Estimation of Impact of Rainfall Variability and Slope on Sediment Yield and Surface Flow in Runoff Sediment Plots

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Dedicated

to my

Parents

Sher-e-Kashmir
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Certificate – I

This is to certify that the thesis entitled, **“Estimation of Impact of Rainfall Variability and Slope on Sediment Yield and Surface flow in Runoff Sediment Plots at SKUAST-K, Shalimar Campus**” submitted in partial fulfillment of the requirements for the award of the degree of **Master of Technology in Agricultural Engineering (Soil and Water Engineering)**, to **the Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Ms. Aaliya Mustafa (Regd.No.MTAE-2018-59)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

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ABSTRACT

The experiment was carried in micro runoff plots of (1.8 × 1.2 m) in size. Plots were installed on the bench terraces with different slopes (70, 65 and 60%) to determine the sediment yield and runoff. Experimental treatments were shade net and black mulch, bare plot was kept as control. Soil erosion was measured directly by observing the sediment being carried by natural rainfall with different intensities. The runoff was measured after each rainfall event using measuring cylinder. Properties like texture, organic carbon, organic matter and erodibility was determined for the collected sediment. Highest organic carbon and organic matter was found in Plot-2 (1.0% and 1.93%) respectively. The results indicate that the runoff and sediment yield of the bare plot were greater than plots covered with shade net and mulch. Mean total runoff volume was highest 6.4 litres and sediment yield was 261.3g/m^2 for bare plot having 70 % slope. Empirical equations were developed for estimating soil loss and runoff for various intensities of rainfall and land slope. The best fit of regression equation for sediment yield was found for Plot-1 with 70% slope having bare soil surface i.e., $E=222.6-68.4I+10.2I^2$ ($R^2=1.00$) and best fit of regression for runoff was found Plot-3 with 65% slope for bare soil surface $Q=2.36+0.47I+0.01I^2$ ($R^2=0.99$).Soil loss from the three plots were estimated by using USLE technique. Results indicate that the highest soil loss was observed in Plot-2 with 60% (44.8 ton/ha/yr.) due to higher LS factor and the lowest soil loss was observed in Plot-3 with 65% slope (32.4 ton /ha/yr.).

Keywords: Soil erosion, rainfall intensity, runoff, sediment, erodibility, organic carbon, soil texture.

Signature of Student	Signature of Major Advisor
Dated____________	Dated _________________

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Aaliya Mustafa

Place: Shalimar, Srinagar

Date: ___________________

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LIST OF NOTATIONS

% = Per cent

UT = Union Territory

ha = Hectares

mm = Millimeter

Sq. m = Square Meter

J&K = Jammu and Kashmir

°C = Degree Celsius

SWC = Soil and Water Conservation

SOC = Soil Organic Carbon

ml = Mililitre

h = Hour

m = Metre

M = Million

@ = At the rate

cm/s = Centimeter per second

g/m^2 = gram per Metre square

SKUAST-K = Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir

COAE&T = College of Agricultural Engineering and Technology

Chapter–1

INTRODUCTION

Soil is the basis of production in agriculture and forestry, the nourisher of mankind and vital component of the human environment. Humans acquire about 99.7% of their food from the land and less than 0.3% from the other sources. Every year about 10 million ha of cropland are lost due to soil erosion, thus reducing the crop land available for food production (Pimentel, 2006 and Zachar, 2011). The challenge, therefore, is not only to increase productivity on sustainable basis, but also to preserve and maintain soil resource bases for the posterity. The land's ability to produce is limited and its limits are determined by soil, climate, and landform conditions, which are further defined by intrinsic characteristics that include agro-ecological settings, use and management. Therefore, comprehensive account of our land resource ascertaining its potential and problems towards optimizing land use on sustainable basis is necessary.

Soil erosion is a complex and natural phenomenon that occurs when productive surface soil is detached by physical forces such as water and wind, exposing subsurface soil and causing sedimentation in reservoirs. It is influenced by a variety of factors, including topographic slope location, vegetation, and soil composition, all of which have a significant impact on the erosional activity of soil (Mohamadi and Kavain, 2015). Under the same conditions of rainfall, topography, and vegetal cover, soil loss from runoff plots on various soil types has demonstrated different erosion rates. (Hussein, Karien and Othman, 2007). Natural variability and experimental design also contribute to the inconsistency in soil erosion data (Boix-Fayos *et al.,* 2006).

India has total geographical area of 328.73 million hectare (M ha).Soil degradation in India is estimated to be occurring on 147 million hectares of land, including 94 M ha from water erosion, 14 M ha from flooding, 9 M ha from wind erosion, 16 M ha from acidification, 6 M ha from salinity, and 7 M ha from a combination of factors (Bhattacharyya *et al.,* 2015). Further it has been approximated that about 5334 m-tonnes (16.4 t ha-1) of soil is detached annually in India about 29% is carried away by the rivers into the sea and 10% is deposited in reservoirs which means the storage capacity is reduced by 1-2 per cent annually (Pandey *et al.,* 2007). The total area under land degradation in Jammu and Kashmir is 35.86% as compared to 29% in the rest of the country (ISRO, 2016). Erosion is closely interrelated to water availability, especially for crop growth and production (Suyana and Senge, 2010). Soil cover, soil texture, soil structure, porosity/permeability and topography are the factors involved in soil erosion (Rashid *et al.,* 2015). In the recent past, problem quantification has been regarded as an urgent need to develop appropriate and suitable means to minimize the degradation of valuable land (Sarangi *et al.,* 2007).

Most of the rainfall and snowmelt carry about significant runoff which causes severe erosion and sediment transfer to rivers, leading to deprivation of soil resources and contributes to negative off-site impressions downstream, such as flooding, pollution and the siltation of water bodies and reservoirs (Lin-Jing *et al*., 2012). There are many factors affecting soil water erosion, including soil condition, topography, land use/vegetation, conservation measures, and rainfall characteristics. Among these rainfall is a prerequisite for runoff and soil water erosion, and the amount of soil erosion and runoff is determined not only by rainfall intensity and quantity, but also by land use patterns (Han *et al.,* 2020 and Chang *et al.,* 2011). The impact of high intensity rainfall accompanied by runoff results in huge soil loss over greater slope length and this effect becomes more deleterious with the steepness (Rai and Mathur, 2007). It has also been reported that due to climate change, there is enormous effect on rainfall events (Kumar *et al.,* 2010). Because of rainfall variability, it has been seen that in last 10 -12 years, there were many extreme events that have been occurred (Ghosh *et al.,* 2012).

The sediment yield is the soil loss delivered to a specific point under consideration. Sediment yield is always less than the total erosion and is highly unpredictable due to temporal variability of hydrological processes, difficulty in measurement, and change of basin land management practices every year. Sedimentation has been considered as a major problem threatening the water carrying capacities of water bodies. Apart from the major watershed problems caused by soil erosion such as significant loss of soil fertility and productivity in the catchment area, increased sediment loads that decreases the capacities and thereby lessens the useful life of reservoirs is also one of the associated effects of soil erosion and sedimentation in the affected area. Because of the high suspended sediment rate, the water quality of rivers and reservoirs has declined significantly. In the recent past, the importance of water reservoirs in respect of irrigation, flood control, hydropower generation, drinking, and recreation purpose has posed a lot of concern and thus sedimentation problems must also be included in the design of water supply projects.

An insight into the soil erosion and sedimentation mechanism in the watershed are needed for sustainable sediment management. Predicting sediment loss is important for making appropriate provisions in the design and construction of conservation systems, as well as for minimizing the deleterious effects of sedimentation. In modelling the hydrologic processes of the runoff, with hydrologic time series data, causative factors such as climate, soil type, land use, topography, geology, and morphological characteristics are significant.

In the context of accelerated global change, both surface runoff and sediment yield have been identified as significant on-site degradation mechanisms in many dry land ecosystems in the sense of rapid global change (Wei *et al.,* 2015; Yair and Kossovsky, 2002; Foley *et al*., 2005; Kerr, 2007). Severe land degradation is induced by such hydrological behaviors resulting into extensive decline in soil quality and environmental degradation (Aksoy and Kavvas, 2005; Cotler and OrtegaLarrocea, 2006). The particle disaggregation and discharge transports soil organic material to the lower reaches, thereby decreasing the agricultural productivity resulting into the food security hitches and eutrophication of aquatic environments (Bewket and Sterk, 2003; Boix-Fayos *et al.,* 2009).

The erosive action of runoff, which is the catchment's response to precipitation, changes the landscape, and its volume is determined by physical characteristics of the watershed, such as drainage area, elevation, slope, topography, basin shape, soil type, land use, orientation, and vegetation, and so on. When it rains in a catchment area, the impact of the rain and runoff transport causes erosion. According to Pandey *et al.,* (2008), predicting the amount of sediment and runoff from land into rivers and streams is complex and time-consuming. Surface runoff or overland flow occurs when soil is not capable of absorbing rainwater, or removing it through transpiration, and in-situ infiltration.

Need for study

The soil losses are incessantly leading to critical deterioration in soil properties, reduced soil productivity and crop yields, causing agro-ecological, environmental and watershed-function problems (Panomtaranichagul and Nareuban, 2005). Therefore, more effective soil and water conservation strategies are vital for sustainable increases in productivity on cultivated highland slopes. Erosion is expected to increase with increase in slope steepness and slope length could be a result of respective increase in velocity and volume of surface runoff (Rashid *et al.,* 2015). Soil loss on slopes covered with vegetation is very little. However, with removal of the vegetation, surface soil can easily erode. Therefore, when lands on slopes are cleared for cultivation, unless measures to stop soil erosion are taken, fertile surface soils may erode with heavy rain and the land may become barren within only a few years (Itani, 1998). Information of rainfall runoff and runoff-soil loss relationship on the slopes is very important to develop appropriate technology for soil and water conservation for increased crop production.

Keeping in view the long term sustainability and productivity of eroded lands, the present research was carried out to study the effect of slope and rainfall intensity on sediment and runoff by using runoff plots. Runoff plot is the best tool for assembly demonstration on runoff and soil loss events at the field level. By using the runoff plot the impact of vegetation, soil type, soil slope, mulches etc. on runoff and soil erosion /sediment loss can be demonstrated to the concerns. The parameters like slope, conservative practices etc. are changed in the runoff plot as per requirement.

Objectives

The present study entitled "Estimation of Impact of rainfall variability and slope on sediment yield and surface flow in runoff sediment plots" has the following objectives:

1. To design, fabricate and develop runoff sediment plots for analyzing the parameters of erosion and runoff.
2. To estimate the sediment yield and runoff under different slopes, rainfall intensities and conservative practices.
3. To develop empirical equation for sediment yield and runoff in temperate climatic conditions.
4. Comparison of observed sediment yield with universal soil loss equation.

Chapter–2

REVIEW OF LITERATURE

Runoff and sediment quantification are pre-requisites for effective planning and management of soil conservation. The runoff plots with natural rainfall are simple in construction as per design norm and in proper size in an open field. The data collection is carried out depending upon the occurrence of rainfall. Runoff plots are often conducted to evaluate the rainfall-runoff and widely used to study sediment losses. This chapter presents as in depth knowledge of various research works in the field of runoff and sediment yield assessment due to the impact of rainfall intensity and slope using runoff plots in the open field. The available review pertaining to the present study has been organized and presented as:

2.1 Effect of rainfall intensity and slope on sediment yield and runoff

2.2 Soil loss assessment using USLE

2.3 Physico-chemical characteristics of soils

2.1 Effect of rainfall intensity and slope on sediment yield and runoff

Jia *et al.* (2020) studied runoff and sediment losses under different rainfall intensities on a shrub-grass planted, and grass planted, and bare slope. Results of the experiment showed that the slopes implanted with grass or shrub-grass effectively delayed runoff generation. The amount of runoff increased as rainfall rate increased for all treatments, with bare slope runoff increasing the most. The shrub-grass slope's runoff reduction rate ranged from 54.20 per cent to 63.68 per cent, while the grass-only slope's reduction rate ranged from 38.59 per cent to 55.37 per cent, Also results indicate that with rising rainfall intensity in the plot, the sediment yield increased from 662.66g/m^2 (15mm/h) to 2002.95g/m^2 (82 mm/h) from the bare slope. In comparison to the bare slope, the shrub-grass and planted grass slopes were able to carry an average of 0.9 g/m^2 to 4.9 g/m^2 of sediment.

Panme *et al.* (2019) investigated the effects of various rainfall and slope patterns on soil erosion and runoff. The research was conducted on sites with slopes of 20.04 per cent, 30.80 per cent, and 39.83 per cent, with the aid of acrylic sheets, experiment was made on 18 test plots. Found the rainfall nozzle with a diameter of 1 mm produced the lowest intensity (57 mm/h). The nozzle size of 6mm recorded the highest rainfall intensity (132 mm/h) for the same flow rate. The rainfall simulation results were analysed, and it was discovered that the average time to runoff was higher than anticipated. For the three test plots, Plot-1>Plot-2>Plot-3. Plot-3 (Slope=39.83 percent) had the highest runoff volume of 239.70 mL/m^2/min under 132 mm/h rainfall rate, while Plot-1 (Slope=20.80 percent) had the lowest volume of 60.31 mL/m^2/min. Plot-3 (Slope=39.83 percent) had the highest average sediment yield of 76.51 gm/m^2/min under a rainfall rate of 132 mm/h, while Plot-1 (Slope=20.80 percent) had the lowest average yield of 5.32 gm/m^2/min.

Bingqin *et al.* (2019) carried out a study on a slope of 30^0, with seven vegetation treatments subjected to three rainfall intensities on a soil containing rock fragments to determine the effect of rainfall and conservation practices. The results of the experiment shows that the bare plot's runoff volume and sediment load was higher than the vegetation-covered plots under three different rainfall intensities. Results also reveals that the best soil loss control was found in the plot having Cynodon dactylon and indigofera amblyantha combined, with a reduction of 87.88 per cent to 99.11 per cent,

Wu *et al.* (2018) conducted an experiments to indicate the fundamental changing trends of runoff and sediment yield on bare loess soil. During the research study the rainfall intensities were (45, 60, 75, 90, 105, 120 mm/h) and slopes (5°, 10°, 15°, 20°, 25°). Data revealed that the runoff and sediment yield on the slope surface shows an increasing trend when the rainfall intensity increases from 45 mm/h to 120 mm/h, but the increasing trend of runoff yield was higher than that of sediment yield and conclude that sediment yield also has an overall increasing trend when the slope changes from 5° to 25°.

Duan *et al.* (2017) carried out an investigation in the Jiangxi Provincial Soil and Water Conservation Ecological Park to determine runoff under three land cover types (grass, litter cover, and bare land).114 natural rainfall events created subsurface flow during the study period, and were clustered into four groups using k-means clustering based on rainfall length, rainfall depth, and maximum 30-minute rainfall intensity. The findings showed that bare land had the highest runoff and surface flow values under all four rainfall patterns, while covered plots had the lowest. Results showed that in grass and litter cover plots, rainfall patterns with low intensities and long durations had more subsurface flow, while rainfall patterns with high intensities and short durations resulted in greater surface flow over bare land. Pattern of Rainfall for the grass cover and litter cover forms, I had the highest surface and subsurface flow values. During rainfall pattern IV, data reveals that the highest surface flow value and the lowest subsurface flow value for bare land occurred. For bare land, Rainfall Pattern II produced the highest subsurface flow value. As a result, under various rainfall patterns, grass or litter cover may transform further surface flow into subsurface flow. Rainfall patterns had a greater effect on subsurface flow than overall runoff and surface flow for covered surfaces, as well as a greater impact on bare ground surface flows.

Fu *et al.* (2016) conducted a field study to investigate the effect of slope length on sediment yield under various rainfall intensities and land use forms on a low hill gentle slope. And found that rainfall intensity had a greater impact on sediment yield than slope length. Sediment yield increased rapidly as slope length increased when rainfall rate exceeded 90mm/h. Under rainfall intensity less than 120mm/h, sediment yield increased slowly as slope length increased. Both rainfall events resulted in a gradual decrease in sediment yield at 6m slope length. The results shows that Particle size analysis of erosional sediment revealed that silt and clay particles smaller than 0.02mm were always transported on both the capsicum slope (silt 47.1 per cent, clay 40.9 percent) and grassland (silt 47.1 per cent, clay 40.9 percent) (silt 38.3 per cent, clay 35.9 percent).

Rashid *et al.* (2015) conducted an experiment on effect of various vegetation covers and slopes on runoff and soil degradation. Three slope gradients, namely 1, 5, and 10%, with four plots for each slope gradient. On each slope gradient, three crops (groundnut, mungbean, and millet) were sown with a fallow plot (bare soil). Runoff and sediment were collected after each rainfall (≥ 20 mm), runoff and sediment losses were measured for each crop cover and slope gradient. As compared to bare soil, the results showed that groundnut, mungbean, and millet reduced accumulative soil sediment loss by 40, 28 and 38 per cent, respectively, and runoff loss by 31, 30 and 24 per cent, Under all vegetation covers, the highest soil and water losses were observed at a 10% slope gradient following a 5% and 1% slope gradient, respectively.

Wei *et al.* (2015) surface runoff and sediment yield responses to land use and rainfall in a typical loess hilly catchment were studied in 1997, 2005, and 2010. First, the majority of rainfall during the growing season, from June to September, and only marginally increased during the observation years. Second, from June to August, runoff and soil transport concentrations at the catchment outlet were significantly higher than in other months. A similar pattern was found for seasonal rainfall occurrence, suggesting that monthly rainfall distribution dominated intra-annual water erosion trends. Third, mean runoff and sediment transport modulus in 2005–2010 decreased significantly as compared to 1997–2005.

Kurien et *al.* (2014) soil erosion is one of the most severe issues affecting the climate. However, accurate erosion measurements are difficult to come by, and estimates of soil fertility are even rarer. Nonetheless, identifying and assessing erosion issues may have a significant impact on better land management and conservation practices. Simulators allow for the development of preprogrammed storms at any desired time and place. Laterite soils are by far the most common soil type in Kerala, covering the greatest area. The aim of this analysis was to calculate laterite soil loss and runoff at various land slopes under simulated rainfall conditions. With an increase in the rainfall intensity for different slopes studied soil loss and runoff increased.

Luo *et al.* (2013) studied the effect of geotextiles (shade net, non-woven fabrics and straw mats) on runoff and soil loss from bare slopes resulting from road construction. It was reported that Geotextiles are a possible temporary alternative before vegetation establishes itself, and offer immediate soil protections on slopes. Artifical rainfall simulation was installed at study area. The results showed that all the three kinds of geotextiles significantly ($P < 0.001$) decreased runoff b and sediment concentration compared with the bare slope. Furthermore, straw mats had the best effect among them, resulting in the lowest runoff coefficient (10.9%) and sediment yield (8.5 g m^{-2}).

Won *et al*. (2012) conducted a study to examine the effects of loosely woven rice straw mats on runoff, sediment discharge, and suspended solids. Experiment was carried on Small runoff plots of 1 × 1 × 0.5 m in size were filled with loamy sand. Experimental treatments were rice straw mat cover of 0 (control), 300, 600, and 900 g m^{-2}; slopes of 10% and 20%; and rainfall intensities of 30 and 60 mm/h. The results shows that Runoff volume from covered plots was significantly smaller than that from control plots at $\alpha = 0.05$. It was observed in a 30 mm/h rainfall simulation, very little sediment discharge occurred for 10% and 20% slopes. In a simulation of more severe conditions, 60 mm/h rainfall and 20% slope, no sediment was yielded if mat cover was 900 g m^{-2}.

Gholami *et al.* (2013) conducted an experiment to determine the effectiveness of straw mulch applied at a rate of 0.5 g m^{-2} in fluctuating the runoff commencement time, runoff amount, splash erosion, and sediment yield from mid-sized plots under artificial rainfall simulation with rainfall intensities of 30, 50, 70, and 90 mm h^{-1} and a slope of 30% in three replicates. The results indicate that maximum increase in runoff commencement time (110.10%) was perceived for the rainfall intensity of 90 mm h^{-1}. The runoff coefficient had a maximum reduction at rainfall intensities of 30 and 90 mm h^{-1}. The maximum decrease in sediment yield (63.24%) also happened at the rainfall intensity of 90 mm h^{-1}.

Xiang *et al.* (2012) conducted a field experiment to investigate the effects of forest vegetation on soil erosion, surface runoff, and sediment yield. Experiment was carried on five 4.52.1m runoff plots (one bare soil, two pinus tabulaeformis forest plots, and two platycladus orientalist forest plots with row spacing of (1m×1m and 1.5m×1.5m) under three rainfall intensities. The experiment's findings indicate that forest vegetation decreases soil erosion and sediment yield substantially. The four tree stand plots had 93 per cent of the overall runoff volume of the control plot. Runoff in forest plots decreased from 28 per cent to 2.1 per cent as rainfall rate increased. Under different treatments, the mean total sediment yield and mean sediment yield reduction rate was reported 55.05 per cent and 43.17 per cent, respectively those in bare soil control plot. Rainfall intensity influenced runoff and sediment generation, with runoff having a greater effect than soil erosion and sediment generation.

2.2 Soil loss assessment using USLE

Vemu *et al.* (2012) reported that the average erosion rate in a river catchment was discovered 18.00 tons/ha/year with a sediment yield of 22.31 million tons per year at the catchment's outlet by using USLE. Overall, high erosion rates affect 19.71 per cent of the area, contributing significantly to the catchment's sediment yield (low in calories percent).

Srinivasan *et al.* (2019) conducted an experiment in the part of coastal Odisha system to estimate soil erosion in different conditions. Revised Universal Soil Loss Equation (RUSLE) assimilated with GIS had been used for the evaluation of soil loss. And reported that the study area, had undulating topography covering 0-35% slopes. The results of the experiment indicate that 90.9% (22330 ha) of the study area falls in very low erosion category, which may be due to level high erosion occurred in the range of 2.12%, 2.23% and 1.49 %, respectively.

Ali and Hagos (2016) carried out a study to assess the soil erosion by adopting (USLE) equation. The results of study revealed that 97% of the area is characterized by 0–10 t ha^{-1} $year^{-1}$ soil erosion rate, whereas 3% of the area is characterized by 10–202 t ha^{-1} $year^{-1}$ soil erosion rates. The results of research also showed that the study areas having six ordinal classes of soil erosion risk zone, e. g., extremely high risk (91–202), extreme risk (55–91), very high risk (30–55), high risk (10 − 30), moderate risk (5–10) and low risk (0–5) with corresponding percentage of area falling, 0.18, 0.26, 0.43, 1.62, 2.68, and 94.83, respectively.

For horticulture and plantation the soil loss rates were 1.47 and 5.39 tons ha-1 yr-1, respectively. For pasture, fallow and scrub the soil loss rates were 25.47, 28.39 and 35.76 tons ha-1 yr-1, respectively (Shiekh *et al*., 2011).The rainfall erosivity R-factor of USLE was found as 293.96 and the soil erodibility K- factor varies from 0.325 - 0.476. Slopes in the catchment varied between 0 and 83% having LS factor values ranging from 0 - 6.7. In Konar basin having 961.4 km^2 areas the average annual soil erosion at micro-watershed level was estimated as 1.68 tons ha-1 yr-1. Furthermore, micro watershed priorities have been set based on soil erosion risk, with the implements of introducing management practices in micro-watersheds that will minimise soil erosion in the Konar basin (Shinde *et al.,* 2010).

Ampofo *et al.* (2002) Estimate the gross sediment loading into a reservoir from the catchment. The estimated total sediment inflow into the reservoir was about 2871 t, corresponding to an average sedimentation rate of 1063 t km"" year, or about 76 per cent of the total sediment inflow calculated into the reservoir. Depending on the slope and the scale of the catchment the experimental treatments used to estimate soil losses were: traditional tillage (hand hoeing) with maize and soybean intercropping (HOCOBE); conservation tillage (disc plough) with maize and soybean intercropping (COBEAN); and conservation tillage (disc plough) with maize and soybean intercropping (COBEAN). It was reported that Conservation tillage for solely maize cultivation (CNTCORN) and conservation tillage for solely soybean cultivation (CNTCORN) (CNTBEAN). COBEAN, CNTCORN, and CNTBEAN reduced soil loss by 27-47 per cent, 16-29 per cent, and 12-25 per cent, respectively, as compared to HOCOBE, depending on the size and slope of the plot. In general, conservation tillage reduced soil loss relative to conventional tillage. However, with conservation tillage, greater soil loss was resulted in the single cropping than the intercropping system. In comparison to soybean, the reduction in soil loss for maize ranged from 4% to 9% in case of conservation tillage and single cropping.

2.3 Physico-chemical characteristic of soils

The dominant texture of Kashmir soils ranges from clay loam to silt loam (Handoo, 1983). The texture of apple orchard soils in Himachal Pradesh was reported in the range of sandy loam to clay loam (Sharma and Bhandari, 1992). While, Peer (1994) observed texture of soils of Kashmir as loam to clay loam. Najar (2002) reported that texture of high altitudes Karewa and valley basin of Kashmir valley were found medium to moderately find and moderately fine to fine texture with translocation of clay and its subsequent deposition on lower horizon.

Mahapatra *et al*. (2000) investigated that sub humid soils of Kashmir region vary greatly in texture from loamy Skeletal (mostly on steep slopes) to silt clay loam and clay loam (in plains and karewas). The texture of Pattan Karewa of district Baramulla ranged from loam to clay loam with silt showing decreasing trend and clay increasing trend with depth (Kirmani, 2004).

Jourgholami *et al.* (2020) the effects of plot length (2, 5, 10, 20, 30, and

40 m) and soil texture (clayey and loamy) on runoff and sediment yield were investigated. And reported that as plot length increased (2–40 m), runoff decreased significantly in each soil texture group, while sediment yield increased. In clayey soil the runoff and sediment yield were higher than in the loamy soil texture.

2.3.1 Organic carbon

Khadem and Mermat (2003) detected a varied organic carbon content in the Argids of Iran. The organic carbon content ranged from 0.50 to 11.7 g kg-1 of soils which showed a decreasing trend, with depth of the pedon. The organic carbon content showed a fixed relationship with the slope and altitude of the area, besides the type of vegetation (Sharma *et al.,* 2004). According to Patil and Prasand (2004), organic carbon varied from 33 to 2 g kg-1 with depth, being higher in surface and sub-surface horizons. Also topography, slope and type of vegetation showed a definite relationship. Singh *et al.,* (2006) noticed that organic carbon was higher in surface layers as compared to sub-surface layers.

According to Farida (1997), the organic carbon content of some bench mark soils of Kashmir at different altitudes varied from 0.63 to 1.27 per cent.

Bhat *et al.* (2010) studied the organic carbon content in saffron growing soils of Kashmir was found higher in northern aspect pedons than the southern facing pedons. Also with the increase in soil depth it decreased both in the aspects. The organic carbon content of Dara Micro-watershed in Kashmir varied from 1.01 to 2.93 per cent with higher contents observed in locations facing northern aspect than the locations facing southern aspect (Anjum, 2012).

Chapter-3

MATERIALS AND METHODS

This chapter comprises of the materials used and methodology employed during the course of investigation. The present study entitled **"Estimation of impact of rainfall variability and slope on sediment yield and surface flow in runoff sediment plots"** was carried out at College of Agricultural Engineering and Technology SKUAST-K, Shalimar. The details of field experiment are described in the following section.

3.1 Description of the experimental site

3.2 Selection of sample fields

3.3 Soil erosion data acquisition

3.4 Development of empirical equations

3.1 Description of the experimental site

3.1.1 Study area

The experiment was carried out at SKUAST-K, Shalimar, in the field of Agricultural Engineering and Technology. The experimental site is located at $32^{o}08'30.5''$ North latitude and $74^{o}51'42.0''$ east longitude in the vicinity of the Dal catchment, and the elevation of the catchment is 1586 metres above mean sea level.

3.1.2 Climate

The climate in the Shalimar (District Srinagar) falls in temperate zone and remains moderately hot in the summer to bitterly cold in the winter, the maximum precipitation is received in the form of snow during winter. Sub-zero temperatures are recorded from November to January.

3.1.2.1 Rainfall

The rainfall data of the year 2020 shows that annual rainfall varies from 750 mm to 950 mm. The rainfall data was provided by the department of Agronomy SKUAST-K Shalimar. The rainfall generally breaks in the middle of March through May. April and May month's account for the major share of rainfall. The highest and lowest rainfall was recorded in the month of April and July respectively as shown in Fig 3.1.

3.1.2.2 Temperature

Summer is extremely hot, with July and August being the hottest months, and winter is extremely cold, with sub-zero temperatures reported from November to January, according to comparison of temperature data during the time period considered in this study, i.e., between -5^0C and 35^0C. The mean maximum temperature reaches 24.5^oC in month of July, while the mean minimum temperature reaches minus 2.0^oC in month of January.

3.1.3 Natural vegetation

Naturally grown local grasses and hedges/shrubs make up the scattered vegetation in the study area. Rainfall causes erosion, resulting in the depletion of top soil, and these lands are usually eroded and polluted.

3.2 Selection of sample fields

The study area was divided into three plots based on relative topographic location and slope conditions. Micro runoff plots were installed on the bench terraces as Plot-1, Plot-2, and Plot-3. Following that, sample sites were chosen from these plots based on management and cropping trend homogeneity, slope characteristics, and conservation practices. Slopes in the range of 60-70 per cent were chosen in the region.

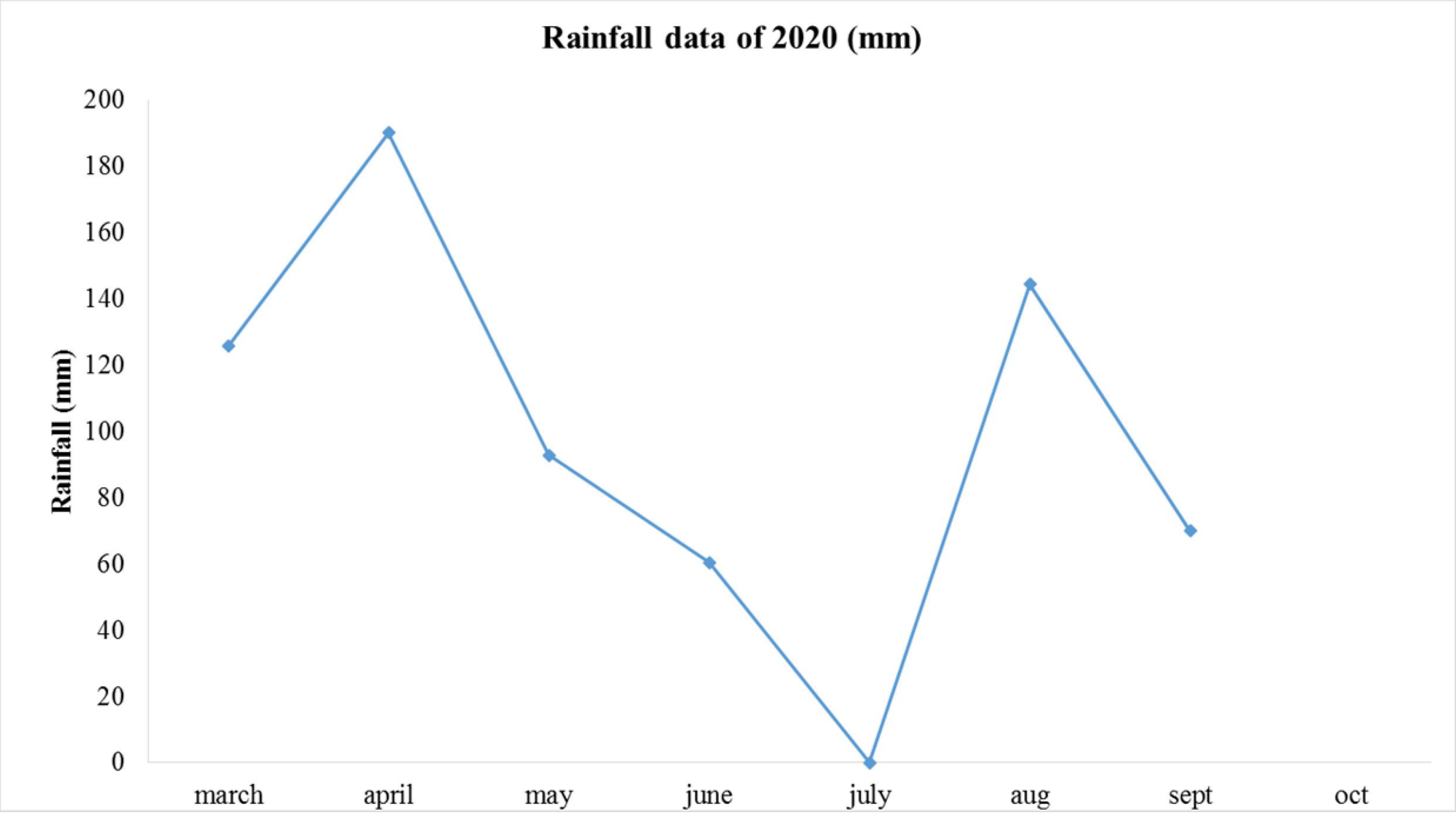


Fig. 3.1: Monthly Rainfall distribution of Shalimar campus in 2020, district Srinagar, Jammu and Kashmir

3.2.1 Preparation of slopes

Three slopes were prepared in between the constructed bench terraces and slope was measured as ratio of rise distance of land and the run.

$$\text{Slope (\%)} = \frac{\text{rise}}{run} \text{ x } 100 \text{ ……. (3.1)}$$

Where,

rise = (elevation of the highest point – elevation of the lowest point)

run = horizontal distance (distance between the points)

The slope of bench terraces were 60%, 65% and 70% respectively.

3.2.2 Experimental setup

The prototype was constructed in the workshop of COAE&T, SKUAST-K, Shalimar. Dimensions of runoff plot to be constructed on the ground surface were demarcated. Runoff plots were installed on three bench terraces with different slopes in the study area. A total of three sediment runoff plots with dimensions of (1.8m ×1.2m) and area of each plot was 3.13m^2, a sheet dimension of (1.2m ×1.8m), and a thickness of 2mm were planned. On both sides of the plots, a 1.21m triangular section was given. Mild steel sheets were buried 0.22m deep around the perimeter of each plot to avoid drainage from neighboring areas. At the base of the plot's outlet, a pit was dug to collect runoff and related sediment in buckets of 20, 20, and 10 litres, which were covered with a shade net. An apron between the pit and the lower end of the plot was designed to allow a smooth flow of water from the plot into the pit, as shown in Fig 3.2.The top, side and front view of constructed runoff plots are shown in Fig 3.3.The photographs showing the set up of runoff plot alongwith conservation measures are shown in plate 3.1 and 3.2 respectively.

3.2.3 Rainfall intensity

The rainfall data of season (March-October) was provided by the

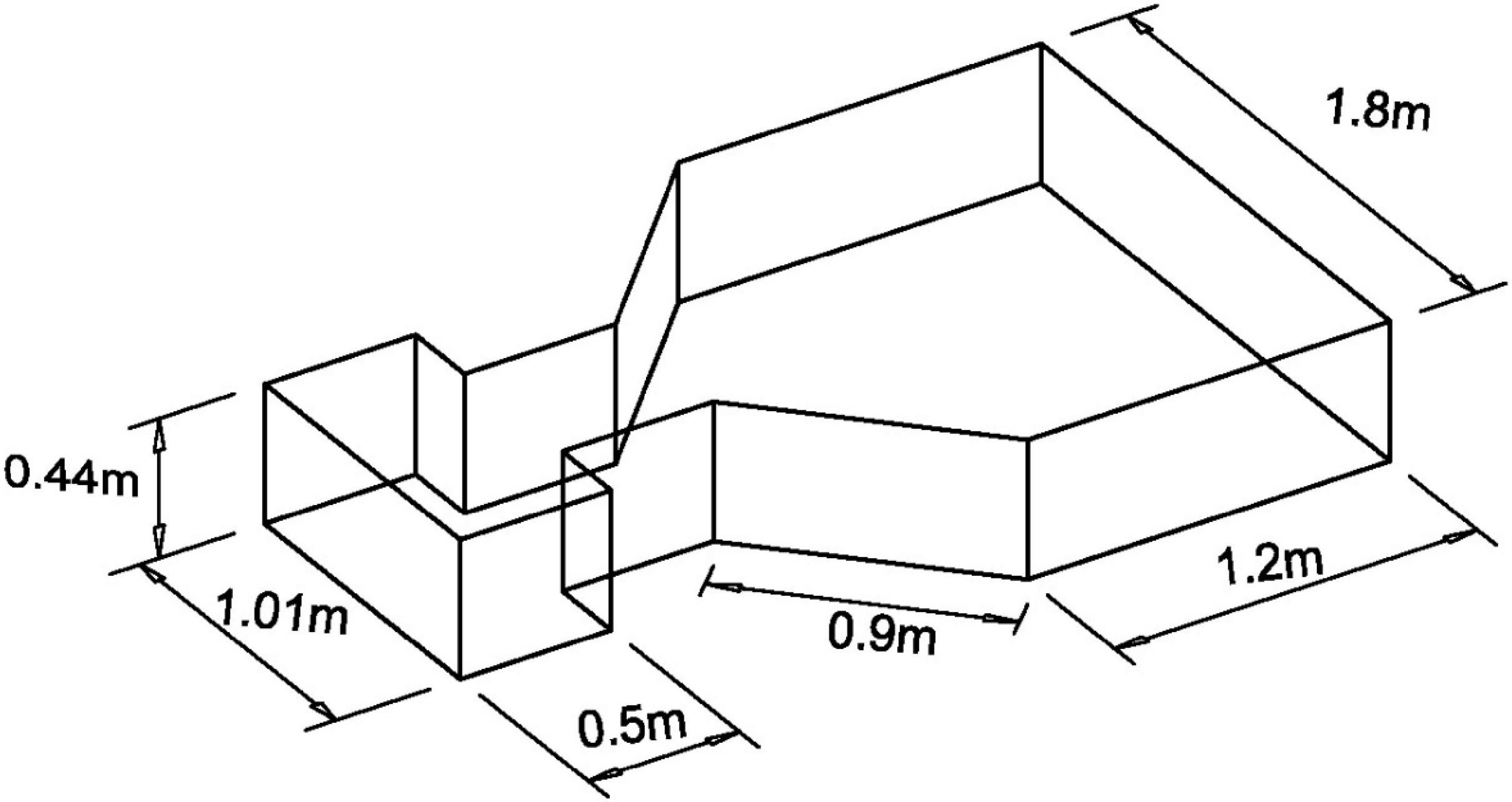


Fig. 3.2: Conceptual view of runoff plot

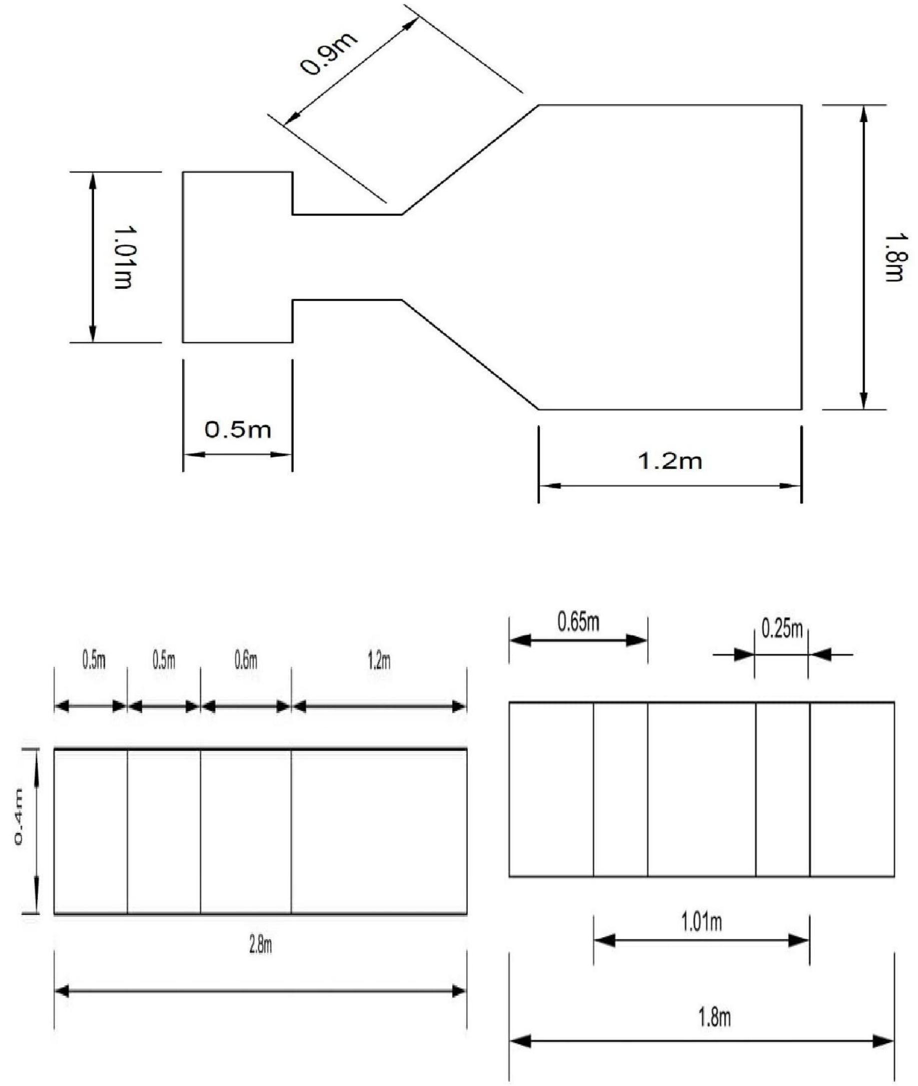


Fig. 3.3: Top, side and front view of runoff plot

Plate 3.1: Sediment ruonff plot at the experimental site

Plate 3.2: Sediment runoff plots during different conservative pratices

Department of Agromet of SKUAST-K Shalimar. Rainfall intensity is the depth of water (in mm) received during a rainfall event divided by the duration of the rainfall event (in hours).

$$R = \frac{P}{T} \qquad \text{….. (3.1)}$$

Where:

R= Rainfall intensity (mm/h)

P= Precipitation (mm)

T =Time (h)

The total rainfall events recorded during the experimental tenure was eighteen and the rainfall intensities are summarized in the given Table (3.1).Rainfall intensities was classified into following categories as,

High intensity (more than 7.5mm/h)

Moderate intensity (2.2-7.5mm/h)

Light intensity (less than 2.2mm/h)

Table 3.1: Rainfall intensities during different rainfall events

Rainfall Event	Bare soil R.I (mm/h)	Rainfall Event	Shade net R.I(mm/h)	Rainfall Event	Mulch cover R.I (mm/h)
1	10.75	7	1.33	13	7.8
2	2.24	8	9	14	7.5
3	6.38	9	7.8	15	1.8
4	5.7	10	6.6	16	1.4
5	2	11	2.2	17	5.8
6	7.7	12	5.1	18	4

R.I = Rainfall intensity mm/h.

3.2.4 Runoff and Sediment Measurement

At the lower end of plot a pit was excavated in which a bucket was used to store the runoff volume and sediment yield data. After the rainfall event, the rainfall water and sediment samples were allowed to settle in a bucket for 24 hours, before the sediment was completely accumulated on the bucket's bottom. The sediment was collected and weighed after the supernatant water was poured out of the sample and measured by the measuring cylinder. To obtain a consistent weight, the sediments were dried in an oven at 105°C for 6–8 hours, and then weighed to determine the dry sediment weight. The sediment samples were taken into the laboratory, to determine the properties of sediment soil.

3.2.4.1 Properties of Sediment soil

Texture determination

`Three sediment samples were taken from runoff plots and texture was determined by hydrometric method which is described below;

- In a conical flask, 50g of sediment soil samples were placed, and 10ml of hydrogen peroxide was added to each flask.
- 50ml of sodium hexametaphosphate and 200ml of distilled water were added to each of them.
- The samples were shaken for a while by hand and kept overnight.
- Next day the samples were shaken on shaker for 4 hours.
- After this, the contents were transfered to 500 ml marked measuring cylinders and volume was made upto 500ml by adding distilled water.
- The samples were again shaken for 1 minute and kept still for 40 seconds.
- Hydrometer/densimeter was dipped in each of the cylinders and first reading was taken and noted.

The procedure for texture determination is shown in Plate 3.3.

Mass of soil in suspension at each time interval was calculated as follows:

$$c_1 = R_1 - R_3$$

$$C_2 = R_2 - R_3$$

$$C_3 = C_1 - C_2$$

Where;

C_1 = mass of silt and clay in suspension at 40 s

C_2 = mass of clay in suspension at 2 hrs

C_3 = silt portion

R_1 = mass of soil suspension at 40 sec

R_2 = mass of soil suspension at 2 hrs

R_3 = mass of soil suspension of blank soln.

$$\text{Clay \%} = C_2 \times 2 \ldots\ldots (3.2)$$

$$\text{Silt \%} = C_3 \times 2 \ldots\ldots (3.3)$$

$$\text{Sand \%} = 100 - (\text{Clay \%} + \text{Silt \%}) \ldots\ldots (3.4)$$

Soil texture class was determined on the basis of percentage of sand, silt and clay using USDA textural classification shown in Fig 3.4.

3.2.5 Determination of organic matter

The soil organic carbon content was determined using the wet oxidation method of Walkley and Black (1934), as revised by Walkley (1935). 1 N $k_2cr_2o_7$ solution oxidises oxidizable matter in soil. When two volumes of H_2SO_4 are mixed with one volume of dichromate, heat is released, which aids the reaction. Ferrous sulphate is used to titrate the remaining dichromate. The sum of C in the soil sample has an inverse relationship with the titre. For the purpose of determining organic matter, nine soil samples were collected from the study field.

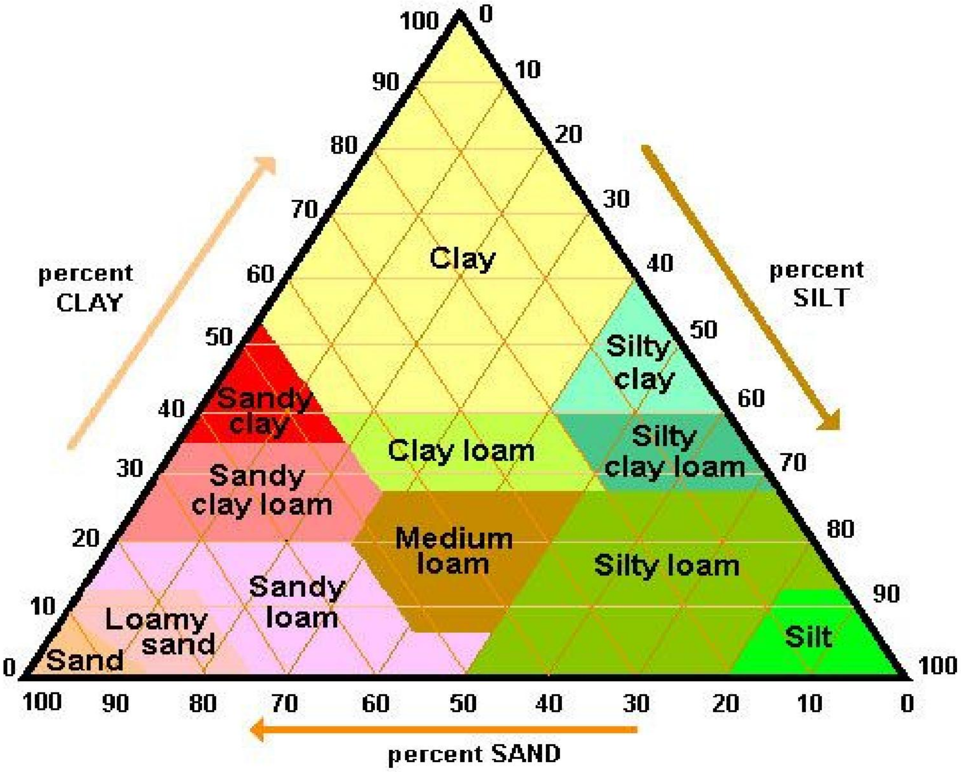


Fig. 3.4: Textural triangle

Plate 3.3: Texture determination

These samples were dried, ground, and sieved before being used. The following approach was used to classify organic matter:

- 2g of each of the each soil samples was weighed and put in 250ml marked conical flasks.
- For each of them, 10 mL potassium dichromate and 20 mL concentrated sulphuric acid were added and left undisturbed for 30 minutes.
- 100 ml distilled water was then added to each of them.
- After then, 10 ml orthophosphuric acid and 10 drops of diphenylamine was added to the flasks.
- Titration was then done with ammonium ferric sulphate until green colour was obtained.
- A blank was also prepared and same procedure was applied to it.

Organic carbon determination is shown in Plate 3.4.

Organic carbon was determined by using the following equation

$$\text{Organic Carbon} = (\text{Blank} - \text{sample}) \times \frac{(0.003 \times 100)}{(2 \times \text{Weight of sample})} \quad \ldots. (3.5)$$

Correction Factor was taken as 1.3

Therefore, total organic carbon = OC x 1.3 ….. (3.6)

Subsequently organic matter was calculated from organic carbon by following formula:

Organic matter = organic carbon× 1.724 …. (3.7)

Where, 1.724 = Van Bemmelen factor

Plate 3.4: Organic carbon determination

3.3 Soil erosion data acquisition

3.3.1 Estimation of soil loss using USLE

To measure soil loss, the Universal Soil Loss Equation (USLE) was used (Wischmeire and Smith 1978). Soil loss is a function of six different variables, according to the USLE, as shown in the equation below. The following are the data preparations for input into the equation:

$$A = R \times K \times L \times S \times C \times P \quad (3.8)$$

Where;

A= Computed annual soil loss rate (tons ha-1 year-1)

R= Rainfall erosivity factor (MJ.mm/ha.h.yr)

K= Soil erodibility factor (tons.ha.h/MJ.mm)

L= Slope length factor (dimensionless)

S= Slope gradient factor (dimensionless)

C= Cover types factor (dimensionless)

P= Land management and conservation practice factors (dimensionless)

3.3.2 Calculating the USLE factor values

3.3.2.1 Rainfall Erosivity Factor (R):

The R factor is a climatic factor that determines how much rain erodes the land. It is the long-term annual average of the product of the maximum rainfall intensity in 30 minutes in mm per and the event rainfall kinetic energy in MJha-1. The EI parameter measures the influence of raindrops on the environment and represents the volume and rate of runoff that is likely to occur as a result of the rain. The R-factor was calculated using (Singh *et al.,* 1981) equation, which is

$$\text{R-factor} = 79 + 0.363R \qquad \ldots (3.9)$$

Where, R is the average annual rainfall in mm.

The rainfall data was provided by the Department of Agronomy, SKUAST-K, and Shalimar.

3.3.2.2 Soil Erodibility Factor (K)

The soil erodibility factor (K) assesses a soil's erosion potential as well as the rate and volume of runoff. The texture, organic matter, structure, and permeability of a soil decide its erodibility (Efe and Ciirebal, 2008). The K-factor indicates how quickly the soil is detached by splash during rainfall and/or surface flow, and thus shows the change in the soil per unit of applied external force of energy (Dumas and Printemps, 2010). This factor is related to the integrated effect of rainfall, runoff, and infiltration and accounts for the influence of soil properties on soil loss during storm events on sloping areas (Lu *et al.,* 2004).The soil erodibility factor is a measure of a given soil's inherent erodibility under the standard condition of the unit USLE plot, which is kept fallow and tilled, (t-ha-h/ha-MJ-mm) is the unit of measurement.

Renard 1997, used Wischmeier and Smith's 1978 equation to calculate the K-factor. It goes like this:

$$K = \frac{(2.1\times10^{-4}) \times (12\text{-OM}) \times M^{1.14} + 3.25(S-2) + 2.5 \times (P-3)}{100} \quad \ldots. (3.10)$$

Where,

OM = Per cent of organic matter,

S = Soil structure class (1-4),

P = Soil permeability class (1-6),

M = (% silt + % very fine sand) × (100- % clay)

The texture of the soil affects the structure and permeability of the soil. Texture determination has already been debated. The USDA-proposed codes were used to assess the soil structure (1972). Table 3.2 contains these codes.

Table 3.2: Soil structure code

Codes	Structure	Size (mm)
1	Very Fine Granular	<1
2	Fine Granular	1-2
3	Medium/Coarse Granular	2-10
4	Blocky, Platy or Massive	>10

The Soil permeability depends upon the soil texture. The permeability codes for various textures proposed by USDA are summarized in Table 3.3.

Table 3.3: Soil permeability code

Texture Type	Permeability Code	Remarks
Clay, Silt clay	6	Very slow
Silt clay loam, Sand clay	5	Slow
Sandy clay loam, Clay loam	4	Slow to Moderate
Silt, Silty loam, Loam	3	Moderate
Loam sand, Sandy loam	2	Moderate to Rapid
Sand	1	Rapid

K-factor values for the soil samples were then calculated.

3.3.2.3 Topographic Factor (LS)

The ratio of soil loss from an area with specified cover and management to that from a 9% slope under equal conditions is known as the slope steepness (S) factor. The ratio of soil loss from a field slope length to that from a standard plot length (22.13 m) under equal conditions is known as the slope length (L) factor. For various lengths and degrees of slope, combined LS factor values have been complied (Smith *et al*., 1962).

$$LS = \frac{\sqrt{L}}{100}(0.75 + 0.53S + 0.75S^2) \quad \text{…. (3.11)}$$

Where,

L = slope length, m

S = land slope, (%)

3.3.2.4 Cover and Management Factor (C)

The crop cover and management factor (C) is the ratio of soil loss in an area with defined cover and management to that in a tilled continuous fallow area. It is the combined effect of cover, cropping sequence, productivity level, and length of growing season, tillage practices, residue management, and the expected time distribution of erosive rainstorms on seeding and harvesting dates in the locality. The values of the cover and management activities were calculated using Wishmeier and Smith's criteria (1978). In this scheme, c values are linked to land usage, canopy, and cover conditions, and different c values are used for different land uses. The c factor has a range of values from 0.04 to 1.00.The value of C-Factor was taken from the Table3.4 provided by Soil and Water Conservation Society, 2003.

Table 3.4: C-Factor values

LU/LC	C-Factor
Agriculture land	0.5
Barren land	0.6
Mixed plantation	0.02
Orchards	0.1
Scrub	0.05
Settlement	0.0
Vegetable fields	0.3
Water bodies	0.0
Wetlands	1.0

3.3.2.5 Conservation Practice Factor (P)

P-factor is the ratio of soil loss with specific practice to the corresponding loss with up and down slope tillage (Renard, 1997).These practices consistently affect erosion by altering the flow pattern, gradient, or direction of surface runoff and by reducing the amount and rate of runoff. The values of practice factor have been calculated by various workers and compiled by (Singh *et al.,* 1981) and Wischmeier and Smith (1978).

The P-factor was determined using the land use/cover of the region. Table 3.5 shows the importance of the practice factor according to the vegetation classification, as given by the Soil and Water Conservation Society in 2003.

Table 3.5: P-Factor values

LU/LC	P-Factor
Agriculture land	0.5
Barren land	1.0
Mixed plantation	0.8
Orchards	0.5
Scrub	1.0
Settlement	0.0
Vegetable fields	0.4
Water bodies	0.0
Wetlands	1.0

3.4 Development of empirical equations

To develop the empirical equations Statistical analysis software (R-software) was used to analyse the runoff and sediment relationship of typical rainfall events. The results was based on statistical criteria such as Coefficient of determination (R^2).

3.4.1 Coefficient of determination

The coefficient of determination (R^2) describes the degree of association between the observed and predicted values by fitting a regression line. R^2 ranges from 0-1, with the higher values indicating less error variance, and typically values greater than 0.5 are considered acceptable (Van-Liew *et al.,* 2003). The value of 1 indicates that the computed values are in perfect agreement with the observed data.

Chapter-4

EXPERIMENTAL FINDINGS

The analysis of the results obtained in the experimental trails is essential to derive a conclusive strategy. The data on various observations obtained during the investigation were subjected to descriptive statistical analysis in order to find out the significance of different treatments by using the analysis of variance technique. This chapter addresses the comparative analogy obtained after imitating the methodological setup discussed in the previous chapter. The experimental findings are presented through tables and illustrated graphically as follows:

4.1 Estimation of sediment yield and surface runoff within three Plots having different slopes.

4.2 Physico-chemical characteristics of sediment yield.

4.3 Development of empirical equations for soil loss and runoff.

4.4 Soil loss assessment using USLE.

4.5 Comparison of observed soil loss with USLE

4.1 Estimation of sediment yield and surface runoff within three Plots having different slopes

The effect of slope and rainfall intensity on sediment yield and surface runoff for three runoff plots is presented in Table 4.1. A review of the data shows that Plot-1, which had a 70% slope, had an average sediment yield of (216.0 g/m^2).While as, Plot-3 with 65% slope had a sediment yield variation with a mean value of (211.75g/m^2). Similarly Plot-2 with 60% slope had sediment yield with a mean value of (174.86g/m^2).In general, decreasing slope and rainfall intensities resulted in a steady reduction in sediment yield.

The results show that the effect of slope on the runoff varied with the rainfall intensity as presented in Table 4.2 and Fig 4.1. The data reveals that Plot-1 with 70% slope had surface runoff with a mean value of (6.54litres).while as, Plot-3 with 65% slope had runoff volume with a mean value of (5.41litres) and Plot-2 with 60% had runoff with a mean value of (4.41litres). Surface runoff showed distinct variation in each of the three plots, with higher mean values in Plot-1 and Plot-2.The sediment yield and runoff was estimated in six rainfall events and the rainfall intensities were 10.75, 2.24, 6.38, 5.7, 2.0 and7.7 mm/h. Different plots are shown in plate 4.1.

Table 4.1: Sediment yield (gm) from three plots with different slopes having bare soil surface at ($P \leq 0.05$) level of significance

Plot No.	Slope (%)	Mean± S.D (sediment)	Std. error	Min.	Max.
Plot-1	70	**261.38 ± 178.10**	72.71	72.71	524.60
Plot-2	60	**174.86 ± 115.86**	47.30	47.30	357.00
Plot-3	65	**211.75 ± 92.86**	37.91	37.91	363.02
Total		**216.00 ± 130.94**	**30.8635**	**72.71**	**524.60**

Table 4.2: Surface runoff (litre) from three plots with different slopes having bare soil surface at ($P \leq 0.05$) level of significance

Plot No.	Slope (%)	Mean ± S.D (runoff)	Std error	Min.	Max.
Plot -1	70	**6.54 ± 1.48**	0.60	4.80	9.00
Plot-2	60	**4.41 ± 1.55**	0.63	2.00	6.51
Plot-3	65	**5.41 ± 1.60**	0.65	3.50	8.00
Total		**5.45 ± 1.70**	**0.40**	**2.00**	**9.00**

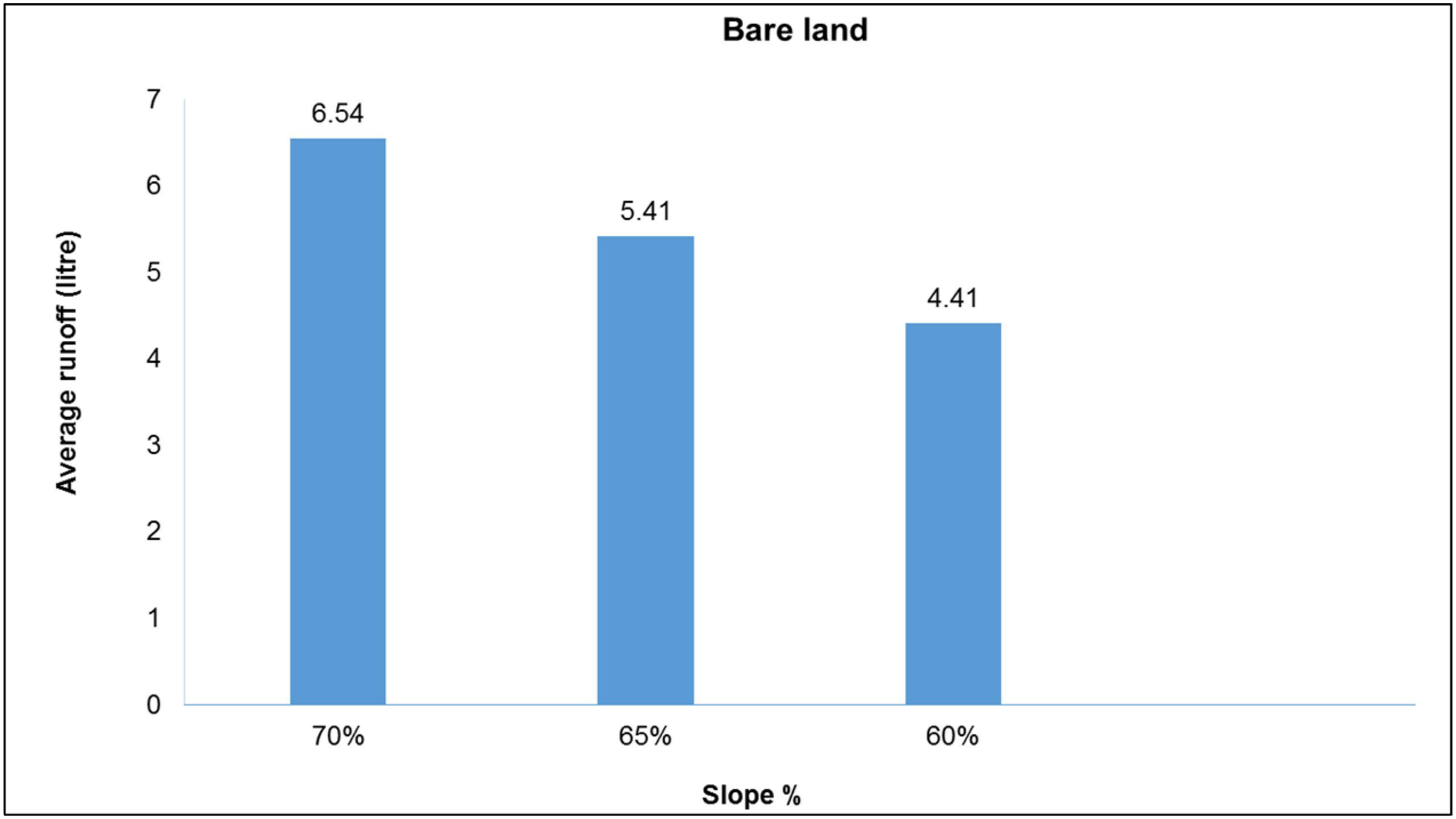


Fig. 4.1: Estimation of surface runoff (litre) under different slopes for bare soil surface

Plate 4.1: Pictoral representation of plots

4.1.1 Effect of shade net on the sediment yield and surface runoff under different slopes

Based on the data in Table 4.3 sediment yield was found to be (49.02 g/m^2), (42.64g/m^2), (39.35g/m^2) for Plot-1, Plot-3 and Plot-2 respectively. Plot-1 with 70% slope had the highest mean value of usable sediment yield, followed by Plot-3 and Plot-2 with 65%, 60% respectively. However, the effect of slope steepness was more obvious on bare soil surface than shade net covered soil.

The data pertaining to the surface runoff showed that the average value of surface runoff was (3.27), (2.94), (2.55) litres for the Plot-1, Plot-3 and Plot-2 respectively. An overall decrease in runoff was noticed while moving from slope 70% to 60% as shown in Table 4.4 and Fig 4.2. Runoff decreases significantly as rainfall intensity decreased for both the bare soil surface and shade net covered soil. During shade net there were six rainfall events with the different rainfall intensities 1.33, 9, 6.6, 2.2, 5.1, and 4.5 mm/h.

Table 4.3: Effect of shade net cover on sediment yield within three plots with different slope at ($P \leq 0.05$) level of significance

Plot No.	Slope (%)	Mean ± S.D (sediment)	Std. error	Min.	Max.
Plot -1	70	**49.02 ± 9.82**	3.71	40.00	65.30
Plot-2	60	**39.35 ± 11.76**	4.44	25.00	55.00
Plot-3	65	**42.64 ± 12.37**	4.67	27.50	60.00
Total		**43.67 ± 11.54**	**2.51**	**25.00**	**65.30**

Table 4.4: Effect of shade net cover on surface runoff (litres) within three plots having different slopes at ($P \leq 0.05$) level of significance

Plot No.	Slope (%)	Mean± S.D(runoff)	Std. error	Min.	Max.
Plot -1	70	**3.27 ± 0.85**	0.32	2.40	4.80
Plot-2	60	**2.55 ± 0.81**	0.30	1.00	3.50
Plot-3	65	**2.94 ± 0.06**	0.24	2.00	4.00
Total		**2.9238±0.79**	**0.17**	**1.00**	**4.80**

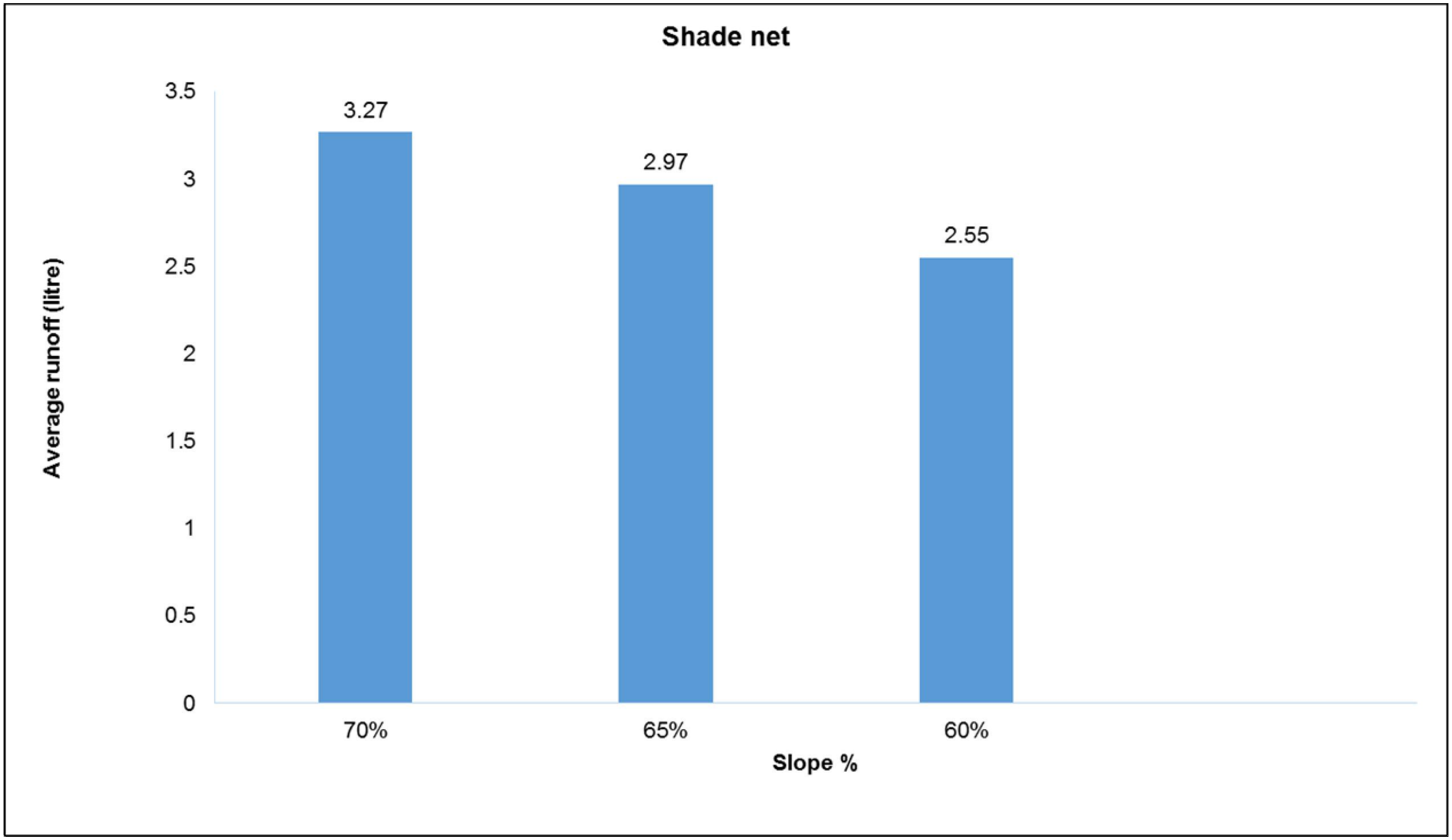


Fig. 4.2: Estimation of Surface runoff (litre) under different slopes for shade net covered soil

4.1.2 Effect of mulch on sediment yield and surface runoff within the three plots under different slopes

Perusal of data Table 4.5 showed that mulch cover was more effective in reducing soil loss at 60% slope than at 70%.The highest sediment yield was (2.60g/m^2) in Plot-1 with 70% slope and the lowest sediment yield (1.95g/m^2) was observed in Plot-2 with 60% slope. The sediment varied considerably from bare surface soil, followed by shade net covered soil in the three plots. In mulch covered soil, rainfall intensities were 7.8, 7.5, 1.8, 1.4, 5.8 and 4 mm/h. with six rainfall events.

The surface runoff varied with the mean values of 2.80, 2.18 and 2.61, (litres) as shown in Table 4.6 of Plot-1, Plot-2 and Plot-3 respectively. No distinct variation could be seen in the mean value of runoff between the Plots as shown in Fig 4.3.

Table 4.5: **Effect of mulch cover on sediment yield (gm) from three Plots having different slopes at ($P \leq 0.05$) level of significance**

Plot No.	Slope (%)	Mean±S.D (sediment)	Std. error	Min.	Max.
Plot -1	70	**2.60 ± 2.08**	0.85	0.23	5.50
Plot-2	60	**1.95 ± 1.36**	0.55	0.14	3.50
Plot-3	65	**1.98 ± 1.30**	0.53	0.22	3.30
Total		**2.18 ± 1.55**	**0.36**	**0.14**	**5.50**

Table 4.6: **Effect of mulch cover on surface runoff (litre) from three plots having different slopes using at ($P \leq 0.05$) level of significance**

Plot No.	Slope (%)	Mean±S.D (runoff)	Std. error	Min.	Max.
Plot -1	70	**2.80±1.36**	0.55	0.50	4.00
Plot-2	60	**2.18±1.46**	0.59	0.80	4.50
Plot-3	65	**2.61±1.42**	0.58	1.30	4.80
Total		**2.53±1.36**	**0.32**	**0.50**	**4.80**

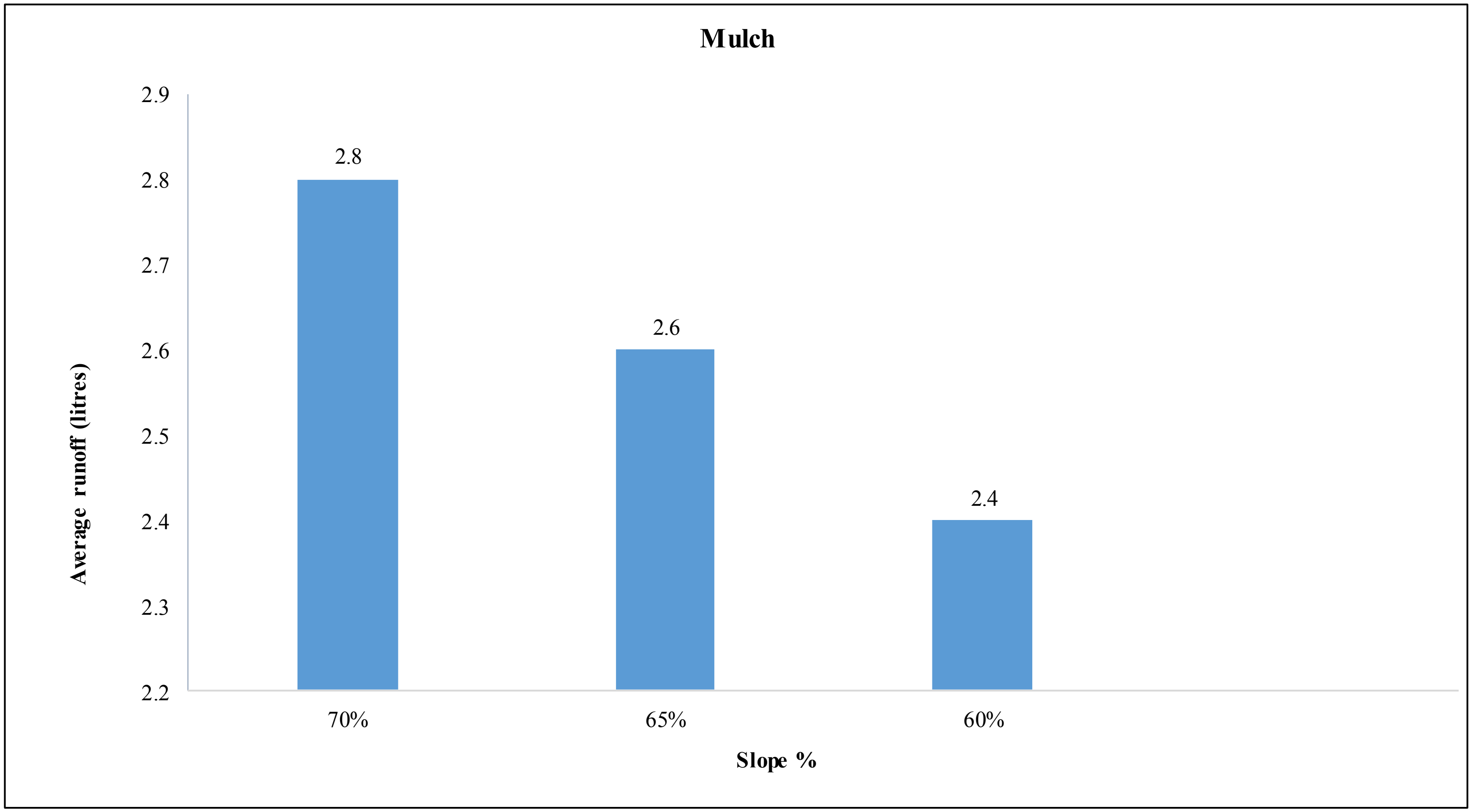


Fig. 4.3: Estimation of Surface runoff (litre) under different land slopes for mulch covered soil

4.2 Physico-chemical characteristics of sediment yield

Nine soil samples were taken from three plots with different slopes from the field of COAE&T at SKUAST-K and the results are as follows:

4.2.1 Particle size distribution

The data pertaining to the particle size as presented in Table 4.7 shows that textural class for three runoff Plots was silt clay loam soil texture although a difference in the relative percentages of sand, silt and clay was observed. Plot-1, which had a 70 per cent slope had 20% sand, 5% fine sand, 50% silt, and 30% clay material. Plot-2, on the other hand with values ranging from 24% sand, 9% fine sand, 44% silt, and 32% clay. Plot-3, with 65 per cent slope had values of sand 14%, fine sand 2.5%, 50% silt, and 36% clay content. In general the clay content gradually increases down the slope.

Table 4.7: Particle size distribution of sediment in the three sediment runoff plots

Plot No.	Sand (%)	Silt (%)	Clay (%)	Fine sand (%)	$\bar{X}$±S.D	Textural class
Plot-1	20	50	30	5	**26.25±18.8**	Silt clay loam
Plot-2	24	44	32	9	**27.25±14.6**	Silt clay loam
Plot -3	14	50	36	2.5	**25.62±21.3**	Silt clay loam

4.2.2 Organic carbon

The organic carbon content of surface soils for Plot-1 varied from 0.67 to 1.01%, and for Plot- 2, 0.82 to 1.26 % and 0.64 to 1.09% for Plot-3 with mean values of 0.98%, 1.0% and 0.87% in the Plot-1, Plot-2 and Plot-3, respectively as shown in Table 4.8. The content of organic carbon varied in three plots, although not considerably, with higher mean values recorded in Plot -2 and Plot-1.

4.2.3 Organic matter

The organic matter content of the surface soil ranged from 1.5 to 2.24 per cent, 1.5 to 2.5 per cent, and 1.44 to 2.4 per cent, with mean values of 1.83, 1.93, and 1.76 per cent in Plot-1, Plot-2, and Plot-3, respectively as presented in Table 4.8. Organic matter content differed slightly across the three plots, with higher mean values observed in Plot-2 and Plot-1.

Table 4.8: Percentage of organic carbon and organic matter

Plot No.	S.O.C (%)			Mean	T.O.C (%)	O.M (%)			Mean
Plot 1	0.67	1.01	0.87	**0.98**	1.31	1.5	2.2	1.8	**1.83**
Plot 2	0.99	1.26	0.82	**1.0**	1.46	1.5	2.5	1.9	**1.93**
Plot 3	0.64	1.09	0.88	**0.87**	1.4	1.4	2.4	1.5	**1.76**

4.3 Development of Empirical equations for soil loss and surface runoff for bare soil surface

Regression equations were used to observe the relative contribution of slope steepness, rainfall intensity on sediment yield and runoff on bare soil surface Table 4.9 and Fig 4.4 and 4.5.The results showed that slope and rainfall intensity had greater influence in explaining variations in sediment and runoff.The two factors described 69% to 100% variation in sediment but 79% to 99% of the variation in runoff. The goodness-of-fit was found in Plot-1, with a slope of 70 per cent for soil loss and rainfall intensity with R^2 equal to 1. Similarly, Plot-3 had the best match for runoff and rainfall intensity, with a slope of 65 per cent and R^2 equal to 0.99.

Table 4.9: Empirical equations developed for sediment and runoff for bare soil surface

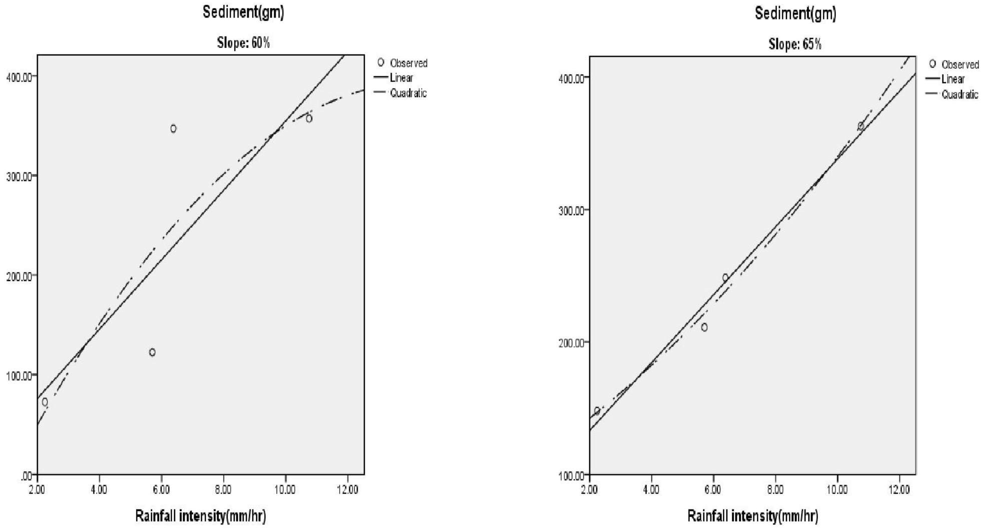
Plot No.	Slope (%)	Sediment (gm)	Runoff(litre)
Plot-1	70	$E=222.6-68.4I+10.2I^2$ $(R^2=1.00)$	$Q=5.41+0.15I+0.01I^2$ $(R^2=0.76)$
Plot-2	60	$E=69.72+64.12I-2.21I^2$ $(R^2=0.69)$	$Q=0.14+1.08I-0.03I^2$ $(R^2=0.96)$
Plot-3	65	$E=108.6+15.37I+0.77I^2$ $(R^2=0.99)$	$Q=2.36+0.47I+0.01I^2$ $(R^2=0.99)$

Where

E = Soil loss (g/m^2)

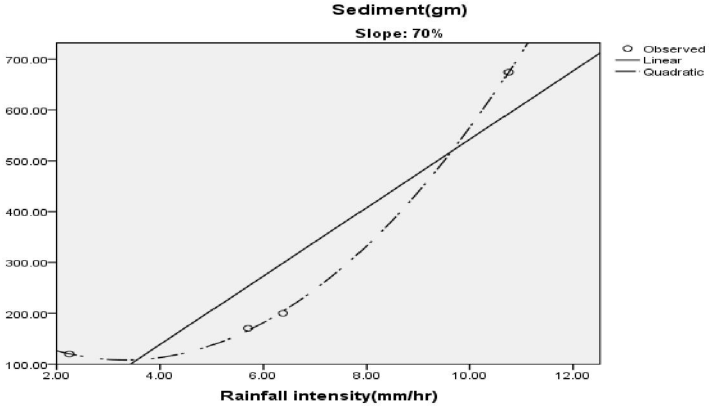
I = Rainfall intensity (mm/h)

R^2 = Coefficient of determination



$E = 69.72 + 64.12I - 2.21I^2$ ($R^2 = 0.697$) $E = 108.6 + 15.37I + 0.77I^2$ ($R^2 = 0.991$)

(a) (b)



$E = 222.6 - 68.4I + 10.2I^2$ ($R^2 = 1.000$)

(c)

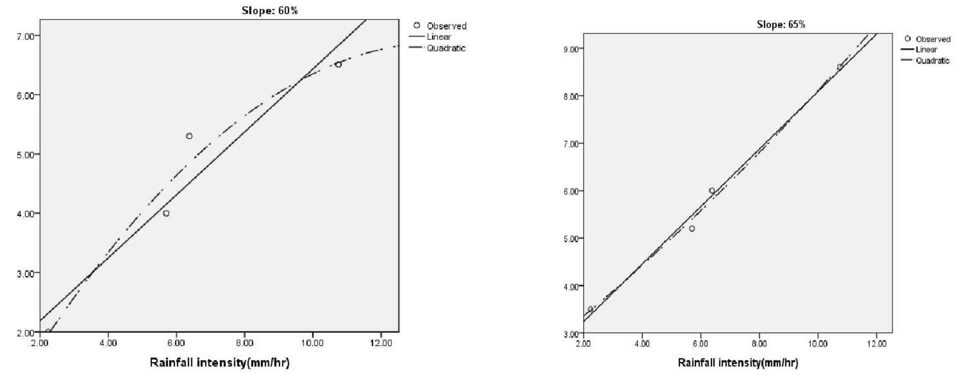
Where:

E = soil loss (dependent variable) g/m^2

I = rainfall intensity (independent variable) mm/h

R^2 = coefficient of determination

Fig 4.4: Impact of rainfall intensity and slope on sediment load for bare soil surface



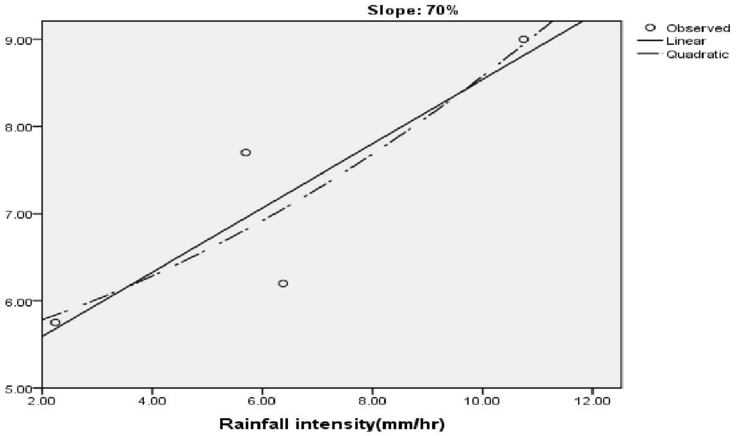
Q

$= 0.14 + 1.08I - 0.03I^2$ ($R^2=0.96$)

$Q = 2.36+0.47I + 0.01I^2$ ($R^2=0.99$)

(a)

(b)



$Q = 5.41+0.15I + 0.01I^2$ ($R^2=0.76$)

(c)

Where:

Q = Runoff (dependent variable) litre

I = Rainfall intensity (independent variable) mm/h

R^2= Coefficient of determination

Fig 4.5: Effect of rainfall intensity and slope on runoff for bare soil surface

4.3.1 Emprical equations developed using shade net cover on soil surface

Linear qudaratic equations were prepared for three runoff plots for relating the imapct of rainfall intensity and slope on sediment and runoff during shade net cover.The rainfall intensity and slope contribution was lower to sediment and runoff than in bare soil surface as presented in Table 4.10, Fig 4.6 and 4.7.The results showed that the two factors explained 69-95% variation in sediment and 57-96% variation in runoff in the sediment runoff plots. Data presented revealed that during the shade net cover, Plot-1 of 70 per cent slope had the best fit of regression for soil loss and rainfall intensity, with R^2 equal to 0.95.

Similarl Plot-2, with a 60 per cent slope and R^2 equal to 0.96, was found to be the resilient relation for runoff and rainfall intensity. In the three plots, the runoff showed distinct variations.

Table 4.10: Empirical equations developed for sediment and runoff using shade net cover on soil

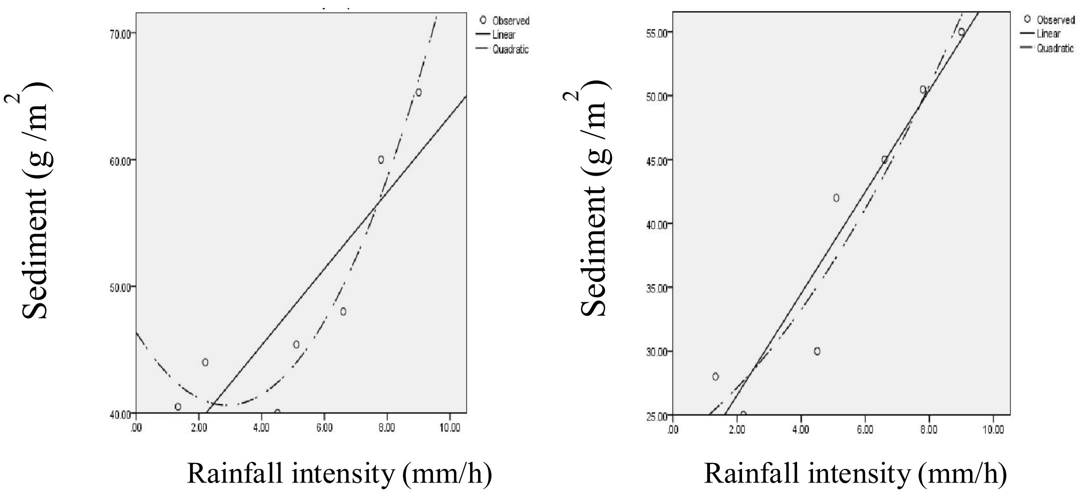
Plot No.	Slope (%)	Sediment(gm)	Runoff (litre)
Plot-1	70	$E = 25.15+1.75I + 0.24I^2$ $(R^2=0.95)$	$Q = 1.56+ 0.44I- 0.02I^2$ $(R^2= 0.57)$
Plot-2	60	$E = 46.3- 3.97I +0.68I^2$ $(R^2=0.69)$	$Q = 2.63- 0.166I +0.044I^2$ $(R^2=0.96)$
Plot-3	65	$E = 22.7+1.74I + 0.22I^2$ $(R^2=0.92)$	$Q = 0.33 +0.75I -0.05I^2$ $(R^2= 0.85)$

E= Soil loss (g/m^2),

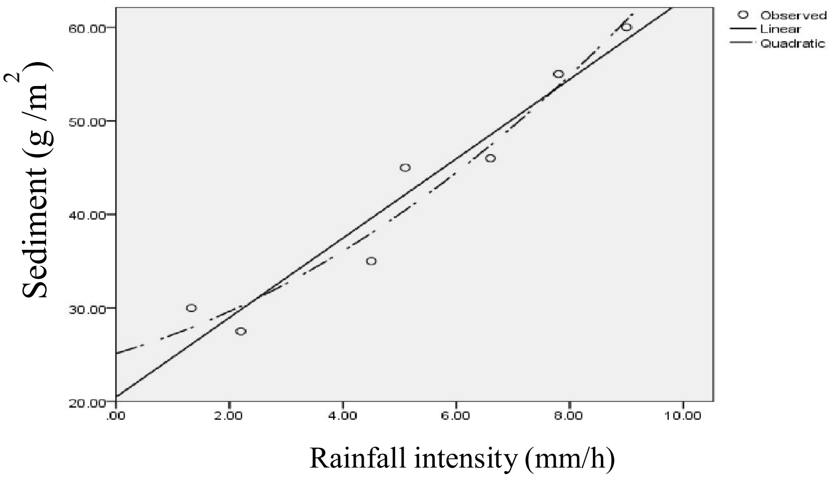
I=Rainfall intensity (mm/h),

R^2 =Coefficient of determination

Slope: 60% Slope: 65 %



$E = 46.3 - 3.97I + 0.68I^2$ (R^2=0.697) $E = 22.7+1.74I + 0.22I^2$ (R^2=0.923)



$E = 25.15+1.75I + 0.24I^2$ (R^2=0.951)

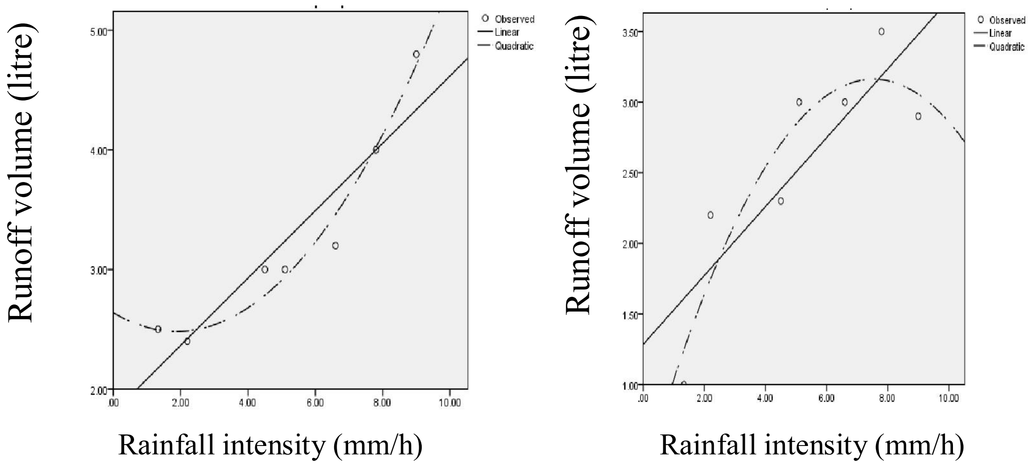
(c)

E = Soil loss (g/m^2)

I = Rainfall intensity (mm/h)

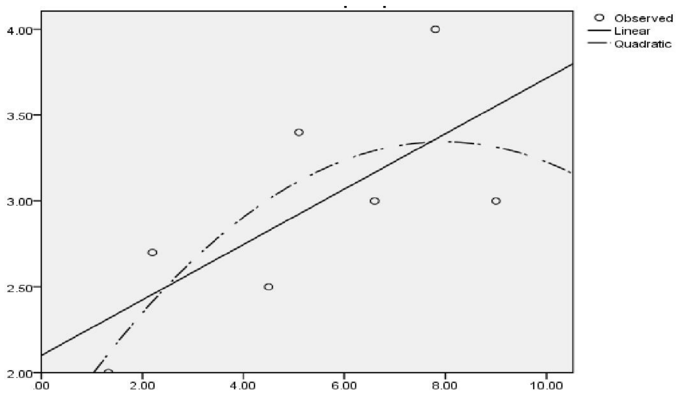
R^2 =Coefficient of determination

Fig. 4.6: **Using a shade net, determine the impact of rainfall intensity and slope on sediment**



$Q = 2.63- 0.166I +0.044$ (R^2=0.969) $Q = 0.33 +0.75I -0.05I^2$ (R^2= 0.850)

(a) (b)



$Q = 1.56+ 0.44I- 0.02I^2$ (R^2= 0.576)

Where:

Q = Runoff (dependent variable) litre

I = Rainfall intensity (independent variable) mm/h

R^2= Coefficient of determination

Fig. 4.7: **Using a shade net, investigate the effects of rainfall intensity and slope on runoff**

4.3.2 Emprical equations using mulch cover on soil surface

It can be observed that variation in the sediment varies from 95% to 97% and 98%-98% in runoff within the three plots shown in Table 4.11, Fig 4.8 and 4.9.The best fit of regression for soil loss and rainfall intensity during mulch cover was found for Plot-1 of 70 per cent slope with R^2 equal to 0.97. In the three plots, the sediment yield does not differ significantly from one another.It also revealed that there was no discernible difference between the plots in terms of runoff and rainfall intensity. With R^2 equal to 0.98, all three equations complement the data equally well.

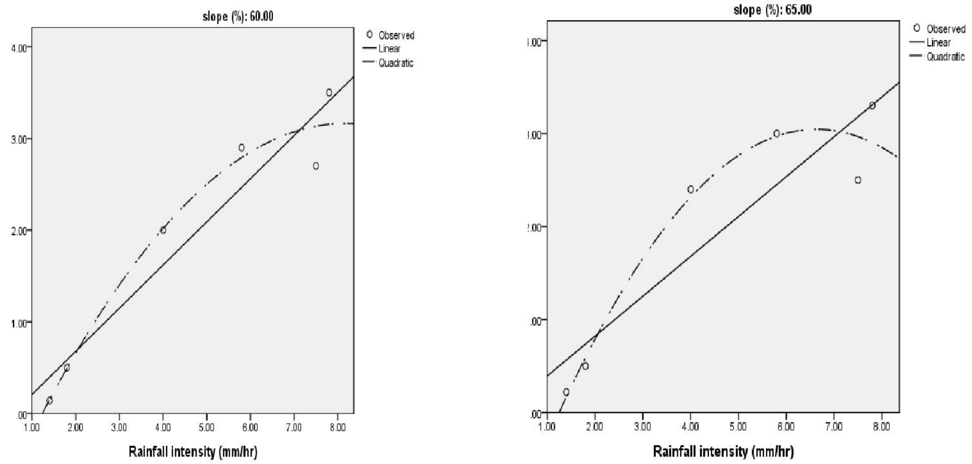
Table 4.11: Empirical equations developed for sediment and runoff using mulch cover on soil

Plot No.	Slope (%)	Sediment (gm)	Runoff (litre)
Plot-1	70	$E = 0.32 + 0.38I + 0.03I^2$ $(R^2=0.97)$	$Q = 0.32 + 0.21I + 0.03I^2$ $(R^2=0.98)$
Plot-2	60	$E = 1.22 + 1.07I - 0.06I^2$ $(R^2=0.96)$	$Q = 0.67 + 0.19I + 0.03I^2$ $(R^2=0.98)$
Plot-3	65	$E = 1.5 + 1.3I - 0.10I^2$ $(R^2=0.95)$	$Q = 1.28 - 0.02I + 0.05I^2$ $(R^2=0.98)$

Where

E= Soil loss (g/m^2)

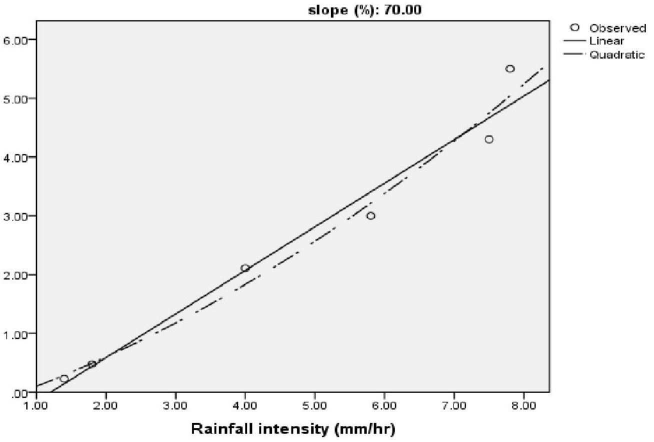
I=Rainfall intensity (mm/h)



E

= 1.22+1.07I - 0.06I^2 (R^2=0.96) E =1.5 +1.3I -0.10I^2 (R^2=0.95)

(a) (b)



E = 0.32 + 0.38I + 0.03I^2 (R^2=0.97)

(c)

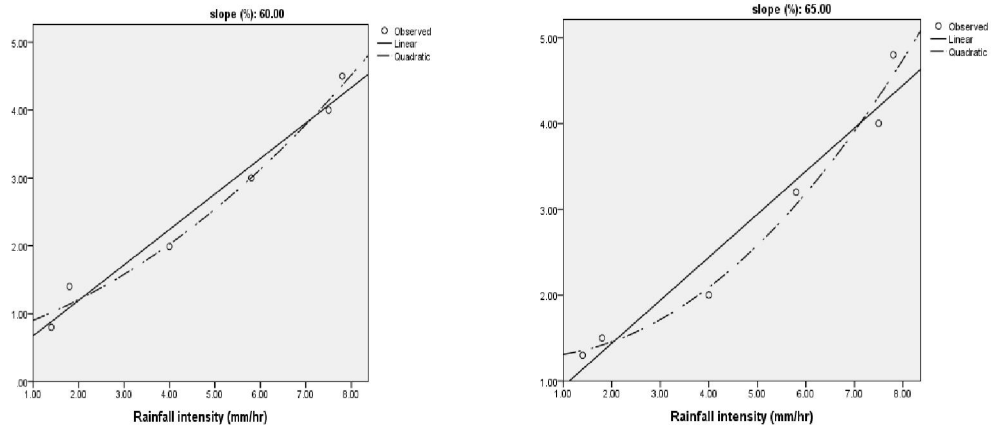
Where:

E = Soil loss (dependent variable) g/m^2

I = Rainfall intensity (independent variable) mm/hr

R^2= Coefficient of determination

Fig 4.8: Effect of rainfall intensity and slope on sediment using mulch cover on soil

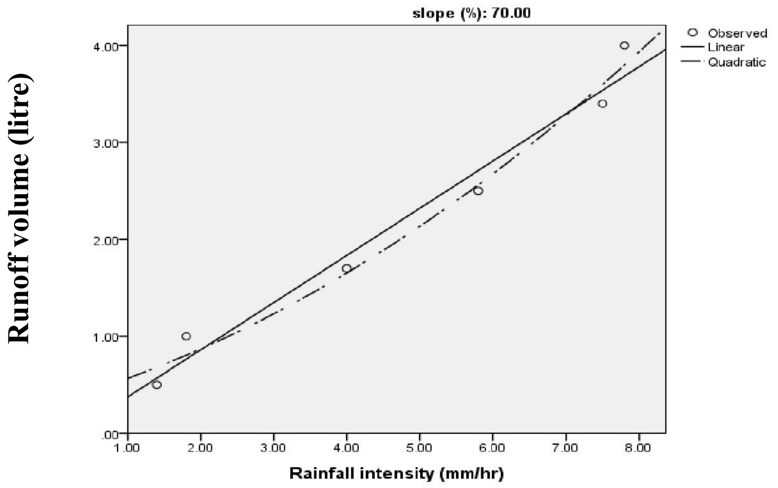


$Q = 0.67 + 0.19I + 0.03I^2$ ($R^2=0.98$)

(a)

$Q = 1.28 - 0.02I + 0.05I^2$ ($R^2=0.98$)

(b)



$Q = 0.32 + 0.21I + 0.03I^2$ ($R^2=0.98$)

(c)

Where:

Q = Runoff (dependent variable) litre

I = Rainfall intensity (independent variable) mm/h

R^2= Coefficient of determination

Fig. 4.9: Effect of rainfall intensity and slope on runoff using mulch cover on soil

4.4 Soil loss assessment using USLE equation

The universal soil loss equation was used to compute the soil loss in different plots making use of the standard parameters used in the soil loss equation. The computation of various USLE factors was used to quantify the soil loss in the plots. The annual soil loss values in the three plots and the factors involved are tabulated in Table 4.12.

Table 4.12: Soil loss by using USLE technique

Plot No	R-factor (MJ.mm/ha.h.yr)	K-factor (tons.ha.h/ mj.mm)	Topographic factor(LS)	C-factor	P-factor	Soil loss (Tons/ha/yr)
Plot 1	100.5	0.36	6.03	0.5	0.4	39.7
Plot 2	100.5	0.31	7.04	0.5	0.4	44.8
Plot 3	100.5	0.30	5.2	0.5	0.4	32.4

4.5 Comparison of observed soil loss with universal soil loss equation

Soil loss from USLE was compared to the observed sediment yield for Plots with different slopes and conservation measures for reducing soil erosion. Plot-1 having 70% slope with bare land had maximum sediment yield (3763.9 g/m^2/yr.) as compared to the results obtained from USLE equation (3610.41g/m^2/yr.). The effect of Shade net cover on sediment yield was observed to be (2059.2g/m^2/yr.).The sediment yield in mulch cover was (187.44 g/m^2/yr.) in a similar way. The sediment content varied between the three activities, with bare land having the highest content, followed by shade net and mulch cover. Due to less LS factor the sediment yield in USLE was less than the observed sediment yield as shown in Fig.4.10.

Similarly soil loss by USLE was compared with the perceived soil loss for Plot-2. The data indicated that soil loss by USLE was (4000g/m^2/yr.).While as, soil loss was (2518 g/m^2/yr.), (1653 g/m^2/yr.) and (140.88g/m^2/yr.) for bare land, shade net and mulch cover respectively as shown in Fig.4.11. Highest soil loss was noticed in USLE and lowest was in mulch cover. Variation in sediment concentration could be attributed due to larger value of LS factor in USLE.

From the Fig.4.12 it is shown that the amount of soil loss caused by USLE was compared to the amount of observed soil loss in Plot-3. The data revealed that USLE caused soil loss of (2939.3g/m^2/yr.). And observed soil loss for bare ground, shade net, and mulch cover, soil loss was (3049.2 g/m^2/yr.), (1791 g/m^2/yr.), and (146.4 g/m^2/yr.), respectively. The bare land had the most soil loss, while the mulch cover had the least. The content of sediment concentration varied in three zones, although not considerably with the higher concentration in bare surface soil of plot-3 than USLE here again the LS factor was less.

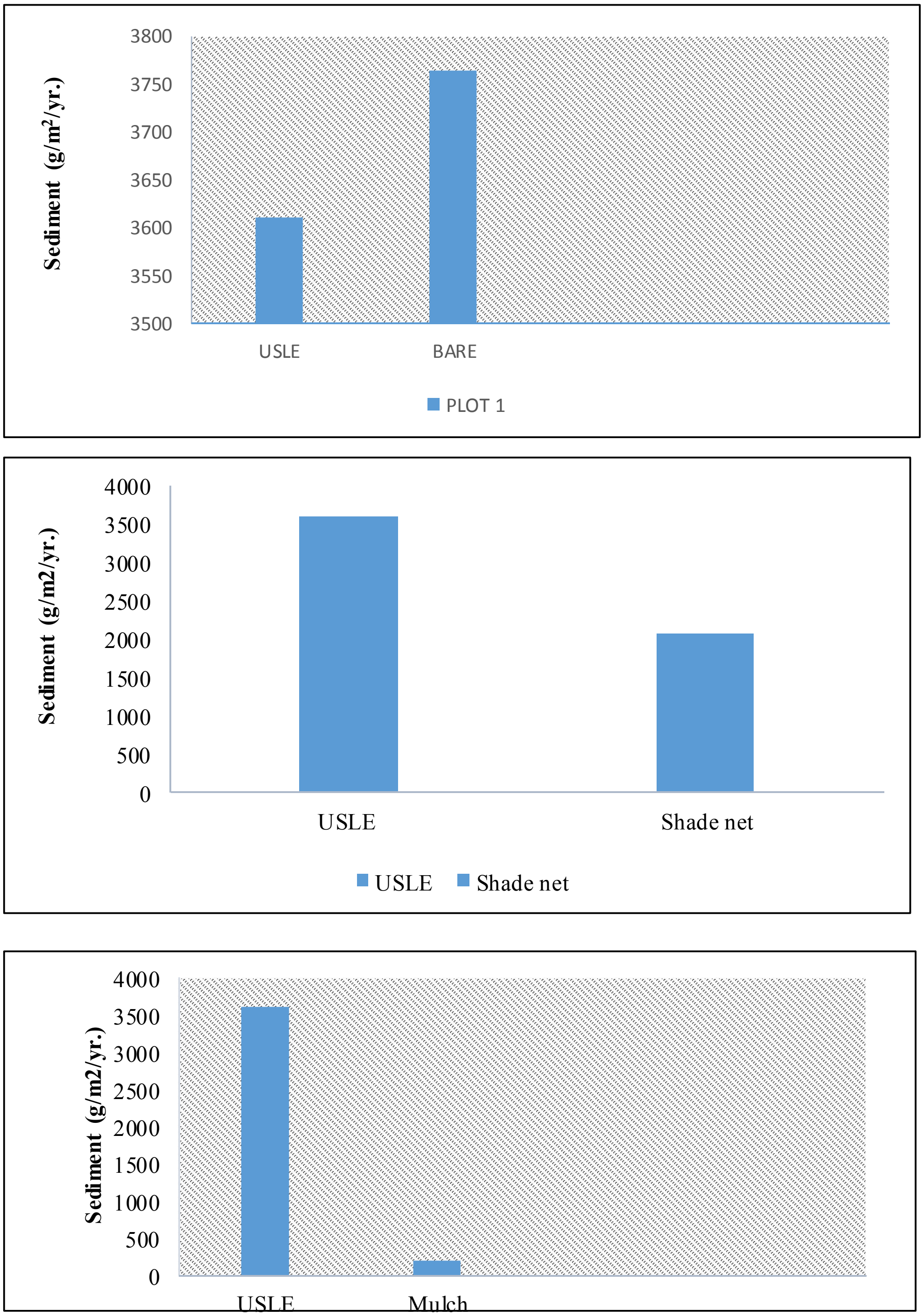


Fig. 4.10: **Comparison of USLE and observed sediment yield for Plot-1 having 70% slope under different conservative practices**

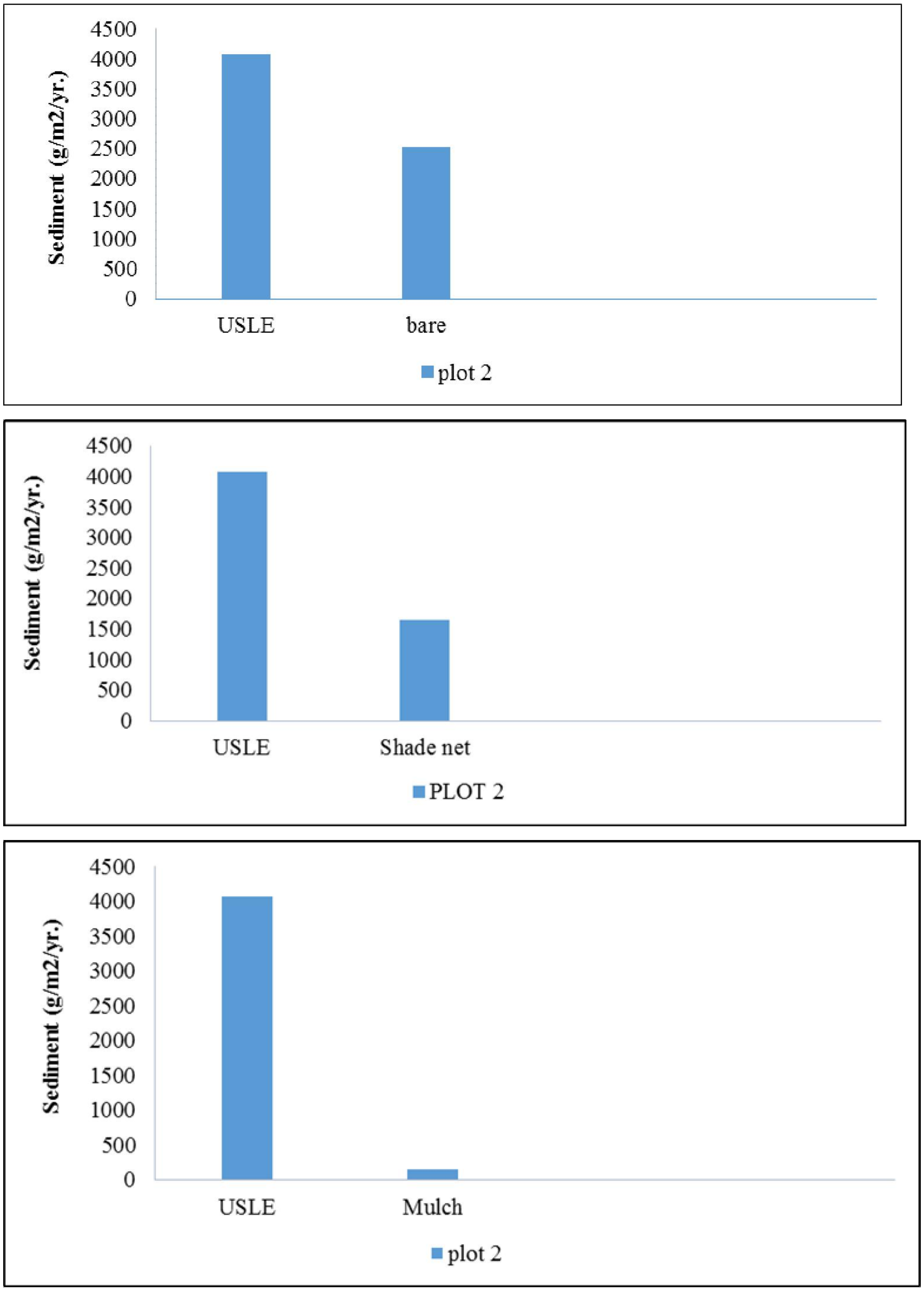


Fig. 4.11: **Comparison of USLE and observed Sediment yield for Plot-2 having 60% slope under different conservative practices**

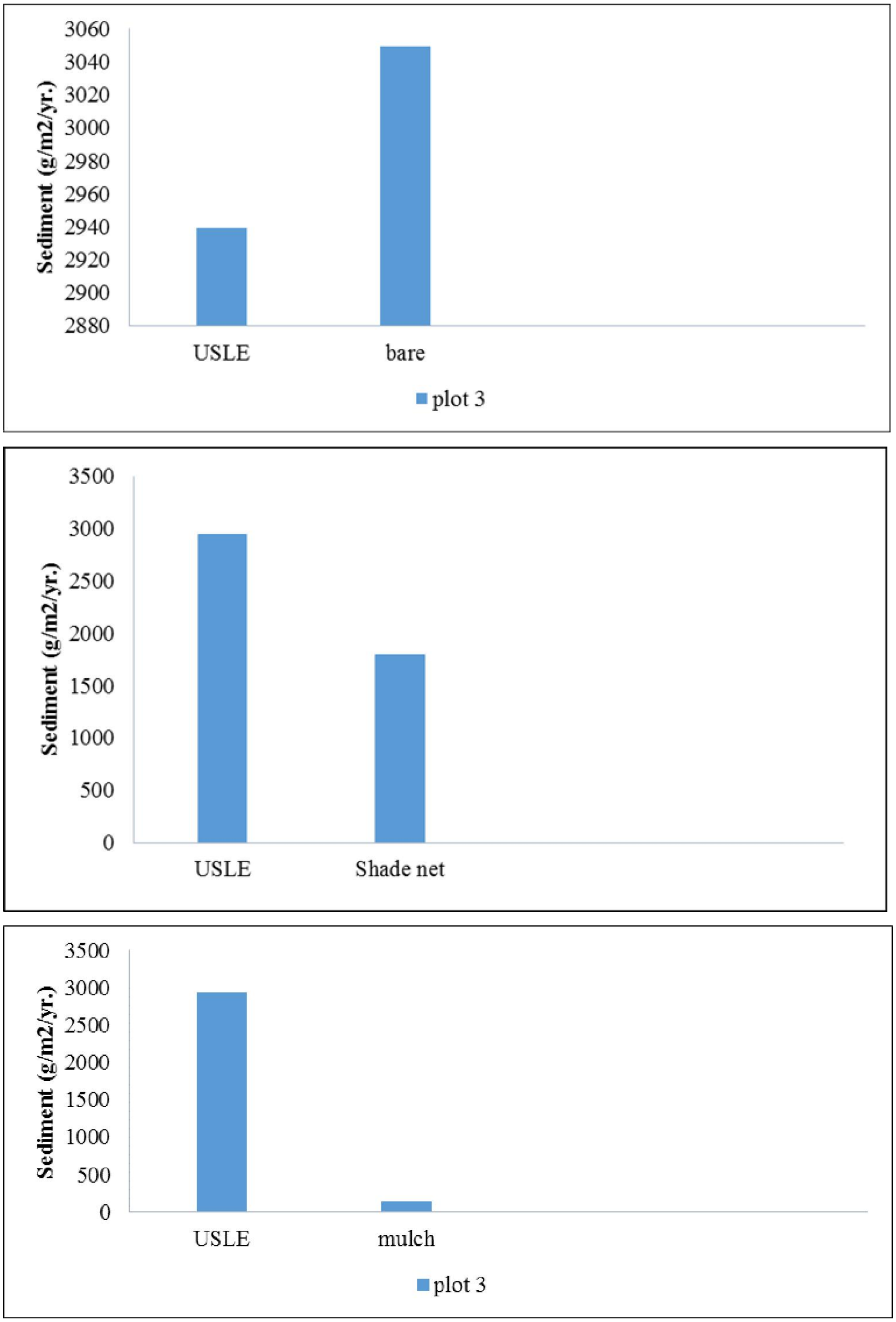


Fig. 4.12: **Comparison of USLE and observed sediment yield for Plot-3 having 65% slope under different conservative practices**

Chapter- 5

DISCUSSION

The present investigation entitled as **"Estimation of impact of rainfall variability and slope on sediment yield and surface flow in runoff sediment plots"** was carried out at College of Agricultural Engineering and Technology, SKUAST-K.The noticeable findings of the present investigation are discussed in light of the relevant literature under the following heads.

5.1 Surface Runoff Response to Different Rainfall Pattern and conservative practices

5.2 Sediment yield response to different rainfall patterns and conservative practices

5.3 Physico-chemical characteristic of sediment yield

5.4 Evaluation of soil loss using USLE

5.1 Surface runoff response to different rainfall pattern and conservative practices

The average volume of runoff generated on bare soil surface under different intensities shows an increasing trend with the increase in slope Table 4.2.The total runoff generated was highest in Plot-1 with 70% slope (6.54 litres), and lowest in Plot-2 with 60% slope (4.41 litres). This variation from three plots could be attributed due to effect of formation of surface crust that reduces infiltration rate and causes runoff (Ziadat *et al.,* 2103). The minimum and maximum runoff were recorded during the lowest rainfall intensity under the lowest slope and highest rainfall intensity with the steepest slope, respectively. Slope is an important factor influencing the runoff generation process (Mu *et al.,* 2015). In the present study, same trend was observed for the runoff for rainfall intensity and slope. In case of shade net covered soil the maximum runoff of (3.27 litres) was observed for Plot-1 with a 70% slope, Table 4.4. Plot -2, which has a

60% slope, had the minimum runoff of (2.55litres). This may be due effect of to the shade net, which slows the flow rate and reduces the amount of water accessible for runoff losses.

Runoff losses in mulch-covered soil increased as rainfall intensity and slope steepness increased. The maximum runoff of (2.8 litres) was registered for Plot-1 at the 70% slope, according to the results Table 4.6. Plot-2 at a 60% slope produced the minimum runoff (2.6 litres).This variation in runoff among the three plots with bare soil surface, shade net and mulch might be due to different rainfall intensities (Khan *et al.,* 2016).Similar observation was made by (Pannme *et al.*, 2016).

5.2 Sediment yield response to different rainfall patterns and conservative practices

The greatest peak sediment concentration was detected on Plot-1 with 70% slope, Table 4.1 the maximum sediment yield recorded was (216.0g/m^2) and minimum sediment yield was (174.6g/m^2) for Plot-2 with 60% slope. Increasing rainfall intensity not only leads to increased runoff volume but also increases the raindrop splash force, and the soil clay particles are eroded by the runoff (Yan *et al.*, 2018). Maximum sediment yield was obtained at 10% slope gradient and the least yield was recorded for 1% slope gradient since the slope gradient is the main factor for controlling soil erosion (Yong and Bao, 2012). While as in shade net soil the maximum sediment yield was recorded from Plot-1(49.02g/m^2) having 70% slope and minimum sediment yield was found in Plot-2 (39.34g/m^2) having 60% slope Table4.3.The shade net cover reduces the sediment loss than bare soil and makes less water available for soil loss (Jankauskas *et al.*, 2012). Similarly, sediment losses were almost negligible under mulched condition the maximum sediment yield was recorded (2.60g/m^2) in Plot -1 with 70% slope and minimum sediment yield was (1.95g/m^2) in Plot-2 with 60% slope. The effect of impacting raindrops was diminished by mulching (Zhou *et al.*, 2013). In the present study, same trend was observed for mulching strongly reduced sediment loss at higher rainfall intensities and slopes relative to reductions in runoff loss.

5.3 Physico-chemical characteristics of sediment yield

5.3.1 Particle size distribution in surface soil of micro-plots

The proportion of the particle size distribution show that the mechanical composition of soils in three plots differed Table 4.7. The proportion of Silt (50%) and clay (36%) content was highest for the plot -3 at the bottom slope followed by top slope and middle slope. (Khan *et al.,* 2013) clay content (20.39 %) and silt content (49.17%) were the highest at bottom slope followed by mid and top-slopes, respectively, The deterioration in physico-chemical properties of top slope as compared to mid and bottom slopes were assumed to be due to past soil erosion effect that removed the finer soil particles including soil organic matter and other plant nutrient.

5.3.2 Organic matter and organic carbon content

In all three plots, the organic matter content of the soil varied. The maximum organic matter content was found at 60 per cent slope. Increasing extent of soil erosion due to slope effect can decline soil properties (Khan *et al.,* 2013).while as organic carbon content was maximum in Plot-2 with 60 per cent slope and could be attributed due slower mineralization rate. These findings were in close proximity with Bangroo (2017).

5.3.3 Soil erodibility (K) factor.

Soil erodibility is an important parameter for assessing a soil's erosion susceptibility. It is the product of the interaction of soil texture, structure stability, permeability, and organic matter. The erodibility of the soil increases as the soil texture becomes finer. Fine loamy soils (silt loam) are more susceptible to erosion because they have a higher proportion of silt and very fine sand. Organic matter in the soil influences the accumulation of soil particles into a stable soil structure. Erodible soils are those that have less than 3.5 per cent organic matter (Evan

1980). Higher erodibility values mean that the soil is more prone to erosion. Soil erodibility was not considerably varied in the three plots. Plot-1 was highest erodibility factor followed by Plot-3 and Plot-2 (Richter and Negendank, 1997) pointed that the soils with 40-60 per cent silt content are most erodible.

5.3.4 LS factor

The highest LS factor was observed in Plot-2 followed by Plot-1 and Plot - 3 the larger values and higher variation in the three plots could be attributed to the steeper slope and length of slope (Somil *et al.,* 2018) LS factor shows considerable variation, particularly in the mountainous region where its value ranges from 5 to 22.3.

5.4 Evaluation of soil loss using USLE method

The most critical factors causing soil loss in mountainous watersheds are topographic and vegetation cover factors (King *et al*., 2005; Zhou *et al*., 2008). Surface runoff is increased in open forests with little vegetation cover, resulting in higher soil erosion (Sidle *et al.,* 2004).Highest soil loss was observed in Plot-2 having 60% slope (44.8 ton/ha/yr.) Table 4.12 and lowest soil loss was observed in Plot-3 having 65%. Slope 32.4 ton/ha/yr. (Panagos *et al*., 2015) combined LS – factor pronounces the influence of topography on soil erosion.

Chapter-6

SUMMARY AND CONCLUSION

The investigation entitled **"Estimation of impact of rainfall variability and slope on sediment yield and surface flow in runoff sediment plots"** was undertaken in the College of Agricultural Engineering and Technology SKUAST-K, Shalimar, Geographically the experimental site is located at 32°08′30″ North latitude and 74°51′42″ East longitude with an altitude of 1586 meters above mean sea level. The experiment was carried to assess extent of sediment yield and surface runoff in sediment runoff plots. The soil physico-chemical properties were determined in the laboratory. The soil loss and sediment was estimated under bare soil surface, shade net and mulch covered soils. The average annual soil loss was estimated for three runoff plots by using USLE. Quadratic linear equation was developed to relate the soil loss, runoff with rainfall intensity and slope.

SUMMARY OF THE PROJECT

6.1 Sediment and runoff parameters

- For bare surface soil, the highest sediment loss was observed in Plot -1 (216.38 g/m^2) having 70% slope and the lowest sediment loss was noticed in Plot-2 (174.86g/m^2) having 60% slope. The highest surface runoff was found in Plot-1(6.54 litre) and lowest in Plot-2 (4.41 litre) with 70%, 60% slope respectively.
- For shade net covered soil, the maximum sediment loss (49.03g/m^2) was found in Plot-1 of 70% slope and minimum sediment loss was (39.35g/m^2) in Plot-2 of 60% slope. Similarly the runoff was max.in Plot-1(3.27 litre) and min.in Plot-2(2.55litre). The shade net cover reduced the sediment loss as well as surface runoff.
- For mulch covered soil, the sediment loss was found negligible as compared to bare surface and shade net covered soil. The maximum the

sediment loss was observed ($2.6 g/m^2$) and minimum sediment loss was ($1.98 g/m^2$).

- The maximum surface runoff values was observed (2.80 litre) and minimum (2.62litre).In the values of surface runoff, there was no discernible difference between the three plots.

6.2 Physico –chemical properties of sediment soil

- The physico-chemical properties confirmed the variation in content of percentage of sand silt and clay in plot-1, plot-2 and plot-3. Highest silt per cent was found in plot-1 plot-2 (50%) and lowest in plot-2 (44%).
- The highest value of organic carbon was recorded in Plot-2 soils followed by Plot-1 and Plot -3 soils. Organic matter was observed highest in Plot-2 followed by Plot-1 and Plot-3.

6.3 Empirical equations

- The relationship of slope, rainfall intensity on sediment and runoff could be expressed by the equations, $E=222.6-68.4I+10.2I^2$ ($R^2=1.00$) and $Q = 2.36+0.47I + 0.01I^2$ ($R^2=0.99$) was best fit of linear quadratic equation for Plot-1 having 70% slope and Plot-2 having 60% slope respectively for bare soil surface.

6.4 Soil loss estimation using USLE

The study demonstrated how USLE can be used to quantify soil erosion and soil depletion potential, as well as to classify high-risk areas for soil conservation. The highest soil loss was observed in Plot -2 (44 t/ha/yr.) and the lowest soil loss was found in Plot-3 (29.3 t/ha/yr.).

CONCLUSION

The research programme comes to a close with the following conclusions:

- Runoff plots were simple in construction and an effective tool for estimating soil loss and surface runoff at field level.
- The results of this study reveals that rainfall intensity and slope are the most dynamic and most important factors affecting surface runoff and sediment yield
- Storms with increasing rainfall intensity, in particular, produced the most runoff, soil erosion, and sediment concentration. Rainfall is thought to be the most significant cause of erosion.
- Slope was the most important factor in sediment loss and runoff in bare soil treatments for all rainfall intensities.
- An upward trend of the parametric values of runoff and sediment load was found to be continuous with the increase of rainfall intensity and slope (plot1>plot3>plot2).
- The Plot- 2 revealed its best concert for soil loss and runoff volume when covered with shade net.
- Mulch cover was found to be an efficient and suitable method of reducing sediment yield. The reduction in sediment yield was noticed than bare and shade net covered soil.

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Dr. Sudhir Thaman, Scientist, PAU, Ludhiana during Viva-Voce examination held on 18-05-2021 have been incorporated in the manuscript entitled **"Estimation of Impact of Rainfall Variability and Slope on Sediment Yield and Surface Flow in Runoff Sediment Plots at SKUAST-K, Shalimar Campus**" submitted by **Ms. Aaliya Mustafa (Regd.No.MTAE-2018-59).**

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