ESTABLISHMENT OF CROP MANAGEMENT FACTOR IN UNIVERSAL SOIL LOSS EQUATION FOR COWPEA

A thesis
submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI - 413 722,
DIST. AHMEDNAGAR, MAHARASHTRA, INDIA

by

Ms. Deokate Swapnali Ramchandra
B. Tech. (Agril. Engg.)
Reg. No. 2008/005

In partial fulfillment of the requirements for the degree of

MASTER OF TECHNOLOGY
(AGRICULTURAL ENGINEERING)
in

SOIL AND WATER CONSERVATION ENGINEERING

DEPARTMENT OF SOIL AND WATER CONSERVATION ENGINEERING
DR. ANNASAHEB SHINDE COLLEGE OF AGRICULTURAL ENGINEERING
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Approved by

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DEPARTMENT OF SOIL AND WATER CONSERVATION ENGINEERING
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MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI
DIST. AHMEDNAGAR, M. S. (INDIA)

2012

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
thereof has not been submitted
by me or any other person
to any other University
or Institute for
a Degree or
Diploma

Place: M.P.K.V., Rahuri

Dated: / / 2012 **(Deokate S. R.)**

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Dist. Ahmednagar, Maharashtra State (India)

CERTIFICATE

This is to certify that the thesis entitled **"Establishment of crop management factor in universal soil loss equation for cowpea"**, submitted to the Faculty of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.) in the partial fulfillment of the requirements for the degree of **Master of Technology (Agricultural Engineering)** in **Soil and Water Conservation Engineering,** embodies the results of a piece of bonafide research work carried out by **Miss. Deokate Swapnali Ramchandra,** under my guidance and supervision.

The results embodied in this thesis have not been submitted to any other university or institute for the award of Degree or Diploma.

The assistance and help received during the course of this investigation has been duly acknowledged.

Place: M.P.K.V., Rahuri

Date: / / 2012 **(N. L. Bote)**

Dr. P. A. Turbatmath
Dean,
Faculty of Agricultural Engineering,
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Dist. Ahmednagar,
Maharashtra State (India)

C E R T I F I C A T E

This is to certify that the thesis entitled **"Establishment of crop management factor in universal soil loss equation for cowpea"**, submitted to the Faculty of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.) in partial fulfillment of the requirements for the degree of **Master of Technology (Agricultural Engineering)** in **Soil and Water Conservation Engineering** embodies the results of a piece of bonafide research work carried out by **Miss Deokate Swapnali Ramchandra,** under the guidance and supervision of **Prof. N. L. Bote**, Head, Department of Soil and Water Conservation Engineering, Dr. A. S. College of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra (India) and that no part of the thesis has been submitted for any other Degree or Diploma.

Place: MPKV, Rahuri.

Date: / / 2012 **(P. A. Turbatmath)**

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Place: MPKV, Rahuri

Dated: / /2012 **(Deokate S. R.)**

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LIST OF SYMBOLS

Symbol	**:**	**Descripition**
A	:	Soil loss
C	:	Crop management factor
I	:	Rainfall intensity
K	:	Soil erodibility factor
LS	:	Topographic factor
m	:	Exponent
P	:	Conservation practice factor
R	:	Rainfall erosivity factor
□	:	Field slope length
□	:	Angle of slope

LIST OF ABBREVIATIONS

Abbreviation	Description
Agril.	Agricultural
Am.	American
Av.	Average
ASAE	American Society of Agricultural Engineers
Cm	Centimetre
cm/h	Centimetre per hour
Col.	Colum
Cons.	Conservation
CSWCRTI	Central Soil Water Conservation Research and Training Institute
DAS	Days after sowing
Engg.	Engineering
Fig.	Figure
g	Gram[s]
g/cc	Gram per cubic centimeter
h	Hour
ha	Hectare
ICAR	Indian Concil of Agricultural Research
J.	Journal
kg	Kilogram
K.E.	Kinetic energy
kg/ha	Kilogram per hectare
lit	Litre
msl	Mean sea level
Met.	Meteorology
MPKV	Mahatma Phule Krishi Vidyapeeth
mm	Millimetre
mm/h	Millimetre per hour
mmhos/cm	Milli mhos per centimeter
m	Metre [s]

Mha	Million hectare
Mt.	Metric tonne
Mt/ha-cm	Metric tonne [s] per hectare centimetre
M.W.	Meteorological week
No.	Number
Proc.	Proceedings
q/ha	Quintle per hectare
Sci.	Science
Trans.	Transactions
t/ha	Tonne per hectare
U.S.D.A.	United States Department of Agriculture
USPRA	United State Public Roads Administration
Vol.	Volume

ABSTRACT

"ESTABLISHMENT OF CROP MANAGEMENT FACTOR IN UNIVERSAL SOIL LOSS EQUATION FOR COWPEA"
by

SWAPNALI RAMCHANDRA DEOKATE

Mahatma Phule Krishi Vidyapeeth, Rahuri-413 722,
Dist. Ahmednagar
2011

Research Guide : Prof. N. L. Bote

Department : Soil and Water Conservation Engineering

The experiment was conducted during *Kharif 2009* on the Instructional Farm of the Department of Soil and Water Conservation Engineering, Dr. A. S. College of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri. The experiment was carried out in four plots of size 28 x 12 m each. The slope of each plot was 1.20 %. In these four plots two plots were kept fallow and two plots for cowpea crop. The present study was carried out with prime objective, to study rainfall-runoff relationship and runoff-soil loss relationship for cultivated fallow treatment and cultivated crop treatment and to determine crop management factor for cowpea.

The seven runoff producing storms of intensities 7.0, 2.25, 3.88, 7.33, 14.0, 3.2 and 5.19 mm/h were recorded during the study period resulting in runoff and soil loss. The less runoff was observed in cropped area than that of cultivated fallow treatment. The total runoff 3.62mm and 7.02mm was observed in cultivated crop treatment and cultivated fallow treatment respectively.

The linear relationships were developed between rainfall and runoff for cultivated fallow as well as cultivated crop treatment. The following equations were developed for cultivated fallow treatment and cultivated crop treatment respectively.

$Y = 0.073X - 0.114, \quad (R^2 = 0.621)$ ------------ for cultivated fallow treatment and

$Y = 0.062X - 0.437, \quad (R^2 = 0.852)$ ------------- for cultivated crop treatment.

Where,

Y = Runoff, mm

X = Rainfall, mm.

Abstract Contd….. **S.R.Deokate**

In cultivated crop treatment produced less soil loss (0.077t/ha) than that of cultivated fallow treatment (0.216t/ha). The linear relationship was developed between the runoff and soil loss for cultivated fallow treatment and cultivated crop treatment. The following equations were developed-

$Y = 0.028X + 0.002, \ (R^2 = 0.953)$ ------------- for cultivated fallow treatment and

$Y = 0.019X + 0.001, \ (R^2 = 0.993)$ ------------- for cultivated crop treatment.

Where,

Y = Soil loss, t/ha

X = Runoff, mm.

By combining the equations developed for rainfall-runoff and runoff-soil loss for both the treatment. The following rainfall-soil loss equations were developed-

$Y = 0.04 \times 10^{-3} \ (X) - 1.192 \times 10^{-3}$ ------------- for cultivated fallow treatment and

$Y = 1.178 \times 10^{-3} \ (X) - 7.30 \times 10^{-3}$ ------------- for cultivated crop treatment.

Where,

Y = Soil loss, t/ha

X = Rainfall, mm.

The crop management factor, C for cowpea was found to be 0.299 by using definition and by using other parameters of USLE it was found to be 0.225. Both the computational procedure has given nearly same values of ‘C’ for cowpea. The observed soil loss from cultivated crop treatment and cultivated fallow treatment was found to be 0.077t/ha and 0.216t/ha respectively. The rainfall erosivity factor, R for the season was found to be 59.62 metric units. The erodibility factors, K was found to be 0.015. The value of topographic factor LS, has been computed to be 0.1385. The conservation practice factor, P taken as 1.0.

During crop growth period, soil moisture content ranges from minimum of 30.23% and maximum of 57.65% for cultivated crop treatment and minimum of 38.67 and maximum of 60.85%. The average yield of cowpea obtained was 10.41 q/ha.

1. INTRODUCTION

Soil erosion by water poses a serious threat to the agricultural production. Action of raindrop and runoff as overland flow causes physical degradation of soil and carries away nutrients. The soil erosion reduces the productivity of land and adversely affects the environment. The erosion rates can be reduced to certain extent by adopting proper management and cultivation practices like contour farming, mulch tillage, contour and graded ridges, contour conservation ditches, etc. Mechanical measures such as contour bunds, graded bunds, bench terracing, etc. can also be used for erosion control. But these are the costly measures and require considerable time and skill, which restrict their adoption by an individual farmer.

In India about 5334 million tonnes (16.5 t/ha) of soil is eroded annually (Mandal *et al.,* 2009). Among all the factors contributing to the soil erosion, water is the main factor. About 5.37 to 8.40 million tonnes of soil nutrients are lost through water erosion (Mandal *et al.,* 2009). The 130 million hectares of land (45% of the total geographic area) is affected by erosion through gulling, shifting cultivation, sandy areas, deserts and water logging. Out of this 136 lakh hectares of land in Maharashtra is under degradation having total annual soil loss of 775 million tonnes (www.maharashtra.gov.in).

The soil erosion is greatly influenced by rainfall, topography, vegetation and soil characteristics like soil type, depth, structure, permeability, infiltration rate, organic matter content, moisture content and other factors. So as to reduce soil erosion, selection of erosion resistant crops, cropping mixtures and estimation of their parameters which could be utilised to predict soil loss, is of great significance for land use planning and watershed management.

Wischmeier and Smith (1965 and 1978) developed the Universal Soil Loss Equation (USLE) for prediction of gross soil erosion from agricultural watersheds in USA. On a close look, the USLE appears to have been based on the Musgrave Equation (1947) that had been developed earlier. The USLE has proved to be very popular, and is being widely used after incorporating the necessary modifications in the values of its parameters for different regions of the world. The equation is especially being employed as a guide for conservation planning of small agricultural watersheds. The equation states that:

$$A = RKLSCP \text{ --------------- } (1.1)$$

Where,

A = Average annual soil loss (tonnes per hectare)

R = Rainfall factor (erosivity index)

K = Soil erodiblity factor

L = Length of slope factor

S = Steepness of slope factor

C = Crop management factor

P = Conservation practice factor

Out of these parameters Rainfall factor, Soil erodibility and Cropping management factor are major determinants of runoff and soil loss. The major part of rainfall in India occurs during the monsoon period, which is called the *kharif* crop season, and during this period the maximum amount of soil erosion takes place. Rao (1981) and Pratap Narain *et al*. (1980), as quoted by Dhruvanarayana (1993), divided the crop growth period into following three stages:

Stage 1	Germination and seedling establishment stage
Stage 2	Active vegetative stage
Stage 3	Final growth and maturity stage

Crop management factor 'C' is defined as the expected ratio of soil loss from a cropped land under specific crop to the soil loss from a continuous fallow land, provided that the soil type, slope and rainfall conditions are identical. In order to reduce the soil loss from the field, it is desirable to have the value of cropping management factor as small as possible. As vegetative cover does not affect directly on reduction of soil loss but it dissipates the impact force of rainfall on the soil surface and protects the soil from erosion by modifying the volume, drop size, coefficient of distribution, impact velocity and kinetic energy of rainfall. The crop canopy is primarily responsible for effectiveness of the vegetative cover. The quality of cover depends on the foliage characteristics, plant height and the area covered by the vegetation. This can be achieved by selecting the crop, which has wide canopy and covers the field area very quickly. Many legume crops such as Soybean, Cowpea, Green gram, Black gram etc. fall under this category.

Cowpea is most commonly cultivated crop in India. It has the useful ability to fix atmospheric nitrogen through its root nodules, and it grows well in poor soils with more than 85% sand and with less than 0.2% organic matter and low levels of phosphorus. In addition, it is shade tolerant, and therefore, compatible as an intercrop with maize, millet, sorghum, sugarcane and cotton. This makes cowpea an important crop of traditional intercropping systems. It also is cultivated as sole crop. In India, cowpea is grown on about 0.5 million ha with an average grain productivity of 600 to 750 kg/ha and green fodder yield of 150-250 q/ha.

This study was, therefore, undertaken to estimate the cropping management factor for cowpea through runoff and soil loss studies with the following specific objectives,

1. To study the rainfall – runoff relationship.
2. To study the runoff- soil loss relationship.
3. To determine the crop management factor for cowpea.

2. REVIEW OF LITERATURE

The research work done in the past on rainfall-runoff-soil loss relationship from small agricultural fields and crop management factor (C) by various researchers in India and abroad is reviewed in this chapter.

2.1 Relationship between rainfall –runoff and runoff- soil loss

Patil (1987) developed an exponential relationship between rainfall and runoff for 1% slope as $Q = 1.0123\,(1.0372)^I$ where Q is runoff in mm and I is rainfall in mm. He also established non-linear relationship between runoff and soil loss of the form $A = 0.0084\,(Q)^{1.9835}$ where A is soil loss in tons/ha and Q is runoff in mm.

Sonawane (1988) established exponential relationship between rainfall and runoff for different land slope shape of the form $Q = ab^I$ where Q is runoff in cm, I is rainfall in cm and a, b are the constant. Same form of relationship was observed between the runoff and soil loss.

Satbhai (1990) found that quadratic equation of the form $Y = a + bX + cX^2$ where Y soil loss in t/ha, X is runoff in mm and a, b, c are the constant, gave correlation between runoff and soil loss for different land treatments.

Sthool (1997) found out the relationship between runoff and soil loss and obtained the linear equation of the form $Y = 0.0829\,X + 0.1188$ where, Y = Soil loss, t/ha and X = Runoff, mm.

Sharma *et.al.* (2000) developed the linear relationship between rainfall, runoff and soil loss.

Narayan and Bhushan (2002) conducted a field experiment on Inter-relationship between crop canopy and erosion parameters in alluvial soils. They found the inter-relationship between crop canopy and erosion parameters (runoff, soil loss and splash). From the storm wise data on canopy, runoff, soil loss and rainfall intensity (I_{30}) developed a soil loss prediction model under crop cover and cultivated fallow conditions as $Y = a + bX + cX_1 + dX_2 + eX_3$. Where, Y = soil loss, (kg/ha); X = crop canopy, (%);

X_1 = runoff, (mm); X_2 = rainfall, (mm); X_3 = rainfall intensity for 30 minutes, (mm/hr); constant; b, c, d and e = regression coefficient.

Khatal (2010) found out the polynomial relationship between rainfall and runoff and exponential relationship between runoff and soil loss for both cultivated fallow treatment and cultivated crop treatment. For the relationship between rainfall and runoff, the equation of the form $Y = 0.0201X^2 - 0.263X + 3.1499$ for cultivated fallow treatment and the equation of the form $Y = 0.0219X^2 - 0.389X + 3.206$ for cultivated crop treatment. Where, Y = Runoff, mm and X = Rainfall, mm. For the relationship between runoff and soil loss, the equation of the form $Y = 0.0394\ e^{0.2825X}$ for cultivated fallow treatment and for cultivated crop treatment the equation of the form $Y = 0.0078e^{0.5644X}$. Where, Y = Soil loss, t/ha and X = Runoff, mm.

2.2 Cropping management factor

Wishchmeier (1960) classified the individual storm data by using five crop stage periods defined for relative uniformity of cover and residue effects for finding out the value of 'C' factor

Period F: Rough fallow. Turn ploughing to seeding.

Period 1: Seedbed to 1 month thereafter.

Period 2: Establishment. One to two months after spring seeding. For fall seeded grain, period 2 includes the winter period.

Period 3: Growing crop. Period 2 to crop harvest.

Period 4: Residue or stubble. Crop harvest to turn ploughing or new seeding.

The results indicated that the 4 year rotation cropping management factor value for central Indiana is found to be 0.607. The 'C' value is to be expressed on an average annual basis. Hence, 'C' value comes to be 0.162.

Battwar and Rao (1969) experimented on the effectiveness of crop cover for reducing runoff under the natural rainfall and soil conditions. The experiment was conducted for four different crops (cowpea, paddy, arhar, and maize). The results showed that the 'C' factor values were high in initial stages due to poor cover of any type of vegetation. As the vegetative cover increases, the 'C' factor values decrease and soil loss reduces. Cowpea vegetation proved to be the best crop as its growth was dense and covered maximum land parts**.**

Sharma and Panwar (1977) worked out the cropping management factor ‘C’ and soil cover rating (R) of various crops to find out the effectiveness of crop cover. Urd and groundnut + red gram offered better cover, low cropping management factor (C) and high value of soil cover rating (R), thereby reducing soil loss to the maximum where as tall growing crops such as maize, jawar + red gram and bajara + red gram gave poor canopy, high C factor value and low soil cover rating (R) and hence failed to reduce soil loss efficiently. The higher C factor values were found for maize (0.46 to 0.84), for jawar + red gram (0.54 to 1.00) and for bajara + red gram (0.56 to 1.00) due to slow rate of growth, low vegetal cover and tall growing nature, where as the C factor values for Urd (0.23 to 0.69) and for groundnut + red gram (0.23 to 0.62) were low due to the close growing, spreading legumes having excellent growth and highest canopy from germination to the harvest of crop.

Gregor (1978) determined the cropping management factor for no-till and conventional – till soybean. He divided the crop season into growth periods and confirmed the conservation benefits of zero tillage.

Nema *et al*. (1978) conducted experiment for predicting some parameters of Universal Soil Loss Equation. They conducted the experiment at Soil Conservation Research Demonstration and Training Centre, Vasad. They worked out the crop management factor ‘C’ for Mung, Groundnut and Cowpea as 0.465, 0.374 and 0.317, respectively.

Dissmeyer and Foster (1981) developed a new procedure for calculating the crop management factor ‘C’ in the USLE for forest condition. The procedure has 9 sub-factors, viz. amount of naked soil, canopy, soil reconsolidation, high organic content, fine roots, on site storage, residual binding effect, steps and contour tillage.

Mutcher *et al*. (1981) studied the sub-factor method for computing ‘C’ factor for continuous cotton. They found that the sub-factors are multipliers that represent the effect of land use residual, incorporated residue, tillage intensity and macro roughness canopy and cover. They pointed out the need for assessing the variation of soil erodibility.

Agnihotri *et al.* (1982) estimated the crop management factor 'C' for maize crop raised in a plot bunded 67m apart as 0.048 for Chandigarh.

Narain P. *et al.* (1982) conducted an experiment on runoff plots at Soil Conservation Research Demonstration and Training Centre, Kota to work out some parameters of USLE. The cropping management factor 'C' for various *Kharif* legumes ranged between 0.386 to 0.427, for cereals between 0.503 to 0.619 and for natural covers and grasses between 0.01 to 0.22.

Gregor and Mutchler (1983) derived the cropping management factor values for use in the USLE by crop stage and annual periods for no-till corn grown for silage or grain and for reduced-till corn grown for grain. The low C-values as compared to those for conventional- till corn for silage and grain reflected the soil erosion control benefits of no-till and reduced-till corn. The C-values measured for all treatments were much lower than previously accepted.

Verma (1984) conducted an experiment to work out soil loss and parameters of USLE with runoff plots. He suggested following procedure to estimate crop management factor 'C' for Indian conditions. Crop season was divided in four stages as under.

STAGE I : Germination and seeding establishment,

STAGE II : Active vegetative stage,

STAGE III : Final growth and maturity and

STAGE IV : Crop residue, cultivation till sowing of next crop.

He worked out the crop management factor 'C' and developed the formula as

$$C = \frac{\text{Percent R} \times \text{Percent Soil loss}}{10000}$$

Where,

R = Rainfall erosion index.

Gutal (1985) studied the effect of land slope and cultivation practice on runoff and soil loss. He reported the cropping management factor ‘C’ for green gram under simulated rainfall condition as 0.263.

Agnihotri *et al*. (1987) estimated the crop management factor, ‘C’ for the four stages of crop growth during kharif season following standard procedure. He found that the ‘C’ factor for various crop practices varies from 0.266 to 0.526. Maize sown along the slope has given the highest ‘C’ value (0.526), whereas the lowest ‘C’ value (0.266) was obtained by sowing maize in strip with guar. The ‘C’ value for maize sown across the slope and maize in combination with black gram worked out to 0.435 and 0.292, respectively.

Patil and Bangal (1990) studied the effects of field conservation practices in pearl millet (*bajra*) cultivation. They found that crop management factor was higher in contour ridges across the slope. The 1.5% slope contour ridge with across the slope cultivation recorded more ‘C’ value (0.4685).

Satbhai (1990) worked out the crop management factor ‘C’ for sunflower at Rahuri as 0.333.

Verma *et al.* (1990). conducted an experiment on runoff plots at Research centre, Kota to study the effect of different vegetative covers on erosion losses at 1% slope. They worked out the value of cropping management factor ‘C’ for sorghum and sorghum+ pigonpea (1:1) as 0.50 and 0.60 respectively.

Jayaram *et al*. (1991) conducted an experiment on runoff, soil loss to work out crop management factor ‘C’ of USLE under different vegetative covers for 2% slope on black soils. The crop management factor ‘C’ for *Centchrus ciliaris* grass as a permanent vegetative cover was found to be 0.015 and that for jawar , safflower, bengalgarm and *Dolichos lab lab* was 0.58, 0.64, 0.84 and 0.57 respectively, where the crops were grown only with receeding moisture.

Prasad *et al*. (1991) conducted an experiment on soil and water loss studies under different vegetative covers under 1% slope in Kota clay soils. The result indicated that castor or castor + green gram proved their effectiveness in reducing erosion (‘C’ factor 0.20 to 0.36 respectively).

Narain *et al* (1994) worked on runoff, soil loss and USLE parameters for Doon valley on runoff plots at 8% slope. The crop management factor 'C' for cowpea was 0.31 and for Mandua and Jhingora was 0.17 and 0.18, respectively, which is close to the 'C' factor for grass species. The 'C' factor values for til, maize and soybean were found to be 0.32, 0.37 and 0.46, respectively.

Kurothe and Singh (1995) conducted an experiment to determine 'C' and 'P' factors of USLE for important crops in Vasad region. The results indicate that the crops like Mung which developed higher percentage of canopy during early rainy season has been more effective in reducing soil erosion. The 'C' factor for Tur, Bajra, Jawar, Jawar + Tur and Mung were found to be 0.47, 0.41, 0.40, 0.37 and 0.32 respectively.

Sharma and Santraj (1995) conducted an experiment to determine runoff, soil loss and crop management factor under different vegetative covers on 2 % slope at Datia. They found that *Dichanthium annulatum* gave the lowest 'C' value of 0.04 followed by green gram (0.28), sorghum (0.38), sorghum + green gram (0.44) and pigeonpea (0.49), respectively.

Sthool (1997) conducted the experiment on establishment of crop management factor for pearl millet, red gram and green gram for semi -arid region of Maharashtra. He found crop management factor, 'C' for green gram to be lower (0.2466) than red gram (0.3080) and pearl millet (0.3427).

Ali *et al.* (2001) conducted the experiment on evaluation of some parameters of USLE for various cropping management practices in South Eastern Rajasthan. They found cover and crop management factor 'C' for row crops, legumes and inter cropping of row crops with legumes, which ranged from 0.536 to 0.6165; 0.3115 to 0.5115 and 0.3048 to 0.3718, respectively.

Gabriels *et al*. (2003) worked on assessment of USLE cover management C – factors for 40 crop rotation systems on arable farms in the Kemmelbeek watershed, Belgium. The different rotation systems were composed of the following crops: sugar beet (SB), winter wheat (WW), potato (PO), maize (M), beans (B), winter barley (WB), peas (PE), chicory (CH), leek (L), carrot (CA), celeriac (CE), rye grass (RG) and temporal grassland (TG). The erosivity factor *R* during the rotation was calculated on the basis of a detailed rainfall time series over a time period of 27 years. The crop data (development of cover, sowing and harvesting date, amount of residue) were collected from literature and personal communications. For most rotation systems the *C*-factors ranged between 0.28 and 0.38. High *C*-factor values were obtained with M/M/M/PO (*C*=0.47), and with CE/L/PO (*C*=0.51). Remarkable small *C*-values (*C*= 0.24–0.27) were found when winter cereals (WW and WB) were put in the rotation scheme. Whether or not the foliage of the sugar beets was removed, had no effect on the *C*-factor. The effect of green manuring on the *C*-factor in some rotation schemes was smaller than that could be expected. The *C*-factor was also affected by the position of the crop in the rotation scheme. The calculated *C*-factors indicated that the application of some rotation systems might cause more erosion by runoff. Therefore, these calculated *C*-factors can be used as a criterion to select an appropriate rotation system to reduce erosion risk on site. However, validation of these values using experimental field plot data is still required.

Tyagi *et al.* (2003) worked on crop cover management in maize through legume intercropping for conservation and sustainable production. Data on canopy cover revealed that maize + cowpea and maize + black gram gave maximum canopy than sole maize and also recorded less runoff and soil loss over maize. They also found that the correlation coefficient of rainfall/crop cover Vs runoff and soil loss was significant.

Sargar and Mali (2004) conducted the experiment on role of cropping management factor 'C' in USLE for different crops. They determined crop management factor 'C' for low forest lands as lower as 0. 0024 followed by orchards lands (0.0026), waste lands (0.0299) and grass land (0.0231).

Madhu *et al*. (2006) worked on crop management and conservation factors of the USLE for Tea in the Nilgiris. Growing of tea on sloping land without any soil and water conservation measures causes enormous soil loss in the initial years. Therefore a field experiment was conducted to evaluate the performance of different conservation measures *viz.*, Contour staggered trenching (CST), cover crop of beans and CST + beans on runoff and soil loss in new tea (*Commellia sinensis*) plantations in the Nilgiris. Average soil loss for seven years was minimum in contour staggered trenching (CST) (0.93 t ha -1 year -1) followed by CST + beans (1.02 t ha -1 year -1) and cover crop of beans alone (1.95 t ha -1 year -1) as against 2.84 t ha -1 year -l from the control. The crop management factor (C) of tea and conservation factor (P) for different conservation measures for use in the universal soil loss equation (USLE) were estimated. Based on the canopy development, the growing period of tea was divided into three stages *viz.*, initial stage (1st year), establishing stage (2nd to 4th year) and established stage (5th year onwards). The average values of crop management factor for initial stage, establishing stage and established stage were found to be 0.193, 0.0267 and 0.0163, respectively. The average value of conservation factor for CST, cover crop of beans and CST + beans were found to be 0.39, 0.38 and 0.69, respectively.

Khatal (2010) conducted the experiment on establishment of crop management factor in Universal Soil Loss Equation for soybean. She found out crop management factor, 'C' for soybean at Rahuri as 0.49.

The extract from various references reviewed regarding the work done on 'C' factor is summarized in Table 2.1

Table 2.1 Values of Crop management factor 'C' for different crops

Place	Crop	'C' Value	Source
Azad University of Agril and Tech., Kanpur	Maize,	0.46 to 0.84,	Soil Conservation Digest, 1977
	Jawar + red gram,	0.54 to 1.00,	
	Bajara + red gram,	0.56 to 1.00,	
	Urd,	0.23 to 0.69,	
	Groundnut + red gram	0.23 to 0.62	
ICAR, Vasad	Mung	0.46	Indian J. Soil Cons., 1978
	Cowpea	0.32	
	Groundnut	0.37	
CSWCRTI, Research centre, Chandigarh	Maize	0.084	Indian J. Soil Cons., 1982
Research Centre, Kota	*Kharif* legumes	0.39 to 0.43	Indian J. Soil Cons., 1994
	Cereals	0.50 to 0.62	
	Natural cover and	0.01 to 0.22	

	grasses		
MPKV, Rahuri	Green Gram	0.26	M.Tech thesis, 1985
CSWCRTI, Research centre, Kota	Sorghum	0.50	Indian J. Soil Cons., 1990
	Sorghum + Pigeonpea (1:1)	0.60	
MPKV, Rahuri	Sunflower	0.33	M.Tech thesis

Table 2.1 contd.-----
-

Research centre, Vasad	Tur	0.47	Soil and Water Cons. Annual Report, CSWCRTI, Dehradun 1995
	Bajara	0.41	
	Jawar	0.40	
	Jawar + Tur	0.37	
	Mung	0.32	
CSWCRTI, Dehradun	Cowpea	0.31	Indian J. Soil Cons., 1994
MPKV, Rahuri	Green gram	0.24	M.Tech thesis
	Red gram	0.31	
	Pearl millet	0.34	
CSWCRTI, Research centre, Kota.	Row crops	0.53 to 0.61	Indian J. Soil Cons., 2001
	Legumes crop	0.31 to 0.51	
	Inter cropping of rows crops with	0.30 to 0.37	

	legumes		
MPKV, Rahuri	Forest land	0.0024	B.Tech thesis
	Orchards land	0.0026	
	Waste land	0.0299	
	Grass land	0.0231	
MPKV, Rahuri		0.49	M.Tech thesis, 2010

The above extract of references indicates that not much work has been done for establishing the crop management factor for cowpea, though it is fast growing, fast covering legume crop with thick canopy, which can reduce the soil erosion to a great extent.

3. MATERIAL AND METHODS

The details of material used and the methods adopted during conduct of the present work are described in this chapter.

3.1 Material

3.1.1 Experimental site

The experiment was conducted during *Kharif* 2009 on the Instructional Farm of the Department of Soil and Water Conservation Engineering, Dr. A.S. College of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri**.** It is located at 19^{o} $24^{'}$ N latitude and $74\ ^{o}$ $39\ ^{'}$E longitude having an average elevation of 657 m above mean sea level.

3.1.2 Experimental setup

The experimental field of size 48 X 28 m was divided into four plots of size 12 X 28 m each. At the end of each plot multislot divisor was constructed for measurement of runoff and soil loss. The slope of each plot was 1.20%. Field plot was divided into four treatment plots, in which two plots were for crop (Cowpea) and two for cultivated fallow. Layout of the experimental plot is shown in Fig. 3.1.The general experimental plot is depicted in Plate 3.1.

3.1.3 Treatment details

The four plots were used to accommodate two treatments in two replications.

T_1 = Cultivated crop (Cowpea) treatment.

T_2 = Cultivated fallow treatment

3.2 Methods

3.2.1 Soil properties

For determination of pertaining physico-chemical properties of experimental field, representative soil samples were collected from different depths and locations. The properties and methods for their determination are reported in Table 3.1.

Table 3.1 Methods adopted for physico-chemical properties of soil

Sr. No.	Particulars	Method adopted	Reference
1	Slit + very fine and sand (0.002 to 0.1 mm)	International pipette method	Punmia (1974)
2	Sand (0.1 to 2.0 mm)	International pipette method	Punmia (1974)
3	Clay	International pipette method	Punmia (1974)
4	Soil type (Textural classification)	Triangular method (USPRA)	Punmia (1974)
5	Organic matter content	Walkey and Black method	Somawashi *et al.* (1999)
6	Field capacity	Field method	Michael (2006)
7	Bulk density	Core cutter method	Michael (2006)
8	Soil structure	Porosity method	Michael (2006)
9	Soil pH	pH meter	Michael (2006)
10	Basic infiltration rate	Double ring infiltrometer	Michael (2006)

3.2.2 Agronomical practices

Before the commencement of monsoon, the field was given one ploughing followed by discing, along the slope. The crop cowpea was manually dibbled at recommended spacing (30 X 10 cm) on 16.07.2009. Two protective irrigations of depth 5cm to 6 cm were given on 21/07/2009 and 15/08/2009 to the field for proper germination and growth of crop as there was less rainfall during this period. The details of crop (cowpea) and cultivation details are given in Table 3.2 and 3.3, respectively.

Table 3.2 Scientific classification of cowpea

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Magnoliopsida
Order	:	Fabales
Family	:	Fabaceae
Subfamily	:	Faboideae
Genus	:	Vigna
Species	:	V. unguiculata
Binomial name	:	*Vigna unguiculata*

3.2.3 Biometric observations

For biometric observations, three sample plots of 1 x 1 m were selected randomly in each plot. Observations like plant height, number of leaves per plant and crop canopy were recorded weekly, throughout the crop growth period. Plate 3.2 shows the field after germination of cowpea.

3.2.3.1 Plant height

The height of the plant measured at three different locations in plot i.e. head end, midway and tail end. It was measured from ground level up to the tip of the plants.

3.2.3.2 Number of leaves per plant

Number of leaves per plant from the sample plot of 1 x1 m was counted and average value was considered.

3.2.3.3 Crop canopy

Crop canopy was measured with the help of a quadrant frame at three randomly selected locations in each plot. The quadrant frame was held in horizontal plane over the top of the crop and percent canopy cover of the crop was determined. Cowpea with good crop canopy is shown in Plate 3.3 and Plate 3.4 shows the view of fallow plot.

Table 3.3 Agronomical details for Cowpea

Sr. No.	Particulars		Details
1	Crop		Cowpea
2	Local name		Chavali
3	Variety		Phule Pandhari
4	Spacing, cm		30 x 10
5	Seed rate, kg/ha		40
6	Date of sowing		16/07/2009
7	Fertilizer dose kg/ha (N:P:K)		20:40:00
8	Irrigations	First	21/07/2009
		Second	15/08/2009
9	Date of Pesticide/Insecticide application	Endosulfan	17/08/2009
		DAP (00:52:34)	05/09/2009
10	Weeding	First	05/08/2009
		Second	18/09/2009
11	Date of Harvesting		03/10/2009
12	Duration of crop, days		79
13	Total rainfall during crop growth period, mm		222.0

14	Root Density, gm/cc	0.011
15	Average yield of Cowpea	10.41 q/ha

3.2.4 Rainfall

The rainfall was monitored with automatic raingauge installed adjacent to the experimental field, throughout the season. The daily chart were analysed for total amount of rainfall, average intensity, I_{30} and rainfall erosivity index. Daily rainfall during the crop growth period is given in Appendix-A.

3.2.5 Runoff

The multislot divisor constructed at the end of each plot was used to measure the runoff from each plot. Knowing the dimensions of sedimentation tank and measuring the depth of water in it, runoff volume was calculated. The volume was then converted into depth of runoff. The sample calculation is presented in Appendix-B. Actual runoff from cultivated crop treatment is shown in Plate 3.5 and from cultivated fallow treatment is shown in Plate 3.6

3.2.6 Soil loss

For the determination of soil loss half litre of runoff sample bottle was used. Three runoff samples were collected from the sedimentation channel of each plot by stirring the water in the channel prior to sampling. These runoff samples were kept in laboratory for 48 hours for settlement and clear water was removed from the sample bottle. Remaining water in the soil was removed by filtration method. Then that soil was transferred into aluminum boxes and dried in hot air oven at 105 ^{o} C temperature for 24 hours. The total soil loss in gram per litre was estimated and then reported as soil loss in terms of tones per hectare for respective plot, of a particular treatment. The sample calculation for soil loss is given in Appendix-B. Plates 3.5, 3.6, and 3.7 show the soil loss determination procedure.

3.2.7 Determination of crop management factor ‘C’ in USLE

Crop management factor in the USLE is the ratio of soil loss from a cropped land under specific crop to the soil loss from a cultivated fallow, provided that the soil type, slope and rainfall conditions are identical. The crop management factor was worked out by using equation (3.1)

$$\text{Crop Management Factor 'C'} = \frac{\text{Soil loss from a cropped land}}{\text{Soil loss from a continuous fallow land}} \quad \text{---------} (3.1)$$

Another method for determining crop management factor is using parameters of USLE. Equation (1.1) gives the USLE. The measured soil loss from cropped plot was equated to RHS of USLE. The rainfall erosivity factor, soil erodibility factor, topographic factor and conservation practice factor were estimated explicitly by following the procedure given below and then the remaining crop management factor was determined by equating LHS and RHS for cropped plot.

3.2.7.1 Rainfall erosion index, R

For determination of rainfall erosivity index automatic recording rain gauge chart were analyzed. The erosion index values for all the storms were computed. The period of uniform rainfall intensities were separated from the daily rainfall charts to compute the average intensity for different periods. The kinetic energy for all such segments was computed in metric units with the help of equation (3.2) (Wischmeier and Mannering, 1969 and Raghunath *et al*., 1970) and totaled for a single storm.

$$K.E. = 210.3 + 89 \log_{10} I \quad \text{------------} (3.2)$$

Where,

K.E. = Kinetic energy, Mt/ ha-cm

I = Rainfall intensity, cm/hr

On determination of kinetic energy, the erosivity index was worked out by using equation (3.3) (Wischmeier and Smith, 1958). These erosivity indices (EI_{30}) values were further considered as rainfall erosion index (R) for each storm.

$$EI_{30} = \frac{K.E. \times I_{30}}{100} \quad ----------- (3.3)$$

Where,

EI_{30} = Erosion index

K.E. = Kinetic energy, Mt/ ha-cm

I_{30} = Maximum 30 min rainfall intensity of the storm (cm/hr)

3.2.7.2 Soil erodibilty factor, K

The soil erodiblity factor is the mean annual soil loss per unit erosivity index for a standard condition of bare soil with no conservation practices, from field of 9 percent slope and 22.13 m as field length. The erodibility factor (K) is determined with the help of nomograph (Troeh *et al.*, 1980,). The soil erodibility factor, K was determined for known soil properties like persent silt plus very fine sand, persent fine to medium coarse sand, organic matter content, soil structure and soil permeability. The methods adopted for determination of different soil properties are given in Table 3.1. Using various soil properties the erodibility factor was determined as shown in Appendix-C.

3.2.7.3 Topographic factor, LS

The factors of slope length (L) and slope steepness (S) are combined in a single index called topographic factor (Wishmeier and Smith, 1978). The topographic factor in USLE is considered for the uniform slope. It is computed using the following relation.

$$LS = (\lambda/ 22.13)^{m} [65.41 \sin^{2}\theta + 4.56 \sin\theta + 0.065] \quad ------------ (3.4)$$

Where,

LS = Topographic factor

λ = Slope length, m

m = Constant depending upon percent slope, (0.2 for slopes less than 1%

0.3 for slopes ranging from 1% to 3%

0.4 for slopes ranging from 3% to 5%

0.5 for slopes grwater than 5%)

θ = Angle of slope, degrees

3.2.7.4 Conservation practice factor, P

Conservation practices factor (P) is the ratio of soil loss from a plot with a specified supporting conservation practices like contouring, strip cropping, terracing etc. to the corresponding soil loss from a plot with up and down slope cultivation under identical conditions. The numerical value of P is always ≤ 1.0.

In the present studies, no special conservation practice was adopted. Hence, the value of conservation practice ‘P’ was considered as 1.0.

4. RESULTS AND DISCUSSION

The experiment was conducted to determine the crop management factor (C) for cowpea. Rainfall-runoff and runoff-soil loss relationship was also studied. As detailed in Chapter 3, various observations were recorded during the study to estimate pertaining parameters in the context of objectives of the study. The results of the study are reported and discussed in this chapter.

4.1 Physico-chemical properties of soil

Various soil properties of the experimental field were determined as detailed in 3.2.1. The findings are reported in Table 4.1

From Table 4.1, the proportion of sand, silt and clay indicated that the soil is clay loam. The basic infiltration rate of soil was 6.39 cm/h. The mean values of field capacity and bulk density were 39.7% and 1.39 g/cc, respectively. The data pertaining to chemical properties of soil revealed that the soil of experimental site was alkaline in reaction.

Table 4.1 Physico-chemical properties of soil

Sr. No.	Particular	Values
1	Silt + very fine sand (0.002 to 0.1mm)	14.17%
2	Sand (0.1 to 2.0)	41.52%
3	Clay	43.33%
4	Organic matter content	0.980%
5	Soil type	Clay loam
6	Field capacity	39.7%
7	Coefficient of permeability	1.5 cm/h
8	Bulk density	1.39 gm/cc
9	Soil structure	Coarse granular
10	Soil pH	7.95
11	Basic infiltration rate	6.39 cm/h

4.2 Biometric observations

4.2.1 Plant height

The data recording to plant height is given in Table 4.2. From the table it is seen that the plant height increased rapidly from early stages from 17 DAS upto 67 DAS. The maximum height attained was 67.72 cm. After 67 DAS, there was no increase in plant height.

4.2.2 Number of leaves per plant

The data pertaining to number of leaves per plant is given in Table 4.2. From the table it is observed that the number of leaves per plant increased from beginning to 44 DAS however, thereafter increase in number of leaves was insignificant up to 53 DAS. After 53 DAS leaves dried off and thus, count of number of leaves decreased afterwards in 15 days period.

4.2.3 Crop canopy

The data pertaining to crop canopy during the experiment is given in Table 4.2. From Table 4.2, it is seen that the crop canopy of cowpea was maximum from 37 DAS till up to harvesting it becomes 100%. After this the crop leaves dried and there was decrease in the crop canopy. Crop canopy plays an important role in shading the soil thereby decreasing the evaporation losses. It also absorbs the erosive power of rainfall thereby reducing the soil loss. The crop canopy depends upon plant height and number of leaves. As number of leaves increases, crop canopy also increases. Fig 4.1 shows the crop canopy and plant height during crop growth period.

Table 4.2 Biometric observations of crop

Date	DAS	No. of leaves per plant	Plant height (cm)	Crop canopy (%)
03-08-2009	17	5	11.92	15
10-08-2009	24	13	23.33	30
17-08-2009	31	17	27.33	53
24-08-2009	37	34	45.83	84
31-08-2009	44	47	57.50	94
07-09-2009	53	48	62.33	96
14-09-2009	60	44	66.83	100

21-09-2009	67	41	67.72	100
28-09-2009	74	36	67.72	95

4.3 Rainfall

The total seasonal rainfall received during the monsoon season in year 2009 is reported in Appendix-A_I. It is seen from Appendix-A_I that the total rains received were 1410 mm. Maximum of 45 mm was received on 03.10.2009 and minimum of 0.5 mm on 24.08.2009. Out of total rainfall of 1410.75 mm, total rains received during the crop growth period from21-08-2009 to 03-10-2009 were 222.0 mm. Seven runoff producing storms of 53.65 mm rainfall, resulting in soil loss were considered. The details of these seven runoff producing storms are given in Table 4.3.

Table 4.3 Runoff producing storms

Date	Rainfall duration, hr	Rainfall, mm	AverageIntensity, mm/hr	Rainfall erosivity index (R)
01/09/2009	1.00	07.0	07.00	01.103
02/09/2009	2.00	04.5	02.25	17.198
03/09/2009	4.00	15.5	03.88	04.660
13/09/2009	2.25	16.5	07.33	05.371
15/09/2009	1.00	14.0	14.00	07.871
30/09/2009	1.25	04.0	03.20	00.730
03/10/2009	8.67	45.0	05.19	19.580

4.4 Runoff

As reported in earlier para only seven storms were effective in producing runoff. Event wise occurance of runoff data are given in Table 4.4 and sample calculations are given in Appendix-B.

From Table 4.4 it is observed that the maximum runoff occurred on 03/10/2009. The rainfall received on this day was 45mm with an average intensity of 5.19 mm/h. The runoff for this day from cultivated fallow treatment was 3.32 mm and from cultivated crop (cowpea) treatment was 2.69 mm. This was due to the fact that there was dence crop canopy in cultivated crop (cowpea) treatment.

The total runoff recorded from cultivated fallow treatment was 7.02 mm whereas from the cultivated crop (cowpea) it was 3.62 mm.

Table 4.4 Observed runoff volume and runoff depth from cultivated fallow and cultivated crop (cowpea) treatment.

Date	**Rainfall (mm)**	**Runoff volume (m^3)**		**Runoff depth (mm)**	
		Cultivated fallow plot	**Cultivated crop plot**	**Cultivated fallow plot**	**Cultivated crop plot**
01/09/2009	07.0	0.120	0.114	0.360	0.340
02/09/2009	04.5	0.099	0.031	0.290	0.092
03/09/2009	15.5	0.114	0.086	0.339	0.225
13/09/2009	16.5	0.024	0.019	0.071	0.057
15/09/2009	14.0	0.828	0.044	2.460	0.130
30/09/2009	04.0	0.060	0.030	0.179	0.089
03/10/2009	45.0	1.115	0.905	3.320	2.690
			Total	7.019	3.623

4.5 Relationship between rainfall and runoff for cultivated fallow and cultivated crop treatment

The empirical, location specific relationship between rainfall and runoff for cultivated fallow and cultivated crop (cowpea) treatments for Rahuri conditions was developed.

The observed values of runoff for cultivated fallow plot and cultivated crop (cowpea) plot are given in Table 4.6. Relationship between rainfall and runoff was studied for cultivated fallow plot and it was found that the linear relationship exists between the two parameters. The correlation coefficient was found to be 0.621. Fig. 4.2 shows the relationship between rainfall ranges from 4 mm to 45 mm and runoff for cultivated fallow treatment which gives the following equation.

$$Y = 0.073X - 0.114 \qquad (R^2 = 0.621) \qquad \text{---------} (4.2)$$

Where,

Y = Runoff from cultivated fallow plot, mm

X = Rainfall, mm

Table 4.5 Observed and predicted runoff in cultivated fallow treatment

Sr. No.	Date	Rainfall, mm	Observed Runoff, mm	Predicted Runoff, mm
1	01/09/2009	07.0	0.360	0.397
2	02/09/2009	04.5	0.290	0.215
3	03/09/2009	15.5	0.339	1.018
4	13/09/2009	16.5	0.071	1.091
5	15/09/2009	14.0	2.460	0.908
6	30/09/2009	04.0	0.179	0.178
7	03/10/2009	45.0	3.320	3.171

The relationship between rainfall and runoff was also studied for cultivated crop plot and it was found that the linear relationship exists between the two parameters. The correlation coefficient was found to be 0.852. Fig. 4.3 shows the relationship between rainfall ranges from 4 mm to 45 mm and runoff for cropped area which gives the following equation

$$Y = 0.062X - 0.437 \qquad (R^2 = 0.852) \qquad \text{------------------} (4.3)$$

Where,

Y = Runoff from cultivated crop plot, mm

X = Rainfall, mm

Table 4.6 Observed and predicted runoff in cultivated crop treatment

Sr. No.	Date	Rainfall, mm	Observed Runoff, mm	Predicted Runoff, mm
1	01/09/2009	07.0	0.340	0.421
2	02/09/2009	04.5	0.092	0.152
3	03/09/2009	15.5	0.225	0.524
4	13/09/2009	16.5	0.057	0.586
5	15/09/2009	14.0	0.130	0.431
6	30/09/2009	04.0	0.089	0.189
7	03/10/2009	45.0	2.690	3.353

Sonawane (1988) found the relationship between rainfall and runoff from moth bean cropped area in the form of $Q = a\ b^I$. where, Q = Runoff, cm; I = Rainfall, cm and a, b are constants. Khatal (2010) found the polynomial relationship between rainfall and runoff from soybean crop area of the form of $Y = 0.0219X^2 - 0.389X + 3.206$, where Y = Runoff, mm and X = Rainfall, mm at Rahuri. The observed and predicted values of runoff from cultivated fallow and cultivated cropped area given in Table 4.6 and 4.7, respectively. The equation 4.2 and 4.3 were used for estimating the runoff under cultivated fallow and cultivated crop treatment.

4.6 Soil Loss

The eventwise occurrence of rainfall and soil loss are given in Table 4.8 and sample calculations of soil loss are given in Appendix-B. From the Table 4.8, it is observed that maximum soil loss was found to be 1.765 t/ha from cultivated fallow treatment and 0.053 t/ha from cultivated crop treatment, on 03/10/2009. The soil loss from cultivated fallow treatment was more than soil loss from cultivated crop treatment for all storms as expected.

The total soil loss during the crop growth period was found to be more in cultivated fallow treatment (2.56t/ha) followed by cultivated crop treatment (0.0767t/ha). Jayram *et al*. (1991) have also reported soil loss of (7.20t/ha) from cultivated fallow plot of 2% slope. Similarly, Sharma and Santraj (1995) have also reported that the soil loss of (8.87 t/ha) from cultivated fallow plot followed by red gram (4.51 t/ha) and green gram (2.45 t/ha) on 2% slope at Datia. Sthool (1997) have also reported total soil loss during the crop growth season was found to be maximum (7.24 t/ha) in cultivated fallow plot followed by pearl millet (3.79 t/ha), red gram (3.40 t/ha) and green gram (2.82 t/ha) at Rahuri. Khatal (2010) have also reported soil loss of (2.019 t/ha) from cultivated fallow plot followed by soybean (0.989 t/ha) at Rahuri.

Tabe 4.7 Observed rainfall and Soil loss data from cultivated fallow and cultivated crop treatment.

Date	Rainfall (mm)	Soil loss (kg/plot)		Soil loss (t/ha)	
		cultivated fallow plot	cultivated crop plot	cultivated fallow plot	cultivated crop plot
01/09/2009	07.0	378.0 x 10^{-3}	336.0 x 10^{-3}	11.30 x 10^{-3}	10.00 x 10^{-3}
02/09/2009	04.5	188.1 x 10^{-3}	75.25 x 10^{-3}	05.59 x 10^{-3}	02.24 x 10^{-3}
03/09/2009	15.5	343.0 x 10^{-3}	86.00 x 10^{-3}	10.20 x 10^{-3}	02.56 x 10^{-3}
13/09/2009	16.5	80.00 x 10^{-3}	53.00 x 10^{-3}	02.38 x 10^{-3}	01.58 x 10^{-3}
15/09/2009	14.0	2898 x 10^{-3}	119.0 x 10^{-3}	86.00 x 10^{-3}	03.54 x 10^{-3}
30/09/2009	04.0	486.0 x 10^{-3}	126.0 x 10^{-3}	14.50 x 10^{-3}	03.75 x 10^{-3}
03/10/2009	45.0	2888 x 10^{-3}	1765 x 10^{-3}	86.00 x 10^{-3}	53.00 x 10^{-3}

4.7 Relationship between runoff and soil loss from cultivated fallow treatment and cultivated crop treatment

The location specific empirical relationship between runoff and soil loss for cultivated fallow and cultivated crop (cowpea) treatments for Rahuri conditions was developed.

The event wise observed values of soil loss and predicted soil loss for cultivated fallow and cultivated crop plot are given in Table 4.8 and Table 4.9, respectively. Relationship between runoff and soil loss was studied for cultivated fallow as well as cultivated crop plot. It was found that the linear relationship exists between the two parameters of cultivated fallow treatment. Fig.4.4 shows the relationship between runoff and soil loss for cultivated fallow treatment was found to be linear. Following equation was developed, which shows correlation coefficient of 0.953.

$$Y = 0.028X + 0.002 \qquad (R^2 = 0.953) \qquad \text{------------------ (4.4)}$$

Where,

Y = Soil loss in cultivated fallow plot, t/ha

X = Runoff in cultivated fallow plot, mm

Table 4.8 Observed soil loss and Predicted soil loss for cultivated fallow

Date	**Rainfall**	**Runoff**	**Observed soil loss**	**Predicted soil loss using relationship between soil loss and runoff**	**Predicted soil loss using relationship between soil loss and rainfall**
01/09/2009	07.0	0.36	11.30×10^{-3}	12.10×10^{-3}	13.00×10^{-3}
02/09/2009	04.5	0.29	05.59×10^{-3}	10.10×10^{-3}	08.00×10^{-3}
03/09/2009	15.5	0.34	10.20×10^{-3}	11.50×10^{-3}	30.00×10^{-3}
13/09/2009	16.5	0.07	02.38×10^{-3}	04.00×10^{-3}	33.00×10^{-3}
15/09/2009	14.0	2.46	86.00×10^{-3}	71.00×10^{-3}	27.00×10^{-3}
30/09/2009	04.0	0.18	14.50×10^{-3}	07.00×10^{-3}	07.00×10^{-3}
03/10/2009	45.0	3.32	86.00×10^{-3}	95.00×10^{-3}	91.00×10^{-3}

Similarly, the relationship between the runoff and soil loss for cultivated crop treatment was found to be linear. The correlation coefficient was found 0.993. Fig. 4.5 shows the relationship between runoff and soil loss for cultivated crop treatment. Following equation was developed, which shows correlation coefficient of 0.993.

$$Y = 0.019X + 0.001 \qquad (R^2 = 0.993) \qquad \text{----------------- (4.5)}$$

Where,

Y = Soil loss in cultivated crop plot, t/ha

X = Runoff in cultivated crop plot, mm

Table No. 4.9 gives data observed and predicted soil loss for cultivated crop treatment.

Table 4.9 Observed soil loss and Predicted soil loss for cultivated crop treatment

Date	Rainfall	Runoff	Observed soil loss	Predicted soil loss using relationship between soil loss and runoff	Predicted soil loss using relationship between soil loss and rainfall
01/09/2009	07.0	0.340	10.00×10^{-3}	07.00×10^{-3}	01.00×10^{-3}
02/09/2009	04.5	0.092	02.24×10^{-3}	03.00×10^{-3}	00.00×10^{-3}
03/09/2009	15.5	0.225	02.56×10^{-3}	04.00×10^{-3}	11.00×10^{-3}
13/09/2009	16.5	0.057	01.58×10^{-3}	02.00×10^{-3}	12.00×10^{-3}
15/09/2009	14.0	0.130	03.54×10^{-3}	03.00×10^{-3}	09.00×10^{-3}
30/09/2009	04.0	0.089	03.75×10^{-3}	03.00×10^{-3}	00.00×10^{-3}
03/10/2009	45.0	2.690	53.00×10^{-3}	52.00×10^{-3}	46.00×10^{-3}

Sonawane (1988) found out the relationship between runoff and soil loss for mothbean and obtained the exponential equation of the form $A = a (Q)^b$ where, A = Soil loss, t/ha; Q = Runoff, cm and a, b are constants. Satbhai (1990) found out the relationship between runoff and soil loss for sunflower and the quadratic equation of the form $Y = a + bX + cX^2$ where, Y = Soil loss, t/ha; X = Runoff, mm and a, b, c are constants. Sthool (1997) found out the relationship between runoff and soil loss and obtained the linear equation of the form $Y = 0.0829X + 0.1188$ where, Y = Soil loss, t/ha and X = Runoff, mm. Khatal (2010) found out the relationship between runoff and soil loss for both cultivated fallow and cultivated crop (soybean) treatment. The exponential equation of the form $Y = 0.0394\ e^{0.2825X}$. Where, Y = Soil loss, t/ha and X = Runoff, mm for cultivated fallow treatment and for cultivated crop treatment it was $Y = 0.0078\ e^{0.5644X}$. Where, Y = Soil loss, t/ha and X = Runoff, mm. The observed and predicted runoff and soil loss were studied for cultivated fallow and cultivated crop treatment and are given in Table 4.9 and 4.10. The equation 4.4 and 4.5 were used to estimate the soil loss under cultivated fallow and cultivated crop treatment. From the above discussion, it is observed that many workers have found out the relationship between runoff and soil loss. The relationship may be linear, exponential or quadratic in nature.

4.8 Prediction of Soil Loss from Rainfall Data

4.8.1 Prediction of soil loss in cultivated fallow plot

By combining equation 4.2 and equation 4.4, the relationship between rainfall and soil loss was developed for cultivated fallow plot. The following equation was obtained.

$$Y = 2.044 \times 10^{-3} (X) - 1.192 \times 10^{-3} \qquad \text{------------------ (4.6)}$$

Where,

Y = Soil loss from cultivated fallow plot, t/ha

X = Rainfall, mm

The observed values and values obtained by calculation of soil loss from cultivated fallow treatment are given in Table 4.9. Table 4.9, shows that there are less differences in observed and predicted values

4.8.2 Prediction of soil loss in cultivated crop plot

By combining equation 4.3 and equation 4.5, the relationship between rainfall and soil loss was developed for cultivated crop (cowpea) plot. The following equation was obtained.

$$Y = 1.178 \times 10^{-3} (X) - 7.303 \times 10^{-3} \qquad \text{------------------ (4.7)}$$

Where,

Y = Soil loss from cultivated crop plot, t/ha

X = Rainfall, mm

The observed values and values obtained by calculation of soil loss from cultivated crop (cowpea) are given in Table 4.10. From Table 4.10, shows that there are less differences in observed and predicted values. In order to evaluate these two equations statistical analysis was done as suggested by different research workers. The sample calculations are given in Appendix-C.

Table 4.10 Data of soil loss obtained from cultivated crop (cowpea) to calculate Mean absolute error and Root mean square error.

Date	Soil loss (cultivated crop treatment)		$\lvert Xci – Xoi \rvert$	$(Xci – Xoi)^2$
	Observed	Predicted		
01/09/2009	10.00×10^{-3}	01.00×10^{-3}	09.00×10^{-3}	8.21×10^{-5}
02/09/2009	02.24×10^{-3}	00.00×10^{-3}	02.24×10^{-3}	5.02×10^{-6}
03/09/2009	02.56×10^{-3}	11.00×10^{-3}	08.44×10^{-3}	7.12×10^{-5}
13/09/2009	01.58×10^{-3}	12.00×10^{-3}	10.42×10^{-3}	1.08×10^{-4}
15/09/2009	03.54×10^{-3}	09.00×10^{-3}	05.65×10^{-3}	3.19×10^{-5}
30/09/2009	03.75×10^{-3}	00.00×10^{-3}	03.75×10^{-3}	1.41×10^{-5}
03/10/2009	53.00×10^{-3}	46.00×10^{-3}	07.00×10^{-3}	4.90×10^{-5}
Total	76.67×10^{-3}	79.00×10^{-3}	46.56×10^{-3}	3.6182×10^{-4}

Table 4.11 Data of soil loss obtained from cultivated fallow to calculate Mean absolute error and Root mean square error.

Date	Soil loss (cultivated fallow treatment)		$\lvert Xci – Xoi \rvert$	$(Xci – Xoi)^2$
	Observed	Predicted		
01/09/2009	11.30×10^{-3}	13.00×10^{-3}	01.70×10^{-3}	2.89×10^{-6}
02/09/2009	05.59×10^{-3}	08.00×10^{-3}	02.41×10^{-3}	5.81×10^{-6}
03/09/2009	10.20×10^{-3}	30.00×10^{-3}	19.80×10^{-3}	3.92×10^{-4}
13/09/2009	02.38×10^{-3}	33.00×10^{-3}	30.60×10^{-3}	9.36×10^{-4}

15/09/2009	86.00×10^{-3}	27.00×10^{-3}	59.00×10^{-3}	3.48×10^{-3}
30/09/2009	14.50×10^{-3}	07.00×10^{-3}	07.52×10^{-3}	5.66×10^{-5}
03/10/2009	86.00×10^{-3}	91.00×10^{-3}	05.00×10^{-3}	2.50×10^{-5}
Total	215.97×10^{-3}	209.00×10^{-3}	126.03×10^{-3}	97.60×10^{-3}

4.8.3 Mean absolute error

Raghuwanshi and Wallender (2000) used mean absolute error (MAE) for comparing their results of forecasting of daily evapotranspiration. Mathematically, MAE can be expressed as:

$$\mathrm{MAE} = \sum_{i=1}^{N} \frac{|\mathrm{Xci} - \mathrm{Xoi}|}{N} \text{ ------------------ } (4.8)$$

This error should be nearly zero for good estimation. The data of soil loss obtained from cultivated crop (cowpea) are given in Table 4.11 and the data of soil loss obtained from cultivated fallow are given in Table 4.12. The value of MAE for soil loss predicted in cultivated fallow plot is 0.018 and for soil loss in cultivated crop plot is 0.0067 which is nearly zero. It means the obtained relationship between rainfall and soil loss for prediction of soil loss in both cases are good. The sample calculations are given in Appendix-C.

4.8.4 Root mean square error

The root mean square error is another measure for performance evaluation of model suggested by Yu *et al*. (1994). The RMSE can be computed using the relationship:

$$\mathrm{RMSE} = \left[\frac{\sum_{i=1}^{N} (\mathrm{Xci} - \mathrm{Xoi})^2}{N} \right]^{0.5} \text{ ---------------- } (4.9)$$

The results obtained for RMSE are nearly equal to zero means good estimation. The RMSE for data obtained in Appendix-C. The value of RMSE for soil loss predicted in cultivated fallow plot is 0.0118 and for soil loss in cultivated crop plot is 0.0072 which is nearly zero. It means the obtained relationship between rainfall and soil loss for prediction of soil loss in both cases are good.

4.9 Determination of crop management factor 'C' in Universal Soil Loss Equation

4.9.1 Crop Management Factor by using definition

The values of crop management factor (C) for cowpea were estimated by the method given by Wischmeier and Smith (1965) as explained in Section 3.2.8.1. The value of crop management factor for cowpea was found to be 0.2998. Battawar and Rao (1969) have reported that crop management factor for cowpea as 0.342. Nema *et al.* (1978) have also reported the crop management factor for cowpea as 0.317. Narain (1994) has reported the crop management factor for cowpea as 0.31. The results obtained in this study are in conformity with those reported by Battawar and Rao (1969), Nema *et al.* (1978) and Narain (1994). The sample calculations for computation of crop management factor for Cowpea are given in Appendix-D.

4.9.2 Crop Management Factor using other parameters of USLE

The crop management factor was estimated by using Universal Soil Loss Equation by adopting the procedure mentioned in section 3.2.8.2. The various parameters of USLE *viz* R, K, LS and P were computed as under.

4.9.2.1 Rainfall erosivity factor, R

Rainfall erosivity factor (R) is found out as discussed in 3.2.8.1, as suggested by Wischmeier and Smith (1958). The rainfall erosivity values of runoff producing storms are presented in Table 4.4. The sample calculation of rainfall erosivity factor is given in Appendix-D for the rainfall on 03/10/2009.

From Table 4.4 it is seen that the rainfall erosivity factor for the season was 59.62 metric units. Gross soil erosion (A) is the soil erosion per unit area per unit time. Since the LSCP factor are dimentionless, gross soil erosion (A) has units of R x K. The time units of A are of the time period of R which is generally taken to be the average annual value for a calendar year (Das, 2009). Hence, to calculate crop management factor, average annual erosion index was used, which is 317.43 metric units for Rahuri (Atre *et al.*, 1999)

4.9.2.2 Soil erodibility factor, K

The value of soil erodibility factor, (K) was found out as discussed in 3.2.8.2. A nomograph (Troeh *et. al.*, 1980) was used to find out the value of soil erodibility factor which was 0.015. Procedure is given in Appendix-C.

4.9.2.3 Topographic Factor, LS

The topographic factor, (LS) was computed by using equation 3.4 given in 3.2.8.3. The value of topographic factor, LS was computed and was found to be 0.1385. Computations are reported in Appendix-C.

4.9.2.4 Conservation practice factor, P

During experiment, the conservation practices like contouring, terracing, strip cropping etc. were not adopted. Hence, the value of conservation practice factor, P was considered to be 1.

The crop management factor by using the above parameters of USLE was found to be 0.255.

5. SUMMARY AND CONCLUSIONS

This chapter summarizes all the aspects of research work done.

5.1 Summary

From experiment was conducted to determine the rainfall-runoff and runoff-soil loss relationship and to find out crop management factor for cowpea. For this study, two treatments, *viz*. cultivated fallow and cultivated crop (cowpea) were considered. The results of the study can be summarized as follows.

5.1.1 Physico-chemical properties of soil

The proportion of sand, silt and clay indicated that the soil is clay loam. The structure of soil was coarse granular.

5.1.2 Biometric observations

5.1.2.1 Plant height

The maximum plant height observed was 67.72 cm. A rapid increase in the growth of cowpea was observed from 17 DAS to 52 DAS (12 to 62 cm). The maximum plant height with maximum crop canopy is known to reduced the runoff and soil loss.

5.1.2.2 Number of leaves per plant

The average number of leaves ranged from 34 to 48 from 37 to 53 DAS. Thereafter the number of leaves per plant decreased.

5.1.2.3 Crop canopy

It was observed that the maximum crop canopy of 100% was achived at 60 DAS. Thereafter the leaves dried and crop canopy decreased.

5.1.2.4 Rainfall

The total rainfall during the monsoon in year 2009 was 1391 mm and the rainfalls during the crop growth period are 222.0mm. However, only 53.65mm rainfall was found to be effective for causing runoff.

5.1.2.5 Runoff

The maximum runoff from cultivated fallow treatment occurred on 25/08/2009 and 03/10/2009. The rainfall received on these days were 13.5 and 45 mm respectively. The maximum runoff was recorded in cultivated fallow treatment (10.33 mm) followed by runoff from cultivated crop treatment (6.75 mm).

5.1.2.6 Relationship between rainfall and runoff for cultivated fallow and cultivated crop treatment

Relationship between rainfall and runoff was studied for cultivated fallow. Linear relationship was found to exists between the two parameters. The correlation coefficient was found to be 0.621. The equation developed is

$$Y = 0.073X - 0.114$$

Where,

Y = Runoff from cultivated fallow plot, mm

X = Rainfall, mm

Also relationship between rainfall and runoff was studied for cultivated crop plot and it was found that the linear relationship exists between the two parameters. The correlation coefficient was found to be 0.852. The equation developed is,

$$Y = 0.062X - 0.437$$

Where,

Y = Runoff from cultivated crop plot, mm

X = Rainfall, mm

5.1.2.7 Soil loss

The total soil loss during the crop growth period was found to be more in cultivated fallow treatment (2.56t/ha), followed by the cultivated crop treatment (0.0767t/ha).

5.1.2.8 Relationship between runoff and soil loss from cultivated fallow treatment and cultivated crop treatment

Relationship between runoff and soil loss was studied for cultivated fallow as well as cultivated crop plot. It was found that the linear relationship exists between the two parameters of cultivated fallow treatment. The correlation coefficient was found to be 0.953. The equation for cultivated fallow plot developed is,

$$Y = 0.028X + 0.002$$

Where,

Y = Soil loss in cultivated fallow plot, t/ha

X = Runoff in cultivated fallow plot, mm

Similarly, the relationship between the runoff and soil loss for cultivated crop treatment was found to be linear. The correlation coefficient was found 0.993. The equation developed is,

$$Y = 0.019X + 0.001$$

Where,

Y = Soil loss in cultivated crop plot, t/ha

X = Runoff in cultivated crop plot, mm

5.1.2.8 Prediction of Soil loss from Rainfall data

5.1.2.8.1 Prediction of soil loss in cultivated fallow plot

By combining equation developed between rainfall-runoff and runoff-soil loss for cultivated fallow plot, relationship between Soil loss and rainfall for cultivated fallow plot developed is,

$$Y = [2.044 \times 10^{-3} (X)] - 1.192 \times 10^{-3}$$

Where,

Y = Soil loss from cultivated fallow plot, t/ha

X = Rainfall, mm

5.1.2.8.2 Prediction of soil loss in cultivated crop plot

By combining equation developed between rainfall-runoff and runoff-soil loss for cultivated crop plot, relationship between Soil loss and rainfall for cultivated fallow plot developed is,

$$Y = [1.178 \times 10^{-3} (X)] - 7.303 \times 10^{-3}$$

Where,

Y = Soil loss from cultivated crop plot, t/ha

X = Rainfall, mm

5.1.2.8.3 Mean absolute error

The value of MAE for soil loss predicted in cultivated fallow plot is 0.018 and for soil loss in cultivated crop plot is 0.0067. It means obtained relationship between soil loss and rainfall for prediction of soil loss in both cases are good.

5.1.2.8.4 Root mean square error

In case of soil loss in cultivated fallow plot, the value of RMSE is 0.0118, it means obtained relationship between soil loss and rainfall in cultivated fallow plot is quite satisfactorily while in case of soil loss in cultivated crop plot, the value of RMSE is 0.0072. This shows that the estimated relationship is good.

5.1.2.9 Determination of crop management factor 'C' in Universal Soil Loss Equation

5.1.2.9.1 Crop Management Factor by using defination

The value of crop management factor for cowpea was found to be 0.2998. Battawar and Rao (1969) have reported that crop management factor for cowpea was 0.342. Nema *et al.* (1978) also reported that the crop management factor for cowpea was 0.317. Narain P. (1994) have reported that the crop management factor for cowpea was 0.31

5.1.2.9.2 Crop Management Factor using other parameters of USLE

The crop management factor using other parameters of USLE was found to be 0.255. The Observed soil loss from cropped plot was found to be 0.1965 t/ha. The average annual erosion index for Rahuri was found 317.43 metric units. The value of soil erodibility factor, (K) was found to be 0.015. The value of topographic factor, LS was computed to be 0.1385. The conservation practices factor, P was taken as 1.0.

5.2 Conclusions

Based on the results of the study the following conclusions are drawn.

1. The relationship between rainfall and runoff was found to be linear in nature for both the treatments. The expressions were Y = 0.073X – 0.114 and Y = 0.062X-0.437 for cultivated fallow treatment and cultivated crop treatment, respectively.

2. The relationship between runoff and soil loss was found to be linear in nature for both the treatments. The expressions were Y = 0.028X + 0.002 and Y = 0.019X+ 0.001 for cultivated fallow treatment and cultivated crop treatment, respectively.

3. The relationship between rainfall and soil loss was found to be linear in nature for both the treatments. The expressions were $Y = [(2.044 \times 10^{-3})X] - (1.192 \times 10^{-3})$ and $Y = [(1.178 \times 10^{-3})X] - (7.303 \times 10^{-3})$ for cultivated fallow treatment and cultivated crop treatment, respectively.

4. The value of crop management factor ‘C’ for cowpea by using definition was found to be 0.2998 computation using parameters of USLE revealed value of C to be 0.255. Both the computational procedure has given nearly same values of ‘C’ for cowpea.

6. LITERATURE CITED

Agnihotri, Y., R.K. Gupta, A.D. Sud and P.R. Mishra. 1982. Determination of crop management factor and conservation factor of the USLE. Indian J. Soil Conservation, 10 (1): 23-25.

Agnihotri, Y., A.D. Sud, S.P. Mittal, and R.C. Bansal. 1987. A Note on Estimation of Crop Management Factor of the Universal Soil Loss Equation at Chandigarh. Indian J. Soil Conservation, 15 (2) : 113.

Ali, S., S.N. Prasad, K.D. Singh and J.S. Samra. 2001. Evalution of some parameters of USLE for various cropping management practices in south-eastern, Rajasthan. Indian J. Soil Cons., 29 (3): 235-240.

Atre, A.A., M.G. Shinde and G.B. Bangal. 1999. Estimation and probability Distribution of Rainfall Erosivity Index at Rahuri. J. MAU. 24(3): 294-295.

Battawar, H.B. and Y.P. Rao. 1969. Effectiveness of crop – cover for Reducing Runoff and Soil loss. Journal of Soil and Water Cons.17 (3&4):39-50.

Das, G. 2009. A Text Book of Hydrology and Soil Conservation Engineering. PHI Learning Private Limited. New Deihi-110001.

Dissmeyer, G.E and G.R. Foster .1981.Establising the cover management factor “C” in USLE. Journal of Soil and Water Cons.36 (4):235-240.

Gabriels, D.G. Ghekiere, W. Schiettecatte and I. Rottiers. 2003. Assessment of USLE cover-management c-factor for 40 crop rotation systems on arable farms in the Kemmelbeek Watershed, Belgium. Soil and Tillage Research.74 (1):47-53.

Gregor M.C. 1978. C-factors for No-Till and Conventional Till Soybeans from plot data. Transactions of ASAE, 21(6): 1119-1122.

Gregor M.C. and C.K. Mutchler, 1983. C factors for NO-Till and Reduced-Till Corn. Transactions of ASAE, 26 (3): 785-788.

Gutal, G.B. 1985. Effect of land slopes and Cultivation Practices on Soil Loss and Runoff. A thesis of M.Tech (Agril. Engg.) submitted to M.P.K.V., Rahuri.

Hadda, M.S. and D.P. Singh. 2005. Effect of management practices on soil properties and yield of maize on slopy land. Indian J. Soil Cons., 33 (2): 178-179.

Jayaram, N.S., S. Chittaranjan and M.S. Rama Mohan Rao. 1991. Runoff, Soil and Nutrient Losses under different Vegetative Covers on 2% Slopes of Black Soils. Soil and Water Conservation, Annual Report, CSWCRTI Dehradun : 109-110.

Khatal, D.Y. 2010.Establishment of cropping management factor ‘C’ in Universal Soil Loss Equation for soybean. A M.Tech (Agril. Engg.) thesis submitted to M.P.K.V., Rahuri.

Kurothe, R.S. and H.B. Singh. 1994. Determination of ‘C’ and ‘P’ factors of the USLE for important Crops and Management Practices in Vasad Region. Soil and Water Conservation, Annual Report, CSWCRTI, Dehradun : 82.

Madhu M., D.C. Sahoo and P. Muralidharan. 2006. Crop management and conservation factors of the USLE for the Tea in the Nilgiris. J. of the Indian Society of Soil Sci. 54 (2).

Mandal, D., Patra, N.K. Sharma, P. Dongra and V.N. Sharda. 2009. Impact of soil erosion on crop yield in Tropical Humid Regions of India. International Conference on Food Security and Environment Sustainability. Dec. 17-19, at IIT Kharagpur.

Michael, A.M. 2006. A Text Book of Irrigation Theory and Practice. Vikas Publishing house, Pvt. Ltd. New Delhi.

Mutchler, C.K., Murphree, and K.C. Mc Gregor. 1981. Subfactor method for computing C- factor for continuous cotton. Transactions of ASAE, 25(2): 327-332.

Narain P., B. Verma and D.H.Rao. 1982. Prdiction of rainfall erosion potential and some parameters of USLE at Kota (Rajasthan).Indian J. Soil cons., 10(2&3):60-68.

Narain P., M.L. Khybri, H.P.S. Tomar, and N. S. Sindhwal. 1994. Estimation of Runoff, Soil Loss and Universal Soil Loss Equation parameters for Doon Vally. Indian J. Soil Cons., 22(3): 1-9.

Narayan V.V.D. and L.S. Bhushan. 2002. Interrelationship between crop canopy and erosion parameters in alluvial soil. Indian J. Soil Cons. 30(1): 41-45.

Nema, J.P, B. Verma and A.P.Patel. 1978. Predicting some Universal Soil Loss Parameters. Indian J. Soil Cons., 6(2):75-79.

Patil, P.P. 1987. Evaluation of effect of field soil conservation practices on crop management factor and conservation practice factor and on soil erosion retardation. M. Tech. Unpublished thesis, M. P. K. V., Rahuri.

Patil, P.P. and G.B. Bangal. 1990. Effect of Field Soil Conservation Practices in Pearl Millet. Mining Engineering J., (1): 71

Prasad, S.N., Ratan Singh and C. Prakash. 1991. Soil and Water Loss studies under different vegetative covers under 1% slope in Kota clay soils. Soil and Water Conservation, Annual Report, CSWCRTI, Dehradun: 89-90.

Punmia, B. C. 1974. A Text Book of Soil Mechanics and Foundation. Laxmi publication (P) Ltd. New Deihi.

Raghuwanshi, N.S. and W.W. Wallender. 2000. Forcasting daily evapotranspiration for a grass reference crop. International Agril. Engg. J., 9(1) : 1-16.

Sargar, S. M. and S. S. Mali, 2004. Role of cropping management factor ‘C’ in Universal Soil Loss Equation for different crops. B. Tech., Unpublished thesis, M. P. K. V., Rahuri.

Satbhai, S.J.1990. Establishment of cropping management factor “C” and conservation practices factor “P” in USLE. A thesis of M.Tech (Agril. Engg.) submitted to M.P.K.V., Rahuri.

Sharma, A.K. and Santraj. 1995. Runoff, Soil Loss and Nutrient Losses under different Crop Covers on 2% Slope at Datia. Soil and Water Conservation, Annual Report, CSWCRTI, Dehradun: 131-132.

Sharma, I.P., Sushil Kumar and J. C. Sharma. 2000. Rainfall-Runoff-Soil Loss Relationship under different land uses in mid-hill region of Himachal Pradesh. Indian J. Soil Cons. (2): 91-97.

Sharma, S.G. and K.S. Panwar. 1977. Effectiveness of crop-cover for reducing splash erosion. Soil Conservation Digest, 15(1): 1-7.

Somawashi, R.B., P.P. Kadu, B.D. Tamboli, Y.M. Patil and B.D. Bhakare. 1999. Determination of organic matter content by neutralization method. Analysis of Plant, Irrigation Water and Soils. M.P.K.V., Rahuri: 222-223.

Sonawane, M. G. 1988. Study of effect of complex slope on runoff and soil loss. M. Tech., Unpublished thesis, M. P. K. V., Rahuri.

Sthool, V. A. 1997. Establishment of Crop Management factor for pearl millet, red gram and green gram for semi-arid region. M. Tech., Unpublished thesis, M.P.K.V., Rahuri.

Troeh, R.T., J.A. Hobbs and R.L. Donahue. 1980. Soil and Water Conservation for Production and Environmental Protection. Prentice Hall Inc. Englewood Cliffs, New Jersy 07632: 158.

Tyagi, P.C, S.C.Mohan, B.P.Joshi, S.S.Shrimali and N.S.Sindhwal. 2003. Crop Cover Management in Maize through Legume intercropping for conservation and sustainable production. Indian J.Soil cons., 31 (1):30-34.

Verma, B. 1984. Determination of Erosion and Parameters of USLE with Runoff Plots. ICAR Publication, 1984.

Verma, B., S.N. Prasad, C. Prakash, Ratan Singh and D.H. Rao. 1990. Runoff and Soil Loss under Sorghum at 1 percent Slope in Kota Clay Soil. Indian J. Soil Conservation, 18 (1&2): 16-20.

Wischmeier, W.H. 1960. Cropping management factor evaluation for Universal Soil Loss Equation Soil Sci. Soc.Am. Proc.24 (4):322-326.

Yu, P.S.; Liu, C.L. and Lee, T.Y. 1994. Application of a transfer function model to a storage-runoff process. In : Hipel, K.W.; McLeod, A.I.; Pannu, U.S. and Singh, V.P. eds. Stochastic and Statistical Methods in Hydrology and Environmental Engineering. Kluwer Academic Publishers, Dordrecht. Pp. 87-97.

7. APPENDICES

Appendix- A

Appendix-A_{1}: Seasonal rainfall data from 20/06/2009 to 16/11/2009.

Sr.No.	Date	Rainfall, mm
1	20/06/2009	17.5
2	03/07/2009	5.25
3	07/07/2009	29.0
4	08/07/2009	0.75
5	15/07/2009	1.75
6	20/07/2009	1.5
7	21/07/2009	7.25
8	22/07/2009	7.5
9	17/08/2009	4.0
10	18/08/2009	8.5
11	19/08/2009	5.0
12	20/08/2009	9.75
13	21/08/2009	30.0
14	22/08/2009	24.5
15	23/08/2009	23.5
16	24/08/2009	0.5
17	25/08/2009	13.5
18	27/08/2009	4.25
19	01/09/2009	7.0
20	02/09/2009	4.5
21	03/09/2009	15.0
22	04/09/2009	6.0
23	10/09/2009	0.75
24	11/09/2009	13.0
25	13/09/2009	16.5
26	15/09/2009	14.0

27	30/09/2009	4.0

Appendix- A_1 Contd…..

28	03/10/2009	45.0
29	09/11/2009	10.5
30	10/11/2009	26.0
31	11/11/2009	25.5
32	13/11/2009	10.0
33	14/11/2009	25.25
34	15/11/2009	1.75
35	16/11/2009	2.0
	Total:	1410.75

Appendix-A_2: Rainfall during crop growth period

Date	Rainfall, mm
21/08/2009	30
22/08/2009	24.5
23/08/2009	23.5
24/08/2009	0.5
25/08/2009	13.5
27/08/2009	4.25
01/09/2009	7
02/09/2009	4.5
03/09/2009	15
04/09/2009	6
10/09/2009	0.75
11/09/2009	13
13/09/2009	16.5
15/09/2009	14
30/09/2009	4
03/10/2009	45
Total rainfall	222.0

Appendix-B

Runoff and soil loss calculations

For cultivated fallow teratment

Date: 20/08/2009

1. **Runoff calculations**

Rainfall = 10m

Size of runoff collection channel= 12 m x 0.5 m

Average depth of ponding water in collection channel= 0.17m

Runoff volume, m^3 = Length x Width x Ponding depth

= 12 x 0.5 x 0.17

= 1.02 m^3

Total runoff volume, m^3 = Runoff volume – rainfall

= 1.02 – (12 x 0.5 x 0.01)

= 1.02 – 0.06

= 0.96 m^3

Area of runoff plot, m^2 = 12 x 28

= 336 m^2

$$\text{Runoff depth, mm} = \frac{\text{Volume of runoff, m}^3}{\text{Area of runoff plot, m}^2} \times 1000$$

$$= \frac{0.96}{336} \times 1000$$

= 2.86 mm

2. Soil Loss Calculation :

Soil loss obtained from

Runoff sample = 2.7 gm/lit

Runoff volume =1020 lit

Total soil loss = 2.75 kg/plot

Plot size = 12 x 28 m

= 336 m^2

Soil loss per hectare $= \frac{2.75 \times 10000}{336 \times 1000}$

= 0.082 t/ha

Appendix – C

Prediction of Soil loss from Rainfall data

i. Prediction of soil loss in cultivated fallow plot

The following equation is used to calculate soil loss

$$Y = 2.044 \times 10^{-3} (X) - 1.192 \times 10^{-3}$$

Where,

Y = Soil loss from cultivated fallow plot, t/ha

X = Rainfall, mm

Date: 03/09/2009

Rainfall = 15.5 mm

Soil loss for cultivated fallow plot,

$$Y = 2.044 \times 10^{-3} (15.5) - 1.192 \times 10^{-3}$$

$$= 0.0317 - 1.192 \times 10^{-3}$$

$$= 0.025 \text{ t/ha}$$

ii. Mean absolute error

The following equation is used to calculate mean absolute error and the data obtained by calculations are given as following.

$$MAE = \sum_{i=1}^{N} \frac{|Xci - Xoi|}{N}$$

Date	Soil loss (cultivated crop treatment)		$\|Xci - Xoi\|$	$(Xci - Xoi)^2$
	Observed	Predicted		
01/09/2009	0.01	0.94×10^{-3}	9.06×10^{-3}	8.21×10^{-5}
02/09/2009	2.24×10^{-3}	0	2.24×10^{-3}	5.02×10^{-6}
03/09/2009	2.56×10^{-3}	0.011	8.44×10^{-3}	7.12×10^{-5}
13/09/2009	1.58×10^{-3}	0.012	0.01042	1.085×10^{-4}
15/09/2009	3.50×10^{-3}	9.19×10^{-3}	5.65×10^{-3}	3.19×10^{-5}
30/09/2009	3.75×10^{-3}	0	3.75×10^{-3}	1.41×10^{-5}
03/10/2009	0.053	0.046	7×10^{-3}	4.9×10^{-5}
Total	0.07667		0.04656	3.6182×10^{-4}

Date	Soil loss (cultivated fallow treatment)		$\|Xci - Xoi\|$	$(Xci - Xoi)^2$
	Observed	Predicted		
01/09/2009	0.0113	0.013	1.7×10^{-3}	2.89×10^{-6}
02/09/2009	5.598×10^{-3}	8.01×10^{-3}	2.41×10^{-3}	5.81×10^{-6}
03/09/2009	0.0102	0.030	0.0198	3.92×10^{-4}
13/09/2009	2.381×10^{-3}	0.033	0.0306	9.36×10^{-4}
15/09/2009	0.086	0.027	0.059	3.48×10^{-3}
30/09/2009	0.0145	6.98×10^{-3}	7.52×10^{-3}	5.66×10^{-5}
03/10/2009	0.086	0.091	5×10^{-3}	2.5×10^{-5}

Total	0.216		0.12603	0.0976

Mean absolute error for cultivated crop treatment:

$$\text{MAE} = \sum_{i=1}^{N} \frac{|\text{Xci - Xoi}|}{\text{N}}$$

$$= \frac{0.04656}{7}$$

$$= 0.0067$$

Mean absolute error for cultivated fallow treatment:

$$\text{MAE} = \sum_{i=1}^{N} \frac{|\text{Xci - Xoi}|}{\text{N}}$$

$$= \frac{0.1260}{7}$$

$$= 0.018$$

iii. Root mean square error

The following equation are used to calcúlate root mean square error

$$\text{RMSE} = \left[\frac{\sum_{i=1}^{N} (\text{Xci - Xoi})^2}{\text{N}}\right]^{0.5}$$

Root mean square error for cultivated crop treatment

$$\text{RMSE} = \left[\frac{\sum_{i=1}^{N} (\text{Xci - Xoi})^2}{\text{N}}\right]^{0.5}$$

$$= 7.19 \times 10^{-3}$$

Root mean square error for cultivated fallow treatment:

$$\text{RMSE} = \left[\frac{\sum_{i=1}^{N}(\text{Xci - Xoi})^2}{\text{N}}\right]^{0.5}$$

$$= \left[\frac{0.0976}{7}\right]^{0.5}$$

$$= 0.0118$$

Appendix – D

Determination of crop management factor 'C' in USLE

1. Crop management factor by using defination

   The following equations is used to determine crop management factor, C

$$\text{Crop management factor, C} = \frac{\text{Soil loss obtained from cultivated crop treatment}}{\text{Soil loss obtained from cultivated fallow treatment}}$$

Here,

Total soil loss from cultivated crop treatment = 0.1967 t/ha

Total soil loss from cultivated fallow treatment = 0..656 t/ha

$$\text{Crop management factor, C} = \frac{\text{Soil loss obtained from cultivated crop treatment}}{\text{Soil loss obtained from cultivated fallow treatment}}$$

$$C = \frac{0.1967}{0.656}$$

$$C = 0.2998$$

2. Crop management factor by using parameters of USLE,

$$C = \left[\frac{A}{RKLSP}\right]$$

Where,

A = Actual soil loss (cultivated crop treatment)

R = Rainfall erosion factor (erosivity index)

K = Soil erodibility factor

LS = Topographic factor

P = Conservation practice factor

i. Rainfall erosion index, R (For storm on 03.10.2009, Rainfall = 45 mm)
   The equation to compute the kinetic energy of rainfall-

$$K.E. = 210.3 + 89 \log I$$

Where,

K.E. = Kinetic energy, Mt/ha-cm

I = Rainfall intensity, cm/hr

The equation for the determination of erosivity index is

$$EI_{30} = \frac{K.E. \times I_{30}}{100}$$

Where,

EI_{30} = Erosive index

K.E. = Kinetic energy, Mt/ha

I_{30} = Maximum 30 min rainfall intensity of the storm (cm/hr)

Starting time (hr min)	**Shifting time (hr min)**	**Time interval (min)**	**Rainfall (cm)**	**Rainfall intensity (I) (cm/hr)**	**K.E. (Mt/ha-cm)**	**K.E of the rain (Mt/ha)**
1500	1510	10	0.3	1.8	223.02	69.91
1700	1730	30	1.05	2.1	238.98	250.93
1730	1800	30	0.1	0.2	148.09	14.81
1800	1900	60	0.1	0.1	121.3	12.13
1900	1915	15	0.1	0.4	174.88	17.49
1915	2100	105	0.55	0.31	165.03	90.77
2100	2145	45	1.22	2.067	238.37	367.47
2145	2245	60	0.35	0.35	169.72	59.40
2245	0300	255	0.4	0.094	118.91	47.56
					Total	930.47

Maximum 30 min rainfall intensity of the storm = 2.1 cm/hr

$$EI_{30} = \frac{K.E. \times I_{30}}{100}$$

$$EI_{30} = \frac{930.47 \times 2.1}{100}$$

= 19.58 Mt/ha

The average annual erosion index for Rahuri was found 317.43 metric units.

ii. Soil erodibility factor, K

For known soil properties i.e

Silt + very fine sand = 14.17

Sand = 41.52

Organic matter content = 0.980

Soil structure = coarse granular and

Coefficient of permeability = 1.5 cm/h (moderate slow)

The value of soil erodibility factor, K from the nomograph (Troeh *et. al*., 1980) (fig. C-1) is 0.015. The dotted line shows how the nomograph is used to obtain a K value of 0.015 for the above mentioned soil properties.

iii. Topographic factor, LS

$LS = (\lambda / 22.13)^{m} [65.41 \sin^{2}\theta + 4.56 \sin\theta + 0.065]$

Where, λ = field slope length, m

m = exponent factor varying from 0.2 to 0.5

θ = angle of slope, degrees

Here, λ = 28m, m = 0.3 for slope < 3 percent

θ = 0.6875 [since slope is 1.20 percent]

$LS = (28/ 22.13)^{0.3} [65.41 \sin^{2} (0.6875) + 4.56 \sin (0.6875) + 0.065]$

LS = 0.1385

Crop management factor by using parameters of USLE,

$$C = \left[\frac{A}{RKLSP}\right]$$

$$C = \frac{0.1965}{371.43 \times 0.015 \times 0.1385 \times 1}$$

$$C = 0.255$$

8. VITA

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MASTER OF TECHNOLOGY
(Agricultural Engineering)
in
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2012

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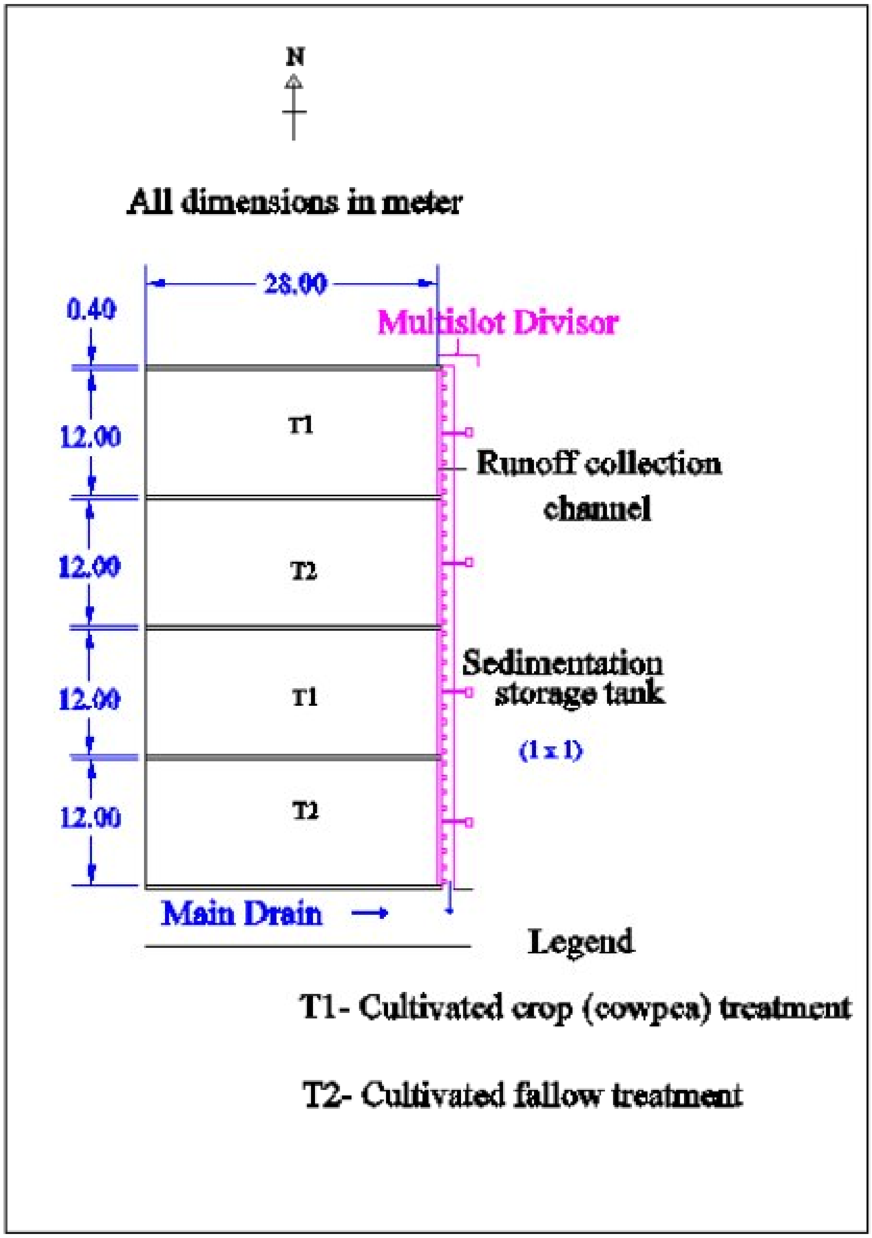

Fig 3.1 Layout of experimental field

Plate 3.1 Layout of the Experimental Field.

Plate 3.2 Field after germination of Cowpea

Plate 3.3 Cowpea with good crop canopy.

Plate 3.4 View of fallow plot

Plate 3.5 Actual runoff from cultivated crop treatment.

Plate 3.6 Actual runoff from cultivated fallow treatment.

Plate 3.7 Runoff sample bottles.

Plate 3.8 Filtration of runoff sample.

Plate 3.9 Soil retained after filtration process.

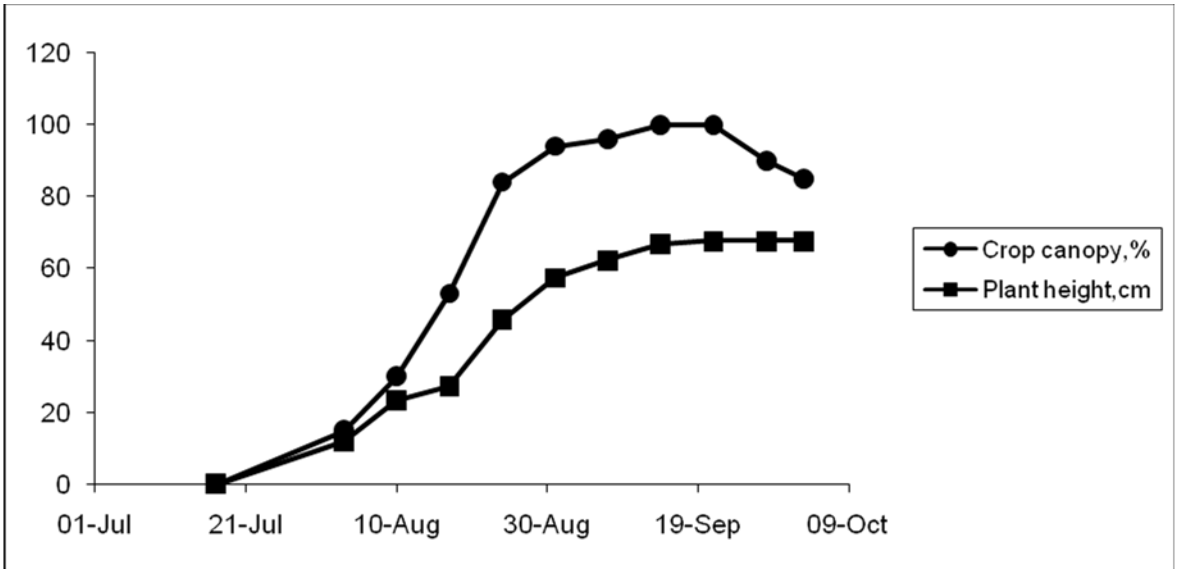

Fig 4.1 Crop canopy and Plant height of cowpea during growth period.

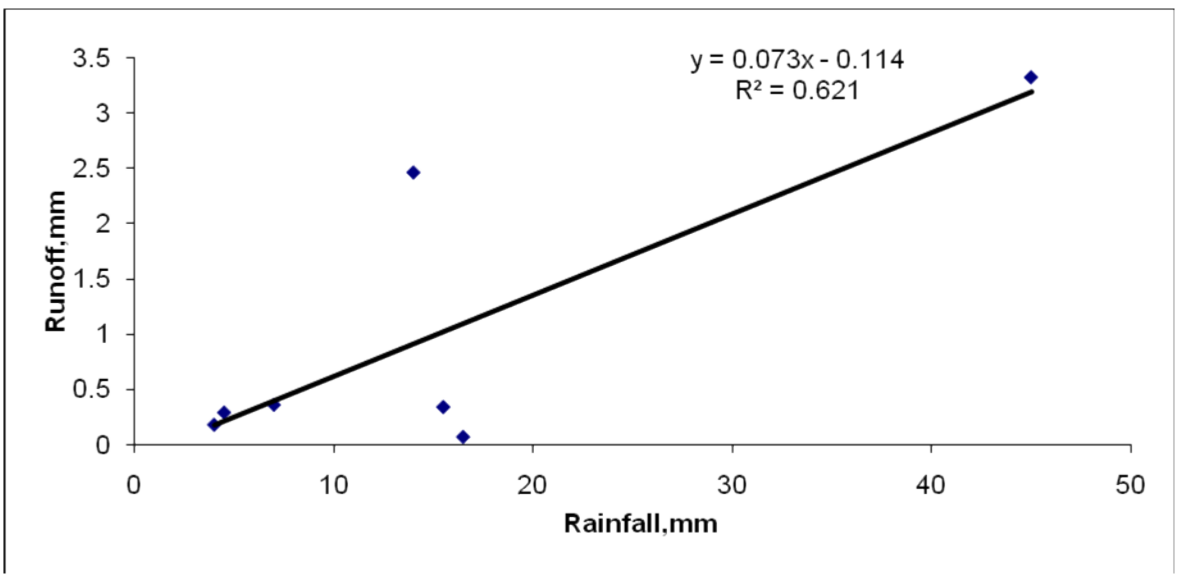

Fig 4.2 Relationship between Rainfall and Runoff from cultivated fallow treatment

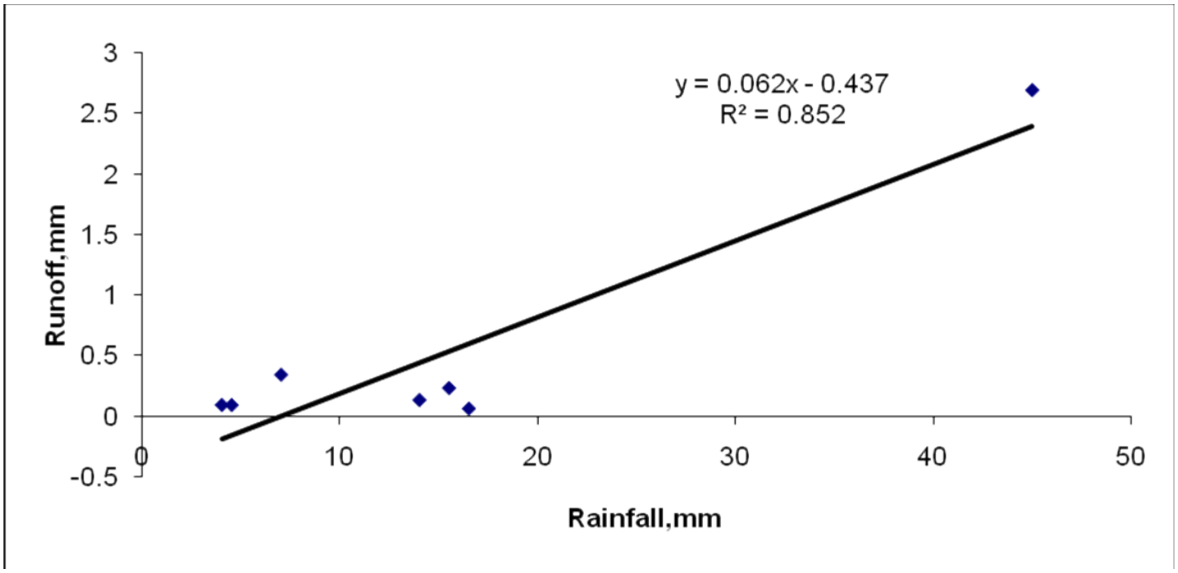

Fig 4.3 Relationship between Rainfall and Runoff from cultivated crop treatment

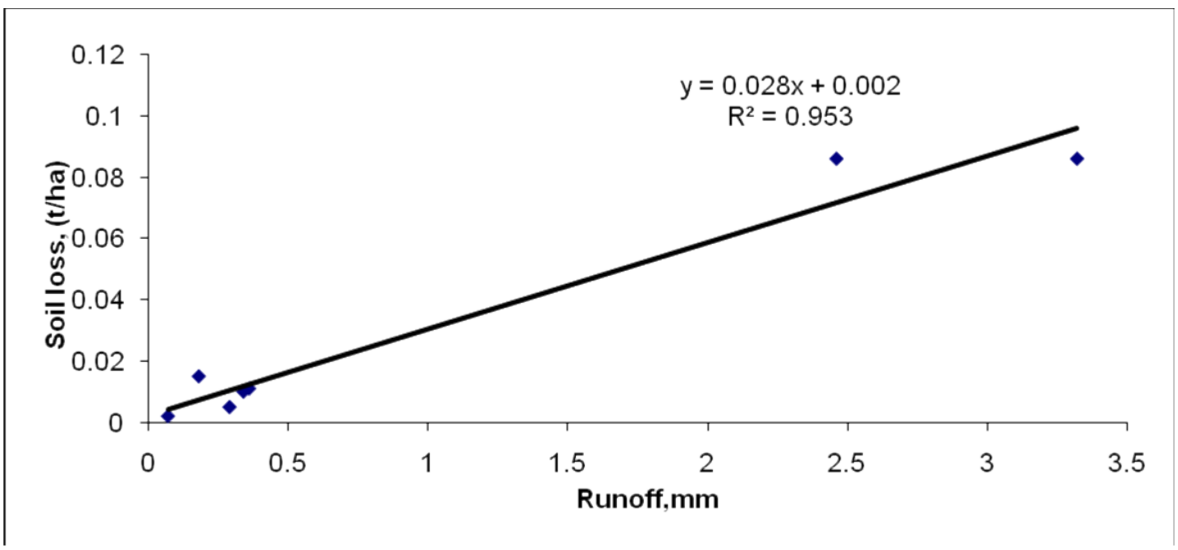

Fig 4.4 Relationship between runoff- soil loss for cultivated fallow treatment

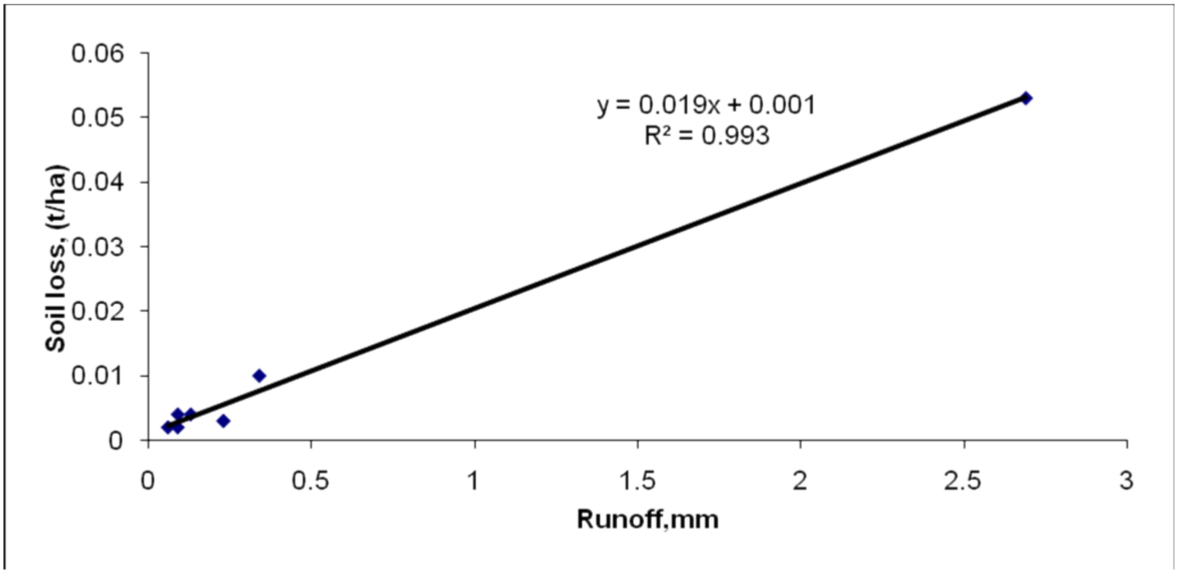

Fig 4.5 Relationship between Runoff and soil loss from cultivated crop treatment