

DEVELOPMENT OF A PROCEDURE FOR DETERMINATION OF SUB-MODELS
FOR CROP AND LAND MANAGEMENT FACTORS FOR SOIL LOSS
PREDICTION UNDER MOROGORO CONDITIONS

9/14

BY

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ABSTRACT

One of the most useful means of ameliorating land degradation through sediment losses is by application of soil prediction models. These associates all sources of information including soil physical characteristic data, long term weather data as well as crop management data into a prescribed categorisation effective in conservation.

Weather and soil physical characteristic data vary significantly regional-wise, this necessitates their accumulation on regional basis so as to develop regional specific models.

The purpose of this study was to develop a procedure for determining crop and land management factor(s) sub-models for soil loss prediction under Morogoro condition. A pascal program was employed in determination of the procedure. The procedure involved calculation of the C (Cover and Management factor) and P (Support practice factor) and then compared the obtained results with desired management factors set for the specified location. Weather data, soil data and crop canopy (%) were considered in determination of effective parameters for soil loss prediction. There was a good correlation between soil loss and rainfall intensity, rainfall amount,

canopy cover, organic carbon content as well as runoff for all rainfall events and treatments. The correlation coefficient ranged from 0.50 to 0.99. The correlation coefficient for average runoff and sediment loss was found to be 0.86, 0.95 and 0.99 for cropped, natural vegetated and bare plots respectively.

The overall coefficient of correlation for runoff and sediment losses at different storms ranged from 0.83 to 0.98. The correlation coefficient for soil loss and rainfall intensity was found to be 0.64, 0.50 and 0.60 for cropped, natural vegetated and bare plots respectively.

It was further revealed that rainfall intensity, rainfall amount, canopy cover, soil organic carbon as well as runoff variables correlated better with soil losses. The later concluded that the parameters mark effects in determining crop and land management factor(s) sub-models.

Determination of the relationship existing between soil loss and runoff variables indicated a linear relationship.

DECLARATION

I, Shayo, August Joachim, hereby declare to the senate of the Sokoine University of Agriculture, Morogoro, Tanzania, that the work presented here is my own, and has not been submitted for a higher degree in any other University.

Date: 20TH NOVEMBER 1997

Signature: *August*

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DEDICATION

This work is dedicated to my beloved parents.

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ABBREVIATIONS AND SYMBOLS

A	Computed soil loss per unit area
R	Rainfall erosivity factor
K	Soil erodibility factor
L	Slope length factor
S	Slope steepness factor
C	Cover and management factor
P	Support practice factor
EI ₃₀	Erosion index
KE	Kinetic energy of storm
ASL	Adjusted soil loss
I	Rainfall intensity
EI _t	Total EI
OSL	Observed soil loss for plot length L and slope S
LS	Slope length factor
λ	Field slope length
m	Exponent factor
Q	Angle of slope
Min.	Minimum
Max.	Maximum
TEMP	Temperature
RH	Relative humidity
Nat. Veg.	Natural vegetated plot

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RF	Rainfall amount
RI	Rainfall intensity
EVAP	Evaporation
SL-1	Soil loss from cropped plots
SL-2	Soil loss from bare plots
SL-3	Soil loss from plots with specified tillage practice
SL-4	Soil loss from plots with up and down tillage practice

CHAPTER 1

INTRODUCTION

In order to come up with proper land conservation methods, there is a need to have a good understanding of all the factors involved in the process of land degradation. However, the process of finding out and ranking the factors with the intention of conserving the land is of prior importance as far as land management is concerned.

The most serious form of soil degradation is accelerated erosion. Accelerated erosion has lowered the productivity of many soils. Erosion results in loss of soil with the greatest content of organic matter and nitrogen (Rosenberry, 1980). Erosion selectively removes the finer soil particles and organic matter and reduces soil depth and rooting volume thereby causing water stress in plants during periodic breaks in rain (Nelson and Sommer, 1984). Erosion reduces plant biomass and hence replenishment of organic matter. The loss of fine fraction and organic matter reduces the total available nutrients (Foth, 1984).

Erosion affects surface soil structure, increasing runoff and reducing infiltration as a result of the exposure of argillic

horizon (NRI, 1993). Erosion is also effective in removing applied inorganic nutrients, either dissolved in runoff and ground water or attached to the cation exchange of clays and organic matter (Foth, 1984).

Erosion is a symptom of poor soil use. Bad farming and forestry operations encourage erosion. Increased pressure on the land, for example, has resulted in deforestation, expansion of cultivated agriculture into marginal areas and intensification of agricultural activities on unsuitable lands (FAO, 1974). This has resulted in increased runoff and soil erosion as well as accelerated sedimentation in reservoirs.

The improvement of eroded areas depends mainly upon soil type. Improved management not only restores the productivity in many instances but may also raise it above the level it had when first ploughed (Morgan, 1979).

The basic system of soil management-tillage, crop rotation, liming and fertiliser application is of first importance, supplementary where they are adopted are strip cropping, contouring, use of terraces and small dams together with other practices for direct control of runoff and erosion.

Vegetation for example, plays a great role in keeping the soil in natural state from eroding (Moldenhauer and Foster, 1980).

Soil conservation research is aimed at a better understanding of soil erosion and its control. Conservation practices aim at the efforts to minimise erosion and other forms of soil degradation. The latter can be achieved by using land in accordance with its capabilities. Applying measures to restore the productivity of the soil where it has been damaged and prevent further damage from taking place (Moldenhauer and Foster, 1981).

One of the best ways to achieve effective soil conservation practices is by application of models.

A soil erosion model is a way of bringing together various factors and processes in such a way that they reproduce, to a good extent, what occurs in reality and thus can be used to predict soil loss more accurately.

Models used to predict soil loss for soil conservation planning require evaluation of climatic erosivity, soil erodibility, topographic factors, crop and land management parameters as their essential inputs.

Among the models (soil prediction) used frequently are those based upon statistical inferences of observed and response data such as the Universal Soil Loss Equation (USLE) and the Unit Hydrograph method.

The methods used to determine erodibility, crop and land management factors in one place cannot be transferred to other environments outside the area of their development (Wischmeier and Smith, 1978). This condition necessitates site specific methods to be developed for determination of the parameters.

Crop and land management parameters require long term data and extensive experimentation to cover all the effects of different crops, soils, land and crop management practices on soil erosion.

Effective planning of soil conservation needs appropriate tools for predicting soil erosion. Relevant methods and data collection must therefore be planned prior any experimentation in order to come up with desired factors which are important in soil loss prediction.

1.1 Objectives of the study

This study was carried out with the overall objective of developing locally applicable procedures for the determination of crop and land management factor(s) sub-models for soil loss prediction under Morogoro conditions. Specific objectives of the study were:

- (i) to develop a procedure for determining crop and land management factor(s) sub-models for soil loss prediction under selected crops;
- (ii) to determine effective crop and land management factors for soil loss prediction for the area studied; and
- (iii) to determine relationship existing between sediment loss and runoff by application of regression analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 Soil conservation

Soil conservation practices are the physical application of land, crop and water management knowledge by skilful or artful means, with the goal of protecting soil resources from exploitation, destruction or neglect (Meyer, 1980). They may be structural or support practices, such as channel terraces, contour bunds, and sediment basins (Panabokke, 1977). Alternatively, they may be cultural or agronomic practices, such as conservation tillage, sod-based rotations, and surface mulches or they may be a combination, such as contour-listing, grassed waterways and strip cropping (Meyer, 1980).

A number of soil researches have been carried out so as to come up with better conservation practices. In Kenya, Othieno and Laycock (1977) at Kericho, studied the influence of different tea cultivation practices on runoff and soil erosion and found that erosion losses were significantly correlated with rainfall intensity. Intensity was included in

a multiple regression with runoff and ground cover accounted for as much as 86% of the variability in soil erosion (Ulsaker and Onstad, 1984).

In Tanzania soil erosion and management studies have been made in conjunction with various regional development schemes, water master plans etc, a good example for this is the Mwanza regional integrated planning project in western Tanzania (Stromquist, 1981). Such studies have concentrated on simple field measurements of erosion rates (Rapp et al., 1973), e.g. from tree root exposure or pedestal development, runoff plots to compare erosion on cultivated fields, rangelands, fallow, stream and reservoir sedimentation studies to assess erosion rates in catchments (Rapp et al., 1973; Christianson, 1981). For instance at Lyamungu, in Kilimanjaro, Region. Temple (1972), collected data on runoff and soil erosion while studying different cropping practices.

Kauzeni et al, (1987), reported that soil erosion in Tanzania occurs mainly in the mountain areas and in the semi-arid plains. The causes of soil degradation in the highlands have been reported as deforestation, high density of population, overgrazing cultivation and burning of vegetation. The report further concluded that in semi arid regions, soil erosion is

caused by wind during the dry season and sheet erosion during the rainy season. This necessitates soil erosion studies to be conducted during both, wind and rainy seasons.

2.2 Methods to estimate soil erosion

The rate of erosion depends on a complex interrelationship among erosive forces of rainfall and runoff and susceptibility to soil practice detachment by these forces (Ulsaker and Onstad, 1984).

The purpose of soil loss estimation is to bring all sources of information into a formal arrangement which represents the best advice available (Elwell, 1978).

Generally, there are two methods for predicting soil erosion (Mtakwa, 1986), these can either be direct or indirect methods.

For indirect methods, several correlation equations for predicting sheet and rill erosion have been proposed where the annual soil loss rate is usually correlated with rainfall, soil erodibility, slope length, slope shape and slope steepness of slope, crop management and conservation practices. Among the equations, Universal Soil Loss Equation

(USLE) is the most widely used (Wischmeier and Smith, 1978).

As it is impossible to develop a comprehensive correlation covering all types of soils, empirically derived prediction equations involve experimental errors and potential estimation errors due to effects of unmeasured variables.

Direct methods comprise of those techniques employed in estimating soil loss without using correlation equations. They include the use of conventional runoff plots, use of erosion pins, pegs and stakes etc (Mtakwa, 1978).

2.2.1 Models and sediment loss prediction

Models can be classified as probabilistic, deterministic or parametric. Probabilistic models describe processes occurring in time governed by certain probability laws (Mtakwa, 1986).

Deterministic models are those which when the initial and boundary conditions and inputs are specified, the output is known with certainty. One of the most useful means of describing the response of runoff and associated sediment losses in overland flow has been the development of physical conceptual models (Bennett, 1974).

Mathematical models that describe the effect of conservation practices on soil erosion and sedimentation can be valuable for land use management planning (Meyer and Wischmeier, 1970). In this aspect, several correlation equations for predicting sheet and rill erosion have been proposed. In these equations, the annual soil loss rates have been correlated with rainfall, soil erodibility, length and steepness of the slope as well as land and crop management practices (Wischmeier and Smith, 1978).

Models used frequently are those based upon statistical inferences of observed response data such as the crop cover (C) and the management practices (P) in the Universal Soil Loss Equation (Bennett, 1974).

To develop mathematical models of sediment concentration, expressions are needed to describe the rate at which each separate process involved in erosion or deposition contribute to the overland flow (Bennett, 1974). This is because soil erosion is a result of complex factors and interrelationships and therefore, perfects models with universal applicability and extension to any combination of circumstances, are unattainable.

Physical deterministic models, using mathematical equations are the best way of advancing understanding of the intricacies of the erosion process and of accurate modelling. The models incorporate interrelationships among the various components that influence soil detachment. Unfortunately, they are very complex, difficult to apply and extremely 'data hungry'. They should be able to consider the separate influences of rainfall and runoff, detachment size, sediment load and deposition, and other such processes, giving due attention to various elements that interact (Meyer, 1980). They should also accommodate dynamic changes in time and space, such as seasonal changes.

Universal Soil Loss Equation (USLE) and Soil Loss Estimator for Southern Africa (SLEMSA) are the two principal predictive equations in use for sheet and rill erosion. They can be used to predict and assess possible future erosion rates under different land use management systems.

The USLE is the most widely used erosion model, while on the other hand SLEMSA was developed based on African economic, environmental and agricultural conditions (Meyer, 1980).

2.2.1.1 Universal Soil Loss Equation (USLE)

USLE is a factor-based equation. It permits the prediction of long term average soil erosion as a result of overland flow (Wischmeier and Smith, 1978). The erosion process is quantified and approximated by a series of factors, (Figure 1). The factors identify major variables that affect upland soil erosion by water, climate, inherent soil characteristics, topography, type of land use, and runoff management practices (Wischmeier and Smith, 1978).

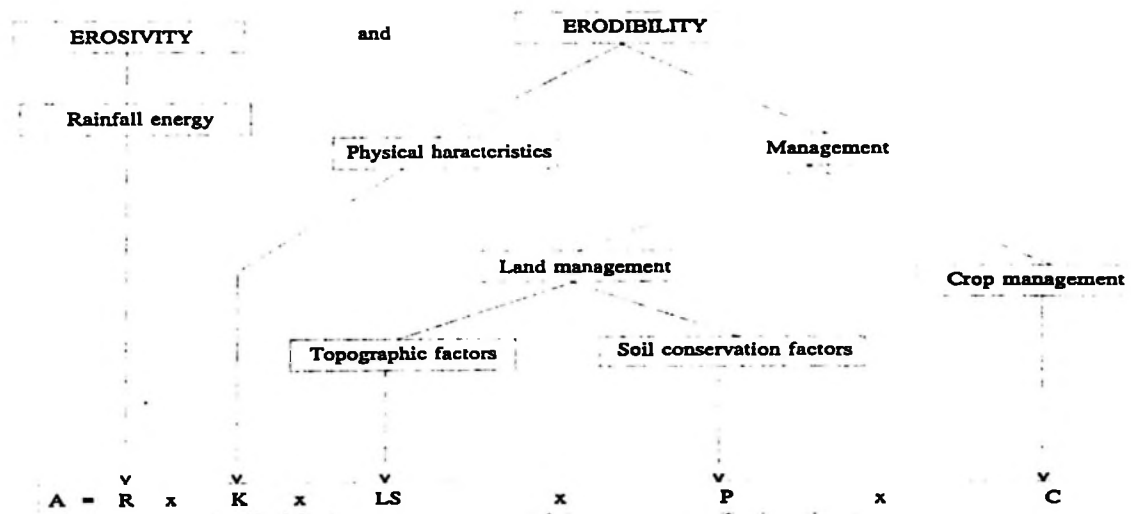


Figure 1: Model building (USLE)

SOURCE: Elwell, 1978.

Little can be done to change the climate, soil or long slope, but there is a room to determine land use that can affect

runoff management (Wischmeier and Smith, 1978). Each factor may quantify one or more processes and their interactions. Land use, especially as expressed by the cover management and supporting practices factor, is the most important aspect of the equation. A major limitation is the effort needed to apply the USLE to other areas than those it was developed for.

To transfer USLE would require determination of appropriate values for each of the factors: rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), cover management (C) and conservation practices (P), (Elwell, 1978).

According to Wischmeier and Smith (1978), USLE was designed for estimation of long time averages of soil loss from a specified land in a specified cropping and management system. The equation only predicts the losses from sheet and rill erosion under specified conditions. It computes the soil loss for a given site, as a product of the six major factors mentioned above and can be expressed numerically (Wischmeier and Smith 1978) as

$$A=RKLSCP \quad (1)$$

Where

- A = The computed soil loss per unit area, expressed in the units selected for K (see K below) and for the period selected for R (see R below). In practice, these are usually so selected that they compute A in tonnes per hectare per year, but other units can be selected.
- R = The rainfall erosivity factor, (Joules/ha).(mm/hr)
- K = The soil erodibility factor, is the soil loss rate per erosion index unit for a specified soil, measured on a standard plot (21.1 m length, 4.5 m wide) plot.
- L = The slope length factor is the ratio of soil loss from the field slopes length, to that from a standard plot under identical conditions.
- S = The slope-steepness factor, is the ratio of soil loss from the field slope gradient, to a 9% slope under identical conditions.

C = The cover and management factor, is the ratio of soil loss from an area with specified cover and management, to that from an identical area in tilled continuous fallow.

P = The support practice factor, is the ratio of soil loss with a support practice like contouring, strip_cropping or terracing to that with straight_row farming up and down the slope.

The erosivity factor R in the USLE is the number of rainfall erosion index units (EI_{30}) for a particular location. It is the measure of erosive force of specific rainfall.

The erosive force or available energy is related to both quantity and intensity of rainfall (Foth, 1984).

Wischmeir (1959) defined R as

$$EI_{30} = (KE) \frac{I_{30}}{100} \quad (2)$$

Where

EI_{30} = Erosion index

KE = Kinetic energy of storm (Joules/ha)

I_{30} = Maximum 30 minute rainfall intensity of the storm

According to Wischmeier and Mannering (1969), the KE value is expressed as

$$KE=210.3+89\text{Log}I \quad (3)$$

Where

I = Rainfall intensity, cm/hr.

Thus the rainfall erosion index measures only the erosivity of rainfall and the associated runoff (Foth, 1984).

The soil erodibility factor K, relates to the rate at which different soils erode due to inherent soil properties (Foth, 1984) such as:-

- a) those affecting infiltration rate, permeability and total water capacity; and
- b) those resisting dispersion, splashing, abrasion and transporting forces of rainfall and runoff.

The erodibility factor K, can be expressed as

$$K=\frac{ASL}{(EI_c)} \quad (4)$$

Where

ASL = Adjusted soil loss (tonnes/ha)

ET_c = Total EI

ASL is given as

$$ASL = \frac{OSL}{LS} \quad (5)$$

Where

OSL = Observed soil loss for plot length, L and slope S.

SL = Slope_length factor obtained from the slope effect chart/topographic factor, LS (Nomograph).

The topographic factor LS, is a combined effect of slope steepness and slope length. Slope length is defined as distance from the point of origin of overland flow to either a point where the slope decreases to the extent that deposition occurs or the point where runoff enters a well defined channel. Runoff from the upper part of the slope contributes to the runoff produced on the lower part of the slope compared to the upper part. As the slope increases the velocity of the runoff water increases, which increases the erosive power (Foth, 1984).

The combined slope length and gradient factor (LS) is given as

$$L = \left(\frac{\lambda}{22.13} \right)^m [65.4 \sin^2 Q + 4.56 \sin Q + 0.065]$$

Where

λ = Field slope length, (m)

m = Exponent factor varying from 0.2 to 0.5

Q = Angle of slope

The crop management factor C , reflects the combined effect of cover crop sequence, productivity level, length of the growing season, tillage practices, residue management and the expected time for distribution of erosive rain storm with respect to seedling and harvesting dates.

Vegetation cover can absorb the kinetic energy of falling raindrops and defuse the rain's erosive potential. Furthermore, vegetation by itself retains a significant amount of rainwater and slows the flow of runoff water as a result of the presence or absence of complete vegetation cover.

Studies done in Ethiopia, showed that areas with limited vegetation are severely affected by erosion, see table 1.

Table 1: Estimated rates of soil loss on slopes of Ethiopia dependent on soil cover

	Area †	Estimated soil loss (t/ha/yr)	Total soil loss(t/yr)
Crop land	13.1	42.0	672 000
Perennial crops	1.7	8.0	17 000
Grazing and browsing land	51.0	5.0	312 000
Currently unproductive	3.8	70.0	325 000
Currently uncultivated	18.7	5.0	114 000
Forests	3.6	1.0	4 000
Wood and bush land	8.1	5.0	49 000
	100.0	132.0	1 493 000

Total area of Ethiopia = 122 190 000 ha = 100%

Source: NRI, 1993.

The crop management factor, however, is complicated, as there are infinite number of ways for managing growing crops . The supporting conservation practice (P), refers to the ratio of soil loss with a specific supporting practice to the corresponding loss with up-and-down cultivation (Panabokke, 1977) .

In general, whenever sloping land is to be cultivated and exposed to erosive rains, the protection offered by the sod

or closely growing crops in the system needs to be supported by practices that will slow down runoff water, thus reducing the amount of soil carried. Important practices for crop lands includes contour tillage, strip cropping on the contour and terrace system. P values for contouring are given in Table 2. In cases where both strip cropping and contour tillage are used, the P value is divided by 2.

Table 2: Practice factor values for contouring

Land slope %	P value
1.1 - 2	0.6
2.1 - 7	0.5
7.1 - 12	0.6
12.1 - 18	0.8
18.1 - 24	0.9

Source: Foth, 1984, pg. 383.

2.2.1.2 Soil Estimator for Southern Africa

SLEMSA (Fig. 2) combines basic simplicity with use of locally available data and an emphasis on some of the most important interactions in tropical environments. The most important interactions in predicting the mean annual soil loss arising from sheet erosion are especially those between vegetation cover, raindrop interception and rainfall erosivity (Elwell

and Stocking, 1982).

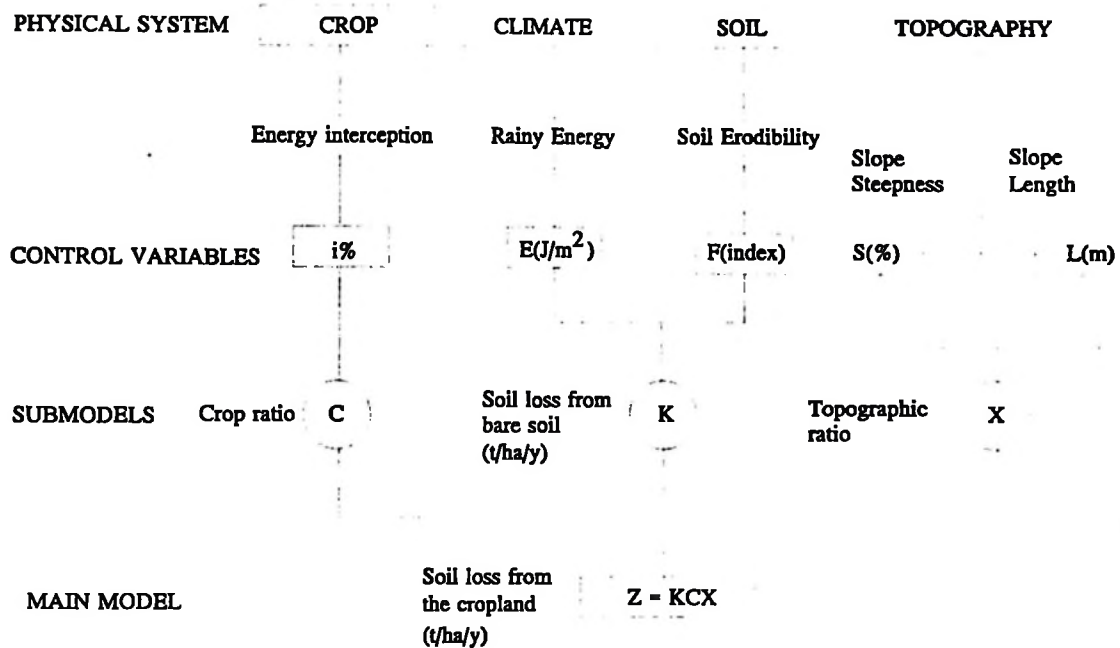


Figure 2: Model building (SLEMSA)

SOURCE: Elwell, 1978.

2.3 Management practices

Research results obtained from a range of soils and climatic environments indicate that the best method of soil control, is good soil and crop management (Lal, 1980). Preference is given to soil and crop management techniques that minimise runoff through improvement in soil structure and water infiltration (Panabokke, 1977).

One main aim of crop and soil management was to keep the soil surface protected from the rain for as long as possible each year Foth (1984).

2.3.1 Crop management practices

Crop management is by far the most important aspect of soil conservation, because it has the greatest impact. It falls under man-induced vegetation with the key parameter being canopy cover, which minimises splash erosion by providing a protective vegetative cover.

Rain drop impact on freshly tilled soil causes break_down of surface aggregates. This break_down affects infiltration (Hillel and Gardner, 1970), surface sealing (Farrel, 1978), and soil detachment (Francis and Cruse, 1983).

The break_down of surface aggregates is very much reduced by vegetative cover. Canopy cover differs widely with crops at different times of the year, thus different crops require different management practices to influence soil degradation (FAO, 1974).

With different crops, however, the use of fertilisers and plant protection may markedly improve vegetative cover and thus provide good soil protection.

2.3.1.1 Cropping sequences

Cropping sequences that provide early continuous ground cover, permits less erosion than those with less or delayed cover. Most researchers believe that soil and water losses are greater if the preceding crop is soybeans than if it is corn. However, data for predicting such losses are few (Wischmeier, 1960).

Mannering and Johnson (1969), in a study using simulated rainfall to evaluate the effect of row crop spacing on erosion and infiltration, found no significant difference in soil loss between corn and soybeans for similar row spacing during the growing season.

Research done by Lal (1976) indicated that cowpeas permits less soil erosion than maize and that maize following cowpeas permits more erosion than maize following maize.

2.3.1.2 Crop combination

Crop combination with multi-storey canopy structure should be more effective against erosion as it provides a continuous ground cover (Lal et al, 1979). However, mixed cropping

cannot be followed on large scale mechanized commercial farms because seeding and harvesting operations are difficult to perform (Lal, 1976).

2.3.1.3 Crop residues and mulch farming

Mulch prevents the direct impact of raindrop on soil aggregates, maintains pore space continuity and high infiltration rate and enhances crop growth, thus providing early ground cover (Lal et al, 1979). Annual crops cannot, however, provide cover during the periods before planting and after harvesting or during the young stages of growth. Protection at these times should be provided in other ways. Thus, covering the soil with crop residue such as straw and stubble of grain crops and grasses or banana leaves, will reduce soil loss very considerably.

2.3.1.4 No or minimum tillage

Excessive tillage destroys soil structure in the long term (Lal et al, 1979). Infiltration capacity is reduced as a result of crusting and the formation of impermeable soil layer beneath the plough layer (Collis and Lal, 1971). This increases runoff which in turn accelerates soil erosion. Minimum tillage is used to achieve the effect of residual mulch. For no till to be effective for crop production,

considerable information is needed for different soils, crops and ecological regions. Special requirements of the no tillage system are means of weed control, suitable crop combination, suitable cropping sequences and adequate amount of residue for mulch (Lal et al, 1979).

2.3.1.5 Strip cropping

Strip cropping refers to division of land into alternative strips of close growing erosion resistant plants such as grass, grass/legume mixtures, small grains or natural vegetation with strips of wider spaced crops such as maize, sorghum, cotton and root crops.

2.3.2 Land management practices

The most fundamental principle of soil conservation is that it can only be effective where land use is ecologically sound. (Hudson, 1981).

While land degradation results primarily from incorrect land use and management, it is the mismanagement of the land itself that cause desertification. Thus, land management practices refers to the aspect of land use which match the

aspects of environment; the soil in terms of structure; texture and permeability; the slope in terms of its steepness; length and shape as well as climate in terms of erosivity of rainfall and wind.

Erosion hazards vary with slope steepness, length and shape. Studies by Young and Mutchler (1969) showed that concave slopes had much lower sediment losses than sediments from uniform or convex slopes of the same average steepness. Meyer and Cramer (1969) also showed that sediment losses are reduced when the lower part of the slope flattens.

CHAPTER 3

MATERIALS AND METHODS

3.1 Location, soils and climate

The experimental site was located at Sokoine University of Agriculture farm. The area represents the agro-climatic conditions and major soils of the region (Mtakwa, 1986).

Climate and soil characteristics were determined in details using various field and laboratory methods and procedures as described below.

The land form of the site is gentle, the slope being 3%. Most of the soil material appears to have been derived from the Uluguru mountains (Usagarian system rocks, which consist of metasediments of precambrium age, mainly composed of pyroxene granulates) by fluvial erosion.

Some of the soils are devised from Mindu hills that are rich in muscovite, biotite and hornblende gneiss (Sampson and Wright, 1964). The soils are moderately structured, red, clayey, kaolinitic with pH in water (5.8), organic carbon (0.88 %), and exchangeable bases (10.3 m.e/100g).

The climate of the study area is sub-humid tropical type with total annual rainfall varying between 500 mm and 1300 mm with the mean of 840 mm. Long term data indicates highest rainfall in April with mean maxima varying between 70 and 300 mm and lowest in June with mean minima varying between 0 and 40 mm. Figure 3 shows the variation in the monthly mean maxima, monthly mean and monthly mean minima rainfall for the period of 1970/95.

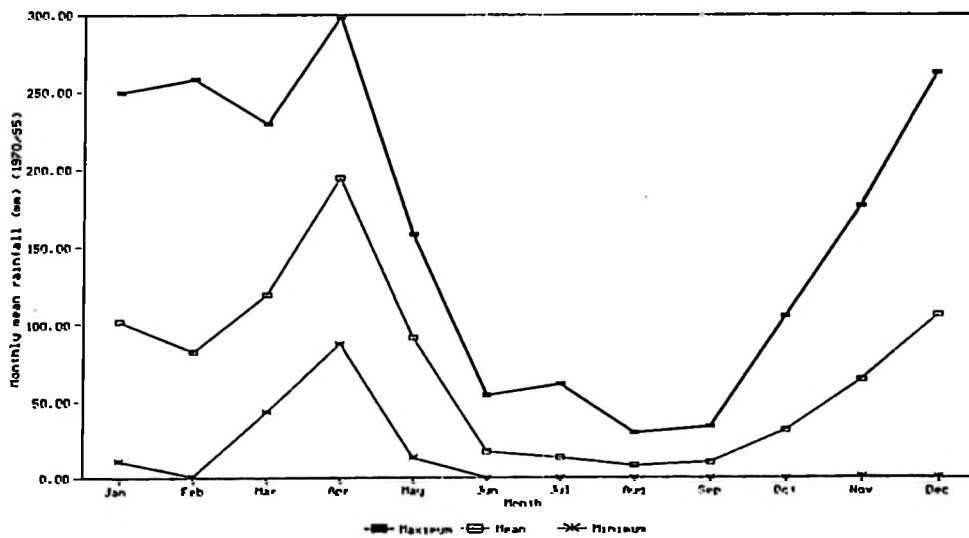


Figure 3: Monthly mean maxima, mean and minima rainfall for Morogoro (1970/95).

SOURCE: Meteorological station Morogoro.

The area experiences bimodal rainfall with short and long rains, short rains last from November to January with a peak in December, while long rains last from March to May with a

peak in April. Temperatures are highest in November and lowest in April. Monthly mean temperature maxima vary between 28 °C and 34 °C and minima temperature vary from 25 °C to 30 °C, (figure 4).

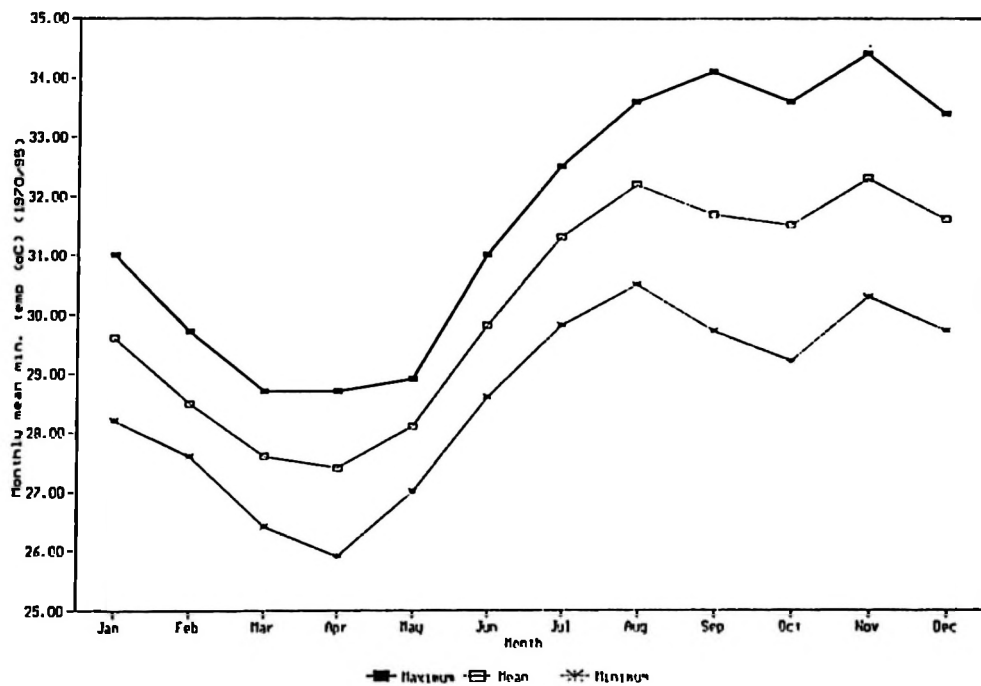


Figure 4: Monthly mean maxima, mean and minima for maximum temperature in Morogoro (1970/95)

SOURCE: Meteorological station Morogoro.

Mean monthly relative humidity varies from 33% in August 75% in January. Figure 5 shows the monthly mean maxima, monthly mean and monthly mean minima for maximum relative humidity in Morogoro (1970/95).

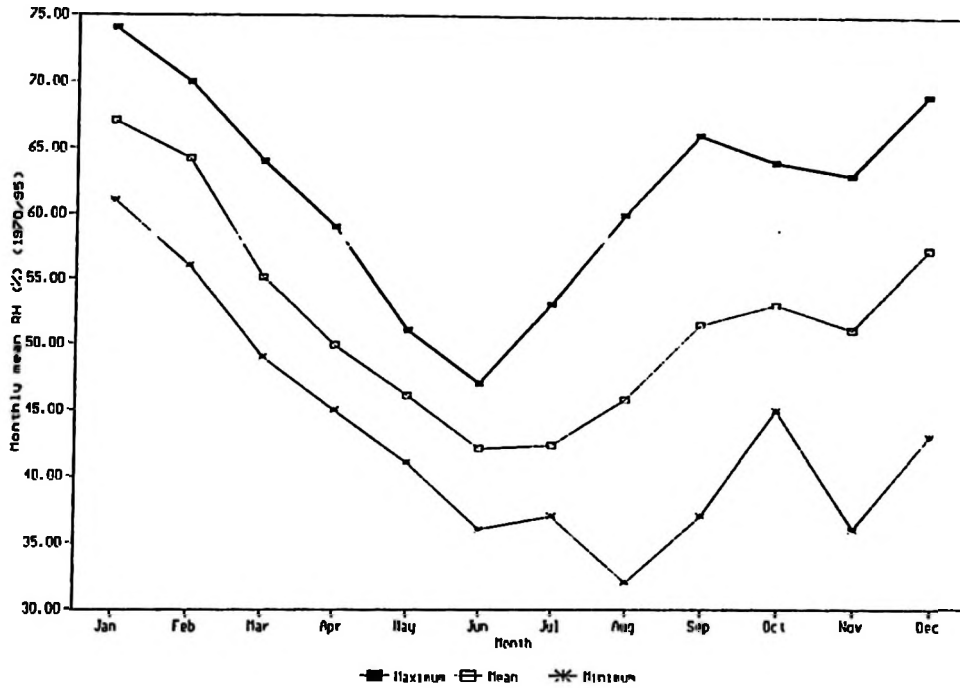


Figure 5: Monthly mean maxima, mean and minima relative humidity in Morogoro (1970/95)

SOURCE: Meteorological station Morogoro.

Appendix 3 (a) to 2(e) indicate climatic data collected during the study period.

3.2 Experimental set-up and data collection

The preparation of the experimental site started in November 1995 while the actual field experiments were conducted between February and June, 1996.

3.2.1 Runoff plots

Twelve runoff plots of the size 22.1 m long by 4.5 m wide and slope of 3% were set up for runoff and sediment collection (figure 6).

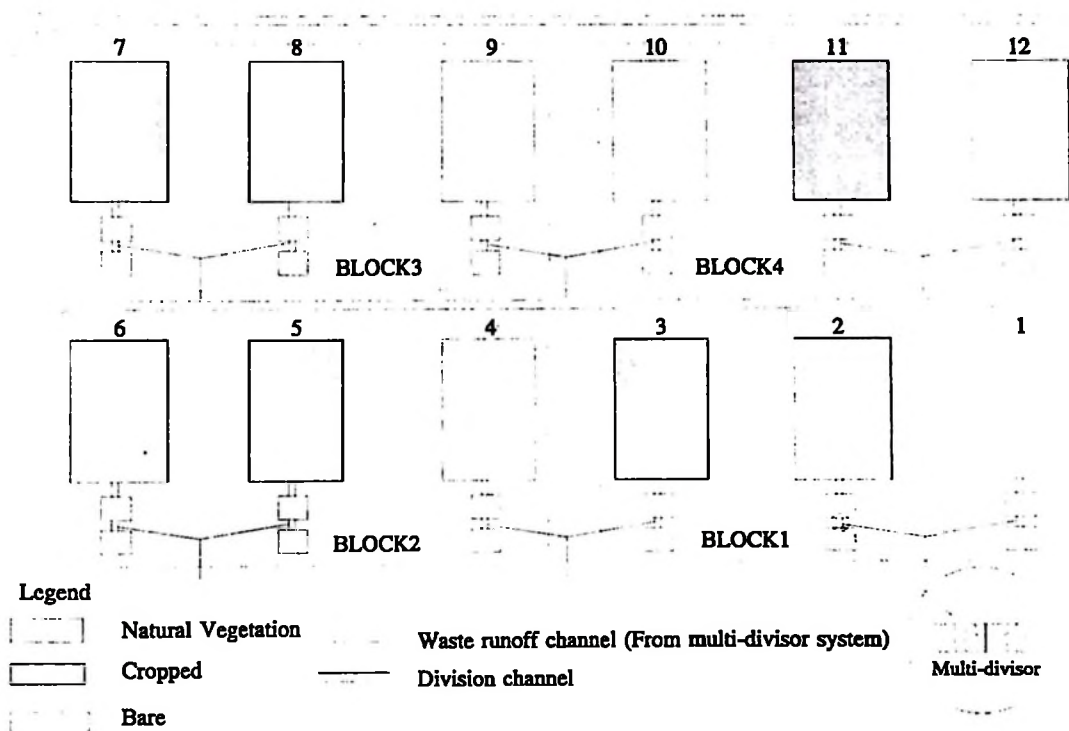


Figure 6: Experiment layout

The runoff plots consisted of side walls of corrugated iron sheets, measuring 20 cm above the ground (see, appendix 3, 4 and 5), with two collection tanks (each 1 m³) located down slope (Figure 7).

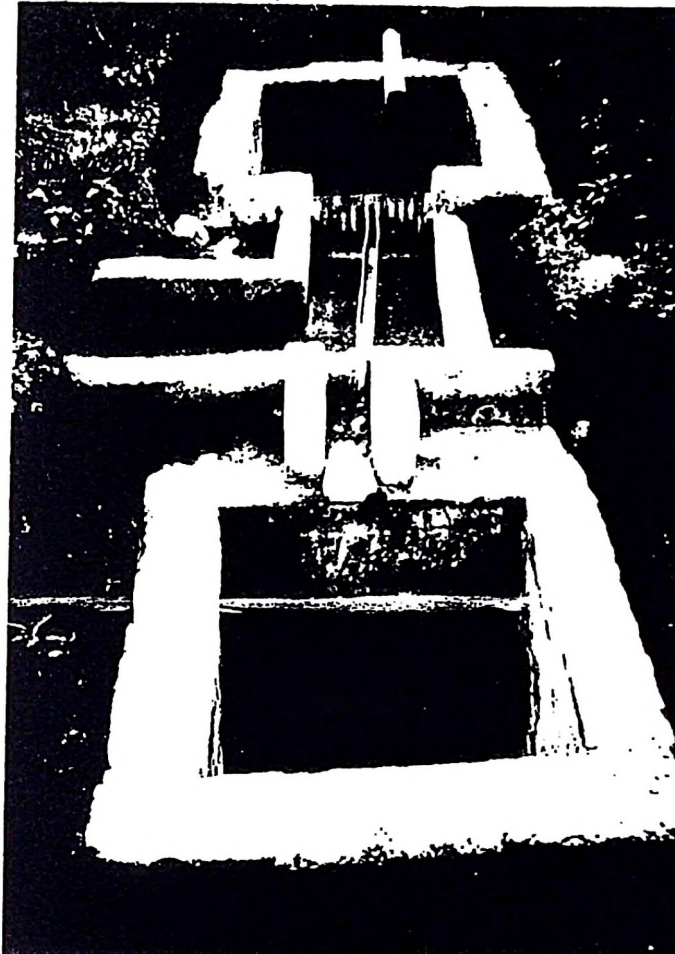


Figure 7: Collection tanks

Four plots were cropped under maize, four plots had natural vegetation, while four plots were left bare.

3.2.2 Tillage operations and planting

Tillage operations were done by tractor while site clearing, weeding, planting and fertiliser application were done manually.

With the exception of the plots with natural vegetation, the rest were ploughed before the onset of the rainy season and the crop was planted some days before the expected onset of rains.

Maize was planted at a spacing of 0.9 m between rows and 0.3 m within rows. Thinning and replanting was carried out to ensure an average of 260 plants per plot and a population of 2.6×10^4 plants per hectare were maintained (plants population recommended for both vigorous healthy crops for good yield and canopy cover for soil protection), see appendix 4 (cropped plots).

3.3 Crop management

A mono-crop of maize (*Zea mays* L.), star, recommended for Morogoro area was used in the experiment. The same crop management practices were applied for all cropped plots.

The essence of crop management was not only to provide healthy crops for good yield, through good crop husbandry, but also for soil protection by providing protective vegetative cover and good root distribution which holds the soil together.

3.3.1 Fertiliser application

Fertiliser application was done by hand during planting. Bare plots were ploughed every three weeks and not fertilized whilst cropped plots received 200 Kg/ha nitrogen, 50 Kg/ha phosphos and 60 Kg/ha potassium (NPK) during planting.

3.3.2 Weeding and pest control

Weeding was carried out with a hand hoe as often as necessary to keep the plots weed free, two weeding were found to be sufficient.

Pests which appeared to be common over the study period, especially during the 5th and 6th weeks were the stalk borer. This pest had an effect of retarding the growth of the crop and hence provided poor vegetative protection of the soil for the plots which were first attacked. Diplterex was applied at

recommended concentrations to control the pests. One application was found to be sufficient.

3.3.3 Harvesting

Although this was not a yield experiment, crop yield was measured because of its effect on soil loss.

For each cropped plot, total number of plants and ears were recorded. Other data recorded included weight of ears, seeds, cobs, leaves and stems as well as husks, table 5 and table 6.

3.4 Rainfall measurement

A standard rain gauge together with an automatic rainfall recording gauge were installed in the field for measurement of the rainfall.

Equation (2) (pp. 16) was used to determine the erosivity index (EI_{30}). The 30 minute maximum intensity was obtained from the automatic recording rain gauge charts by taking the greatest amount of rainfall in any 30-minutes of the storm. To get the rainfall intensity in mm h^{-1} , the amount obtained above was multiplied by 2.

3.5 Soil data measurement

The following soil parameters were determined: particle size distribution using pipette method (Gee and Bauder, 1986); bulky density and particle density according to Blake and Hartge (1986a,b); Organic matter content using Walkley-Black method (Nelson and Sommers, 1984); dispersion ratio according to Middleton (1930); cation exchange capacity and exchangeable cations using ammonium acetate method (Chapman, 1965); soil Ph using electrometric method (Mclean, 1984); infiltration capacity using double ring infiltrometer method (Bouwer, 1986) and exchangeable acidity using potassium chloride according to Thomas (1984).

3.6 Runoff collection and measurement

Runoff from the plots was first collected in the collection channel, (Figure 8) before passing through the PVC pipe to the tank. The tanks had a divisor system made of aluminium plate which divided the total runoff into 9 parts.

For small storms, the entire runoff was collected in the first tank while for large storms, the first tank was filled and the second tank collected 1/9 of the overflow which passed through the multi-slot divisor system.

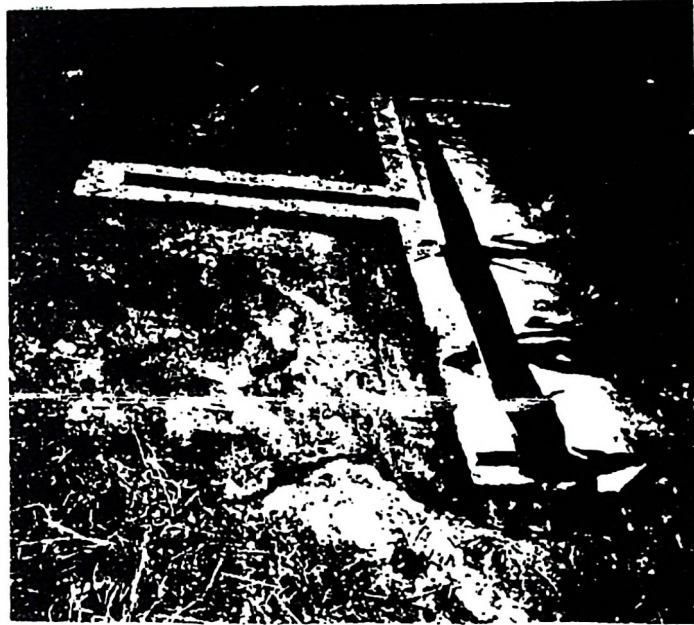


Figure 8: Collection channel

Levelling of the divisor system was done to ensure accurate division of the flow. Care was taken in tank design to ensure collection of the peak flow.

To aid fast settling of the sediments in the collected runoff, flocculating agent (calcium chloride) was added to the runoff suspension, This enabled easy separation of water from the soil.

3.7 Sediment loss measurement

To measure the eroded sediments, the entire runoff and eroded material from individual storms were caught in the tanks, the supernatant fluid was siphoned off and the soil removed and weighed.

With heavy storms, the weight of the soil from the second tank (i.e. through the multi-slot divisor) was measured. The weight obtained was then adjusted in accordance with the proportion of the total runoff and the sediment passed into the tank. This weight was then added to the weight obtained from the first tank to get the total wet soil loss from the plot.

A sample was taken from the wet soil, oven dried at 105 °C for 24 hours and weighed. The dry weight of the sample was used to determine the total dry soil loss collected in the tank. This total dry weight of soil from a standard plot was then used to compute soil loss in t/ha for each storm.

3.8 Canopy cover measurement

Canopy cover was determined by using a quadrat sighting frame (Figure 9).

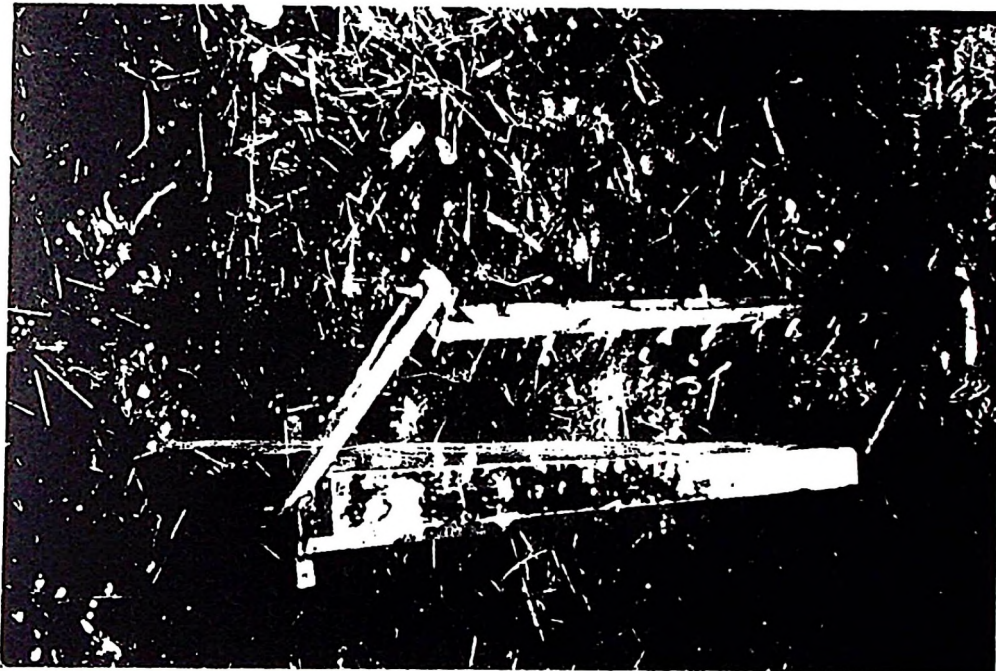


Figure 9: Quadrat sighting frame

The quadrat frame consisted of two horizontal wooden bars which were set above each other, each bar had ten small holes at regular intervals along each bar to allow the observer to see through and record whether there was a presence or absence of leaf covering the ground. Each plot had fifty

stations for the quadrat frame and each station had ten observations, making a total of five hundred observations per plot. Locations for the quadrat frame were randomly done on each row, with each row having one station and therefore ten observations. The average of the sights gave the average canopy cover of the plot at a given period.

3.9 Statistical layout

To reduce sampling variability of the experimental units and therefore reducing the measure of error (MSE) in each block, the randomized block design was employed.

Four matched sets of experimental units, i.e. four blocks were formed. Each block consisted of three experimental units that were similar. One experimental unit from each block was randomly assigned to each treatment, resulting in a total of 12 treatments (figure 6).

3.10 Data analysis

Data analysis was done both manually and with the aid of a computer. A statistical program INSTAT was employed in Analysis of Variance (ANOVA) so as to test the amount of

variation attributable to treatments by checking the unexplained (residual) variation. The error mean square was used to measure the variation among plots.

For this experiment simple linear regression was adopted to find out the relationship existing between sediment loss and various parameters measured on site. For the whole exercise, soil loss was considered as the dependent variable and other parameters were considered as the explanatory variables. The least square method was employed in the analysis. The general form of the regression obtained was in the form:

$$Y=a+bX \qquad (13)$$

To measure how well the regression fits the data, the coefficient of correlation (r) was determined and presented. The essence of carrying out the analysis was generally to try and find out the relationship existing between the parameters and soil loss.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Effective parameters for determination of crop and land management factor(s) sub-models for soil loss prediction

Development of sub-models for determination of crop and land management factors for soil loss prediction requires meteorological data for as many years as possible so that the norm and variability of climatic conditions can be presented (Timlin *et al*, 1986). In this study however, data for one season were collected (due to limited time for the study) so as to assist in determination of effective crop and land management parameters for soil loss prediction.

Results in table 3 indicates that rainfall with high intensity and duration resulted in high runoff with significant soil losses. Vegetative cover reduced raindrop splash, this reduced the kinetic energy of the drops which could otherwise detach soil particles. On the other hand vegetative cover provided a prolonged infiltration period resulting to a significant reduction in runoff.

Table 3: Soil and runoff data for different rainfall amounts, intensities and treatments over the study period

Date	Rainfall (mm)	Duration (minutes)	Rainfall intensity (mm/hr)	Treatment	Average soil loss (Kg/ha)	Average runoff
03.2.96	39.60	195	36.00	Bare	747.60	12.86
				Natural vegetation	30.20	2.01
				Cropped	450.80	10.06
19.3.96	38.50	480	28.00	Bare	670.10	12.01
				Natural vegetation	70.09	1.74
				Cropped	126.60	8.18
28.3.96	32.40	135	35.00	Bare	138.70	2.60
				Natural vegetation	28.40	1.00
				Cropped	70.90	1.60
26.4.96	26.10	165	27.50	Bare	125.00	2.11
				Natural vegetation	27.00	0.33
				Cropped	53.65	1.03
30.3.96	16.30	240	19.00	Bare	81.03	1.71
				Natural vegetation	22.80	0.33
				Cropped	44.68	0.54
02.4.96	6.80	60	14.50	Bare	47.68	0.38
				Natural vegetation	7.95	0.11
				Cropped	18.95	0.30
05.4.96	6.30	300	1.50	Bare	42.20	0.36
				Natural vegetation	13.70	0.07
				Cropped	25.40	0.20

Table 4 presents correlation coefficients between soil loss and weather data (rainfall amount, rainfall intensity, temperature, relative humidity, and evaporation) canopy cover as well as soil organic carbon for the separate treatments (bare plots, cropped plots and natural vegetated plots). Rainfall amount, rainfall intensity, canopy cover and soil organic carbon indicated a better correlation with soil loss for all the treatments. For bare plots r varied from 0.60 to

0.90 whereas it varied from 0.59 to 0.67 and 0.50 to 0.96 for cropped and natural vegetated plots respectively. This was a good indication of how well soil loss was explained by the parameters. Since all parameters indicates a positive correlation with soil loss, the implication is that there was a linear relationship between soil loss and the parameters. As the parameters increased in value, soil loss increased as well.

Table 4: Regression equations, std error of slope and coefficients of correlation between soil loss and selected parameters under bare, cropped and natural vegetated plots

Parameter	Treatment	Regression equation (soil loss = ...)	std	r
Rainfall (amount) (mm)	Bare	-154.5 + 17.6 * RF	5.63	0.81
	Cropped	- 59.1 + 7.6 * RF	3.61	0.67
	Nat. Veg.	3.1 + 1.1 * RF	0.41	0.76
Rainfall (intensity) (mm/hr)	Bare	- 78.8 + 14.9 * RI	8.93	0.60
	Cropped	- 56.7 + 7.4 * RI	4.50	0.59
	Nat. Veg.	9.8 + 0.8 * RI	0.63	0.50
Canopy cover (%)	Bare			
	Cropped	64.4 + 6.0 * COVER	4.21	0.71
	Nat. Veg.	-39.1 + 1.1 * COVER	0.99	0.63
Temperature (oC)	Bare	1610.0 - 48.5 * TEMP	45.33	0.43
	Cropped	-57.1 + 6.1 * TEMP	24.97	0.12
	Nat. Veg.	185.2 - 5.6 * TEMP	2.10	0.77
Relative humidity (%)	Bare	-101.7 + 483.0 * RH	13.27	0.16
	Cropped	381.8 - 3.6 * RH	6.53	0.24
	Nat. Veg.	-18.7 + 0.6 * RH	0.83	0.32
Evaporation (mm)	Bare	31.4 + 73.9 * EVAP	190.40	0.17
	Cropped	-8.0 + 38.3 * EVAP	95.07	0.18
	Nat. Veg.	3.6 + 7.9 * EVAP	12.13	0.28
Soil PH	Bare	713.9 + 5.5 * PH	33.63	0.11
	Cropped	958.9 - 83.0 * PH	84.39	0.57
	Nat. Veg.	169.4 - 23.1 * PH	33.78	0.43
Soil OC	Bare	-2.3 + 3505.0 * OC	1227.00	0.90
	Cropped	76.3 + 430.0 * OC	344.80	0.66
	Nat. Veg.	144.4 + 189.6 * OC	37.75	0.96

4.1.1 Rainfall and erosivity

Rainfall amount during the study period had a mean value of 10.32 mm with a maximum value of 39.60 mm, (Appendix 6). Rainfall intensities and duration are presented in Appendix 7. Rainfall amount, intensity and duration had a direct relationship with runoff amount and soil losses. High rainfall amount, high intensity as well as low intensity rainfall with long duration resulted in high runoff and soil losses.

Table 5: Rainfall erosivity and soil losses over the study period

Rainfall (mm)	Erosivity indices		Soil loss from plots (Kg/ha)		
	EI ₃₀ MJmm/m ²	AI ₃₀ (mm ² /hr)	Bare	Cropped	Natural vegetation
39.60	0.12	1433.25	747.60	450.80	30.20
38.50	0.07	920.48	670.10	126.60	70.09
32.40	0.09	798.00	138.70	.90	28.40
26.10	0.64	564.28	125.00	53.65	27.00
16.30	0.01	112.67	81.03	44.68	22.80
6.80	0.01	152.25	47.68	18.95	7.95
6.30	0.00	10.75	42.20	53.65	13.70

Rainfall erosion indices given for each rainfall event in Table 5, provided the basis for comparing soil erosion from the plots under different treatments (Wischmeier and Smith, 1958).

The results of the Analysis of Variance (ANOVA) for soil loss for the individual storms on runoff are presented in

Appendix 8 to appendix 14. The results of employing blocks was appreciably good, however the error mean square was slightly greater than the block mean square for storms of 39.6 mm, 32.4 mm and 6.4 mm. This is probably a result of inadequate data gathered due to limited time for the study.

For bare plots the correlation coefficient between soil loss and rainfall amount was 0.81 whereas it was 0.60 for rainfall intensity. This indicated how effective rainfall intensity and rainfall amount was on soil loss.

Canopy cover results for cropped and natural vegetated plots at different stages of growth (During the 4th, 8th and 12th week after planting) are presented in Appendix 17.

Table 6: Harvest record (Weights in this table are for undried material)

Date	(Plot)	(Plants) (No.)	(Ears) (No.)	(Wt. Ears) (Kg)	(Wt. seeds) (Kg)	(Wt. stem) + leaves (Kg)	(Wt. Husks)		(Wt. sample (g))	
							Husks	Seeds	Cob	Stem+leaves
27.6.96	3	284	289	41.80	31.60	48.80	10.20	17.30	194.10	155.50
28.6.96	5	281	295	44.90	34.30	55.60	10.60	15.11	165.20	160.00
29.6.96	7	279	271	42.80	33.00	52.40	11.80	16.88	170.00	152.60
30.6.96	11	280	283	42.60	36.00	60.20	10.40	18.17	192.30	164.40

4.1.2 Runoff

Runoff data obtained from this study have been presented in appendix 16. There was a significant difference ($p < 0.05$) in runoff between treatments at different rainfall amounts, intensities and duration. High rainfall amount, high intensity as well as low intensity rainfall with long duration resulted to high runoff amount.

There was a significant difference ($p < 0.05$) between runoff from natural vegetated plots and that from cropped ones. Natural vegetated plots showed the least runoff amount where as bare plots showed the highest runoff amount. This is probably a result of a prolonged infiltration time provided by vegetation. Runoff from bare plots ranged from 0.09 mm with a rainfall of 6.30 mm and intensity of 6.00 mm/hr to 13.28 mm with a rainfall of 39.60 mm and intensity of 7.52 mm/hr.

There was a significant difference ($p < 0.05$) between runoff and rainfall intensity for both cropped and natural vegetated plots. Cropped plots' runoff ranged from 0.05 mm with a rainfall of 6.30 mm and intensity of 6.00 mm/hr to 10.37 mm with a rainfall of 39.60 mm and intensity of 7.52 mm/hr.

Natural vegetated plots' runoff ranged from 0.02 mm with a rainfall of 6.30 mm and intensity of 6.00 mm/hr to 2.40 mm with a rainfall of 39.60 mm and intensity of 7.52 mm/hr. The average maximum runoff from bare plots was 12.86 mm whereas it was 10.06 mm and 2.01 mm from cropped and natural vegetated plots, respectively. However, the results showed an insignificant difference in runoff within the treatments. The reduction in runoff for both cropped and natural vegetated plots was observed as an effect of canopy cover.

Soil losses presented in appendix 17 and rainfall data in appendix 7, indicates that some high rainfall amounts had low runoff, this was probably a result of long drought periods before the storms.

The coefficient of variation for soil loss ranged between 4.3% and 10.8% whereas r^2 for the regression of soil loss on runoff ranged between 0.55 and 0.97 indicating how well soil loss was explained by runoff.

4.1.3 Treatments

Sediment loss results are presented in appendix 17. As it was with runoff data, there was a significant difference ($p < 0.05$)

in soil loss between treatments at different rainfall amount, intensities and duration.

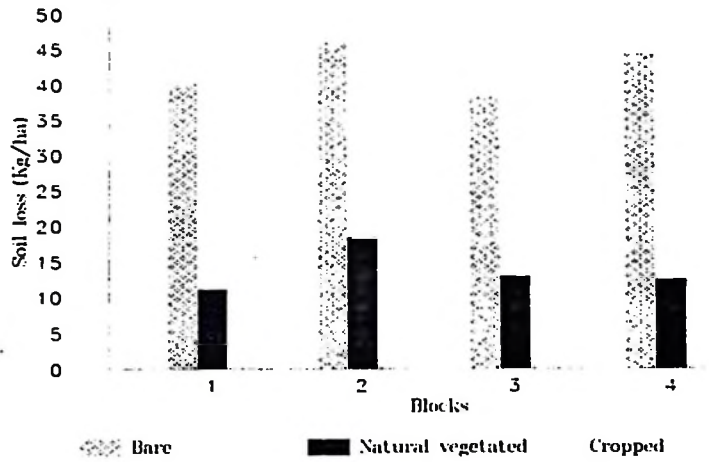


Figure 10(a): Variation of soil loss with treatments (With rainfall 6.3 mm)

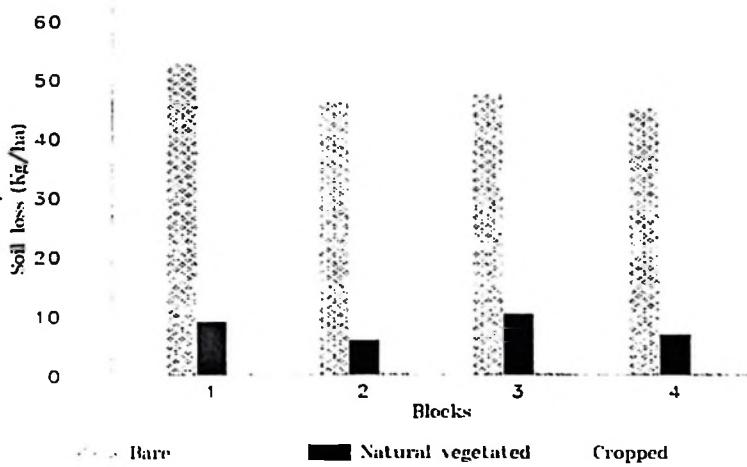


Figure 10(b): Variation of soil loss with treatments (With rainfall 6.8 mm)

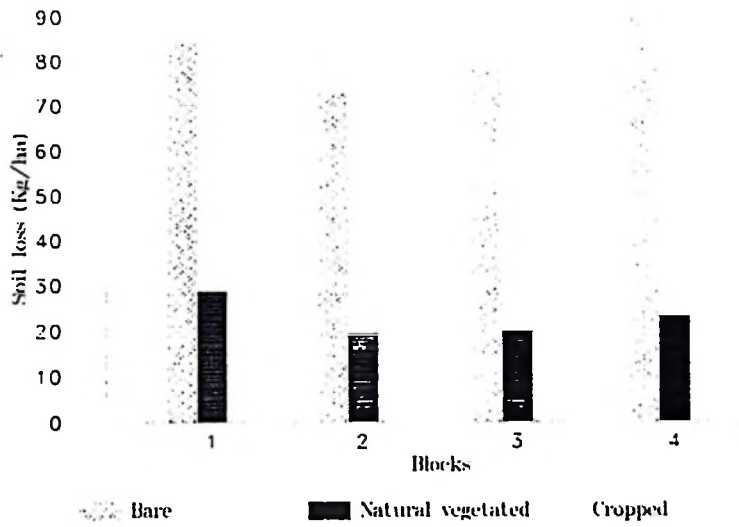


Figure 10(c): Variation of soil loss with treatments (With rainfall 16.3 mm)

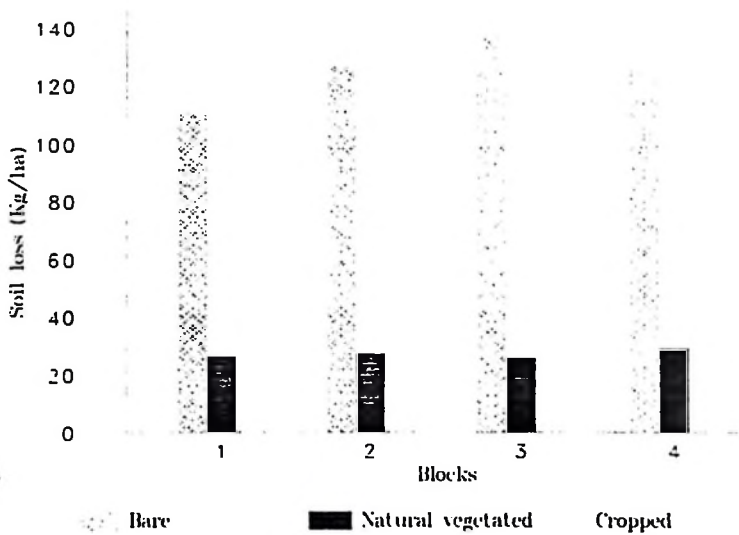


Figure 10(d): Variation of soil loss with treatments (With rainfall 26.1 mm)

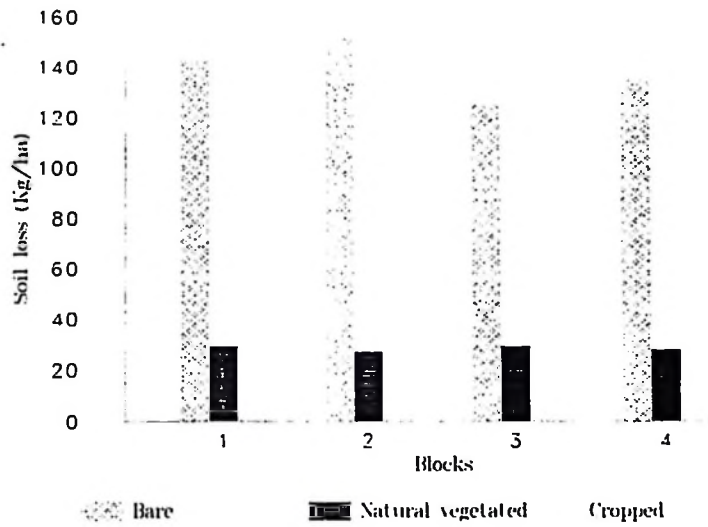


Figure 10(f): Variation of soil loss with treatments (With rainfall 32.4 mm)

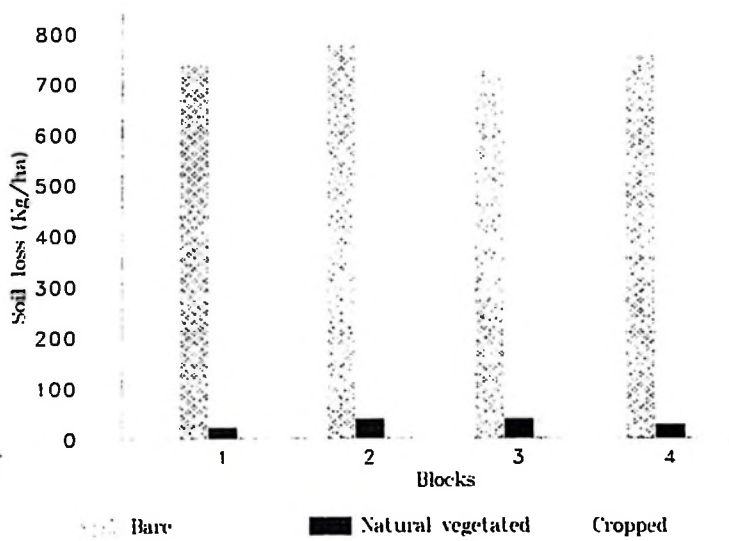


Figure 10(g): Variation of soil loss with treatments (Rainfall 39.6)

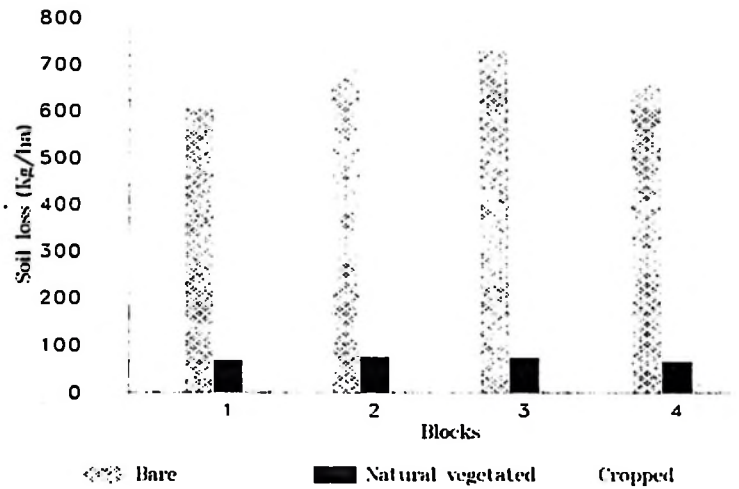


Figure 10(e): Variation of soil loss with treatments (With rainfall 38.5 mm)

On both natural vegetated and cropped plots, there was a significant ($p < 0.05$) soil loss reduction effect. The average maximum soil loss was 747 Kg/ha, 450 Kg/ha and 30 Kg/ha for bare, cropped and natural vegetated plots respectively figure 10(a) to figure 10(g).

The reduction in soil loss on cropped and natural vegetated plots was a result of two phenomenon, a reduced raindrop splash which in consequence reduced soil particle detachment.

The second one was an increased infiltration period. The overall effect of the two phenomenon was in two folds, reduction in rainfall erosivity and transport capacity of runoff.

As explained earlier, canopy cover reduced raindrop splash and thereby reduced soil particle detachment and increased infiltration period.

4.2 Procedure for determination of crop and land management factor(s) sub-models

In this study a procedure for determination of crop and land management factor(s) sub_models have been developed using a Pascal program. The algorithm for the program is presented in appendix 19(a) whereas the program is presented in appendix 19(b).

The procedure involves inputting area description data in a questionnaire format as well as soil loss data which must be presented with a filename A:\Data.Pas. The data must be presented in four columns (soil loss from cropped plots, soil

loss from bare plots, soil loss from plots with given tillage practice and soil loss from plots with up and down slope tillage).

Taking into consideration the type of the crop planted and tillage method employed, application of crop and land management sub-model(s) have to assume that soil loss prediction are done when management factors are optimal.

Optimal management factors include crop rotation practices, recommended fertiliser application, pest control and good cultivation practices.

4.3 Relationship between sediment loss and runoff

Regression results obtained for each storm are presented below. Y represents the estimated regression line for soil loss, 95% confidence band for the line was presented by Y_1 for the upper band and Y_2 for the lower band. 95% confidence limit for the points was presented by Y_3 for the upper limit and Y_4 for the lower limit.

With rainfall amount = 6.3 mm

Correlation Soil loss, Runoff = 0.9008

$$Y: 9.7549+80.989*X$$

$$Y1 : 9.7549+80.989*X-2.2281*\text{sqr}(33.241*(1/12+((x-0.21417)^2)/0.21809))$$

$$Y2 : 9.7549+80.989*X+2.2281*\text{sqr}(33.241*(1/12+((x-0.21417)^2)/0.21809))$$

$$Y3 : 9.7549+80.989*X+2.2281*\text{sqr}(33.241*(1+1/12+((x-0.21417)^2)/0.21809))$$

$$Y4 : 9.7549+80.989*X-2.2281*\text{sqr}(33.241*(1+1/12+((x-0.21417)^2)/0.21809))$$

Std. error of slope : 12.35

With rainfall amount = 6.8 mm

Correlation Soil loss, Runoff = 0.8632

$$Y:-7.5593+124.28*X$$

$$Y1 :-7.5593+124.28*X-2.2281*\text{sqr}(87.254*(1/12+((x-0.26083)^2)/0.16509))$$

$$Y2 :-7.5593+124.28*X+2.2281*\text{sqr}(87.254*(1/12+((x-0.26083)^2)/0.16509))$$

$$Y3 :-7.5593+124.28*X+2.2281*\text{sqr}(87.254*(1+1/12+((x-0.26083)^2)/0.16509))$$

$$Y4 :-7.5593+124.28*X-2.2281*\text{sqr}(87.254*(1+1/12+((x-0.26083)^2)/0.16509))$$

Std. error of slope : 22.99

With rainfall amount = 16.3 mm

Correlation Soil loss, Runoff = 0.9385

$$Y : 17.024 + 37.837 * X$$

$$Y1 : 17.024 + 37.837 * X - 2.2281 * \text{sqr}(86.973 * (1/12 + ((x - 0.85833)^2) / 4.4906))$$

$$Y2 : 17.024 + 37.837 * X + 2.2281 * \text{sqr}(86.973 * (1/12 + ((x - 0.85833)^2) / 4.4906))$$

$$Y3 : 17.024 + 37.837 * X + 2.2281 * \text{sqr}(86.973 * (1 + 1/12 + ((x - 0.85833)^2) / 4.4906))$$

$$Y4 : 17.024 + 37.837 * X - 2.2281 * \text{sqr}(86.973 * (1 + 1/12 + ((x - 0.85833)^2) / 4.4906))$$

Std. error of slope : 4.401

With rainfall amount = 26.1 mm

Correlation Soil loss, Runoff = 0.9727

$$Y : 4.5498 + 55.364 * X$$

$$Y1 : 4.5498 + 55.364 * X - 2.2281 * \text{sqr}(113.5 * (1/12 + ((x - 1.1558)^2) / 6.5059))$$

$$Y2 : 4.5498 + 55.364 * X + 2.2281 * \text{sqr}(113.5 * (1/12 + ((x - 1.1558)^2) / 6.5059))$$

$$Y3 : 4.5498 + 55.364 * X + 2.2281 * \text{sqr}(113.5 * (1 + 1/12 + ((x - 1.1558)^2) / 6.5059))$$

$$Y4 : 4.5498 + 55.364 * X - 2.2281 * \text{sqr}(113.5 * (1 + 1/12 + ((x - 1.1558)^2) / 6.5059))$$

Std. error of slope : 4.177

With rainfall amount = 32.4 mm

Correlation Soil loss, Runoff = 0.9058

$$Y: -20.157 + 57.89 * X$$

$$Y1 : -20.157 + 57.89 * X - 2.2281 * \text{sqr}(451.77 * (1/12 + ((x-1.7183)^2) / 6.1606))$$

$$Y2 : -20.157 + 57.89 * X + 2.2281 * \text{sqr}(451.77 * (1/12 + ((x-1.7183)^2) / 6.1606))$$

$$Y3 : -20.157 + 57.89 * X + 2.2281 * \text{sqr}(451.77 * (1 + 1/12 + ((x-1.7183)^2) / 6.1606))$$

$$Y4 : -20.157 + 57.89 * X - 2.2281 * \text{sqr}(451.77 * (1 + 1/12 + ((x-1.7183)^2) / 6.1606))$$

Std. error of slope : 8.563

With rainfall amount = 38.5 mm

Correlation Soil loss, Runoff = 0.8271

$$Y: -98.375 + 53.015 * X$$

$$Y1 : -98.375 + 53.015 * X - 2.2281 * \text{sqr}(28034 * (1/12 + ((x-7.3058)^2) / 216.05))$$

$$Y2 : -98.375 + 53.015 * X + 2.2281 * \text{sqr}(28034 * (1/12 + ((x-7.3058)^2) / 216.05))$$

$$Y3 : -98.375 + 53.015 * X + 2.2281 * \text{sqr}(28034 * (1 + 1/12 + ((x-7.3058)^2) / 216.05))$$

$$Y4 : -98.375 + 53.015 * X - 2.2281 * \text{sqr}(28034 * (1 + 1/12 + ((x-7.3058)^2) / 216.05))$$

Std. error of slope : 11.39

CHAPTER 5

CONCLUSIONS

Improved crop and land management practices applied to all phases in crop production (from land preparation to harvesting) have a great potential for generating economically viable agricultural production while maintaining the quality of the land.

The major challenge in maintaining the quality of the land however, lies on development of operational mechanisms to achieve an efficient coordinating system, which will act as a remedy to consumptive land use. Such a system has to bear the responsibility of ensuring optimal crop and land management practices.

To achieve such a system in Morogoro, effective parameters for determination of crop and land management factor(s) sub-models for soil loss prediction were determined. The results indicated that soil loss was best explained by rainfall amount, rainfall intensity, canopy cover and the amount of organic carbon as well as runoff.

The parameters indicated high correlations with soil loss. The correlation coefficients varied from 0.50 to 0.81 for the three treatments. It was then deducted that, the above parameters had marked effects on soil loss and thus needs to be considered effective in determining crop and land management factor(s) sub-models.

A procedure for determination of crop and land management parameters for soil loss prediction under selected crops was developed.

The algorithm and the developed program are presented in appendix 19(a) and 18(b) respectively. However as a result of limited time for the study as well as financial constraints to conduct various crop and tillage practices, data inputs, tests and processing of the program may require modifications to meet crops and tillage practices of keen interests.

The relationship between soil loss and runoff was determined. Correlation coefficients between soil loss and runoff variable ranged between 0.83 and 0.98 for all rainfall events.

The regression carried out indicated that soil loss and runoff variables were best described by a linear relationship.

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APPENDICES

Appendix 1

Climatic data for Morogoro (1970-1995)

1 (a). Monthly mean rainfall (mm) for Morogoro (1970-1995)

	January	February	March	April	May	June	July	August	September	October	November	Dec.
Max.	249.0	258.0	229.0	298.0	158.0	54.0	61.0	29.0	33.0	105.0	176.0	262.0
Mean	102.0	82.0	119.0	194.0	91.0	17.0	13.0	8.0	10.0	31.0	64.0	106.0
Min.	11.0	1.0	43.0	87.0	13.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0

1 (b). Monthly mean maximum temperatures at Morogoro (°C)
(1970-1995)

	January	February	March	April	May	June	July	August	September	October	November	December
Max.	31.0	29.7	28.7	28.7	28.9	31.0	32.5	33.6	34.1	33.6	34.4	33.4
Mean	29.6	28.5	27.6	27.4	28.1	29.8	31.3	32.2	31.7	31.5	32.3	31.6
Min.	28.2	27.6	26.4	25.9	27.0	28.6	29.8	30.5	29.7	29.7	30.3	29.2

1 (c). Monthly mean minimum temperatures at Morogoro (°C)
(1970-1995)

	January	February	March	April	May	June	July	August	September	October	November	Dec.
Max.	21.3	19.8	18.6	16.6	17.5	17.7	19.3	20.6	22.0	22.3	22.2	21.8
Mean	20.5	18.9	15.7	15.2	15.7	16.6	18.1	19.9	21.1	21.1	21.1	20.8
Min.	19.5	17.8	14.2	13.9	14.5	15.4	16.8	18.6	19.3	20.6	20.2	19.6

1 (d). Monthly mean relative humidity (%) at 1500 at
Morogoro (1970-1995)

	January	February	March	April	May	June	July	August	September	October	November	Dec.
Max.	74.0	70.0	64.0	59.0	51.0	47.0	53.0	60.0	66.0	64.0	63.0	69.0
Mean	67.0	64.2	55.1	49.9	46.1	42.1	42.3	45.8	51.5	53.0	51.1	57.3
Min.	61.0	56.0	49.0	45.0	41.0	36.0	37.0	32.0	37.0	45.0	36.0	43.0

1 (e). Monthly mean evaporation (mm) at Morogoro (1970-1995)

	January	February	March	April	May	June	July	August	September	October	November	Dec.
Max.	210.0	120.0	125.0	134.0	175.0	199.0	238.0	276.0	312.0	240.0	254.0	268.0
Mean	121.0	97.0	95.0	107.0	129.0	166.0	161.0	195.0	198.0	201.0	185.0	190.0
Min.	85.0	79.0	79.0	87.0	101.0	145.0	161.0	137.0	145.0	141.0	141.0	131.0

Source: Meteorological station Morogoro

Appendix 2

Climatic data for Morogoro over the study
period (January-May 1996)

2 (a). Weather data for Morogoro January 1996

Day	Maximum °C	Minimum °C	3 PM RH (%)	Total evaporation (mm)	Total rainfall (mm)
1	33.0	21.7	38	8.0	0.0
2	33.1	22.0	39	9.0	0.0
3	34.0	20.5	33	10.0	0.0
4	31.8	20.6	49	6.7	19.7
5	30.0	21.7	49	7.0	0.0
6	30.5	22.2	55	5.0	0.0
7	33.0	22.7	44	6.1	36.1
8	28.6	20.0	72	3.4	2.9
9	33.2	20.1	49	6.0	0.0
10	32.0	22.5	53	5.0	0.5
11	30.5	22.6	61	3.5	0.0
12	32.3	22.0	50	5.0	11.0
13	32.0	22.0	49	3.0	0.0
14	31.7	22.6	51	10.0	0.0
15	31.6	22.5	45	7.5	0.0
16	32.0	21.5	51	5.9	0.9
17	31.0	21.1	57	6.0	0.0
18	31.8	23.0	50	8.5	0.0
19	30.8	22.5	57	7.5	0.0
20	32.5	22.0	42	8.0	0.0
21	32.5	24.0	47	9.0	0.0
22	32.5	22.1	44	7.0	0.0
23	33.4	21.4	34	10.5	0.0
24	33.0	19.5	43	7.5	0.0
25	33.0	21.1	47	6.0	0.0
26	32.7	21.4	48	6.5	0.0
27	33.7	23.0	45	8.0	0.0
28	32.8	23.2	43	8.8	31.8
29	29.4	21.6	64	4.5	0.0
30	31.5	22.9	55	8.5	0.0
31	32.3	23.3	52	10.1	2.1
SUM	991.9	679.0	1519	217.5	105.0
MEAN	32.0	21.9	49	7.0	36.1

2 (b). Weather data for Morogoro February 1996

Day	Maximum °C	Minimum °C	3 PM RH (%)	Total evaporation (mm)	Total rainfall (mm)
1	33.0	21.3	50	8.0	0.0
2	32.4	23.5	53	9.0	0.0
3	34.0	22.5	39	8.0	0.0
4	32.0	23.0	59	6.0	0.0
5	32.5	22.8	52	5.9	18.9
6	28.6	21.8	61	4.0	0.0
7	31.1	22.1	50	7.5	0.0
8	30.4	22.7	57	8.0	0.0
9	30.7	21.9	53	7.5	0.0
10	32.0	20.8	45	5.0	0.0
11	32.1	21.1	49	7.0	0.0
12	32.7	21.2	47	8.5	0.0
13	31.5	21.6	50	3.5	0.0
14	33.3	21.7	57	7.3	11.8
15	30.5	20.9	70	5.5	0.0
16	31.5	20.2	54	5.1	2.1
17	29.7	21.2	66	2.5	4.5
18	28.1	21.4	84	8.2	60.7
19	30.6	19.7	54	3.5	0.0
20	33.5	21.1	47	5.3	1.3
21	30.0	21.3	63	4.8	16.8
22	30.0	20.0	62	3.0	0.0
23	30.4	22.0	66	4.0	2.5
24	30.5	21.5	62	7.8	32.8
25	28.3	21.3	76	3.5	0.1
26	31.0	21.0	60	5.0	0.0
27	29.0	21.7	69	4.5	0.0
28	30.6	22.1	60	5.5	0.0
29	31.2	23.2	52	7.5	0.0
SUM	900.2	626.6	1667	170.9	151.5
MEAN	31.0	20.7	57	5.9	30.3

2 (c). Weather data for Morogoro March 1996

Day	Maximum °C	Minimum °C	3 PM RH (%)	Total evaporation (mm)	Total rainfall (mm)
1	31.6	21.4	58	6.5	0.0
2	31.0	22.3	51	7.0	0.0
3	31.5	22.2	51	7.0	0.0
4	32.0	21.0	50	7.0	0.0
5	32.5	23.0	47	8.0	0.0
6	31.7	20.2	45	7.5	0.0
7	32.5	20.6	41	7.0	0.0
8	33.5	22.5	42	7.0	0.0
9	31.2	22.0	62	4.0	1.0
10	32.0	21.4	56	5.5	0.0
11	32.4	21.5	50	5.5	0.0
12	32.7	22.0	49	7.8	3.3
13	30.6	22.1	70	5.9	2.4
14	32.6	23.1	55	7.0	0.0
15	32.4	21.8	53	7.0	0.0
16	33.0	22.0	43	5.5	0.0
17	34.3	22.6	37	8.7	4.2
18	31.0	22.5	55	4.9	28.4
19	30.4	22.0	91	3.2	15.7
20	30.5	22.0	62	4.0	0.0
21	30.6	22.7	63	2.5	2.0
22	29.8	22.6	63	4.9	2.4
23	30.2	22.6	63	4.4	9.9
24	30.6	21.2	63	5.5	0.4
25	29.8	22.0	75	3.9	0.0
26	30.2	20.8	87	4.5	0.0
27	27.2	22.0	82	4.6	44.1
28	29.5	19.9	62	4.0	0.0
29	28.4	21.6	84	2.4	4.4
30	29.6	21.1	73	3.9	3.9
31	28.5	21.8	76	3.8	5.8
SUM	959.5	676.6	1849	170.4	127.9
MEAN	31.0	21.8	59.6	5.5	25.6

2 (d). Weather data for Morogoro April 1996

Day	Maximum °C	Minimum °C	3 PM RH (%)	Total evaporation (mm)	Total rainfall (mm)
1	27.6	22.1	87	---	14.0
2	31.2	21.0	54	3.8	69.4
3	29.5	20.0	69	3.3	10.3
4	27.1	21.6	86	2.8	21.3
5	29.0	21.4	79	1.9	9.8
6	30.0	21.6	68	2.4	4.9
7	27.5	21.7	83	2.1	5.4
8	26.0	21.2	91	3.5	4.6
9	28.5	21.2	72	3.5	0.0
10	29.8	19.8	57	4.7	0.0
11	30.6	20.4	68	4.0	1.7
12	28.6	21.1	72	4.6	0.5
13	29.4	18.4	79	3.5	4.6
14	28.6	20.0	62	1.6	0.0
15	25.0	21.6	76	3.1	0.1
16	28.3	20.5	67	3.0	2.6
17	29.0	21.0	67	3.3	3.0
18	25.2	21.0	70	2.9	1.8
19	28.8	20.6	65	4.5	0.4
20	30.2	20.1	56	7.0	0.0
21	30.5	20.2	51	5.0	0.0
22	30.0	19.0	56	3.9	0.0
23	29.6	18.6	66	3.8	5.4
24	29.0	21.0	70	3.3	23.8
25	27.6	21.0	70	3.0	11.3
26	28.0	21.1	67	2.1	10.0
27	27.1	20.5	70	2.5	3.6
28	26.4	21.0	77	2.5	0.0
29	27.2	19.9	70	3.5	0.0
30	28.0	17.4	61	3.9	0.0
31					
SUM	853.3	615.5	2086	98.4	208.5
MEAN	28.4	20.5	69.5	3.4	20.8

2 (e). Weather data for Morogoro May 1996

Day	Maximum °C	Minimum °C	3 PM RH (%)	Total evaporation (mm)	Total rainfall (mm)
1	25.0	20.5	85	2.0	0.0
2	28.2	18.1	63	2.4	5.4
3	29.2	20.9	64	3.4	29.4
4	27.2	20.4	75	3.4	22.4
5	29.4	21.0	60	2.0	0.0
6	29.0	19.3	63	3.3	1.3
7	29.0	19.0	61	3.4	0.9
8	29.5	20.5	64	3.9	3.4
9	29.0	19.4	60	2.0	0.0
10	29.0	20.6	65	3.0	0.0
11	27.0	20.5	66	2.1	9.1
12	24.8	20.0	84	2.6	2.6
13	30.0	20.8	58	3.3	5.3
14	29.7	20.6	61	3.9	5.9
15	30.5	20.5	88	4.5	12.5
16	26.0	21.0	82	1.8	4.8
17	25.3	20.0	87	1.5	9.5
18	27.6	20.5	70	1.9	4.4
19	27.5	19.0	66	3.4	1.4
20	28.4	20.5	67	2.4	2.4
21	28.8	20.1	55	2.4	0.9
22	25.0	20.3	80	1.9	4.9
23	28.7	20.1	93	2.0	0.5
24	29.2	20.9	59	3.5	0.0
25	29.8	19.3	67	2.5	0.0
26	28.5	19.5	64	4.1	1.0
27	28.5	20.5	60	4.1	1.1
28	29.3	19.3	55	4.8	1.8
29	27.2	19.4	63	2.5	0.0
30	25.5	18.0	73	2.4	0.4
31	27.2	18.0	65	2.7	0.7
SUM	869.0	618.5	2123	89.0	132.0
MEAN	28.0	19.9	68	2.9	16.5

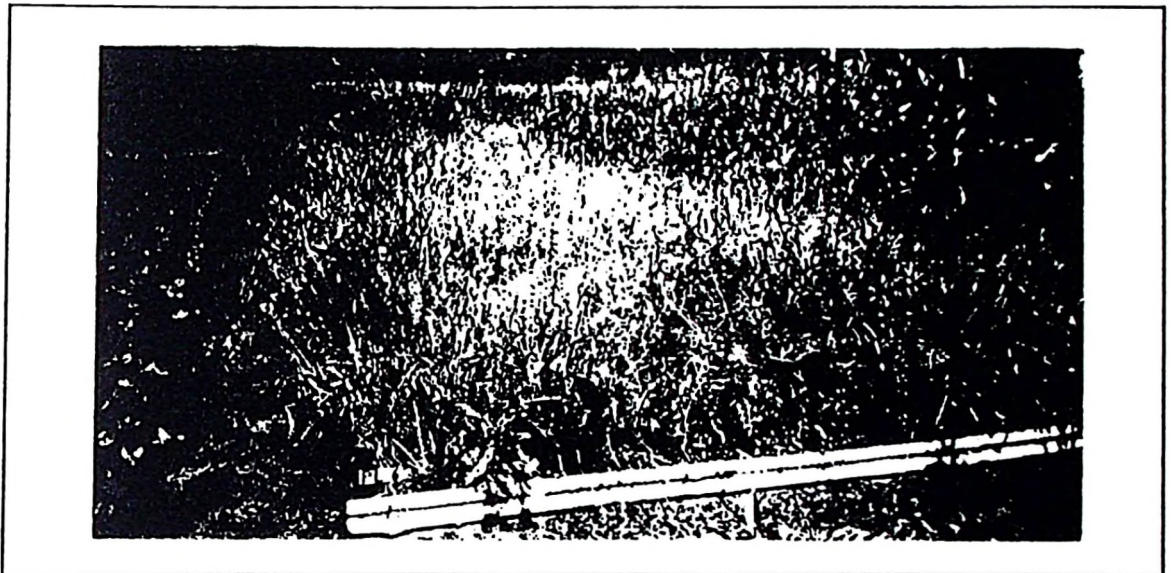
Source: Meteorological station Morogoro

Illustration of a cropped plots



Appendix 4

Illustration of a natural vegetated plots



Appendix 6

Rainfall amount (mm) recorded at the studied area
over the study period (January-April 1996)

January (Date)	(mm)	February (Date)	(mm)	March (Date)	(mm)	April (Date)	(mm)
4	18.60	18	4.50	13	2.40	2	6.80
6	37.20	19	1.50	14	2.20	3	39.60
7	2.40	21	1.30	19	38.50	4	5.50
9	TR	22	17.50	21	1.50	5	6.30
11	10.00	24	6.50	28	32.40	6	5.75
15	TR	25	34.00	30	16.30	7	4.80
16	TR	28	4.00	31	TR	8	3.10
18	TR					9	2.90
27	28.50					10	2.90
30	1.50					13	1.80

Appendix 7

Rainfall duration, amount and intensity as recorded
by an automatic recording rain gauge

Date: 14.3.96

Time from start (minutes)	Rainfall (mm)	Intensity (mm/hr)
0 - 15	0.50	2.00
16 - 30	0.25	1.00
31 - 105	0.00	0.00
106 - 120	0.50	2.00
121 - 135	0.00	0.00
136 - 150	0.50	2.00

Date: 19.3.96

Time from start Intensity (minutes)	Rainfall	
	(mm)	(mm/hr)
0 - 15	2.75	11.00
16 - 30	0.00	0.00
31 - 45	0.13	0.50
46 - 60	0.13	0.50
61 - 75	0.13	0.50
76 - 90	0.13	0.50
91 - 105	0.13	0.50
106 - 180	0.13	0.50
181 - 195	0.00	0.00
196 - 210	0.13	0.50
211 - 225	0.13	0.50
226 - 240	12.50	50.00
241 - 255	1.50	6.00
256 - 270	1.00	4.00
271 - 285	5.00	20.00
286 - 300	0.50	2.00
301 - 315	6.00	24.00
316 - 330	0.50	2.00
331 - 345	0.13	0.50
346 - 360	0.13	0.50
361 - 375	0.13	0.50
376 - 390	0.13	0.50
391 - 405	0.13	0.50
406 - 420	0.13	0.50
421 - 555	0.13	0.50
556 - 570	0.00	0.00
571 - 585	0.25	1.00
586 - 600	0.25	1.00
601 - 615	0.25	1.00
616 - 630	0.25	1.00
631 - 645	0.25	1.00
646 - 660	0.50	2.00
661 - 675	0.50	2.00
676 - 690	0.50	2.00
691 - 705	0.50	2.00

Date: 21.3.96

Time from start (minutes)	Rainfall (mm)	Intensity (mm/hr)
0 - 15	1.25	5.00

Date: 28.3.96

0 - 15	10.25	41.00
16 - 30	7.25	29.00
31 - 45	5.50	22.00
46 - 60	2.50	10.00
61 - 75	1.25	5.00
76 - 90	1.25	5.00
91 - 105	1.00	4.00
106 - 120	1.00	4.00
121 - 135	0.50	2.00

Date: 30.3.96

Time from start (minutes)	Rainfall (mm)	Intensity (mm/hr)
0 - 15	1.50	6.00
16 - 30	7.00	28.00
31 - 45	2.50	10.00
46 - 60	0.50	2.00
61 - 330	0.00	0.00
331 - 345	0.25	1.00
346 - 390	0.00	0.00
391 - 405	0.25	1.00
406 - 420	0.25	1.00
421 - 495	0.00	0.00
496 - 510	0.25	1.00
511 - 525	0.25	1.00
526 - 600	0.00	0.00
601 - 615	0.25	1.00
616 - 630	0.25	1.00
631 - 675	0.00	0.00
676 - 690	1.00	4.00
691 - 705	1.00	4.00
706 - 720	0.50	2.00
721 - 735	0.50	2.00
736 - 750	0.25	1.00

Date: 2.4.96

0 - 15	0.50	2.00
16 - 30	0.50	2.00
31 - 45	5.00	20.00
46 - 60	1.25	5.00

Date: 3.4.96

Time from start (minutes)	Rainfall (mm)	Intensity (mm/hr)
0 - 15	2.75	11.00
16 - 30	14.75	59.00
31 - 45	3.25	13.00
46 - 60	10.75	43.00
61 - 75	0.75	3.00
76 - 90	0.75	3.00
91 - 105	0.75	3.00
106 - 120	0.50	2.00
121 - 135	0.50	2.00
136 - 150	0.50	2.00
151 - 165	0.50	2.00
166 - 180	0.75	3.00
181 - 195	0.75	3.00

Date: 4.4.96

Time from start (minutes)	Rainfall (mm)	Intensity (mm/hr)
0 - 15	1.00	4.00
16 - 30	0.00	0.00
31 - 45	1.00	4.00
46 - 345	0.00	0.00
346 - 360	3.75	15.00

Date: 5.4.96

Time from start (minutes)	Rainfall (mm)	Intensity (mm/hr)
0 - 15	0.50	2.00
16 - 30	0.25	1.00
31 - 45	0.25	1.00
46 - 60	0.25	1.00
61 - 75	0.25	1.00
76 - 90	0.25	1.00
91 - 105	0.25	1.00
106 - 120	0.25	1.00
121 - 135	0.25	1.00
136 - 150	0.25	1.00
151 - 165	0.25	1.00
166 - 180	0.25	1.00
181 - 195	0.25	1.00
196 - 285	0.00	0.00
286 - 300	0.25	1.00
301 - 315	0.25	1.00
316 - 330	0.25	1.00
331 - 345	0.25	1.00
346 - 360	0.25	1.00
361 - 375	0.25	1.00
376 - 390	1.25	5.00

Date: 6.4.9 6

Time from start (minutes)	Rainfall (mm)	Intensity (mm/hr)
0 - 15	0.75	3.40
16 - 480	0.00	0.00
481 - 495	0.25	1.00
496 - 510	0.25	1.00
511 - 525	0.25	1.00
526 - 540	0.00	0.00
541 - 555	0.25	1.00
556 - 645	0.00	0.00
646 - 660	0.25	1.00
661 - 705	0.00	0.00
706 - 720	0.25	1.00
721 - 735	0.00	0.00
736 - 750	0.25	1.00
751 - 765	0.75	3.00
766 - 780	0.50	2.00
781 - 795	0.75	3.00
796 - 810	0.50	2.00
811 - 825	0.25	1.00
826 - 840	0.25	1.00

Date: 7.4.96

0 - 15	0.50	2.00
16 - 30	0.25	1.00
31 - 45	0.25	1.00
46 - 60	0.25	1.00
61 - 90	0.00	0.00
91 - 105	1.00	4.00
106 - 120	0.50	2.00
121 - 135	0.50	2.00
136 - 150	0.25	1.00
151 - 165	0.25	1.00
166 - 180	0.50	2.00
181 - 195	0.25	1.00
196 - 210	0.25	1.00
211 - 225	0.25	1.00
226 - 240	0.13	0.50

Date: 8.4.96

Time from start (minutes)	Rainfall (mm)	Intensity (mm/hr)
0 - 15	1.00	4.00
16 - 75	0.00	0.00
76 - 90	1.50	6.00
91 - 105	1.00	4.00

Date: 9.4.96

0 - 15	1.00	4.00
16 - 30	1.50	6.00

Date: 10.4.96

0 - 15	0.13	0.50
16 - 30	0.13	0.50
31 - 45	0.13	0.50
46 - 60	0.13	0.50
61 - 75	0.13	0.50
76 - 90	0.13	0.50
91 - 105	0.13	0.50
106 - 120	0.13	0.50
121 - 150	0.00	0.00
151 - 165	0.75	3.00
166 - 180	0.50	2.00
181 - 195	0.13	0.50

Date: 13.4.96

0 - 15	0.25	1.00
16 - 150	0.00	0.00
151 - 165	1.00	1.00

Appendix 8

ANOVA table for soil loss (Rainfall 6.3 mm)

Source	DF	SS	MS	F	Prob>F
Block	3	91.607	30.536	6.2	0.029
Treat	2	1641.800	820.920	167.1	0.000
Error	6	29.473	4.912		
Total	11	1762.980			

Coefficient of Variation 8.2%

Main effects

Block	Mean	Treatment	Mean
1	25.90	Bare	42.20
2	31.07	Grassed	13.70
3	23.53	Cropped (maize)	25.40
4	27.90		
SE mean	1.28	SE mean	1.11
SE difference	1.81	SE difference	1.57

Appendix 9

ANOVA table for soil loss (Rainfall 6.8 mm)

Source	DF	SS	MS	F	Prob>F
Block	3	15.523	5.174	0.7	0.562
Treat	2	3365.600	1682.800	243.0	0.000
Error	6	41.545	6.924		
Total	11	3422.768			

Coefficient of Variation 10.6%

Main effects

Block	Mean	Treatment	Mean
1	26.73	Bare	47.68
2	23.90	Grassed	7.95
3	24.80	Cropped (maize)	18.95
4	24.00		
SE mean	1.52	SE mean	1.32
SE difference	2.15	SE difference	1.86

Appendix 10

ANOVA table for soil loss (Rainfall 16.3 mm)

Source	DF	SS	MS	F	Prob>F
Block	3	303.37	101.120	8.1	0.016
Treat	2	6920.00	3460.000	276.3	0.000
Error	6	75.13	12.521		
Total	11	7298.500			

Coefficient of Variation 7.1%

Main effects

Block	Mean	Treatment	Mean
1	55.60	Bare	81.03
2	44.07	Grassed	22.80
3	45.03	Cropped (maize)	44.68
4	53.30		
SE mean	2.04	SE mean	1.77
SE difference	2.89	SE difference	2.50

Appendix 11

ANOVA table for soil loss (Rainfall 26.1 mm)

Source	DF	SS	MS	F	Prob>F
Block	3	277.54	92.514	2.1	0.208
Treat	2	20529.00	10264.000	227.6	0.000
Error	6	270.56	45.093		
Total	11	21077.00			

Coefficient of Variation 9.8%

Main effects

Block	Mean	Treatment	Mean
1	60.97	Bare	125.00
2	72.70	Grassed	27.00
3	72.70	Cropped (maize)	53.65
4	67.80		
SE mean	3.88	SE mean	3.36
SE difference	5.48	SE difference	4.75

Appendix 12

ANOVA table for soil loss (Rainfall 32.4 mm)

Source	DF	SS	MS	F	Prob>F
Block	3	193.34	64.446	1.6	0.275
Treat	2	24735.00	12368.000	316.5	0.000
Error	6	234.43	39.072		
Total	11	25162.77			

Coefficient of Variation 7.9%

Main effects

Block	Mean	Treatment	Mean
1	81.73	Bare	138.70
2	84.17	Grassed	28.40
3	73.60	Cropped (maize)	70.90
4	77.77		
SE mean	3.61	SE mean	3.13
SE difference	5.10	SE difference	4.42

Appendix 13

ANOVA table for soil loss (38.5 mm)

Source	DF	SS	MS	F	Prob>F
Block	3	3640.10	1213.400	1.3	0.371
Treat	2	878124.00	439062.000	453.6	0.000
Error	6	5807.80	967.970		
Total	11	887571.90			

Coefficient of Variation 10.8%

Main effects

Block	Mean	Treatment	Mean
1	266.30	Bare	670.10
2	291.90	Grassed	70.09
3	314.60	Cropped (maize)	126.60
4	282.90		
SE mean	17.96	SE mean	15.56
SE difference	25.40	SE difference	22.00

Appendix 14

ANOVA table for soil loss (Rainfall 39.6 mm)

Source	DF	SS	MS	F	Prob>F
Block	3	856.23	285.410	0.9	0.497
Treat	2	1041553.00	520776.000	1627.3	0.000
Error	6	1920.20	320.030		
Total	11	1044329.43			

Coefficient of Variation 4.3%

Main effects

Block	Mean	Treatment	Mean
1	405.30	Bare	747.60
2	425.20	Grassed	30.20
3	411.80	Cropped (maize)	456.80
4	403.80		
SE mean	10.33	SE mean	8.95
SE difference	14.61	SE difference	12.65

Appendix 15

Runoff data (mm) collected during the study period

Date	Plot number											
	1	2	3	4	5	6	7	8	9	10	11	12
19.3.96	12.17	1.74	8.06	11.84	8.29	2.02	8.20	1.11	11.98	12.03	8.15	2.08
28.3.96	2.44	0.83	1.48	2.31	1.43	0.83	2.12	1.29	2.77	2.86	1.33	0.88
30.3.96	1.66	0.28	0.51	1.50	0.51	0.38	0.60	0.37	1.89	1.77	0.55	0.28
02.4.96	0.38	0.14	0.32	0.37	0.32	0.09	0.28	0.14	0.38	0.38	0.28	0.05
03.4.96	12.45	1.75	9.96	12.86	10.37	2.03	9.96	1.84	13.28	12.86	9.96	2.40
05.4.96	0.37	0.09	0.28	0.38	0.18	0.09	0.05	0.02	0.38	0.32	0.28	0.09
26.4.96	2.16	0.28	0.91	2.20	1.10	0.38	1.08	0.37	1.99	2.09	1.03	0.28

Key

Maize = Plot No. 3, 5, 7 and 11.

Bare = Plot No. 1, 4, 9 and 10.

Natural vegetated = Plot No. 2, 6, 8 and 12.

Appendix 16

Sediment loss (Kg/ha) collected during the study period

Date	Plot number											
	1	2	3	4	5	6	7	8	9	10	11	12
19.3.96	602.17	66.85	129.96	690.07	111.14	74.60	138.32	73.70	731.70	656.51	127.09	65.23
28.3.96	142.30	29.50	73.40	152.20	73.20	27.10	66.60	29.10	125.10	135.00	70.40	27.90
30.3.96	84.20	28.60	54.40	72.80	40.00	19.40	37.10	19.90	78.10	89.00	47.60	23.30
02.4.96	52.70	9.00	18.50	46.00	19.90	5.80	16.90	10.30	47.20	44.80	20.50	6.70
03.4.96	736.40	20.80	458.60	775.60	463.50	36.50	474.60	37.10	723.70	754.60	430.50	26.40
05.4.96	40.10	11.10	26.50	46.10	28.70	18.40	19.40	12.90	38.30	44.30	27.00	12.40
26.4.96	110.90	26.30	45.70	126.80	64.10	27.20	55.40	25.60	137.10	125.10	49.40	28.90

Key

Maize = Plot No. 3, 5, 7 and 11.

Bare = Plot No. 1, 4, 9 and 10.

Natural vegetated = Plot No. 2, 6, 8 and 12.

Appendix 17

Canopy cover data (%) recorded during the study period

	4 Weeks	8 Weeks	12 Weeks
Plot No.			
1	--	--	--
2	92	98	99
3	12	55	64
4	--	--	--
5	11	54	68
6	94	97	98
7	13	62	66
8	89	99	98
9	--	--	--
10	--	--	--
11	12	58	63
12	90	93	97
Mean			
Maize :	12.00	57.30	65.30
nat. Veg.:	91.00	96.80	98.00

Key

Maize = Plot No. 3, 5, 7 and 11.

Bare = Plot No. 1, 4, 9 and 10.

Natural vegetated = Plot No. 2, 6, 8 and 12.

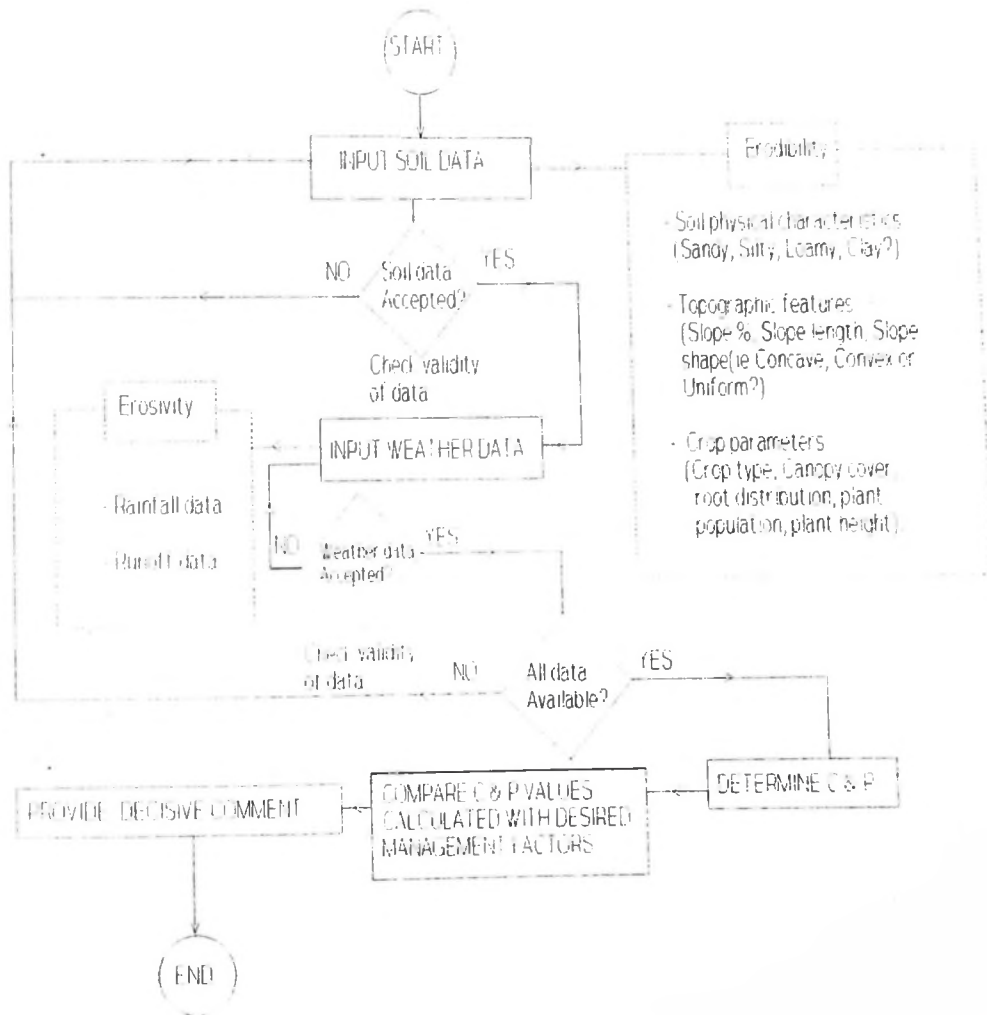
Appendix 18

Soil properties of the area studied

	%Sand	%Clay	%Silt	pH	%O.C	Class (USDA)
Plot No.	-----					
1	53	35	12	6.1	0.86	SCL
2	56	33	11	6.2	0.85	SCL
3	52	35	13	6.0	0.89	SCL
4	58	31	11	5.8	0.87	SCL
5	55	34	11	5.9	0.92	SCL
6	54	32	14	6.1	0.94	SCL
7	57	32	11	6.1	0.88	SCL
8	56	32	12	5.9	0.93	SCL
9	53	36	11	5.8	0.86	SC
10	52	35	13	6.0	0.87	SCL
11	53	32	15	6.2	0.85	SCL
12	54	33	13	5.9	0.90	SCL
Mean	54.4	33.3	12.2	5.8	0.88	SCL

Appendix 19(a)

Algorithm for determination of crop and land management factor(s) for soil loss prediction



Appendix 19 (b)

Program Develop_Procedure

```
*****
PROGRAM Develop_Procedure;
*****
```

```
{This program provides a procedure (stepwise) for
determination of crop and land management for soil loss
prediction under specified crops for Morogoro conditions,
descriptive data are provided so as to bring in mind the
status of the area}
```

```
USES CRT;
```

```
CONST
```

```
    Locations=3;
    DataList=7;
```

```
TYPE
```

```
    Data=Record
```

```
        Location_Name:String;
        Crop_Type:String;
        Slope_Percent,Slope_length:Real;
        Shape:String;
        Percent_Cover,Height:Real;
        Cropping_Period,Pre_Cropping_Period:Integer;
        USDA_Classification:Char;
        Tillage_Type:String;
        Rain,Evap,RH,Temp:Real;
```

```
    end;
```

```
TYPE
```

```
    Values=ARRAY[1..datalist] of Real;
```

```
VAR
```

```
    Location:Data;
    ResultFile:Text;
    DataFile:Text;
    Crops,DataNumber:Integer;
    Location_Name,Crop_Type,Tillage_Type,Shape,
```

```

USDA_Classification,Comment_1,Comment_2:String;
Max_Crop,Max_Land,Slope_Percent,Slope_Length:Real;
Cropping_Period,Pre_Cropping_Period:Integer;
SL_1,SL_2,SL_3,SL_4,
C,P:values;

*****
PROCEDURE Pause;
*****

VAR
    Continue:Char;

BEGIN
    Writeln;
    Writeln;
    Writeln('_____');
    Writeln;
    Writeln('.....Press <ENTER> key twice to
            continue.....');
    Readln(Continue);

end;

*****
PROCEDURE Create_DataFile(var SL_1,SL_2,SL_3,
                          SL_4:values);
*****

VAR
    i:Integer;

BEGIN
    Assign(DataFile,'A:Data.Pas');
    Reset(DataFile);
    Clrscr;
    Readln(DataFile);
    Readln(DataFile);
    Readln(DataFile);
    Readln(DataFile);
    Readln(DataFile);
    For i:=1 to datalist do
        Read(DataFile,SL_1[i],SL_2[i],
            SL_3[i],SL_4[i]);
    Readln(DataFile);
    Readln(Datafile);

```

```

        close(DataFile);
End;

*****
PROCEDURE Area_Specification (Var max_crop:real);
*****
VAR
    Choice,i:Integer;

BEGIN
    Assign(ResultFile,'A:Results.Pas');
    Rewrite(ResultFile);
    Writeln(ResultFile,' Area description ..');
    Writeln(ResultFile);
    Clrscr;
    Write('P');Delay(300);Write('L');Delay(300);
    Write('E');Delay(300);Write('A');
    Delay(300);Write('S');Delay(300);
    Write('E');Delay(300);Write(' ');Delay(300);
    Write('E');Delay(300);Write('N');
    Delay(300);Write('T');Delay(300);Write('E');
    Delay(300);Write('R');Delay(300);Write(' ');
    Delay(300);Write('A');Delay(300);
    Write('R');Delay(300);Write('E');
    Delay(300);Write('A');Delay(300);Write(' ');
    Write('S');Delay(300);Write('P');
    Delay(300);Write('E');Write('C');Delay(300);
    Write('I');Delay(300);Write('F');
    Delay(300);Write('I');Delay(300);Write('C');
    Delay(300);Write('A');Delay(300);
    Write('T');Delay(300);Write('I');Delay(300);
    Write('O');Delay(300);Write('N');Delay(300);
    Write(' ');Delay(300);Write('D');
    Write('A');Delay(300);Write('T');
    Delay(300);Write('A');Delay(300);
    clrscr;
    Writeln;
    Writeln;
    Write('Location name:');
    Readln(Location_Name);
    clrscr;
    Writeln(ResultFile,'Location name is
: ',Location_Name);
    Writeln(ResultFile);
    Write('Crop type is : ');
    Readln(Crop_type);
    Writeln(ResultFile,'Crop type is: ', crop_type);
    Clrscr;

```

```

Write('Slope percent is :');
Readln(Slope_Percent);
Writeln(ResultFile,'Slope_Percent is:
',Slope_Percent:4:2);
clrscr;
Writeln('What is the slope shape, Concave?,
Convex?, Uniform?:');
Readln(Shape);
Writeln(ResultFile,'The slope shape is: ',shape);
Clrscr;
Write('Slope length(m) is: ');
Readln(Slope_Length);
Clrscr;
Writeln(ResultFile,'Slope_Length is :
',Slope_Length:4:2);
Write('Tillage type employed, mulching?
contouring?, ridging? bare?: ');
Readln(Tillage_Type);
Writeln(ResultFile,'Tillage_Type is:
',Tillage_Type);
Clrscr;
Write('Cropping period (Days): ');
Readln(Cropping_Period);
Writeln(ResultFile,'Cropping_Periods:
',Cropping_Period);
Clrscr;
Write('Pre_Cropping_Period: ');
Readln(Pre_Cropping_Period);
Clrscr;
Writeln(ResultFile,'Pre_Cropping_Period is:
',Pre_Cropping_Period);
Write('USDA Classification: ');
Readln(USDA_Classification);
Clrscr;
Writeln(ResultFile,'USDA classification is:
',USDA_Classification);
Writeln('For how many days did you record your
data(Number of dates recorded):');
Read(DataNumber);
clrscr;
Writeln('What is the maximum crop management');
Writeln('factor to be considered as the lower');
Writeln('limit desired?(0-1):');
Readln(Max_Crop);
clrscr;
Writeln('What is the maximum land management');
Writeln('factor to be considered as the lower');
Writeln('limit desired?(0_1):');

```

```

        Readln(max_land);
        Clrscr;
    END;

    *****
    Procedure Determine_C (Var SL_1, SL_2, C:Values; Var
        Comment_1:string; Var ResultFile:text);
    *****

    Var

        i:integer;
        Crop_management_is_OK,Determine_Model:string;

    Begin

        Area_Specification(Max_Crop);
        Assign(ResultFile,'A:Results.Pas');
        Rewrite(ResultFile);
        Writeln(ResultFile,'      THIS IS EXCUTION MODE');
        Writeln(ResultFile,'_____');
        Writeln(ResultFile);
        Writeln(ResultFile,'Determination of crop
        management factor ');
        Writeln(ResultFile);
        Writeln(ResultFile,'''NOTE1''');
        Writeln(ResultFile,'_____');
        Writeln(ResultFile);
        Writeln(ResultFile,'CROPPING MANAGEMENT FACTOR (C)
        IS GIVEN AS');
        Writeln(ResultFile,'THE RATIO OF SOIL LOSS FROM
        CROPPED PLOT TO');
        Writeln(ResultFile,'THAT FROM A BARE PLOT. ');
        Writeln;
        Writeln(ResultFile,'_____');

        Clrscr;
        Write('N');Delay(300);Write('O');
        Delay(300);Write('W');Delay(300);Write(' ');
        Delay(300);Write('C');Delay(300);
        Write('A');Delay(300);Write('L');Delay(300);
        Write('C');Delay(300);Write('U');
        Delay(300);Write('L');Delay(300);Write('A');
        Delay(300);Write('T');Delay(300);
        Write('I');Delay(300);
        Write('N');Delay(300);Write('G');Delay(300);
        Write(' ');Write('T');Delay(300);Write('H');
        Write('E');Delay(300);Write('');
        Delay(300);Write('''C'''); Write(' ');Delay(300);

```

```

Write('F');Delay(300);Write('A');
Delay(300);Write('C');Delay(300);Write('T');
Delay(300);Write('O');Delay(300);
Write('R');Delay(300);
For i:=1 to datalist do

    begin

        C[i]:=(SL_1[i])/(SL_2[i]);

        IF C[i]>max_crop then
            comment_1:=Crop_management_is_OK
        ELSE
            comment_1:=determine_model
        end;
    Close(ResultFile);
End;

*****
Procedure Determine_P (Var SL_3,SL_4,P:Values; Var
    Comment_2:String; Var ResultFile:text);
*****

Var i: integer;
    Land_Management_is_OK,Determine_Model:string;

Begin

    Assign(ResultFile,'A:Results.Pas');
    Rewrite(ResultFile);
    Writeln(ResultFile);
    Writeln(ResultFile,'NOTE2');
    Writeln(ResultFile,'_____');
    Writeln(ResultFile);
    Writeln(ResultFile,'LAND MANAGEMENT FACTOR (P) IS
    GIVEN AS');
    Writeln(ResultFile,'THE RATIO OF SOIL LOSS USING
    SPECIFIC');
    Writeln(ResultFile,'TILLAGE TYPE (PRACTICE) TO THAT
    USING');
    Writeln(ResultFile,'UP AND DOWN SLOPE PRACTICE. ');
    Writeln(ResultFile);
    Clrscr;
    Write('N');Delay(300);Write('O');
    Delay(300);Write('W');Delay(300);Write(' ');
    Delay(300);Write('C');Delay(300);
    Write('A');Delay(300);Write('L');Delay(300);
    Write('C');Delay(300);Write('U');
    Delay(300);Write('L');Delay(300);Write('A');

```

```

Delay(300);Write('T');Delay(300);
Write('I');Delay(300);
Write('N');Delay(300);Write('G');
Delay(300);Write(' ');Delay(300);Write('T');
Delay(300);Write('H');
Write('E');Delay(300);Write(' ');
Delay(300);Write(''P''); Write(' ');Delay(300);
Write('F');Delay(300);Write('A');
Delay(300);Write('C');Delay(300);Write('T');
Delay(300);Write('O');Delay(300);
Write('R');Delay(1000);
clrscr;
Writeln;
Writeln;
Write('.');Delay(300);Write('.');Delay(300);
Write('.');Delay(300);Write('C');
Delay(300);Write('O');Delay(300);
Write('M');Delay(300);Write('P');Delay(300);
Write('A');Delay(300);Write('R');
Delay(300);Write('I');Delay(300);Write('S');
Delay(300);Write('O');Delay(300);
Write('N');Delay(300);Write(' ');Delay(300);
Write('A');Delay(300);Write('N');
Delay(300);Write('A');Delay(300);Write('L');
Delay(300);Write('Y');Write('S');
Delay(300);Write('I');Delay(300);Write('S');
Write(' ');Delay(300);Write('P');
Delay(300);Write('R');Delay(300);Write('O');
Delay(300);Write('C');Delay(300);
Write('E');Delay(300);Write('E');Delay(1000);
Write('D');Delay(300);Write('S');
Write('.');Delay(300);Write('.');
Delay(300);Write('.');Delay(300);Delay(1000);
Writeln;
Clrscr;
Writeln;
Write('.');Delay(300);Write('.');
Delay(300);Write('.');Delay(300);Write('I');
Delay(300);Write('T');Delay(300);
Write('');Delay(300);Write('S');Delay(300);
Write(' ');Delay(300);Write('O');Delay(300);
Write('V');Delay(300);Write('E');
Delay(300);Write('R');Delay(300);
Write('.');Delay(300);Write('.');
Delay(300);Write('.');Delay(300);
ClrScr;

```

```

For i:=1 to datalist do
  begin
    P[i]:=(SL_3[i])/(SL_4[i]);
    IF P[i]>max_land THEN
      Comment_2:=Land_management_is_OK
    ELSE
      Comment_2:=Determine_Model
    end;
    Writeln(ResultFile);
    Close(ResultFile);
End;

*****
Procedure Store_Results (Var C,P,SL_1,SL_2,SL_3,SL_4:values;
  Var Comment_1,Comment_2:String; Var ResultFile:text);
*****

Var i:integer;

Begin
  Assign(ResultFile,'Results.Pas');
  Rewrite(ResultFile);
  Writeln(ResultFile,'_____');
  Writeln(ResultFile);
  Writeln(ResultFile,'Date':4,'
  SL-1':10,'SL-2':9,'SL-3':9,'SL-4':9,'C':9,'P':9,
  'Comment for C':30,'Comment for P':30);
  Writeln(ResultFile,'_____');
  Writeln(ResultFile);

  For i:=1 to datalist do

    Writeln(ResultFile,'Date:',i:3,SL_1[i]:7:2,
    SL_2[i]:9:2,SL_3[i]:9:2,SL_4[i]:9:2,
    C[i]:9:2,P[i]:9:2{Comment_1:10,comment_2:10});
    Writeln(ResultFile,'_____');
    close(ResultFile);
  
```

End;

```
*****
Procedure program_initiation;
*****
```

Begin

```
  clrscr;
  Writeln('_____');
  Writeln;
  Writeln('WELCOME TO THE PROCEDURE FOR DETERMINATION OF
  CROP AND');
  Writeln('LAND MANAGEMENT FACTOR(S) SUBMODELS FOR SOIL
  LOSS ');
  Writeln('PREDICTION');
  Writeln;
  Writeln('_____');
  Writeln;
  Writeln('1. THE PROCEDURE FIRST PROVIDES AREA
  DESCRIPTION DATA');
  Writeln('  BEFORE CALCULATING C AND P VALUES FOR
  SPECIFIED CROPS AND');
  Writeln('  TILLAGE PRACTICES AND THEN COMPARES THE
  RESULTS WITH DESIRED');
  Writeln('  MANAGEMENT FACTORS ENTERED BY THE USER');
  Writeln;
  Writeln;
  Writeln('  COMPARISON ANALYSIS PROVIDES A DECISION
  MAKING FRAMEWORK ON');
  Writeln('  WHETHER CROP AND LAND MANAGEMENT FACTOR(S)
  SUB MODELS SHOULD');
  Writeln('  BE DETERMINED OR NOT');
  Writeln;
  Writeln;
  Writeln('2. THE RESULTS OF THE PROCESSING ARE SENT TO
  THE FILE A:\RESULTS.PAS');
  Writeln;
  Writeln;
  Writeln('3. SOIL LOSS DATA MUST BE SAVED WITH THE
  FILENAME A:\DATA.PAS. ');
  Writeln('  IN THE FORMAT SL_1  SL_2  SL_3  SL_4');
  Writeln;
  Writeln('  WHERE');
  Writeln('  SL_1 = Column for soil loss
  from cropped plots');
  Writeln('  with a specified
  crop');
  Writeln;
```

```

Writeln('                SL_2 = Column for soil loss
Writeln;                from bare plots');
Writeln('                SL_3 = Column with soil loss
Writeln('                from a plot with');
Writeln('                specified tillage
Writeln;                practice. ');
Writeln('                SL_4 = Column with soil loss
Writeln('                from a plot with up
Writeln;                and');
Writeln('                down slope tillage
Writeln;                practice. ');
Writeln;
Writeln;
Pause;
end;

*****
Procedure Continuation(var SL_1,SL_2,SL_3,SL_4,C,P:Values;
  Var Comment_1,Comment_2:String; Var ResultFile:text);
*****

Var
  Choice:integer;

Begin
  Writeln ('Do you have another crop to consider?');
  Writeln;
  Writeln('1: YES');
  Writeln('2: NO');
  Writeln;
  Writeln;
  Write('<ENTER> choice number:');
  Writeln;
  Read(choice);
  IF choice =1 THEN

    begin

      Determine_C(SL_1,SL_2,C,Comment_1,ResultFile);
      Determine_P(SL_3,SL_4,P,Comment_2,ResultFile);
      Store_Results(C,P,SL_1,SL_2,
        SL_3,SL_4,Comment_1,Comment_2,ResultFile);
      Continuation(SL_1,SL_2,SL_3,SL_4,C,P,
        Comment_1,Comment_2,ResultFile);

    end

```

ELSE

```

    Clrscr;
    Write(' '); Delay(300); Write(' ');
    Delay(300); Write(' '); Delay(300); Write('P');
    Delay(300); Write('R'); Delay(300);
    Write('O'); Delay(300); Write('C'); Delay(300);
    Write('E'); Delay(300); Write('S');
    Delay(300); Write('S'); Delay(300); Write('I');
    Delay(300); Write('N'); Delay(300);
    Write('G'); Delay(300); Write(' '); Delay(300);
    Write('C'); Delay(300); Write('O');
    Delay(300); Write('M'); Delay(300); Write('P');
    Delay(300); Write('L'); Write('E');
    Delay(300); Write('T'); Delay(300); Write('E');
    Delay(300); Write(' '); Delay(300);
    Write(' '); Delay(300); Write(' ');
    Delay(1000);

```

End;

```

*****
PROCEDURE Execution_Mode;
*****

```

BEGIN

```

    Clrscr;
    Writeln;
    Writeln;
    Clrscr;
    Write('P'); Delay(300); Write('R');
    Delay(300); Write('O'); Delay(300); Write('G');
    Delay(300); Write('R'); Delay(300);
    Write('A'); Delay(300); Write('M'); Delay(300);
    Write(' '); Delay(300); Write('E');
    Delay(300); Write('X'); Write('E'); Delay(300);
    Delay(300); Write('C'); Delay(300);
    Write('U'); Delay(300); Write('T'); Delay(300);
    Write('I'); Delay(300); Write('O');
    Delay(300); Write('N'); Delay(300); Write(' ');
    Delay(300); Write('H'); Write('A');
    Delay(300); Write('S'); Delay(300); Write(' ');
    Write('B'); Delay(300); Write('E');
    Delay(300); Write('G'); Delay(300); Write('U');
    Delay(300); Write('N'); Delay(1000);

```

End;

```
*****  
{MAIN PROGRAM}  
*****
```

```
BEGIN
```

```
Program_initiation;  
Execution_Mode;  
Create_DataFile(SL_1,SL_2,SL_3,SL_4);  
Determine_C(SL_1,SL_2,C,Comment_1,ResultFile);  
Determine_P(SL_3,SL_4,P,Comment_2,ResultFile);  
Continuation(SL_1,SL_2,SL_3,SL_4,C,P,Comment_1,Comment_2,  
ResultFile);Store_Results(SL_1,SL_2,SL_3,SL_4,C,P,  
Comment_1,Comment_2, ResultFile);
```

```
END.
```