr at Bailahongal in Bailahongal taluk. Infiltration rate in the upstream area is 2.2 cm/hr . In the Ghataprabha command area it is 2.3 cm/hr and in Malaprabha it is 3.5 cm/hr.

(iv) Clays: Clayey soils are found mainly in Belgaum and Khanapur taluks. The average rate of infiltration in the soil stands at 1.8 cm/hr which varies between 1.2 cm/hr under barren condition and 2.4 cm/hr under forest area.

From the present study it is understood that the rate of infiltration depends upon number of physical parameters. Generally it is expected that the rate of infiltration in heavy loam is less when compared to the medium and light loam soil. However, in certain cases, depending upon the land use pattern and other geological and geomorphic condition the infiltration rate shows a varying trend. Typical infiltration curves for Ghataprabha and

Malaprabha sub-basins are shown in figures 31 & 32. It can be noted that heavy loam soil has minimum rate of infiltration than medium and light loam soils.

6.2 Land use pattern and Infiltration rate

(a) Forest/Plantation: Forest areas are fully disturbed in command areas so mainly tests were conducted on plantation land. Infiltration rate in Belgaum and Khanapur taluk (mainly forest area) show an average rate of 3.7 cm/hr which varies from place to place depending on soil texture, structure and topographic condition. Few test were conducted on shrubs which gives the rate of infiltration as 3.6 cm/hr. In the regions covered by plantation the rate of infiltration increased to 6 cm/hr. Maximum rate of 8.4 cm/hr is reported from Ghataprabha command area and 3.75 cm/hr is reported at Malaprabha command area.

(b) Agriculture land: The average rate of infiltration for agriculture land in Belgaum district is 5 cm/hr. Infiltration rate varies between Ø to 2Ø.4 cm/hr, Ø is reported from Ramdurg due to water logging. In general, Malaprabha command area show high rate of infiltration (1Ø.2 cm/hr) than Ghataprabha command area (4.4 cm/hr).

(c) Barren land/ Fallow land: Average rate of infiltration in the barren land is 4.5 cm/hr. Maximum rate of infiltration is reported from light loam soil at Saundatti and minimum of Ø.9 cm/hr is noticed at Raibag in heavy loam soil.

Figure 33 shows typical infiltration curves in different type of soils in Agriculture land. In light loam soil, both initial and final rate of infiltration is more than medium and heavy loam soil. This clearly indicates that, the low clay content and well sorted nature of the soil is responsible for this pattern. Similarly medium and heavy loam soil show a decreasing trend of infiltration rate due to different type of textures.

Typical curves drawn for Barren land (Fig 34) also indicate that light loam soils give rise to high rate of infiltration than the other two types of soil. However, the initial rate is more in the case of medium loam than light loam soil. This could be due to geological variations of the terrain and thickness of the soil cover.

In the Forest or plantation land (Fig 35) the rate of infiltration shows slightly different trend than in other two cases. Here, Heavy loam soil shows higher rate of infiltration than medium loam soil with the same initial rate of infiltration. This is mainly because of the land use pattern where the different type of plants and trees are grown which require water in varying proportion.

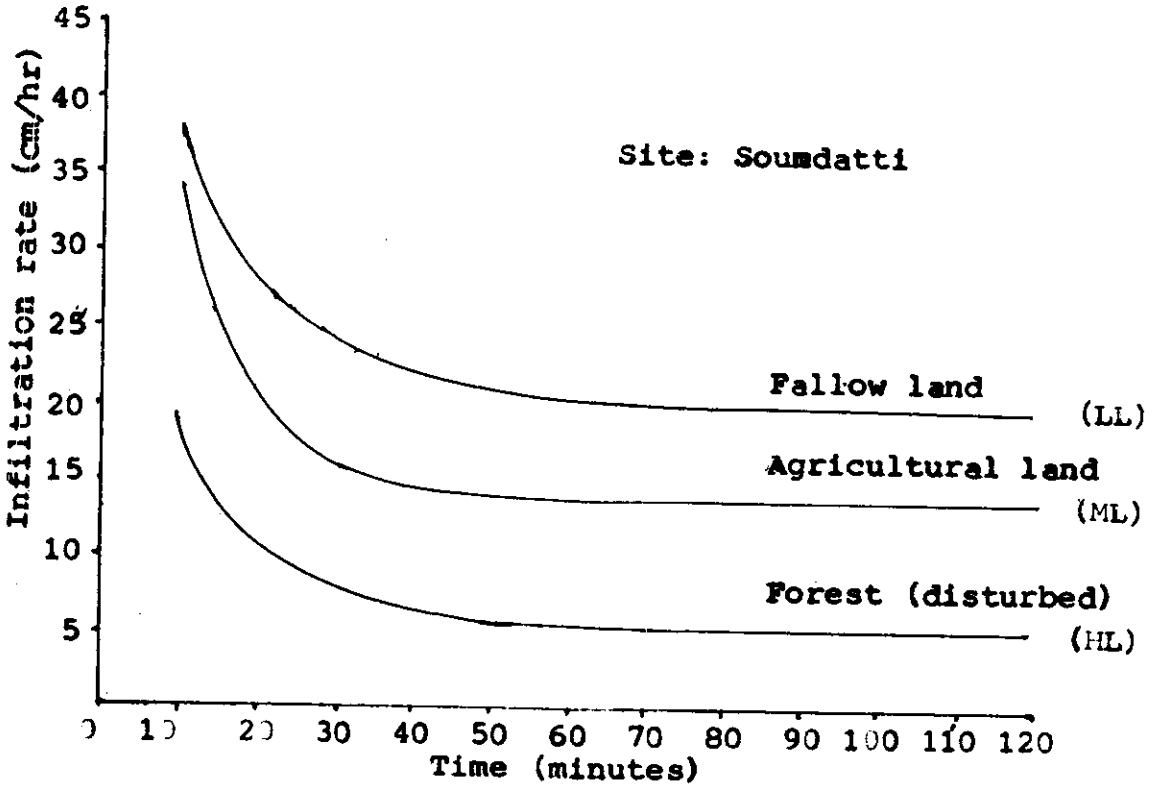

Figure 31 Typical infiltration curve at Saundatti in different land use pattern & soils. (LL=Light loam) ML=Medium Loam, HL=Heavy LoaM)

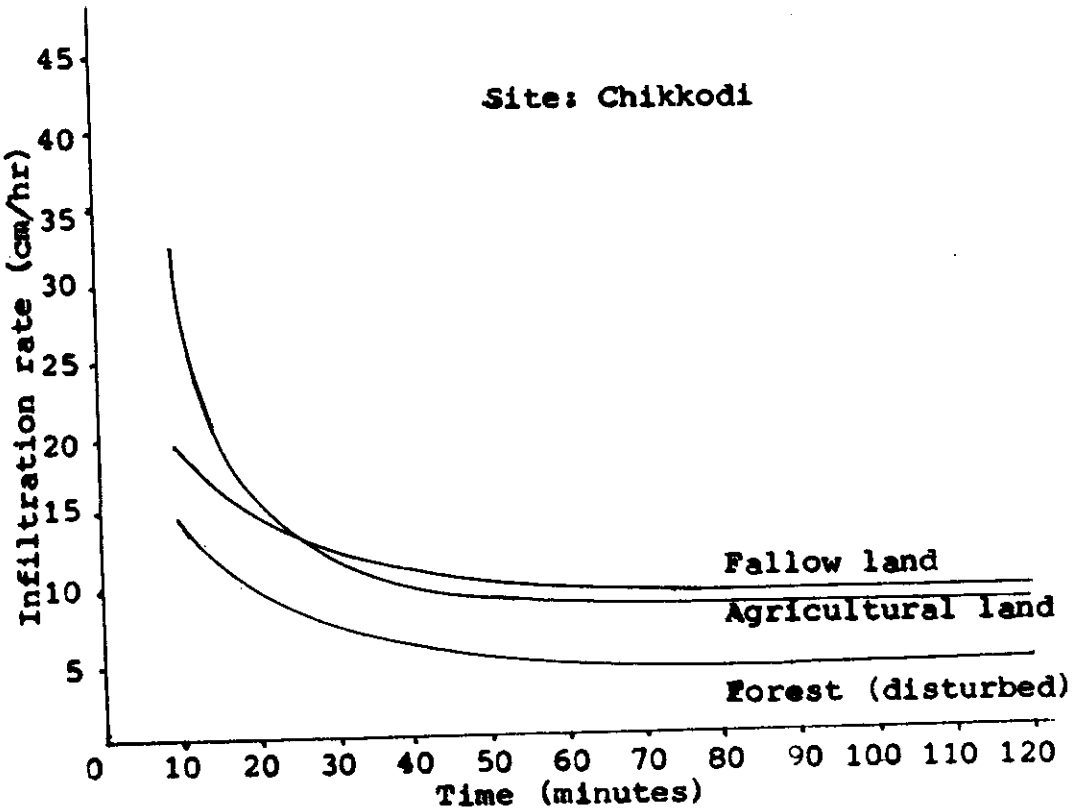

Figure 32 Infiltration curve at Chikkodi on different land use pattern & soils

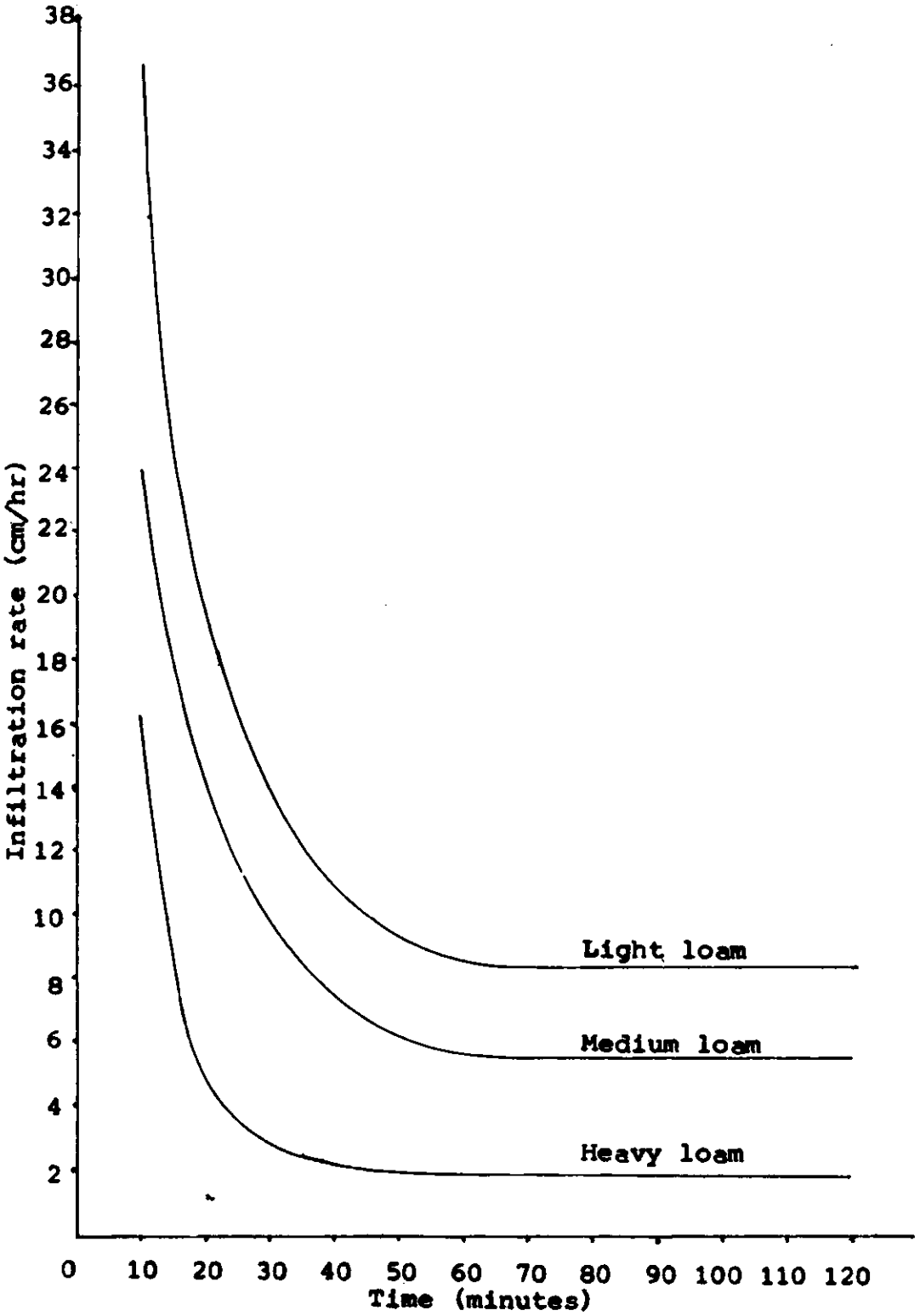

Figure 33 Infiltration curve in different types of soil on Agriculture Land

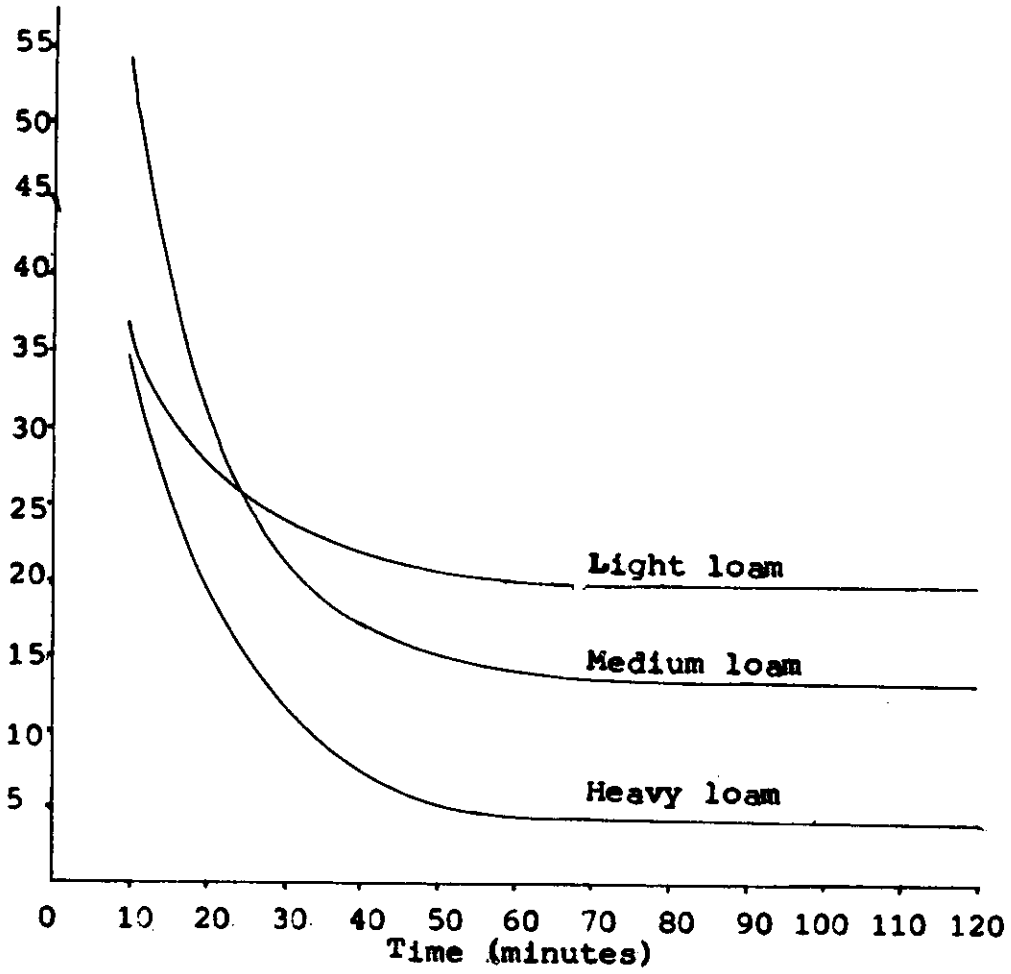

Figure 34 Infiltration curve in different types of soils on Barren Land

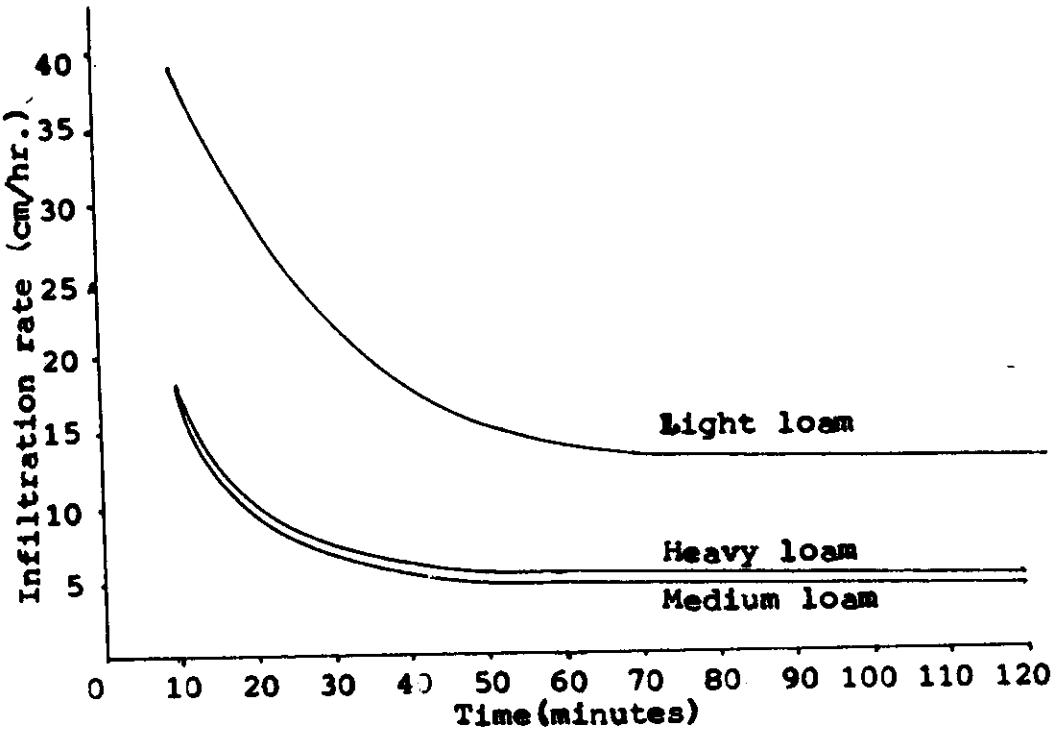

Figure 35 Infiltration curve in different types of soils on Forest Land

Table 1 & 2 show the rate of infiltration in 9 taluks of Belgaum districts with land use pattern and soil type.

6.3 Hydraulic Conductivity and Infiltration

Hydraulic conductivity, like infiltration rate depends on a variety of physical factors including porosity, particle size distribution, shape of particles and other related factors. In general, for consolidated porous media, the hydraulic conductivity varies with particle size. Clayey material exhibits low values of hydraulic conductivity, whereas, sands and gravels display high values.

Table 3 gives the rate of infiltration at few locations for which hydraulic conductivity data are available. Though, there is no definite relationship is observed, it is found that there is an increase of infiltration rate with the decrease of hydraulic conductivity. However, this variation is not uniform.

6.4 Spatial Variability of Infiltration rates

Infiltration characteristics in Belgaum district show wide variations. It varies between less than 3 cm/hr and more than 7 cm/hr. These variations are attributed to multitude of factors which are summarised below.

(a) Surficial characteristics: This include vegetal cover, topography and drainage density. These characteristics may vary widely within the watershed and have vital influence on infiltration capacity. Malaprabha catchment in Khanapur and Belgaum taluks show relatively low infiltration rate than in command area (ref. table 2). This is attributed to the fact that these taluks are mainly covered by forest area (more than 60 %).

(b) Soil Characteristics, land use and geology: The soil type determines the size and number of capillaries through which water must flow. Texture, structure, biologic activity, root penetration and colloidal swelling are the important soil characteristics. These determine the nature and magnitude of the porosity of the soil. Infiltration rate varies with soils containing silts and clays. The varying proportion of silt and clay may change the infiltration rate considerably. Land use and soil temperature are the other factors governing the infiltration rate, which is clearly noticed in the present study.

(c) Precipitation Characteristics: An attempt was made to relate the infiltration rate with the rainfall. However, a definite relationship could not be found out between the two parameters. This may be due to a number of factors such as, rainfall intensity and duration, drop size, angle of incidence and the form of precipitation.

Table 1: Infiltration rate in Belgaum district with land use pattern and soil texture

Sl no	Stn name	Land use	Soil Texture	Infil. rate IR	FR
Malaprabha Sub-basin					
1	Bidi	Agriculture	Med. loam	48.6	2Ø.4
2		Barren land	Light loam	6.Ø	1.8
3		Plantation	Medium loam	9.Ø	3.6
4	Bailahongal	Agriculture	Heavy loam	45.6	6.6
5		Fallow land	Heavy loam	34.8	4.2
6		Shrubs	Heavy loam	21.6	1.2
7	Saundatti	Agriculture	Medium loam	33.6	13.8
8		Barren land	Light loam	36.6	14.8
9		Plantation	Heavy loam	18.Ø	5.4
1Ø	Ramdurg	Agriculture	Heavy loam	7.8	Ø.Ø
11		Fallow land	Medium loam	2Ø.4	5.4
12		Plantation	Medium loam	18.Ø	4.8
Ghataprabha sub-basin					
13	Belgaum	Agriculture	Heavy loam	16.2	1.8
14		Fallow land	Medium loam	42.6	4.8
15	Hidkal	Agriculture	Light loam	12.Ø	3.Ø
16	Gokak	Agriculture	Medium loam	12.Ø	Ø.6
17		Fallow	Medium loam	54.Ø	13.2
18	Chikodi	Agriculture	Medium loam	32.4	8.4
19		Fallow	Light loam	18.Ø	9.Ø
2Ø		Plantation	Heavy loam	14.4	4.2
21	Raibag	Agriculture	Light loam	24.Ø	5.4
22		Fallow	Heavy loam	4.2	Ø.9
23		Plantation	Light loam	39.Ø	12.6

Table 2: Average rate of infiltration in Belgaum and Khanapur taluks (Malaprabha representative basin, After Rawat et al 1993)

Sl no	Land use	Av. rate of infiltration cm/hr	Soil texture	Av. infiltration rate cm/hr
1			Light loam	4.2
2	Forest	3.5	Medium loam	4.Ø
3			Clay	2.4
4	Shrubs	3.6	Heavy loam	3.6
5	Agriculture	1.9	Heavy loam	2.3
6			Medium loam	1.4
7	Barren	2.1	Clay	1.2
8			Light loam	3.Ø

Table 3 : Hydraulic conductivity values for 5 stations in Belgaum district (After Soni et al, 1993)

Sl no	Locations	Hyd. Cond. cm/sec	Infiltration rate cm/hr
1	Bidi	2.37×10^{-4}	8.6
2	Ramdurg	3.62×10^{-4}	3.4
3	Belgaur	2.46×10^{-4}	3.8
4	Hidkal	2.37×10^{-4}	3.0
5	Raibag	0.106×10^{-4}	6.3

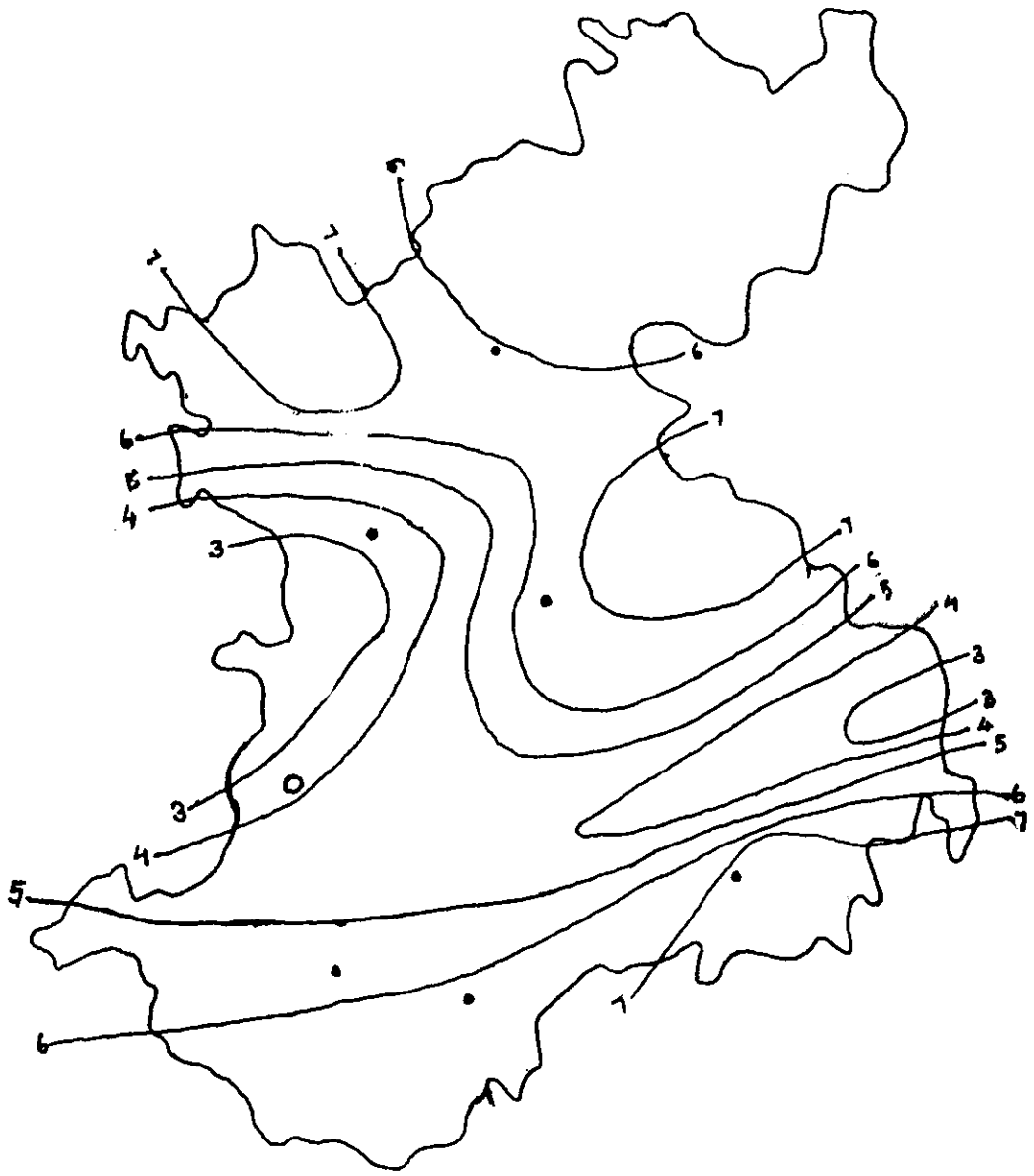

Figure 36 Spatial distribution of infiltration rates in Belgaum district

Spatial variations of infiltration rate in Belgaum district are shown in figure 36.

The relationship between infiltration rate and runoff potential is given in table 4 based on the classification provided by All India Soil and Land Use survey organisation of Ministry of Agriculture.

TABLE 4 Relationship between infiltration rate and runoff potential for Belgaum district.

Sl no	Taluk	Infiltration rate (cm/hr)	Runoff potential
1	Belgaum	3.8	Moderately low to Mod. High
2	Khanapur	5.8	low to moderately low
3	Bailahongal	4.Ø	Mod. low to Mod. high
4	Saundatti	11.Ø	Low
5	Ramdurg	3.4	Mod. low to mod. high
6	Hukkeri (Hidkal)	3.Ø	Mod. high to high
7	Gokak	6.9	Low to Mod. low
8	Chikkodi	7.2	Low to mod. low
9	Raibag	6.3	Low to mod. low

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