CHAPTER FOUR METHODOLOGY

4.1 Introduction

Determination of infiltration rates have been conducted through a wide variety of methods by researchers, depending on the purpose of their study. In this study, the use of a drip-type rainfall simulator infiltrometer (thereafter referred to as a rainfall simulator) has been adopted and shall be briefly discussed. At the same time, this chapter will also focuse on the method used in the determination of the physical properties of soil, namely soil bulk density, total pore space, organic matter content and aggregate stability (shown by its stability index).

4.2 Determination of Infiltration Rates

The determination of infiltration rates are conducted on soils of various landuses using a drip-type rainfall simulator. The construction and operation of the simulator shall be discussed in this chapter, including its advantages as a tool in infiltration determination.

4.2.1 Measurement of Infiltration Rates

Infiltration is usually characterized by theoretical methods for most boundary and initial conditions of interest. These methods provide physically consistent means of quantifying movement of water and air. However, these elaborate procedures are rarely used in practice to describe the infiltration process, because of the large number of computations required to operationalise many of the calculation methods. These are usually time consuming and complicated procedures, with no guarantee of success through their use.

In this study, infiltration rates are determined by converting the volume of runoff produced into the form of cm/hr and substracting it from the intensity of rainfall applied. This method was also adopted by some other researchers such as Mc Nabb, Gameda and Froehlich (1989), Baharuddin (1992), Dunn et.al (1991), and Linsley et.al,(1950). They concluded that since it is impossible to directly measure the quantity of water penetrating the soil surface, infiltration was computed by assuming it to be equal to the difference between water applied and measured surface runoff.

Viessman et.al (1977), stated that for most cases, the difference between the original rainfall and direct runoff can be considered as infiltrated water although exceptions may occur in areas of subsurface drainage or tracts of intensive interception potential. If the rainfall rate at the ground does not exceed the infiltration capacity of the soil, the predictive equation of the infiltration rate is the simplest equation in the hydrologic cycle, namely

$$I = r \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.1)$$ where,

I = rainfall intensity
r = infiltration rate

4.2.2 Construction of the Rainfall Simulator

In general, the rainfall simulator consists of a raindrop producer, water tank, bordered infiltration-square, runoff collector and flow meter. The frame of the raindrop producer is made of eight PVC pipes measuring 60 cm each with diameters of 1.24 cm, lying horizontally 4 cm apart to give a frame size of 60 x 37.8 cm.

For raindrop production, holes of 1 mm diameter are bored along the PVC pipes at 7 cm x 5.24 cm from each other to give a rainfall coverage over an area of 49 cm x 36.7 cm, as shown in Figure 4.1.

Essentially, these are based on the method of drop production used by Imeson (1977), Meyer and Mc Cune, (1958) and Baharuddin (1987), with a slight modification to suit the field conditions and availability of materials.

The bordered infiltration-square consisted of 3 pieces of 2 mm thick metal measuring 30 cm x 15 cm each. They are used to form an actual area for the infiltration plot and

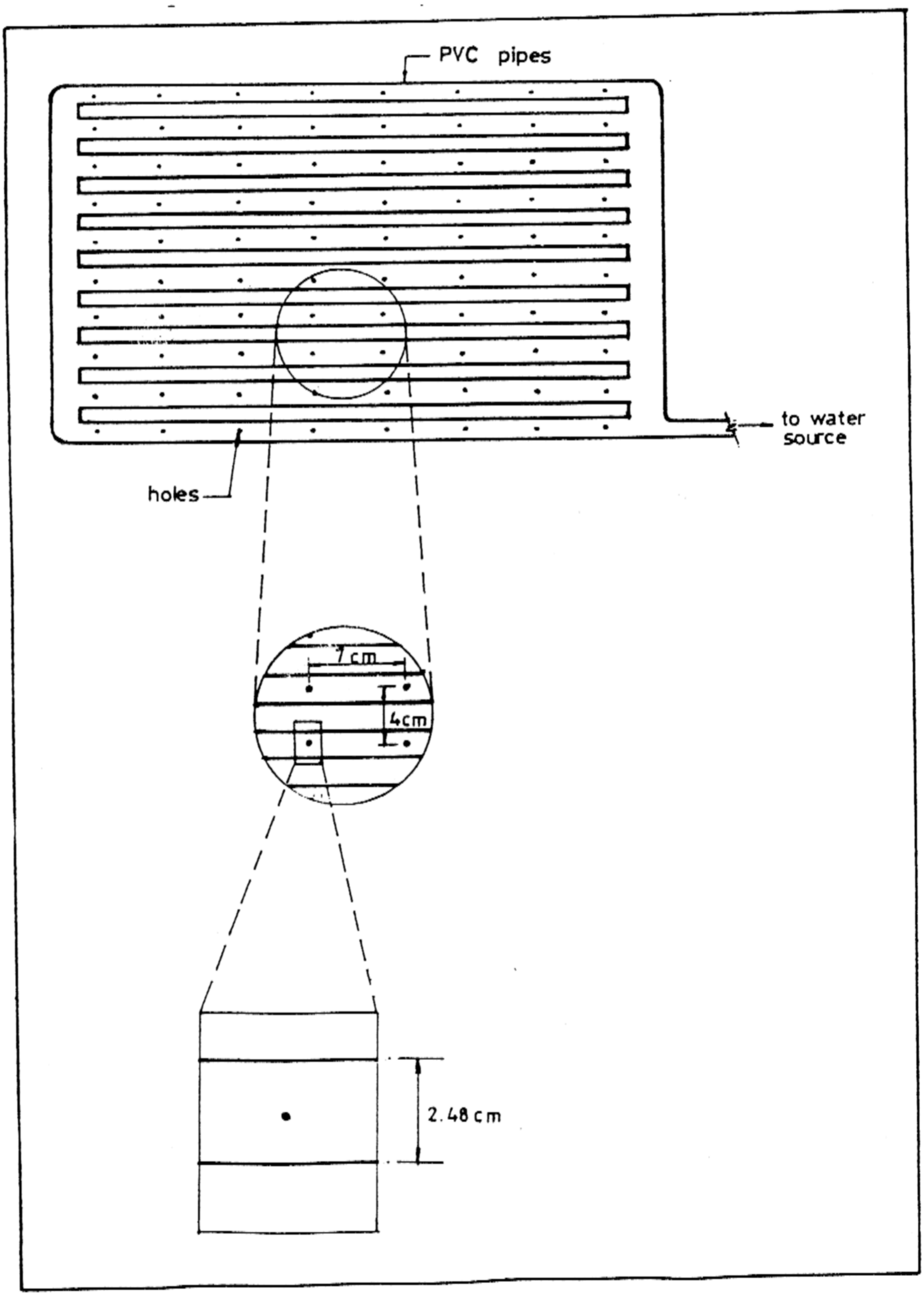


Figure 4.1 The Raindrop Producer

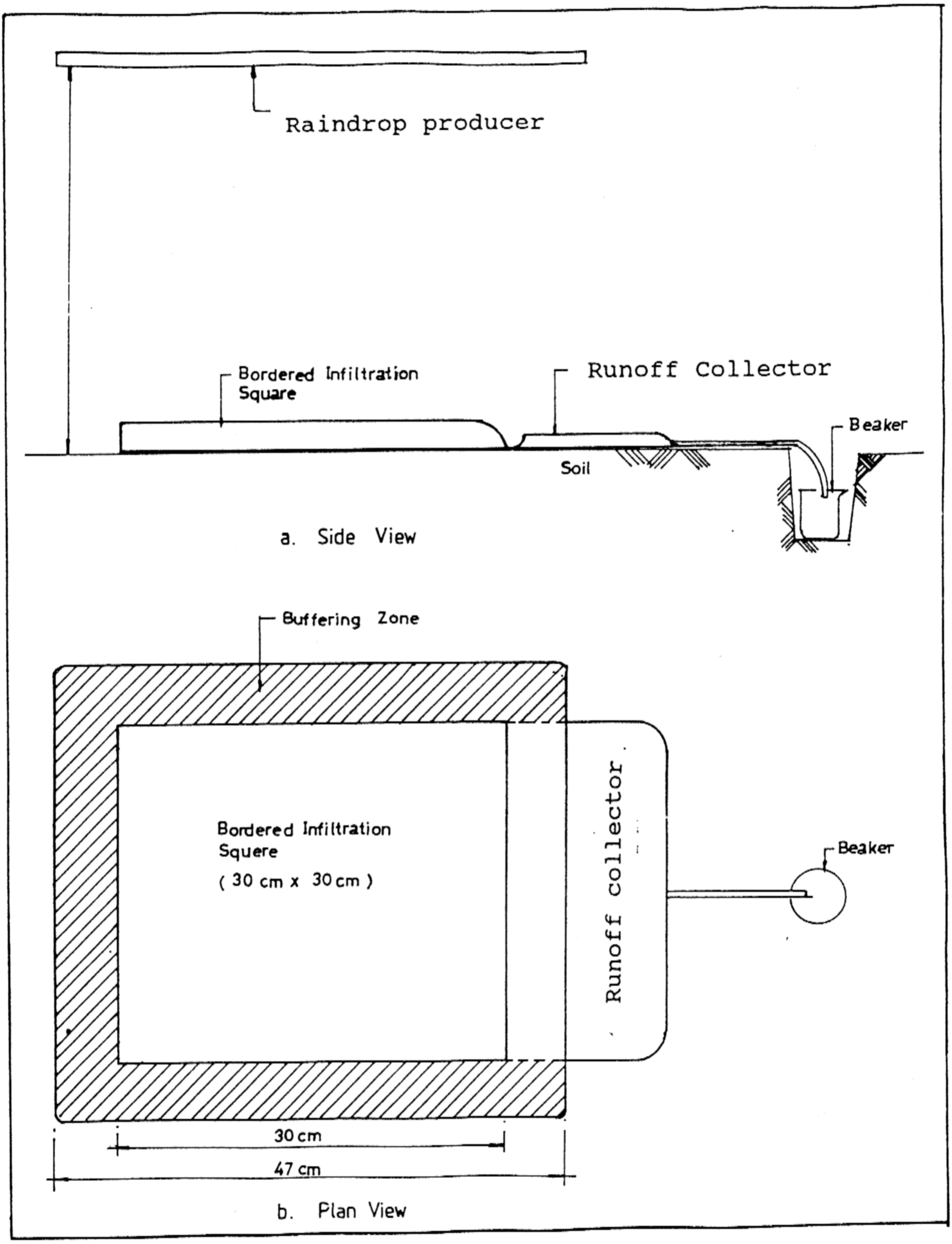
are placed right beneath the raindrop producer at the center of the plot (Figure 4.2 and Figure 4.3).

To complement this, a runoff collector is attached to the lower end of the square. Therefore, any excess runoff during simulation can be collected by a graduated beaker placed at the lowest end of the collector. Placing the bordered infiltration-square at the center of the plot will ensure a buffering effect, ie by reducing seepage of water.

4.2.3 Assemblage and General Procedure

Water is supplied to the raindrop producer by attaching a supply tube (rubber tube, 1.24 cm diameter) to a water tank. Water passing through the tube is recorded using a flow meter which is capable of recording the volume of water passed per hour (litre/hour). A tap attached before the flow meter is used to regulate the amount of water entering the raindrop producer.

A water tank is mounted on a platform specially built for this study. It has four iron legs with an adjustable platform on top. The raindrop producer is mounted on an iron frame supported by four iron legs. Iron legs are chosen because of their lightness and convenience. The fall height from the raindrop producer is generally about 1 to 1.5 meter according to the slope, and the actual area of the infiltration plot is 30 x 30 cm, ie in accordance with the area enclosed by the bordered infiltration-square.



'Figure 4.2 The Rainfall Simulator

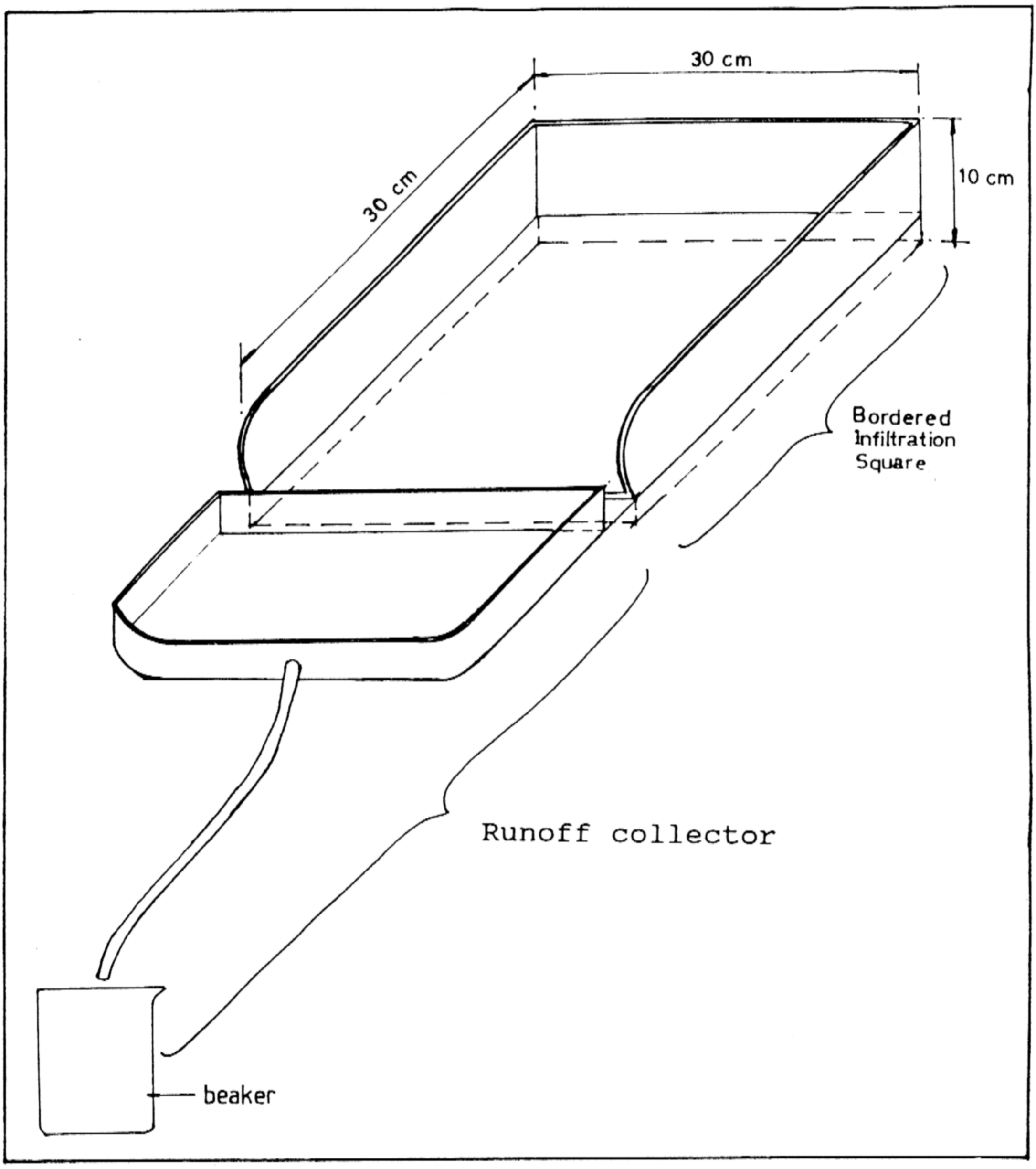


Figure 4.3 The Bordered Infiltration Square and Runoff Collector

At the chosen site, the ground is first covered with a plastic sheet to prevent the surface from being disturbed during assembly. Iron legs with a platform are then placed over the site facing up and down slope. The upper legs are pushed into the soil and the lower legs are supported by blocks, so that the platform is more or less horizontal.

The raindrop producer is then attached to the water tank. Before commencing the simulation, the raindrop producer has to be properly aligned. A spirit level is used to put the raindrop producer in a horizontal position and this would ensure a steady rainfall on the plot under study.

It is necessary too, to establish a relationship between the flow rate of water and the intensity of the rainfall that resulted before the actual simulation commenced. To do so, the tap attached to the water tank is turned on and the flow of water is controlled by another tap attached before the flow meter. This gives the desired rate of flow. The rainfall produced is then simultaneously measured using rain gauges installed randomly beneath the rainfall producer.

Readings are taken at every five-minute interval. The same procedures are repeated to give about 10 to 15 readings of both flow rates and their respective rainfall intensities. All readings are then plotted on a graph paper and is used as a guide for the study. Figure 4.4 shows a typical relationship between flow rates of water and their respective rainfall intensities.

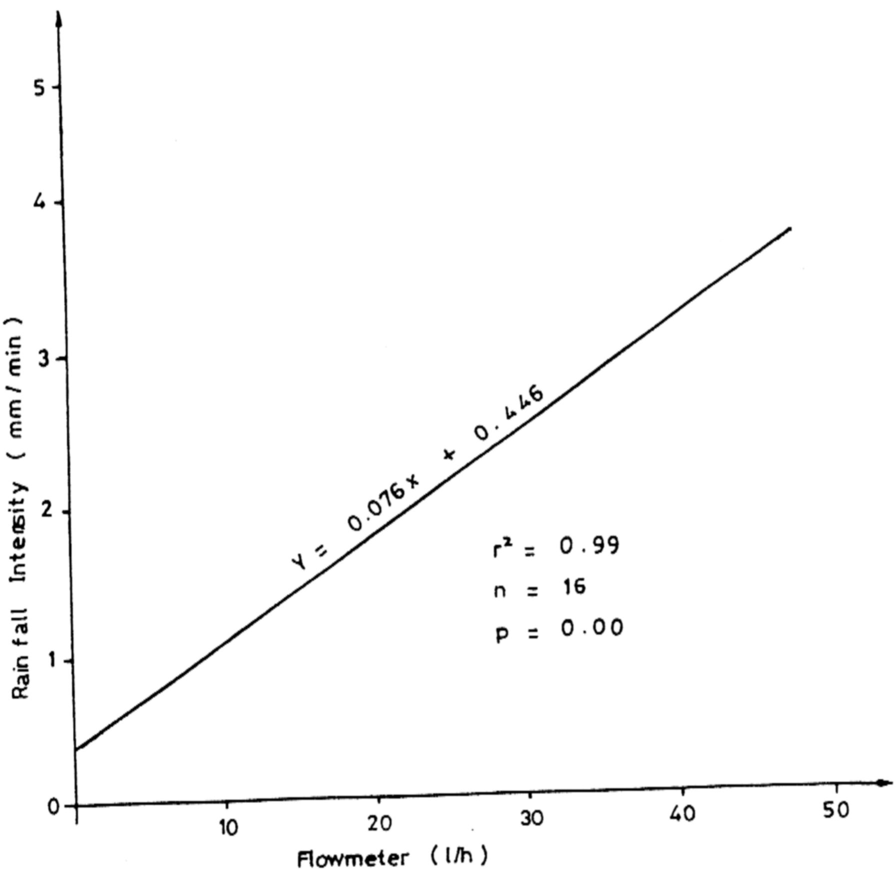


Figure 4.4 Rainfall Intensity vs Flowmeter

4.2.4 Rainfall Simulation Procedure and Determination of Infiltration Rate

1. At a chosen site, the soil surface is swept to ensure minimum disturbance to the soil condition. Vegetation, if any, is cut at its lowest part, leaving no residue or litter on the soil surface.

2. Begin assemblage as shown in Figure 4.5.

3. The plot is covered with a plastic sheet to avoid direct rain drops before actual simulation can begin.

4. Turn on the tap attached to the water tank and flow meter. This would release air trapped in the rubber tube and PVC pipes. Rainfall produced soon after this is regulated by the on-and-off operation of the tap attached before the flow meter. This is to ensure a steady flow of water, thus the rainfall intensity.

5. After a steady desired rate of rainfall is attained, the plastic sheet is removed, and readings are noted. All readings are recorded in a standard data form as shown in Table 4.1.

6. The rainfall simulation is discontinued some time after a steady state of runoff has been

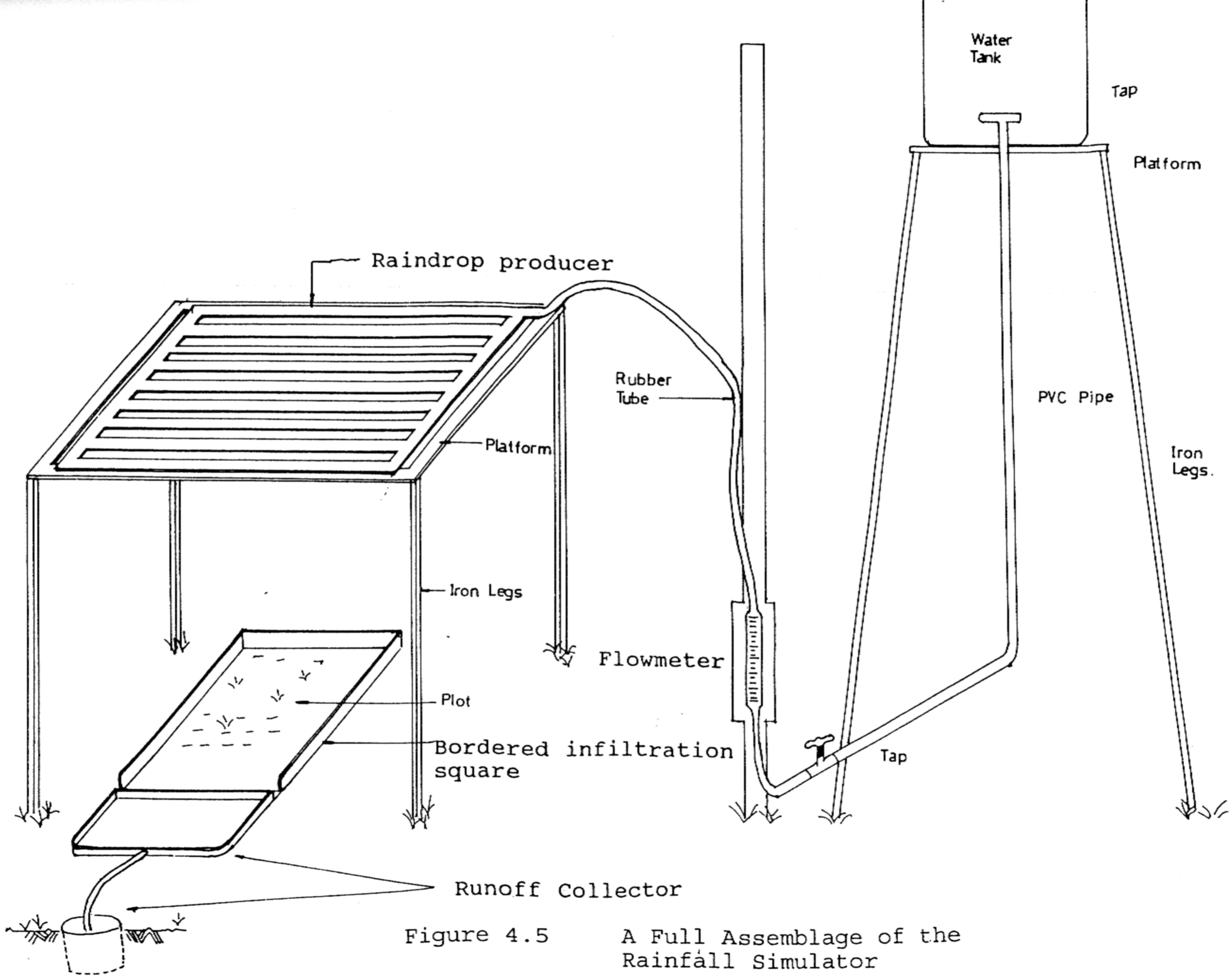


Figure 4.5 A Full Assemblage of the Rainfall Simulator

SITE AREA :

COVERAGE : 144 ind persegi

CALCULATION OF INFILTRATION RATE

SIMULATED R/FALL : 40l/hr
3.5 mm/min
21 cm/hr

DATE :
TIME :
RUN NO :

Time/Min	Time/Min (C)	Run Off (ml)	Run Off (ml/min)	Run Off (mm/min)	Run Off rate (C) (mm/min)	Infiltration Rate (mm/min)
5	5					
5	10					
5	15					
5	20					
5	25					
5	30					
10	40					
10	50					
10	60					
10	70					
10	80					
10	90					
10	100					
10	110					
10	120					
30	150					
30	180					
30	210					
30	240					
30	270					
30	300					

achieved. In a case where no runoff is produced after about 4 to 5 hours of simulation, the rate of infiltration is taken as being equivalent to the rainfall intensity (Morel-Seytoux, Pick and Jonch, 1977).

7. For each landuse, three infiltration plots are chosen, in which for each plot, two or three replications of test-runs are made. An example of the infiltration rate calculation is presented in Table 4.2.

4.2.5 The Advantages of Using a Rainfall Simulator

Before describing the advantages of using a rainfall simulator, the pre-requisites of its design have to be highlighted to ensure that it satisfies the conditions and purpose of the study. Some of the pre-requisites in designing the rainfall simulator were listed by Johnson, et.al (1977) as follows:

1. A reasonable range of rainfall intensities.

2. Areal uniformity of application rate.

3. Drop-size distribution representative of natural rain drops.

Table 4.2 **Calculation of IR**

ALCULATION OF INFILTRATION RATE Rub20yr Site3 Rp.2

ime/min	Time/min C	Runoff ml	Runoff ml/min	Runoff mm/min	Inf.Rate mm/min	Inf.Rate cm/hr	IR Aver.
5	5	0	0	0	3.5	21	2
5	10	0	0	0	3.5	21	2
5	15	0	0	0	3.5	21	2
5	20	0	0	0	3.5	21	2
5	25	0	0	0	3.5	21	2
5	30	0	0	0	3.5	21	2
10	40	0	0	0	3.5	21	2
10	50	0	0	0	3.5	21	2
10	60	0	0	0	3.5	21	2
10	70	0	0	0	3.5	21	2
10	80	0	0	0	3.5	21	2
10	90	0	0	0	3.5	21	2
10	100	0	0	0	3.5	21	2
10	110	0	0	0	3.5	21	2
10	120	0	0	0	3.5	21	2
30	150	0	0	0	3.5	21	2
30	180	4	0.133333	0.001481	3.498518	20.99111	20.9994
30	210	8	0.266666	0.002962	3.497037	20.98222	20.9985
30	240	10	0.333333	0.003703	3.496296	20.97778	20.9974
30	270	4	0.133333	0.001481	3.498518	20.99111	20.9971
30	300	6	0.2	0.002222	3.497778	20.98666	20.9966

Average IR :20.99 cm/hr

4. Reproduction of the terminal velocities of natural raindrops.

5. A low cost, easily assembled unit for use under field conditions.

The rainfall simulator used in this study has fulfilled some of the pre-requisites listed above. A reasonable range of rainfall intensities and its areal uniformity of application rate can be achieved because the rate of water intake is adjustable and maintainable by means of a controlling device, ie by turning the on-and-off operation of the tap attached before the flow meter (Plate 4.1).

The requirements for the drop-size distribution and the terminal velocity reproduction of natural raindrops have been partly fulfilled in this study. Dunn (1976), stated that by using a rainfall simulator of this type (drip-type), the main problem associated are the difficulty in obtaining a reasonable drop-size distribution and the need to mount the raindrop producer high enough to enable the water drops to reach their intended velocities.

Although the problem of obtaining an adequate drop size distribution is to some extent overcomed in the use of this type of rainfall simulator (Imeson, 1991), it is suggested that any attempt to obtain terminal velocities in the field would be impractical and in any case, require a far larger number of computations than desired. An appropriate fall

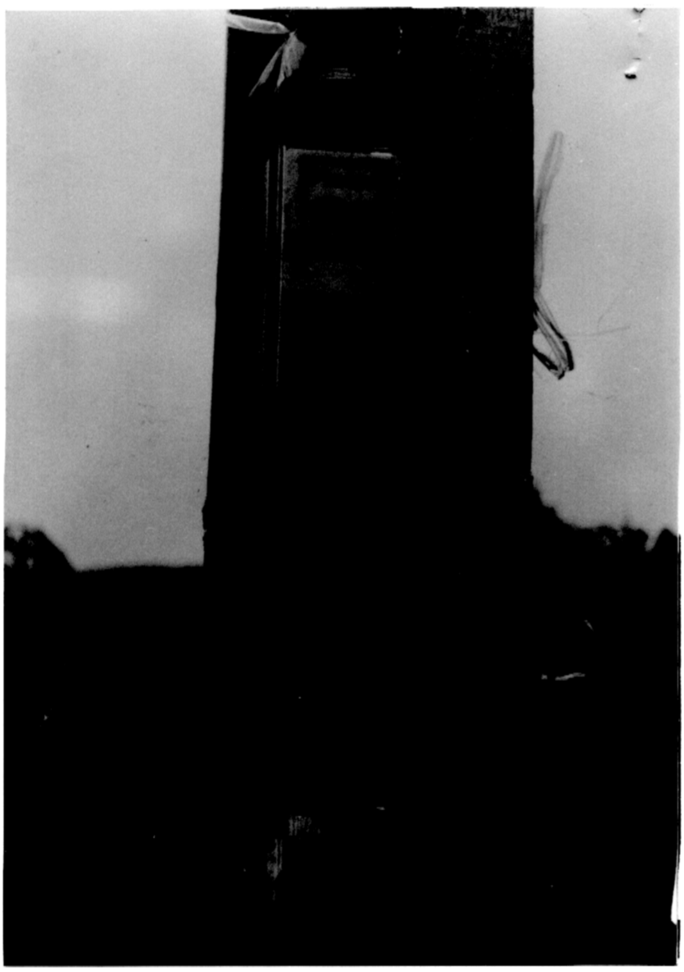


Plate 4.1 Flow Meter

height, upon which to base the simulation, is difficult to ascertain.

Mosley (1982), demonstrated that terminal velocities can only be reached after a fall of 9.0 meter for a 5 mm diameter drop, declining to 4.5 meter for a 1 mm diameter drop. Other benefits of this type of rainfall simulator is that it fulfils the requirements for infiltration study in remote hilly areas with few access roads and limited water supply sources, and its operation is simple and low-cost.

4.2.6 Water Sources for Simulation

For rainfall simulation purposes, the water used must be free of debris, dust, litter or soil particles. This requirement is crucial in order to avoid clogging in the flow meter as the water pass through it. Clogging will retard the flow of water, hence affecting the uniformity of areal distribution of rainfall.

In this study, several means of water supply have been adopted. In the remote and hilly areas, where transportation of fresh water is very difficult, a concrete water tank, drum tank and pools are used to collect fresh water from rain.

For a fairly easily accesible study site, tap water is transported in several 40-litre water containers using a car and motorcycle. For each simulation of about 4 to 5 hours, an amount of approximately 300 litres of water is used. Plates 4.2, 4.3, 4.4 and 4.5 show several means of water supply for the simulation of rainfall.

4.3 Determination of Soil Bulk Density

The core sampling method for bulk density measurement is used in this study. The method consists of taking a core sample of soil using a coring cylinder of known volume (Landon, 1984) which is driven into the soil and then carefully dug out. The cylinder is usually about 5 cm long with a 5 cm diameter, but the larger the better. For transporting purposes, it should be fitted with tightly-fitting caps at the top and the base.

The coring cyclinder consists of thin-wall stainless steel cylinder chamfered on the outer rim of one end to give a cutting edge. The cylinder is carefully driven or pressed vertically into the soil, taking care to prevent lateral movement until the top end of the cylinder is flush with the soil surface inside the core. The cylinder is carefully removed after digging around the core and then the sample is trimmed flush with the end of the cylinder. The bulk density of the removed soil is calculated thus, (Blake, 1965):

Plate 4.2 Means of Water Supply

Plate 4.3 Means of Water Supply

Plate 4.4 Means of Water Supply

Plate 4.5 Means of Water Supply

$$B.D = M/V,\ g/cc \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.1)$$

B.D = bulk density

M = oven-dry weight of soil

V = volume of soil

This method is not suitable for gravelly or stoney soils. Under suitable conditions, however, it has the advantage of producing an undisturbed sample which can be used for non-destructive physical tests. Three replicates of bulk density measurements are made at each site. Plate 4.6 and 4.7 show the core sampling technique used in this study.

4.4 Determination of Soil Total Pore Space (TPS)

The quantity of pores in the soil and their size distribution (as reflected in estimates of total pore space) are useful general indicators of the physical condition of soil. The total porosity or total pore space of the soil is calculated from the dry bulk density and particle density. It is normally expressed as a volume percentage an is equal to the volume of water content at saturation (Vomocil,1965).

$$TPS = 100\ [(P.D - B.D)/P.D] \quad \ldots\ldots\ldots\ldots\ldots \quad 4.2$$

where, P.D = particle density
B.D = bulk density

The particle density of soil is normally assumed to be 2.65 gm/cc. Total porosity is always used as a very general indication of the degree of soil compaction. Therefore, it must be stressed that values of total porosity or total pore

Plate 4.6 Core Sampling Technique

Plate 4.7 Core Sampling Technique

space should not be used as conclusive evidence of over-compaction problems in soil, but rather as an indicator of likely risk. Moreover, the calculation gives only the overall volume % of the pore space and does not characterise the size of the individual pores.

4.5 Determination of Organic Matter Content

Measurements of organic Carbon are very widely quoted and are often made as a measure of the quantity of organic matter in a soil; which in turn is taken as a crude measure of fertility status. Most routine organic Carbon determinations should be made by the Walkey-Blake dichromate method (Hesse,1971). This method requires a reaction temperature of 130^0 C. The results are usually quoted as the percentage by weight of organic Carbon in the soil.

Sometimes, organic Carbon values are multiplied by a further factor to convert them to percentage organic matter. One convention is to assume that the organic Carbon is 58% of the total organic matter or the Carbon percentages is usually multiplied by the conversion factor of 1.72 to give an indication of the total amount of organic matter present (Fitzpatrick, 1971).

Organic matter levels are used in a number of regression equations for prediction of water-holding properties of soils.

4.6 Determination of Soil Aggregate Stability

The aggregate stability of soil, as indicated by the stability index, is a reflection of the structural stability of soil aggregate against detachment by raindrops and water erosion. The technique used to determine the instability index (the stability index of soil is determined by substracting the value of instability index from a value of 1) follows the method of aggregate stability determination described by De Boodt (1959).

The difference between the sum of the mean weight diameter of a dry aggregate and the sum of the mean weight diameter of a wet aggregate gives the instability index.

4.7 Determination of Particle Size Distribution

Particle size analysis, also referred to as mechanical analysis is used to determine the proportion of different-sized particles in the soil and hence its textural classes. The proportion of individual particles range are often needed in correlation studies (eg. to relate available water content to silt and or clay content) and for size-grading studies to indicate for example, potential compactibility.

Samples are wet sieved to separate the sand fraction down to about 0.05 mm diameter and after drying out at 100^0 C, subdivision of the sand can be determined by dry sieving and weighing. The results of particles size analysis are usually quoted as percentage by weight of the whole soil or of the "fine earth" fraction of < 2mm diameter. The proportion of silt, clay and sand are used with the familiar triangular texture diagram (Figure 4.6) to determine the textural classes of the soil (Brady, 1978).

4.8 Conclusion

The method adopted in the determination of the infiltration rate of soil of various landuses is the use of a drip-type rainfall simulator. The infiltration rate is determined by substracting the amount of runoff produced from the applied intensity of rainfall simulated. Using this type of simulator, the determination of infiltation rates were conducted in situ. The reproduction of rainfall through simulation was satisfactorily achieved for the purpose of this study. The determination of several physical properties of soils, which are widely regarded as having some influence on the infiltration rate was also undertaken.

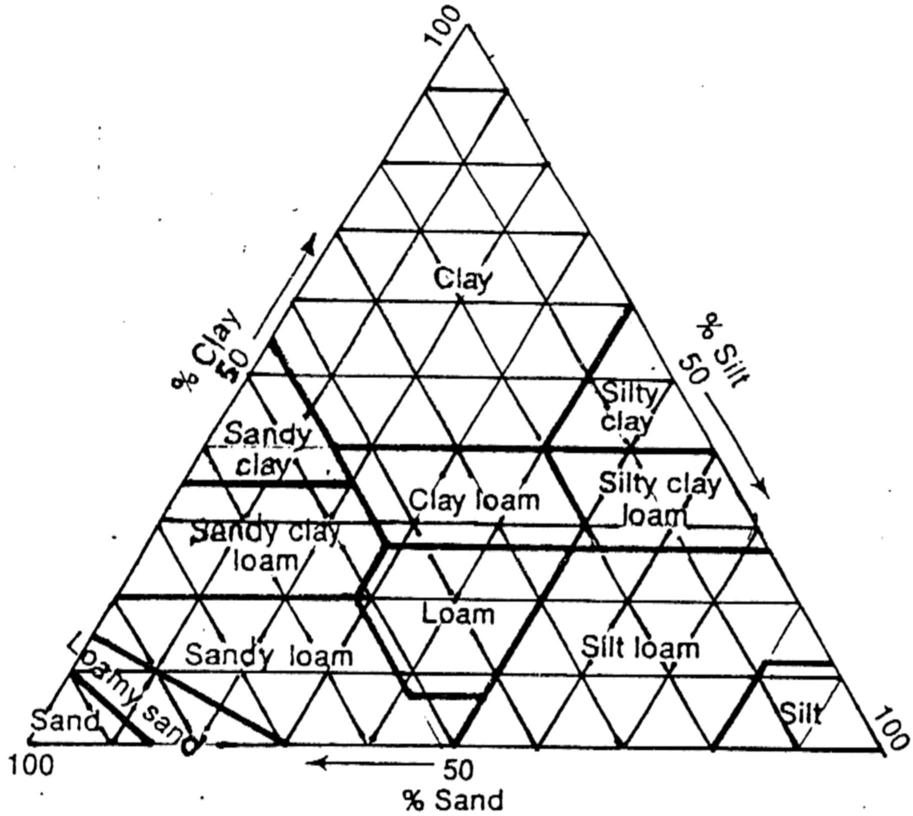


Figure 4.6 The Standard Texture Triangle