SOIL EROSION STUDIES ON MICRO PLOTS

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PROJECT REPORT

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KERALA, INDIA

2012

DECLARATION

We hereby declare that this project report entitled, **“SOIL EROSION STUDIES ON MICRO PLOTS”** is a bonafide record of project work done by us during the course of project and the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Date: 04-05-2012

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CERTIFICATE

Certified that this project report, entitled **"SOIL EROSION STUDIES ON MICRO PLOTS"** is a record of project work done jointly by Ms. Praveena. K. K, Ms. Rehna. M, Ms. Shijila. E under my guidance and supervision and that has not previously formed the basis for the award of any degree, fellowship or associateship to them.

Place: Tavanur
Date: 04-05-2012

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Praveena K K

Rehna M

Shijila Erikottil

Dedicated to
Our Loving Parents
and
Profession

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SYMBOLS AND ABBREVIATIONS

Agric.	– agricultural
Am.	– America
ASAE	– American Society of Agricultural Engineers
Bull.	– Bulletin
ºC	– Degree Centigrade
cm	– centimeter (s)
cm/h	– centimeter per hour
chap.	– chapter
Cir	– Circular
Cons.	– conservation
Contd.	– continued
Dept.	– Department
Eng.	– Engineering
et al.	– and other people
etc.	– etcetra
Fig.	– Figure
ft	– feet
g	– gram(s)
G	– Gauge

G.I	– Galvanized Iron
G.V.	– Gate valve
h	– hour
ha	– hectare(s)
i.e	– that is
J.	– Journal
kg	– kilogram
kg/cm^2	– kilogram per square centimeter
kg/ha/h	– kilogram per hectare per hour
m	– metre(s)
m^2	– square metre(s)
m^3	– cubic metre(s)
min.	– minute
ml	– millilitre(s)
mm	– millimetre(s)
mm/h	– millimetre per hour
m^3/ha/h	– cubic metre per hectare per hour
manag.	– management
No.	– number
pp.	– pages
proc.	– proceedings
Res.	– Research
Resour	– Resources
rpm	– revolutions per minutes
s	– second(s)

Sci	– Science
Soc.	– Society
t	– tonne(s)
t/ha	– tonne per hectare
Tech.	– Technical
Tr.	– Transactions
Univ.	– University
USDA	– United States Department of Agriculture
Vol.	– volume
&	– and
º	– degree(s)
>	– greater than
<	– less than
/	– per
%	– per cent

INTRODUCTION

INTRODUCTION

Soil constitutes the physical basis for our agriculture. One of the principal reasons for low productivity in agriculture is the progressive deterioration of soil due to erosion. Soil erosion is one form of soil degradation along with soil compaction, low organic matter, and loss of soil structure, poor internal drainage, salinisation, and soil acidity problems. These other forms of soil degradation, serious in themselves, usually contribute to accelerated soil erosion. Soil erosion is a naturally occurring process on all land. The agents of soil erosion are water and wind, each contributing a significant amount of soil loss each year.

Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing serious loss of topsoil. The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks. Soil erosion is the outcome of two interactive processes viz., the erosivity of the agent causing erosion and the erodibility of the soil. Rill incision has been linked with critical threshold values of variables such as slope angle and Froude number and selective sediment transport (Savat, 1982), shear velocity (Rauws and Govers, 1988) and soil shear strength/runoff shear stress ratio (Torri et al., 1987). The detachment capacity of water flowing in a rill could be best predicted by a stream power function. The hydraulic conditions in the rills during the erosion process are under constant variation.

In India there is very little area free from the hazards of soil erosion. It is estimated that out of the 305.9 million hectares of reported area of land utilized, 145 million hectares are in need of conservation measures. In Kerala, it is estimated that out of 2.248 lakh hectares of cropped land 1.757 lakh hectares are in need of conservation measures (Gurmel Singh et al., 1990). Severe erosion occurs in the sub – humid and humid areas due to high rainfall and improper management of land and water. The problem of soil erosion and consequent depletion of soil fertility in the State is due to high intensity rainfall and undulating topography of cultivated land.

Rainfall is the chief detaching agent in water erosion. The capacity of rainfall to transport soil by splash is a function of degree of slope, rainfall characteristics, soil properties, micro – topography and wind velocity. Raindrop erosion or splash erosion results from soil splash caused by the impact of falling raindrop. The falling raindrops break down soil aggregates and detach soil particles from soil mass and cause them available for transport. Raindrop splash is of major importance as a contributor to erosion. Runoff and soil loss can be measured from runoff plots as well as from watersheds. Knowledge of runoff and soil loss values under varying field conditions are a prerequisite in the design of soil conservation structures.

In India, laterite soil occupy an area of 1,30,066 sq km and is well developed in summits of Deccan hill, Karnataka, Kerala and Eastern Ghats, West Maharashtra and central parts of Orissa and Assam. In Kerala, laterite soils are the most important soil group covering the largest area. The broad belt of land lying between the sea and the Eastern hilly regions of the State, varying in width from 50 – 100 km, is a lateritic belt. The soil is porous, well drained and have poor capacity for retaining moisture. Kerala state is the ‘‘type locality’’ of laterites. Almost every crop grown in the State is cultivated on laterite soils. The lateritic terrain of Kerala occupies the midland region of the State and this tract can be considered as the backbone of the State, as its economy depends upon this terrain which produces most of its cash crops.

Most of the soil erosion by water occurs during and immediately following a relatively few rainstorms, which may occur almost at any time. Erosion research under such conditions has numerous limitations. Simulated rainfall may be applied at selected intensities, for known duration and land treatment conditions. Simulated rainfall is the application of water in a form similar to natural rainfall. This is an effective aid in soil erosion research. They make the replication of research easier and facilitate the study of storm sequences. However, the characteristics of natural rainfall must be accurately simulated and limitations must be clearly recognized for proper interpretation of results.

Researchers studying runoff and soil loss from rainfall have recognized the desirability of using rainfall simulators to supplement and expedite their investigations. The use of a rainfall simulator enables nearly immediate evaluation of carefully controlled plot conditions as well as observations of the erosion process involved. Basic characters of a natural rain storm which are required to be simulated in a laboratory are rainfall intensity, uniformity of distribution of raindrops, drop size and rainfall velocity approaching the terminal velocity of the natural rainfall.

Several parameters have been suggested for the design of rainfall simulators; the modeling criteria have not been accurately delineated. Most of the criteria suggested are based on rainfall energy and momentum. Both energy and momentum contain the two basic parameters-rainfall mass and impact velocity. The accurate simulation of drop size distribution and impact velocity of natural rainfall is difficult.

Artificial simulation of rainfall has been achieved by employing drop formers of hanging yarn (Elison and Pomerene, 1944), tubing tip (Lane, 1947) and nozzle type (Meyer and McCunne, 1958). In the case of hanging yarn and tubing tip type drop formers, raindrops of the same size fall repeatedly on the same spot and a greater fall height is required to attain terminal velocity. Nozzle type drop formers are efficient but are costly. Therefore simple and cheap rainfall simulator has to be developed.

The project work is undertaken with the following objectives:

1. To fabricate a rainfall simulator.
2. To study the performance of the fabricated rainfall simulator.
3. To study the effect of rainfall on soil loss at different land slopes.
4. To study the effect of rainfall on runoff at different land slopes.
5. To study the development of rills on different land slopes.

REVIEW
OF
LITERATURE

REVIEW OF LITERATURE

Rainfall simulators have been used for many years by researchers to accelerate and extend their study of soil erosion. Conservationists and planners of erosion control and water management systems need simple methods for determining the basic erodibility and runoff potential of specific soil site complexes during the development of land use plans. The previous studies relevant to the topics of soil erosion, runoff and rainfall simulators are briefly reviewed in forgoing sections.

2.1 Laterite soil

Laterite is a near-surface or surficial material formed on any parent rock weathering, precipitation and residual accumulation. This weathering, which comprises the products of the 'laterite profile', cause depletion in alkali and alkaline earth elements leaving a residue of secondary forms of iron and aluminium with or without silicon, quartz and other highly resistant materials.

In Kerala at Angadippuram a ferruginous, vesicular, soft material occurring within the soil which hardens irreversibility on exposure and used as a building material was first recognized as ''laterite'' by Francis Buchanan(1807). He coined the term laterite from ''later'', the Latin word for brick. A number of theories were propounded to explain the genesis of laterite soil. D'Hoor (1954) grouped these theories into

1. Concentration of sesquioxides by removal of silica and bases i.e. relative accumulation.
2. Concentration of sesquioixides by accumulation either across the profile or between profile i.e. absolute accumulation

Typical laterite soil are characterised by a vesicular structure and the accumulation of hydrated oxides of iron and aluminium. Laterite soils may vary in depth from 1.8 to 3m and may have a thick layer of Kaolin clay below. These soils do not manifest typical clay properties such as plasticity, cohesion, expansion and shrinkage to any great extent. They are porous and well drained and have poor capacity for retaining moisture. The base exchange capacity is also low.

From the distribution of the laterite soil it can be seen that this vast region have a large portion of favourable topography for agriculture and adequate temperature for the plant growth. There physical constraints for crop production. These physical constraints include susceptibility to erosion, low water holding capacity and drought stress.

In Kerala, laterite soils are classified into different series according to their locality and profile features (Soil Survey Department, Kerala).

2.2 Soil erosion

Morgan (1986) defined soil erosion as a two phase process consisting of the detachment of individual particles from soil mass and their transport by erosive agents such as running water and wind. When sufficient energy is no longer available to transport the particles, a third phase (deposition) occurs. Key factors influencing soil erosion are erosivity of the causing agents and erodibility of the soil.

Owoputi and Stolte (1994) reported that one of the problems associated with soil erosion is the reduction of soil nutrient and thus decreased agricultural productivity. Another concern with erosion is an increasing turbidity of runoff which has an adverse effect on the quality of our surface water. In addition, the sedimentation lowers available reservoir storage.

2.2.1 Processes of soil erosion

Erosion is a natural process, often referred to as geological erosion. Human intervention and manipulation of soil has lead to an increased amount of erosion, known as accelerated erosion. Soil is made up of structural units containing planes of weakness. When stress is applied, breakdown occurs along these planes, producing soil fragments more stable than the applied stress. As more energy is applied, fragmentation increases. The rate of this degradation is linked to the structural stability between aggregates (Diaz-Zorita et al. 2002). In its simplest form erosion by water is the transformation of soil into sediment (Brady & Weil 2002) and occurs by a three step process; detachment, transport and finally deposition.

There are multiple ways in which detachment takes place, usually following the breakdown of soil aggregates. Raindrops dominate the process of surface aggregate breakdown and are thus the primary detaching agent. As a raindrop hits the surface of an exposed soil aggregate, the mechanical energy from the water droplet dissipates, causing the aggregate to form or shear. Small particles are detached from the main aggregate body and are projected vertically and horizontally from the point of impact. The severity of this action is dependent upon multiple factors including the energy or erosivity of the rainfall and the susceptibility or erodibility of the soil. Detached soil particles are transported in the trajectory jets or ‘splash’ effect of the impacting raindrops , to distances as much as 0.7 m vertically and 2 m horizontally (Brady and Weil 2002) , exacerbated by windy conditions.

Once aggregates are broken down, detached soil particles are then moved via transporting agents; water based processes only are discussed here. There are two main transporting agents (Morgan 2005) - rain-splash (as described previously), which transports detached soil over a uniform area of infinite width, and overland flow. The latter initiates either (a) when soils are saturated or near-saturated, and infiltration capacity is close to zero, or (b) when soil infiltration rates are exceeded by rainfall intensity, as may occur when surface seals or caps are present.

2.2.2 Rill erosion

If rainfall input is greater than the infiltration rate ponds will form in the soil surface depressions. The depth and size of surface ponds is dependent on the soil properties and surface conditions present at the time. If the sides of a pond break or if multiple ponds connect, then surface water flows down slope as surface runoff (also termed overland flow). This movement of water can be as sheet or inter-rill flow; a smooth thin single layer of water that carries rain splash-detached particles down slope. Inter-rill flow is unlikely to detach soil particles, due to low hydraulic energy available for detachment by flow (Morgan, 2005). Also, it is rare that inter-rill flow remains as a continuous water layer, due to the presence of surface irregularities such as soil micro topography, stones, crop residues and vegetation. Such surface irregularities concentrate the flow into channels of various sizes, forming other transporting agents, including micro-rills, rills and gullies. The velocity of such concentrated flow is relatively higher than for interrill flow, so not only are eroded particles transported effectively, but detachment of soil also occurs (Brady & Weil, 2002).

Rills, which by definition can be removed during ploughing or by subsequent rainfall events cut into the soil mass and may start to retreat up slope via the process of undercutting (Morgan, 2005). As this process becomes accelerated, larger erosion feature such as gullies are created. Large quantities of sediment are moved within gullies and once formed, they are extremely difficult to eradicate, as, by definition, they are usually deeper than the depth of ploughing operations.

The transportation of aggregates or soil particles requires energy. If energy levels fall below this threshold point soil particles are deposited. The deposition rates of soil are related to the size and mass of soil particles. The breakdown, detachment, transport and deposition of soil are influenced by soil properties and soil surface characteristics present at the time. These are in turn affected by soil management. Soil management practices have been shown to be an important influence in the development of gullies and other erosion features (Oygarden, 2003)

2.2.3 Factors affecting soil erosion

Major variables affecting soil erosion are climate, soil properties, agitation and topography (Schwab et al., 1981). Of these the vegetation and to some extend the soil properties may be controlled. The climatic factors or the topographic factors, except slope length are beyond power of man to control.

Climatic factors affecting erosion are precipitation, temperature, wind, humidity and solar radiation. Temperature and wind are most evident through their effects on evaporation and transpiration. Wind also changes raindrop velocities and angle of impact.

2.2.3.1 Rainfall characteristics

The amount of erosion from raindrops has been linked to the rainfall characteristics such as the rainfall intensity, drop diameter, impact velocity and rainfall kinetic energy. The size, distribution and shape of rain drops influence the energy, amount and erosivity of rainstorm. Laws and Parsons (1944) reported that median drop size increases with the increase in the rainfall intensity. The relation between median drop size (D_{50} in mm) and rainfall intensity (I) in inches per hour is found as;

$$D_{50} = 2.23 \; I^{0.182}$$

Wischmeier and Smith (1958) reported that intensity is particularly important as a potential parameter of erosivity. The force causing detachment of soil particle is associated with the impact of the individual water drop. The kinetic energy of rain is the causative factor in initiating the detachment of the soil.

The intensity is related to total kinetic energy as;

$$E = 12.1 + 8.9 \log I$$

Where,

E - Kinetic energy in m-Mg/ha-mm,

I - Intensity in mm/h.

Hudson (1963) reported that the medium drop diameter increases up to an intensity of 80 mm/h and then decreases.

Bubenzer and Jones (1971) reported that the mean splash rate of soils exposed to rainfall of a nearly constant kinetic energy level and impact velocity was influenced by drop size at the lower energy levels. The smaller drops produced significantly less splash than the longer ones; eventhough the kinetic energy, total rainfall mass and impact velocity were almost constant. As the energy level increased, the influence of drop size decreased.

Foster (1982) and Rose et al., (1983) developed an equation;

$$\mathbf{D_1=K_1CI^a}$$

Where,

D_1 - raindrop detachment,

K_1 - measure of soil detachability by rainfall,

C - constant that represents the fraction of the surface that is not protected by cover,

I - rainfall intensity,

a - constant that ranges from 1.3 to 2.0.

This equation is used to estimate the detachment caused by raindrop action.

Meyer and Harmon (1984) simulated rainfall to evaluate the effect of rainfall intensity on interrill erosion from 18 cropland soils encompassing a wide range of textures. They found that the interrill erosion rate (E) in $kg/m^2/s$ could be related to rainfall intensity I (m/s) by the power equation;

$$\mathbf{E=aI^b}$$

Where a and b are the coefficients and exponent of best fit respectively. Average value for the exponent b is 1.98 for low clay content soils, suggesting the equation;

$$\mathbf{E=CI^2}$$

Where,

I^2 is the erosivity term and C is the inter rill erodibility co-efficient (kgs/m^4).

The equation for predicting soil detachment by raindrops was developed by Sharma and Gupta (1989). In the equation, soil detachment is related to the raindrop kinetic energy and a critical condition defined as the threshold kinetic energy.

This equation is generally written as;

$$\mathbf{D_1=K_1\ (e-e_0)^{b}}$$

Where,

D_1 - soil detachment by raindrop,

K_1 - soil detachability co-efficient,

e - kinetic energy of drop,

e_0 - threshold kinetic energy,

b - constant that is assumed equal to unity.

The main concept of this equation is that detachment by raindrop is a function of the raindrop energy and of the soil resistance.

2.2.3.2 Soil characteristics

Physical properties of the soil affect the infiltration capacity and the extent to which it can be dispersed and transported. The properties of the soil that influence erosion are soil structure, texture, organic matter content, moisture content and compactness of soil (Schwab et al.,1981). Surface roughness and residue cover have been shown to be effective in reducing erosion (Griffith et al., 1986).Surface roughness increases the water storage capacity in the tilled layer of the soil which reduces the velocity of runoff and the rate of erosion. Small impoundments may form behind residue and provide the same effect as surface roughness.

2.2.3.3 Topography

Topographic features that influence erosion are degree of slope, length of slope, size and shape of the watershed (Schwab et al., 1981). Kinnell and Cummings (1993) studied about the soil gradient interactions in erosion by rain impacted flow, with 0.9 m long inclined soil surfaces eroding under rain impacted flow. Three major forms of sediment discharge to slope gradient relationships were observed when the effect of flow discharge (q_w) on sediment discharge (q_{si}) was considered in terms of equation;

$$\mathbf{q_{si} = q_w\, k_1\, I\, f(s)}$$

Where,

k_1 - a factor which varies with the susceptibility of the soil to erosion by rain impacted flow,

I - rainfall intensity,

f(s) - effect of slope gradient.

2.3 Rainfall simulators

Rainfall simulators have been used to accelerate research in soil erosion and runoff from agricultural lands, high ways etc. Meyer (1965) defined simulated rainfall as water applied in a form similar to natural rainfall. Simulated rainfall provides means for creating a given rainstorm at a desired time and location. It enables investigators to obtain runoff and erosion data in a relatively short period of time (Bubenzer and Meyer, 1965).

2.3.1 Advantages of simulated rainfall

Meyer (1965) stated the advantages of simulated rainfall;

1. More rapid results can be obtained by applying selected simulated storms at selected treatment conditions. In contrast, erosion studies which rely on natural rainfall may require many years to obtain conclusive results.
2. Results from a few simulated storms at selected conditions often provide desirable informations.
3. Various measurements and observations which are difficult during natural rainstorms may be readily obtained during simulated storms.
4. Simulated rainfall is readily adaptable to highly controlled laboratory research.

2.3.2 Limitations of simulated rainfall

The limitations of simulated rainfall as a research tool were pointed out by Mech (1965). These are grouped into modeling and operating limitations.

2.3.2.1 Modeling limitations

Soil and water research problems are usually associated with natural conditions of weather and soil. Factors like wind, light, temperature, humidity, vegetative influences difficult to simulate. Measurements of soil loss, water loss and infiltration are difficult to extrapolate to field conditions and natural rain.

2.3.2.2 Operating limitations

The nature of most rainfall simulators limits the study to small plots, even if the erosion problem is generally associated with large areas and relatively long slopes. The need for an adequate supply of water in the vicinity of the experimental plots limits the location of the work.

2.3.3 Desirable characteristics of rainfall simulator

1. The drop size distribution and fall velocities of the produced rainfall must be near to those of natural rainfall.

2. The intensities of the produced rain should be within the range of storms producing medium to high rates of runoff and erosion.

3. The rainfall application area must be of sufficient size for satisfactory representation of treatments and erosion conditions.

4. The produced rainfall must be uniform over the study area.

5. Rainfall application must be continuous throughout the study area.

2.3.4 Types of rainfall simulators

Mutchler and Hermsmeier (1965) reported that the rainfall simulators for erosion study use one of the following drop forming methods.

1. Hanging yarns
2. Nozzles
3. Tubing tips

2.3.4.1 Hanging yarn type rainfall simulators

The construction details of a simulator using hanging yarns as drop formers were given by Ellison and Pomerene (1944). The drop formers were evenly spaced to give a uniform intensity distribution over the test area. The applicator unit or the test plot was moved to prevent the drops from repeatedly falling over the same spot.

Mutchler and Hermsmeier (1965) reported the working of hanging yarn type simulators. For hanging yarn simulators a muslin cloth was laid loosely on a chicken wire screen so that depressions were formed in the cloth at each screen opening. A piece of yarn was attached to the cloth at each depression. Water applied as a spray to the cloth collected at the depressions and travelled down the hanging yarns to form drops.

2.3.4.2 Nozzle type rainfall simulators

Two basic parts of a nozzle type rainfall simulator are the nozzle or the drop former and the mechanism to apply the spray in the desired manner. Nozzle shape characteristics and the discharge rate govern the range of drop sizes formed. A nozzle with a uniform spray pattern and desirable drop size distribution is not available. However, a near uniform intensity distribution may be achieved by overlapping the spray patterns of same nozzles (Mutchler and Hermsmeier, 1965).

Swanson (1965) developed a trailer mounted simulator. The simulator produced rainfall with characteristics of near natural rainfall drop size and velocity. The simulator could produce storms of medium and high intensities with minimum wind distortion.

Rotating booms are utilized to carry continuously spraying nozzles. Ten booms support thirty nozzles positioned on radii 5, 10, 15, 20 and 25 ft. with 2, 4, 6, 8 and 10 nozzles on each respective radius. Intensities of 2.5 and 5 inch/hour are obtained by operating 15 or 30 nozzles. Each nozzle is mounted on a manually operated globe valve. Water is supplied through the stem to which the booms are attached. A small air cooled engine and a drive train was used to rotate the stem and the booms. The spraying systems company 80100 Veejet nozzle was used for the rotating boom simulator. The nozzles spray downward and are 9 ft above the ground level. The booms are operated at 3.5 to 4 rpm. The simulator can be used on a pair of rectangular plots spaced 9 ft or more apart with an overall width of 40 ft or less. Close control of the rainfall intensity is obtained through a valve in the water supply line to the simulator. A delivery pressure of 15 to 20 psi is adequate. Flows of 65 and 130 gpm are required for intensities of 2.5 and 5 inch/hour.

2.3.4.3 Tubing tip type rainfall simulator

Mutchler and Hermsmeier (1965) reported that the use of tubing tips is a precise method of forming water drops. The simplest type of simulator is a single tip drop former used in single drop studies. Stainless steel tubing and hypodermic needle tips have been used in a forty feet high drop tower to produce 3 to 6 mm diameter water drops. The simulator was used in splash erosion investigation. Drops as small as 0.1 mm can be produced from the tubing tips by the air flowing down around the slope (Lane, 1947).

Mutchler and Mouldenhauer (1963) reported the construction details of a laboratory rain fall simulator using drop formers made by telescoping pieces of tubes. The simulator could produce intensity, drop size near to that of natural rain.

Mutchler (1965) conducted studies on water drop formation from capillary tubes and showed that diameter of the tube, surface tension and kinematic viscosity of the water could be used as power functions in predicting the weight of the drop formed. The diameter of the drop former can be found out from the following equation suggested by Mutchler;

$$W = 4.924 \frac{ø^{0.943} d^{0.832} q^{0.057} r^{0.09}}{g^{1.018}}$$

where,

w - the drop weight in g,

ø - the surface tension of water in g/sec^2 ,

d - tube diameter in cm,

q - flow rate in g/sec,

r - kinematic viscosity in cm^2/sec,

g - gravitational constant.

A tubing tip type rainfall simulator was designed and soil loss characteristics of different soil series of Coimbatore district of Tamilnadu State. Hypodermic needles of 20 gauge are used as drop formers. A probable centrifugal pump with a diesel engine was used for pumping water to the simulator. The pressure of water supplied to the rainfall simulator was varied to vary the intensity of rainfall. The rainfall intensity is related to pressure as;

$$\mathbf{I = -606.67\,P^2 + 366.51\,P - 10.44}$$

Where,

I - intensity in cm/hr,

P - pressure in kg/cm^2.

The drop size decreases with increase in intensity. The intensity and drop size are having a linear relationship;

$$\mathbf{D = 2.387 - 0.033\,I \quad (r = -0.99)}$$

Where,

D - drop size in mm,

I - intensity in cm/h.

Kurien and George (1998) developed an oscillating tubing tip type rainfall simulator to study the soil loss and runoff at KCAET, Tavanur. Hypodermic needles were used as the drop formers. The uniformity coefficient varied from 82 to 88 % corresponding to intensity variations ranging from 4.77 to 8.8 cm/h. The soil loss increased with intensity of rainfall for all the slopes. A relationship between supply pressure and intensity of the following form was obtained,

$$\mathbf{I = 6.0386 - 31.9152\ P + 177.30\ P^2}$$

Where,

I - intensity in cm/h,

P - supply pressure, kg/cm^2.

Roshni (1998) developed a rainfall simulator and a soil trough to conduct the soil hydraulic study at KCAET, Tavanur, Kerala. The portable rainfall simulator comprised of a drop forming mechanism mounted on a supporting frame. The drop forming mechanism consisted of a tank with perforated bottom. Copper wire loops of 20 gauge were suspended through this perforations. A float valve ensured a constant head of water in the tank to get the desired intensity of rainfall. The moisture content, tension, surface runoff and outflow were monitored at different rainfall intensities.

The limitations of these types of rainfall simulators are that continuous jets of rain hit the soil at particular points below the drop former, which may not happen in nature and close spacing of drop formers adopted for getting a better uniformity resulted in high rainfall intensities than desired (Shrivastava and Ghanshyamdas, 1998).

Sajeena S (1999) modified and improved the existing rainfall simulator developed by Kurien and George (1998) at KCAET, Tavanur for better performance and to study the erodibility and runoff potential of the selected series of laterite soils (Mannamkulam, Naduvattom and Vellanikkara) under simulated rainfall conditions. A relationship between supply pressure and intensity of rainfall of the following form was obtained.

$$\mathbf{I = -87.205\,P^2 + 108.61\,P - 10.786 \qquad (R = 0.99)}$$

Where,

I - intensity of rainfall in cm/h,

P- pressure in kg/cm^2,

R - Coefficient of regression.

2.4 Runoff and soil loss

The relationship of erosion to rainfall momentum and energy is determined by the factors such as raindrop mass, size, shape, distribution, velocity and direction. The method used for predicting the soil loss should consider each of the factors involved and should be easily applied to field conditions. The most accurate soil loss equation is the Universal Soil Loss Equation (USLE) suggested by Wischmeier (1976). The average annual soil loss can be estimated from the equation;

$$\mathbf{A = 2.24\,RKLSCP}$$

Where,

A - average annual soil loss in metric tonnes /ha, R - the rainfall and runoff erosivity index by geographic location,

K - soil erodibility factor which is the average soil loss in Mg/ha per unit of erosion index for a particular soil in cultivated continuous fallow land with an arbitrarily selected slope length of 22m and slope steepness of 90%.

L, S - topographic factors,

C - cropping management factor, which is ratio of soil loss for given conditions to soil loss from cultivated continuous fallow.

P - the conservation practice factor, which is the ratio of soil loss for a given practice to that for up and down the slope farming.

The USLE is a powerful tool that has been used by soil conservationists for almost three decades for on - farm planning of soil conservation practice, and assessing the regional and national impact of erosion and implementing policy related to soil conservation.

A revised version of USLE has been developed by updating the USLE and is termed as Revised Universal Soil Loss Equation, RUSLE. Some of the improvements being made to the USLE factors in the RUSLE (Kenneth et al., 1991) are given below;

1. A greatly expanded erosivity map based on more than 1,200 gauge locations.

2. Some revisions and additions including corrections for high R-factor areas with flat slopes to adjust for splash erosion associated with raindrops falling on ponded water.

3. Development of a seasonally variable soil erodibility term (K). The seasonal variability is addressed by weighing the instantaneous estimate of K in proportion to the EI (the percent of annual K) for 15 days intervals.

4. A slope length factor that varies with soil susceptibility to rill erosion.

5. Soil loss is much more sensitive to changes in slope steepness than to changes in slope length.

6. A more nearly linear slope steepness relationship that reduces computed soil loss values for very steep slopes and complex slopes can be represented readily to provide a better approximation of the topographic effect.

7. A subfactor approach for calculating the cover-management term (C), with the subfactors representing consideration of prior land use, crop canopy, surface cover and surface roughness. The subfactor relationship is given by the equation;

$$\mathbf{C = PLU.\ CC.\ SC.\ SR}$$

$$\mathbf{SC = exp\ (-bM)}$$

Where,

PLU - prior land use subfactor,

CC - canopy cover subfactor,

SC - surface cover subfator,

SR - surface roughness subfactor,

M - percentage of ground cover,

b - coefficient assigning a value of 0.025 for USLE, 0.035 or 0.05 for RUSLE.

8. Improved conservation practice values (P) for the effects of contouring, terracing, strip cropping and management practices for range land. The practices require estimates of surface roughness and runoff reduction.

Rai and Singh (1986) studied the runoff and soil loss on steep hill slopes varying from 0 to 100% in Meghalaya. The surface runoff varied between 68 mm on 10% slope to 268 mm on 21% slope. The runoff values showed increasing trend up to 21%, beyond which the runoff amount decreased with the increase in slope. The soil loss was found to vary between 7 t/ha at 0% slope to 891 t/ha at 21% slope and beyond this the soil loss decreased steadily with increase in steepness of the slope for the present study.

Blough et al., (1990) conducted a study to evaluate the effects of residue cover and surface configuration on runoff and erosion responses of Letort silt loam reconstructed in the laboratory under simulated rainfall. Four field conditions were simulated by producing surface configuration and residue covers comparable to field situations. Infiltration and surface storage created as a result of slit tillage nearly eliminated surface runoff and therefore erosion, until the slit overflowed. After the slit overflowed, the erosion rates were approximately equal to the other conservation tillage treatment. Surface residue decreased surface runoff and erosion and increased the amount of water that infiltrated into the soil. The surface storage provided by the slit treatment further increased the opportunity for infiltration.

McIsaac and Mitchell (1992) studied the temporal variation in runoff and soil loss from simulated rainfall on corn and soyabeans. Soil loss per hectare from soyabeans and soil loss per ha - mm of runoff from corn varied by as much as a factor of four from one year to another. Much of the variations in soil loss appeared to be related to variations in runoff, slope steepness and antecedent rainfall.

Grosh and Jarret (1994) studied the interrill erosion and runoff from a 504 mm square box filled with disturbed Hagerstown silty clay loam under a simulated 20 min., 92 mm/h rainfall at six slopes ranging from 5 to 85 percent. Steady state wash soil loss (soil suspended in runoff) increased linearly with slope, with measuring rates ranging from 3.34 g/m^2-min, at 5% slope to 22.47 g/m^2 - min, at 85% slope. Total splash detachment (downslope + upslope) increased with slope. Ninetynine percent of splash moved down slope at the 85% slope. There were no differences between steady state runoff rates for slopes from 15 to 85 %, with a mean runoff rate of 66.5 mm/h.

Myers and Wagger (1996) studied runoff and sediment loss from a Pacolet sand clay loam soil in a two year field experiment. Conventional tillage (CT), no tillage grain production with surface residue (NTG) and no tillage silage production without surface residue (NTS) were compared under simulated rainfall of 12.7 and 50.8 mm/h. residue cover was greater than 90 % in NTG plots, 41 % in NTS and less than 10 % in CT. sediment loss (NTG<NTS<CT) was associated with residue cover. Average first event runoff in both years was 40 % for NTG, 44 % for NTS and 22 % for CT. Runoff doubled with CT on the second event each year suggesting soil surface seal development.

The effect of dead roots on runoff, soil erodibility, splash detachment, and aggregate stability were studied in laboratory by Ghidey and Alberts (1997). Dead roots had no effect on runoff but significantly influenced ($P<0.05$) soil loss and sediment concentrations. Soil loss and sediment concentrations from annual row crops were significantly higher than those from perennial crops; however, the differences in soil loss among the crops were small relative to the differences in root mass and root length. The effect of dead roots was not observed on splash detachment as they were on soil strength, aggregate index and dispersion ratio. Splash detachment was highest during the initial 10 min of simulation and then decreased approximately.

Kurien and George (1998) developed an oscillating tubing tip type rainfall simulator to study the soil loss and runoff at KCAET, Tavanur. Empirical equation between soil loss and intensity, runoff and intensity was obtained for different land slopes as,

$$\mathbf{E = -982.384 + 2834.63\ S + 225.239\ I \qquad (R = 0.94)}$$

$$\mathbf{Q = -216.174 + 1104.65\ S + 79.375\ I \qquad (R = 0.92)}$$

Where,

I - intensity of rainfall (cm/h) ranging from 4.77 to 8.8 cm/h,

S - soil slope (%) ranging from 5 to 20 %,

E - soil loss (kg/ha/h),

Q - runoff (m^3/ha/h),

R - coefficient of multiple regression.

Sajeena S (1999) studied the runoff and soil loss on slopes varying from 5 to 25 % in KCAET, Tavanur using oscillating tubing tip type rainfall simulator. Tests were conducted at the selected intensities of rainfall ranging from 7.41 to 23 cm/h to study the effect of intensity of rainfall on runoff and soil loss. The tests were done on three series of laterite soil say; Mannamkulam series, Naduvattom and Vellanikkara series of soil. A relationship between intensity and soil loss; intensity and runoff of the following form was obtained at different land slopes.

Mannamkulam series, **E = 1167.797 I + 109 S – 21686.07** **(R = 0.90)**

Q = 65.016 I + 16.747 S – 235.923 **(R = 0.99)**

Naduvattom series, **E = 324.766 I + 112.799 S – 3912.219** **(R = 0.97)**

Q = 74.542 I+ 19.434 S – 394.323 **(R = 0.99)**

Vellanikkara series, **E = 1115.662 I + 431.064 S – 11512.284** **(R = 0.98)**

Q = 58.742 I+ 26.837 S – 310.019 **(R = 0.99)**

Where,

I - intensity of rainfall (cm/h) ranging from 7.41 to 23 cm/h,

S - land slope %, ranging from 5% to 25 %,

E - soil loss (kg/ha/h),

Q - runoff (m^3/ha/h),

R - coefficient of multiple regression.

2.5 Measurement of rainfall characteristics

2.5.1 Intensity of rainfall

Rainfall intensity gauge is an experimental rain gauge to measure the intensity of rainfall with out the necessity of using a recording instrument with the inherent daily attendance for the changing of charts. An intensity raingauge with out clockwork was developed in India by Neares in 1921 for monsoon condition, using a horizontal get under varying head and hence varying trajectory. A number of containers placed in line with the trajectory of get caught the rainfall at varying rates of fall, so that both the rates of fall and the quantity of rain with in various rates could be ascertained (Varshiney, 1986)

.

Langsholt (1992) conducted studies on the water balance in the lateritic terrain of Kerala. She reported that the maximum intensity of 10 minute rainfall recorded was 78.6 mm/hr.

Intensity is measure of the quantity of rain falling in a given time. For measuring intensity or quantity of rainfall, non-recording type and recording type raingauges are used. Recording gauges produce a continuous plot of rainfall against time and provide valuable data of intensity and duration of rainfall (Subramanya, 1994).

2.5.2 Uniformity of rainfall

Uniformity coefficient is a measure of the degree of uniformity of rainfall. The coefficient is computed from the field observations of the depth of water caught in open pans placed at a regular intervals within the area. It is expressed by the equation developed by Christiansen (1942);

$$\boldsymbol{CU = 100\ (1 - \frac{\Sigma x}{mn})}$$

Where,

m - average value of all observations, mm

n - total number of observation points,

x - numerical deviation of individual observation from the average application rate, mm.

2.6 Methods of predicting runoff

Methods described below are applicable to small agricultural watersheds of less than a few thousand acres in size. Both runoff rate and runoff volume are important parameters in the watershed management and therefore shall be described separately.

2.6.1 Estimation of runoff rate

Most important method for predicting a design peak runoff rate is the Rational method suggested by Ramser (1932) and is expressed by the equation;

$$\mathbf{Q = \frac{1}{36}\ CIA}$$

Where,

Q - design peak runoff rate, m^3/s,

C - runoff coefficient,

I - maximum average rate of rainfall, cm/h over the entire area which may occur during the time of concentration,

A - watershed area, ha.

Time of concentration of a watershed is the time required for the runoff water to flow from the most remote (in time of flow) point of the area to the outlet. When the duration of a storm equals the time of concentration, it is assumed that all parts of the watershed are contributing simultaneously to the discharge at the outlet. The equation for time of concentration developed by Kirpich (1940) is;

$$\mathbf{T_c = 0.0195\, L^{0.77} S^{-0.385}}$$

Where,

T_c - time of concentration in min,

L - maximum length of flow in m,

S - slope length in m.

The main advantage of the rational formula is that it can always be, used to give an estimate of maximum runoff rates no matter how little recorded information is available (Norman, 1981). The rational method is applicable to watershed of less than 1300 hectares (Schwab et al., 1981).This method of based on two assumptions;

1. Rainfall occurs at uniform intensity for a duration atleast equal to the time of concentration of the watershed, and

2. Rainfall occurs at a uniform intensity over the entire area of the watershed.

2.6.2 Estimation of runoff volume

Knowledge of the volume of runoff from is necessary to design the water storage system and surplussing arrangements. Different mathematical models that are developed to predict runoff deal mainly with prediction characteristics affecting runoff amount and peak rates. In an attempt to simplify and standardised runoff prediction, the soil conservation service (SCS) of the United States Department of Agriculture (USDA) has developed a runoff prediction model, based on many years of storm flow records from agriculture watershed and certain watershed characteristics such as indices of soil cover complex and antecedent moisture condition.

This SCS method is used to predict direct runoff by the relation;

$$\mathbf{Q = (1\text{-}0.2S)^{2} / (1+0.8S)}$$

Where,

Q - direct surface runoff, mm

I - storm rainfall, mm

S - maximum potential difference between rainfall and runoff in mm starting at the storm beginning.

For convenience in evaluating antecedent moisture, soil conditions, land use and conservation practices, the US Conservation Service (1972) defines;

$$\boldsymbol{S = \frac{25400}{N} - 254}$$

Where,

N - an arbitrary curve number varying from 0 to 100.

2.7 Measurement of runoff

The various devices applicable to measure the runoff are current meter, weirs and flumes, float method etc. Current meter is widely used in measuring the flow in large streams. Weirs and Parshall flumes are suitable to measure the runoff from small watersheds.

Runoff measuring stations are often equipped with water stage recorders which continuously record the water level in the stream. The stage recorder consists of a float which is connected to the main channel by a pipe or trench. As the water level rises or falls, the float actuates a pen which records on a clock-driven chart the water level in the stream. This makes possible the calculation of total runoff volume for a period of stream flow (Michael and Ojha, 1993).

For safe disposal of runoff water, channels or ditches are often constructed along the slope in the small or large watersheds. Open channel or open ditch refers to any conduit in whih water flows with a free water surface (Tripathy and Singh, 1993).

2.7.1 Runoff and soil loss measuring devices

Gill and Shachori (1965) designed a box to trap sediment from the runoff water by providing suitable baffles in the box. The box was divided into three equal compartments.

Wischmeir and Smith (1965) designed a runoff plot for soil erosion studies. The plot was 22 m long and 2 m wide with a 9% slope.

Rajput (1988) developed a simple rotary type runoff sampler to measure runoff precisely and permit sediment sampling. Sampler consists of 61 cm diameter water wheel with six curved mains. Six cups were mounted on the conveyor chain, which was connected to a shaft. A suitable counting device was provided to watch number of revolutions.

Reyes et al., (1994) fabricated a multislot divisor from plastic. Performance test were conducted on plastic and metal multislot divisor. Test results showed that the plastic can be used as an alternative to steel without reducing the multislot divisor’s accuracy to equally divided flow. After four years of field installation, more than half of plastic multislot divisor and plastic tank set up needed repairs.

Bonta (1999) studied about water samples and flow measurement for runoff containing large sediment particles. A flow measuring and composit water sampler system was needed for sampling sediment laden flows containing large rock particles from strip mine boil erosion plots. A modified drop base weir was used for measuring flows and for proceeding a well mixed water and sediment flow that could be sampled. A diverter composit sampler was designed to divert the entire flow from a waste position to a sample position and precluded the need to sub-sample the sampled flows. Field evaluation showed the sampler and drop box weir worked well under natural rainfall conditions.

MATERIALS AND METHODS

MATERIALS AND METHODS

Micro soil loss plots were established to study the rill erosion process. The soil is reddish brown and belongs to the textural class of sandy clay loam. The experimental set up consisted of three unit's viz., the runoff plot, the rainfall simulator and the runoff-sediment collection unit. Two runoff plots; (a) flat land and (b) land with a slope of 3 per cent and each with a size of 3.5x2.5 m were prepared. The rainfall simulator designed and fabricated could apply the desired flow over the runoff plot. The runoff containing the sediments was collected at the outlet for analysis. The designed rate of water was applied over the runoff plot using the rainfall simulator i.e., micro sprinklers.

The development of the rills in terms of number and total length was monitored. The experiments were conducted for four surface flow rates of 0.09, 0.096, 0.12 and 0.14 $m^3 h^{-1}$ on the runoff plots. Well-developed rills were monitored for development with respect to length and number.

3.1 Design and fabrication of rainfall simulator

3.1.1 Design of the supporting frame work

Artificial rainfall was simulated using microsprinklers. In order to support the entire sprinkler unit, a frame was fabricated. A rectangular frame work of 3.5 m x 2.5 m was fabricated with round aluminum pipe of diameter 1.91 cm. The pipes were joined at the corners using an elbow, made of GI pipe of diameter 2.54 cm. The frame work was supported by legs of height 1m at the four corners. A 4 cm long GI pipe was welded to the elbow and the legs were connected to it. Two transverse pipes were joined to the frame using a T- joint made of GI pipe.

Plate 1: Installation of the supporting frame work in the plot

3.1.2 Selection of sprinkler heads for rainfall simulator

The microsprinklers used for the study belongs to the company ALPHA. This has a maximum discharge capacity of 160 litre per hour with a wetted circle diameter of 3 m. The sprinkler unit was connected to the lateral and mounted onto the framework. The spacing between the sprinklers was adjusted in order to get maximum intensity and uniformity within the study area. The simulated rainfall could produce rainfall of intensities varying from 3.33 to 4.52 cm/h.

Plate 2: Rainfall simulation using microsprinklers

3.2 Installation of rainfall simulator

The rainfall simulator was first installed in the Soil and Water Conservation Lab for testing it for intensity and uniformity. Later it was transferred to the experimental site for the erosion study. The experimental site was located at the KCAET farm area.

3.2.1 Experimental set up

A framework to support the sprinklers. A tank of 2000 litres capacity to hold the water, an electric motor to pump water from the tank. A PVC pipe connected to the electric motor. Two laterals each of 10 m length were connected to the PVC pipe with the help of a take off valve and washer. Two sprinklers each were connected to the two laterals at appropriate spacing. At the end of two laterals, an end cap was placed. The two laterals each were laid on to the two transverse pipes of the frame work.

Plate 3: Experimental set up in the KCAET farm

3.2.2 Water supply to the rainfall simulator

A centrifugal pump operated by an electric motor was used to lift water from a storage tank of 2000 litres capacity. The discharge line included two gate valves (GV 1 and GV 11) and a ball valve (BV). A pressure gauge was fixed on the discharge line just after the ball valve. GV 1 was provided at the line to control the discharge to the simulator. GV 11 was connected to the bypass flow line and was used to control the bypass flow and set the operating pressure by controlling the bypass flow. The discharge line was controlled easily by the ball valve.

Specifications of the pump:

Head - 20 m

Hp - 1

Speed (rpm) - 2722

Operating condition - 230 V, 2.8 A, 50 Hz.

Plate 4: Water supply to the rainfall simulator.

3.3 Testing of rainfall simulator

3.3.1 Intensity

The pressure of supply water was kept as 0.5 kg/cm². The entrapped air was removed and the simulator was operated freely for 10 minutes. Twenty four catch cans of 13 cm diameter were placed at a grid spacing of 50 cm x 50 cm, simultaneously while raining. The unit was operated for 10 minutes. The volume of water collected in each can was recorded. The volume of water collected was converted into its equivalent depth. The test was repeated for supply pressure of 1.0, 1.5, 2.0 kg/cm² respectively. The intensity was calculated for each supply pressure of water.

3.3.2 Uniformity

The pressure of supply water was kept at 0.5 kg/cm². The entrapped air was removed. Catch cans of 13 cm diameter were placed in the rain at 24 grid stations at an interval of 50 cm x 50 cm. The unit was operated for 10 minutes. The volume of water collected in each can was recorded and was converted into its equivalent depth of rainfall. The uniformity coefficient (Cu) percent was calculated using the Christiansen's formula;

$$\boldsymbol{Cu = 100[1 - \frac{\Sigma x}{mn}]}$$

Where,

Cu - uniformity coefficient, %

m - average value of all observations, mm

n - number of observations

x - numerical deviation of individual observations from the average application rate.

The uniformity coefficient was calculated for the inner area of size 3.5 m x 2.5 m. The experiment was repeated for various intensities of rainfall.

Plate 5: Rainfall simulator testing for intensity and uniformity in the lab

3.4 Determination of soil properties

3.4.1 Texture analysis

Texture analysis of the soil was done by determining the particle size distribution. The analysis was performed at two stages: (1) sieve analysis and (2) sedimentation analysis.

3.4.1.1 Sieve analysis

A representative sample of the soil was dried in the oven at 104°c for 24 hours. From the dried soil 375g was taken for the analysis. The analysis consisted of coarse and fine analysis. A set of 2mm, 1mm, 600μ, 300μ, 212μ, 150μ and 75μ sieves were used. The set of sieves were placed one above the other on a hand sieve shaker such that the 2mm sieve containing the soil sample was on the top and the 75μ sieve at the bottom, with a receiver below it. The sieve shaker was operated for 10 minutes and the portion retained on each sieve was weighed and noted. The percentage of soil retained on each sieve is calculated on the basis of the total mass of soil sample taken and from this results, percentage passing through each sieve is calculated. If the portion passing 75μ size is substantial, wet analysis done for further sub-division of particle size distribution.

3.4.1.2 Sedimentation analysis

The sedimentation analysis was done with the help of a hydrometer. The hydrometer analysis is based on Stoke’s law, according to which the velocity, at which grains settle out of suspension, all other factors being equal, is dependent upon the shape, weight band size of the grain. The hydrometer and the sedimentation jar are calibrated before the start of the analysis.

After calibration, a graph was plotted between effective depth (He) and the density readings (R_h) of the hydrometer. The necessary corrections to be made were also determined. 100g of soil was first treated with hydrogen peroxide solution to remove organic material. Next, the soil was treated with 0.2 N hydrochloric acid to remove calcium compounds, if any. After washing the mixture with warm water till there was no acid reaction to titmus, the oven dried soil was weighed and 100ml dispersing agent (sodium hexa metaphosphate) was added. The soil suspension was washed through a 75 micron IS sieve; the mass of those passing through the sieve was transferred to a 1000ml measuring cylinder making op the volume accurately to 1000ml. the hydrometer was immersed in it and the readings were taken at different time intervals. The percentage finer (N) was determined and a particle size distribution curve was plotted.

3.4.2 Consistency

Consistency is limits which have most useful for engineering purposes are liquid limit and plastic limit. These limits are expressed on a water content index.

3.4.2.1 Liquid limit

The liquid limit was determined with the help of the stantered liquid limit apparatus designed by Cassagraned. About 120 g of the specimen passing through 425µ sieve was mixed thoroughly with distilled water to form a uniform paste. A portion of the paste was placed in the cup of the Cassagraned apparatus and spreading to position and a groove was cutting the soil pat using the Cassagraned BS tool. The number of blows required for the two parts of the soil sample to coming to contact at the bottom of the groove was noted. The water content was determined by taking soil sample from near the closed groove and subjecting it to oven drying method. A graph was plotted between number of blows as abscissa on a logarithmic scale and the corresponding water content as ordinate. The water content corresponding to 25 blows was taken as the liquid limit.

3.4.2.2 Plastic limit

The soil specimen, passing through 425µ sieve was mixed thoroughly with distilled water so that the soil mass could be easily moulded with fingers. A ball was formed of 10g of the soil mass and rolled between fingers and a glass plate into a thread of uniform diameter. When the diameter was 3mm, the soil was remoulded again into ball. The process of rolling and remoulding was repeated till the thread starts just crumbling at a diameter of 3mm. The water content of the crumble threads was determined. The test was repeated twice with the fresh samples. The plastic limit was taken as the average of the three water contents.

3.5 Erosion study

3.5.1 Erosion Plot Layout

Each erosion plot selected for the study was 2.5 meter wide and 3.5 meter in length. The plots were delineated at its four sides by raising the soil level to form bunds. The bunds were raised to a level such that the water falling over the plot does not over flow to the surrounding area. At the top of the erosion plot, the bunds were made into right angles for the corners. At the bottom edge of each plot the bunds were angled across the slope towards a triangular tray made of 22 gauge GI sheet. The runoff generated in the plot was directed to a collector using the triangular tray. The tray had a cover made of the same material to prevent the simulated rain falling outside the test plot from mixing with the runoff. The outlet of the tray was directed to a pit of size 1 m x 1 m x 1 m. The runoff was collected in suitable containers placed in the pit.

Plate 6 : Erosion plot

3.5.2 Study of soil loss and runoff

The experimental plot was exposed to a simulated rainfall of intensity 3.33 cm/h by adjusting the pressure of water supply. A wet run was given until a steady state of runoff generated in the plot. The runoff with eroded soil was collected in a vessel placed below the narrow channel of the triangular tray in the pit, for a period of 5 minutes. The amount of runoff was recorded. The same procedure was repeated for rainfall of intensities 3.7, 4.07 and 4.52 cm/h and collected the corresponding runoff with eroded soil.

Plate 7: Runoff sediment collection unit

3.5.3 Computation of sediment load

The runoff sample was allowed to settle for a period of one week. Then the clear water was removed and the sediment was separated by evaporation technique. The weight of the sediment was recorded. The test was conducted for rainfall of intensities3.33, 3.70, 4.07 and 4.52cm/h. The same procedure was repeated for the second plot.

3.5.4 Development of rills

The development of rills in terms of number and length was monitored at each interval of time during the rainfall. The procedure was conducted for the selected intensities of rainfall at different land slopes.

Plate 8: Development of rills in the plot

RESULTS AND DISCUSSIONS

RESULTS AND DISCUSSIONS

The simulator was tested to determine the intensity and uniformity of application of the rainfall produced. After the performance evaluation of the simulator, it was used for erosion studies on laterite soil. The results of testing of the simulator and the erosion study conducted using it is presented in this chapter.

4.1 Testing of rainfall simulator

4.1.1 Intensity

The simulator was tested for various intensities by changing the supply pressure of water to the simulator. The intensity of rainfall produced at each supply pressure was measured. The results are given in Table 1. It was found that the intensity increased with the increase in supply pressure. A maximum intensity of 4.52 cm/h was obtained for a pressure of 2 kg/cm^2. The intensity was reduced to 3.33 cm/h for a supply pressure of 0.5 $kg/cm^{2.}$ The increase in intensity with pressure was due to the increase in the application rate of water. A graph is plotted with the supply pressure as abscissa and intensity as ordinate and is shown in Fig.1. A relationship between supply pressure and intensity of rainfall of the following form was obtained.

$$\mathbf{I = 0.08\,P^2 + 0.588\,P + 3.02 \quad (R^2 = 0.999)}$$

Where,

I - intensity of rainfall (cm/h),

P - supply pressure (kg/cm^2).

Table 1: Effect of supply pressure on intensity of rainfall

Pressure (kg/cm^2)	Intensity (cm/h)
0.5	3.33
1.0	3.70
1.5	4.07
2.0	4.52

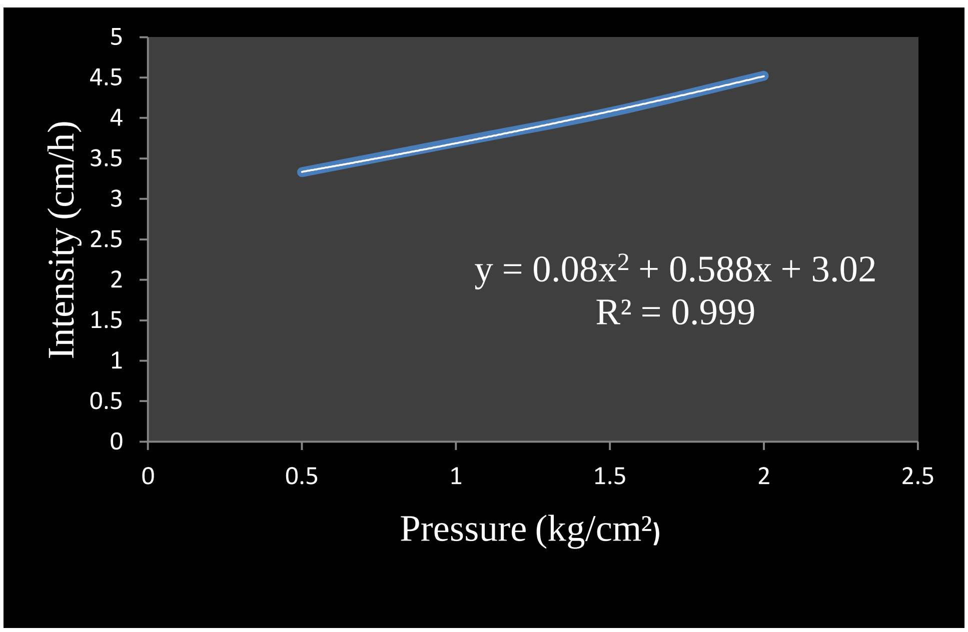

Fig 1: Effect of supply pressure on intensity

4.1.2 Uniformity of rainfall

The Christiansen's uniformity coefficient was worked out at different intensities of rainfall and the results are given in Table 2. A uniformity of 91.41percent was obtained for an intensity of 4.52 cm/h. The uniformity coefficient reduced to 68.67 percent for an intensity of 3.33 cm/h. At higher pressures of application the variation in the discharge of sprinkler was less and this in turn gave higher values of uniformity. A graph is plotted with the supply pressure as abscissa and intensity as ordinate and is shown in Fig.2. A relationship between intensity and uniformity of the following form was obtained.

$$\mathbf{Cu = -\,8.023\,I^2 + 82.70\,I - 118.3 \qquad (R^2 = 0.998)}$$

Where,

Cu - uniformity coefficient (%),

I - intensity (cm/h).

Table 2: Effect of intensity of rainfall on uniformity

Intensity (cm/h)	Uniformity (%)
3.33	68.67
3.70	77.26
4.07	85.85
4.52	91.41

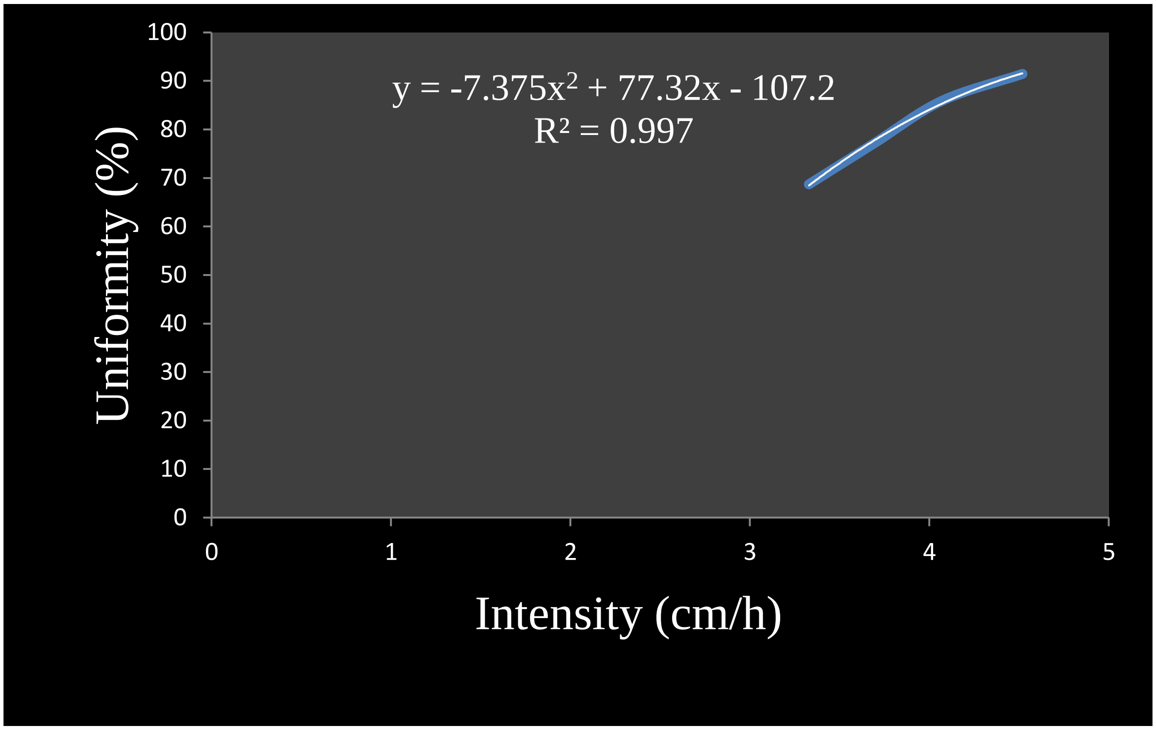

Fig 2: Effect of intensity of rainfall on uniformity

4.2 Soil properties

4.2.1 Texture analysis

The relative proportions of the different grain sizes which make up the soil mass of each plot of soils were determined. Both sieve analysis and sedimentation analysis were carried out. The particle size distribution curve of soils of each plot is given in Figures. The results of sieve and sedimentation analysis are shown in Table 3.

From the figures it was observed that the particle size distribution pattern of the soils is similar. The soil belongs to the class sandy loam.

Table 3: Results of sieve and sedimentation analysis

SI NO	IS Sieve	Mass retained (g)	Percentage retained (g)	Cumulative percentage retained	Percentage finer (N)
1	2 mm	58.0	15.47	15.47	84.53
2	1 mm	50.5	13.47	28.94	71.06
3	600 µ	51.0	13.60	42.54	57.46
4	300 µ	68.5	18.27	60.81	39.19
5	212 µ	91.5	24.40	85.21	14.79
6	150 µ	11.0	2.93	88.14	11.86
7	75 µ	24.5	6.53	94.67	5.33
8	< 75 µ	16.5	4.4	99.07	0.93

4.2.2 Consistency of soils

Consistency limits which are most useful for engineering purposes are liquid limit and plastic limit. Consistency denotes the firmness of the soil which may be termed as soft, firm, stiff or hard. Experiments were conducted to evaluate the liquid and plastic limits of the soils and the results are given are given in Table 4.

Table 4: Consistency of soils

Antecedent moisture content (%)	Liquid limit (%)	Plastic limit (%)
20.64	22.70	28.56

4.3 Erosion and Runoff study

The developed simulator was used in the study of erosion from a plot of size 3.5 m x 2.5 m. Study of the texture and consistency was done. The soils were subjected to erosion and runoff studies using the rainfall simulator fabricated. The soil loss and runoff were measured at the selected intensities of rainfall on slopes.

4.3.1 Effect of intensity of rainfall on soil loss

Experiments were conducted to study the effect of intensity of rainfall on soil erosion. Intensities of rainfall selected were 3.33, 3.70, 4.07 and 4.52 cm/h. Tests were conducted at the selected intensities on the two test plots. The results obtained are presented in Table 5. It was found in flat land that, there is a maximum soil loss of 27.48 kg/ha/h at an intensity of 4.52 cm/h. The soil loss reduced to23.10 kg/ha/h when the intensity reduced to 3.33 cm/h.

In the second plot of 3 % slope there is a maximum soil loss of 36.74 kg/ha/h at an intensity of 4.52 cm/h. The soil loss reduced to 30.67 kg/ha/h when the intensity reduced to 3.33 cm/h. Graphs plotted between soil loss and intensity of rainfall for each plot is shown in Fig.3.

4.3.2 Effect of land slope on soil loss

To study the effect of land slope on soil erosion, experiments were conducted on a flat land and on a land with 3 per cent slope. Experiments were conducted at intensities of 3.33, 3.70, 4.07 and 4.52 cm/h on the two test plots. It was found that there is maximum soil loss in the second plot compared to flat land. The results obtained are presented in Table 5.

4.3.3 Empirical equation for soil loss

Multiple regression equations relating soil loss, intensity of rainfall and land slope were developed for each test plots.

Table 5: Effect of intensity and land slope on soil loss

Plot	Intensity (cm/h)	Soil loss (kg/ha/h)
Flat land	3.33	23.10
	3.70	23.78
	4.07	25.37
	4.52	27.48
Slope – 3 %	3.33	30.67
	3.70	31.48
	4.07	34.56
	4.52	36.74

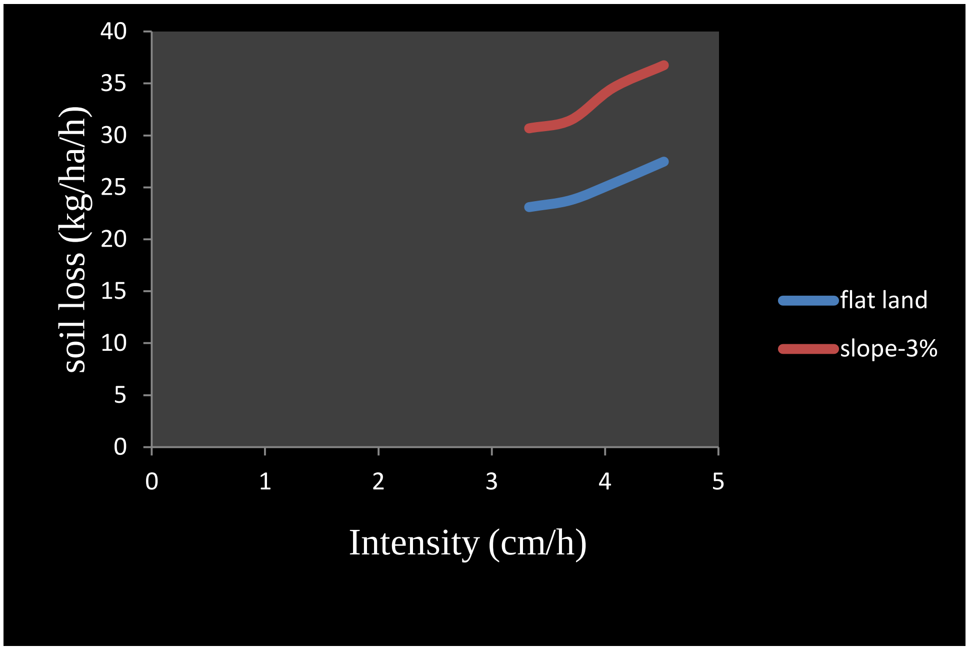

Fig 3: Effect of intensity and land slope on soil loss

The equations are,

Flat land: $\mathbf{E = 1.738\ I^2 - 9.900\ I + 36.74}$ $\quad$ $\mathbf{(R^2 = 0.996)}$

Slope – 3%: $\mathbf{E = 1.310\ I^2 - 4.889\ I + 32.21}$ $\quad$ $\mathbf{(R^2 = 0.970)}$

4.3.4 Effect of intensity of rainfall on runoff

Tests were conducted to study the effect of intensity of rainfall on runoff on the two test plots. Simulated rainfall intensities of 3.33, 3.7, 4.07 and 4.52 cm/h were applied on each plot. The results obtained from each plot are given in Table 6. Graph plotted between runoff and intensity for each test plot is shown in Fig. 4.

In the case of flat land, the runoff obtained for an intensity of 3.33 cm/h was 87.77m^3/ha/h. On increasing the intensity to 4.52 cm/h the runoff increased to 104.28 m^3/ha/h. In the case of land with 3 % slope, there is maximum runoff of 131.66 m^3/ha/h at an intensity of 4.52 cm/h. The runoff reduced to 115.20 m^3/ha/h when the in intensity reduced to 3.33 cm/h.

4.3.5 Effect of land slope on runoff

To study the effect of land slope on soil erosion, experiments were conducted on a flat land and on a land with 3 per cent slope. Experiments were conducted at intensities of 3.33, 3.70, 4.07 and 4.52 cm/h on the two test plots. It was found that there is maximum runoff in the sloppy land when compared to flat land. The results obtained are shown in Table 6.

4.3.6 Empirical equation for runoff

Multiple regression equations relating soil loss, intensity of rainfall and land slope were developed for each test plots.

Table 6: Effect of intensity and land slope on runoff

Plot	Intensity (cm/h)	Runoff (m^3/ha/h)
Flat land	3.33	87.77
	3.70	93.26
	4.07	98.74
	4.52	104.28
Slope - 3 %	3.33	115.20
	3.70	120.69
	4.07	126.17
	4.52	131.66

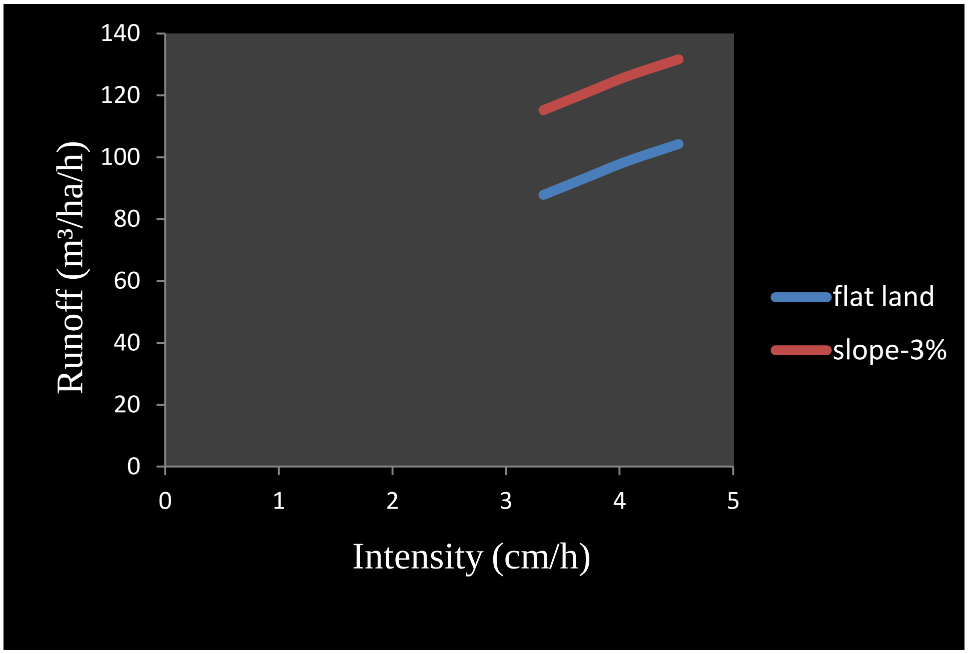

Fig 4: Effect of intensity and land slope on runoff

The equations are ,

Flat land: $\mathbf{Q = -1.713\ I^2 + 27.39\ I + 15.48}$ $\mathbf{(R^2 = 0.997)}$

Slope – 3%: $\mathbf{Q = -1.789\ I^2 + 27.95\ I + 41.91}$ $\mathbf{(R^2 = 0.999)}$

SUMMARY
AND
CONCLUSION

SUMMARY AND CONCLUSION

The major threat for sustainable crop production is soil erosion. Erosion leads to a reduction in soil quality and soil nutrients and thus decreased agriculture productivity. Another concern with erosion is an increase of turbidity of runoff which has an adverse effect on the quality of surface water and sedimentation in reservoirs and canals. Severe erosion occurs with high rainfall due to improper management of land and water. Rainfall is considered as the most important agent responsible for erosion. Rain drops cause the soil to be splashed and flowing water carries the detached particles.

Rainfall simulators are used to study the hydrologic processes such as infiltration, erosion, sediment transport and runoff. As rainfall simulators provide control of natural environmental factors such as rainfall intensity and duration, they are used to determine basic information on these hydrologic processes. Soil erosion data can be obtained more rapidly and efficiently by using simulated rainfall than by relying on natural rainfall. Simulators make it possible to produce predetermined storms at any desired time and location. They make the replication of research easier and facilitate the study of storm sequences.

Artificial rainfall was simulated using microsprinklers. A rectangular framework made of aluminium pipe was fabricated, to support the entire sprinkler unit. The water supply to the simulator was taken from a storage tank having 2000 L capacity. A centrifugal pump operated by an electric motor was used to lift water from the storage tank. A pressure gauge of 0-6 kg/cm^2 range was fixed in the discharge line and the pressure of water supply was controlled by means of two gate valves in the discharge line of pump. The experimental set up was installed in the KCAET farm, Tavanur.

The simulator was tested for different intensities of rainfall by changing the pressure of water supply. From the test results a relationship was established between intensity and supply pressure of water as,

$$\mathbf{I = 0.08\ P^2 + 0.588\ P + 3.02 \quad (R^2 = 0.999)}$$

Where,

I - intensity of rainfall (cm/h),

P - supply pressure (kg/cm^2).

Christiansen's uniformity coefficients were determined for different intensities of rainfall. Higher values of uniformity coefficients were obtained at higher intensities. The uniformity coefficients varied from 68.67 to 91.41 corresponding to intensity variations ranging from 3.33 to 4.52 cm/h.

$$\mathbf{Cu = -\ 8.023\ I^2 + 82.70\ I - 118.3 \qquad (R^2 = 0.998)}$$

Where,

Cu - uniformity coefficient (%),

I - intensity (cm/h).

The erosion plot selected for the study was 2.5 meter wide and 3.5 meter in length. The plots were delineated at its four sides by raising the soil level to form bunds. The plots for the study include a flat land and a land with 3% slope. Physical properties of the soils were determined. The particle size distribution curves when plotted showed that the soils are coarse grained. The liquid limit and plastic limit of the soils were determined by standard methods.

Experiments were conducted to study soil loss and runoff from the two plots at rainfall intensities of 3.33, 3.70, 4.07 and 4.52 cm/h. The soil loss increased with increase in the intensity of rainfall for the two runoff plots. A general trend of increase in the soil loss with increase in the slope was observed for all the simulated intensities of rainfall.

Tests were conducted to study the effect of intensity and land slope on runoff. Similar trend was observed. In general the runoff increased with intensity and slope.

Empirical equations were developed for estimating soil loss and runoff for various intensities of rainfall and land slopes.

The equations are:

Flat land:

$$\mathbf{E = 1.738\ I^2 - 9.900\ I + 36.74 \quad (R^2 = 0.996)}$$

$$\mathbf{Q = -1.713\ I^2 + 27.39\ I + 15.48 \quad (R^2 = 0.997)}$$

Slope – 3%:

$$\mathbf{E = 1.310\ I^2 - 4.889\ I + 32.21 \quad (R^2 = 0.970)}$$

$$\mathbf{Q = -1.789\ I^2 + 27.95\ I + 41.91 \quad (R^2 = 0.999)}$$

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APPENDICES

APPENDIX – I

Intensity and uniformity of simulated rainfall at different pressures

Diameter of the catch can =13 cm

Sl No	Pressure (kg/cm^2)	Total volume of water collected at different grid stations for 10 min (cm^3)	Intensity (cm/h)	Uniformity Coefficient (%)
1	0.5	1660	3.33	68.67
2	1.0	1915	3.70	77.26
3	1.5	2050	4.07	85.85
4	2.0	2560	4.52	91.41

APPENDIX – II

Soil loss and runoff from the test plot

Area of the test plot = 8.75 m^2

Duration = 5 min

II (a) Flat land

SI No	Pressure (kg/cm^2)	Intensity (cm/h)	Runoff (l)	Mean Runoff (l)	Runoff (m^3/ha/h)	Soil loss (g)	Mean soil loss (g)	Soil loss (kg/ha/h)
1	0.5	3.33	6.2 6.6 6.4	6.4	87.77	1.46 1.85 1.73	1.68	23.10
2	1.0	3.70	6.6 6.9 6.9	6.8	93.26	1.93 1.67 1.59	1.73	23.78
3	1.5	4.07	6.6 7.4 7.6	7.2	98.74	1.94 1.81 1.80	1.85	25.37
4	2.0	4.52	7.4 7.8 7.7	7.6	104.28	1.8 2.3 1.9	2.00	27.48

II (b) Slope – 3%

SI No	Pressure (kg/cm^2)	Intensity (cm/h)	Runoff (l)	Mean Runoff (l)	Runoff (m^3/ha/h)	Soil loss (g)	Mean soil loss (g)	Soil loss (kg/ha/h)
1	0.5	3.33	7.9 8.3 9.0	8.4	115.20	2.36 1.94 2.42	2.24	30.67
2	1.0	3.70	8.6 8.4 9.4	8.8	120.69	2.45 2.17 2.28	2.30	31.48
3	1.5	4.07	9.6 8.7 9.3	9.2	126.17	2.47 2.39 2.70	2.52	34.56
4	2.0	4.52	9.9 9.6 9.3	9.6	131.66	2.69 2.55 2.80	2.68	36.74

SOIL EROSION STUDIES ON MICRO PLOTS

By

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ABSTRACT OF THE PROJECT REPORT

Submitted in partial fulfillment of the requirement for the degree

Bachelor of Technology

In

Agricultural Engineering

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Land and Water Resources & Conservation Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR-679573, MALAPPURAM

KERALA, INDIA

2012

ABSTRACT

Soil erosion is one of the most serious environment degradation problems. However reliable measurement of erosion remains limited and estimates of soil productivity are even rarer. Assessing the extent and seriousness of erosion therefore remains a difficult task. Nevertheless, identification and assessment of erosion problems could have an important role in influencing better land use and conservation practices.

Rainfall simulators are considered as effective aids in soil conservation research. Simulators make it possible to produce predetermined storms at any desired time and location. A rainfall simulator suitable for soil erosion studies was designed and fabricated at KCAET, Tavanur. The developed simulator was tested for its performance. Erosion studies on laterite soil were conducted using the developed simulator.

Laterite soils are by far the most important soil group occurring in Kerala and cover the largest area. The objective of this study was to estimate soil loss and runoff of laterite soil under simulated rainfall conditions.

The fabricated rainfall simulator could produce rainfall intensities varying from 3.33 to 4.52 cm/h. Also the uniformity of rainfall produced varied from 68.67 to 91.41 percent, thus giving a better performance. Intensity of rainfall increased as the pressure of supply water to the simulator increased and a relationship was established between intensity and the supply pressure of water as,

$$\mathbf{I = 0.08\,P^2 + 0.588\,P + 3.02 \quad (R^2 = 0.999)}$$

Where,

I - intensity of rainfall (cm/h),

P - supply pressure (kg/cm^2).

Uniformity of rainfall increased with increase in intensity of rainfall. A relationship was obtained between uniformity and intensity as,

$$\mathbf{Cu = -7.375\, I^2 + 77.32\, I - 107.2 \qquad (R^2 = 0.997)}$$

Where,

Cu - uniformity coefficient (%),

I - intensity (cm/h).

Experiments were also conducted to study the soil loss and runoff at different land slopes under simulated rainfall conditions. The soil loss and runoff increased with increase in the rainfall intensity for different slopes studied. A maximum soil loss of 27.48 kg/ha/h and a minimum of 23.10 kg/ha/h were obtained for intensities of 4.52 and 3.33 cm/h on flat land. Similarly, a maximum soil loss of 36.74 kg/ha/h and a minimum of 30.67 kg/ha/h were obtained for intensities of 4.52 and 3.33 cm/h for land of 3 % slope.

Empirical equations were developed for estimating soil loss (E) and runoff (Q) for various intensities of rainfall and land slopes.

The equations are,

Flat land:

$$E = 1.738\, I^2 - 9.900\, I + 36.74 \quad (R^2 = 0.996)$$

$$Q = -1.713\, I^2 + 27.39\, I + 15.48 \quad (R^2 = 0.997)$$

Slope – 3%:

$$E = 1.310\, I^2 - 4.889\, I + 32.21 \quad (R^2 = 0.970)$$

$$Q = -1.789\, I^2 + 27.95\, I + 41.91 \quad (R^2 = 0.999)$$