Soil Erosion in the Tea lands of Sri Lanka

by

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ABSTRACT

Tea, Cammelia sinensis L. is one of the major plantation crops grown Sri Lanka. Soil erosion is considered to be immense in tea land since tea is grown mostly in high rainfall areas on steep slopes. The present research was conducted at the Tea Research Institute of Sri Lanka in Talawakelle with a view of providing qualitative data on soil erosion. A runoff plot experiment was conducted in seedling and clonal tea on approximately 0.5 ha macroplots using a system of collection tanks to collect and measure runoff.

The experiment commenced in October 1981 and data were collected until the end of 1984. Each site was equipped with an automatic rainfall recorder which was used to calculate the erosivity of rainfall using three erosivity indices. The relationships between these indices with runoff and soil loss were also investigated.

In addition to measuring the runoff and soil loss the amount of eroded soil collected in lateral drains was measured during monsoon rains and the loss of nutrients in eroded soil was estimated.

In 1984 a second field experiment was conducted in the tea area of Uva which has high rainfall and severe erosion. The extent of soil loss in lateral drains was monitored for one rainy season in fields with different stages of growth of tea and levels of management.

In the site at Talawakelle runoff and soil loss from seedling tea were found to be greater than from clonal tea. Runoff and soil loss

from both treatments were minimal and the amount of soil carried away from fields did not exceed 1 Mg ha^{-1} $year^{-1}$ in any one of the years of observation. This was far below the estimated tolerable limits of soil erosion for the soil types of the sites.

However, with the amounts of soil deposited in the lateral drains the erosion losses exceeded tolerable limits in seedling tea fields in 1981-1982. This was due to the soil disturbances during the construction work as this trend was not repeated in later years.

Nutrient losses from tea were calculated. There were considerable losses of organic matter and total nitrogen but low amounts of P and K were lost in eroded soil. The nutrient loss caused by runoff was very low.

Experiments carried out in the Uva region demonstrated the importance of managing a good cover in tea. The results showed that if well managed, erosion losses from a 100 year old seedling field can be minimal compared to much younger fields with poor management. The amount of soil that can be conserved by mulching young tea was also significant. The amount of nutrient loss was also estimated in these plots and similar trends in results as in the first site were obtained.

The Universal Soil Loss Equation was used to estimate annual erosion values for St. Coombs. Actual soil losses were in all cases lower than the estimated values.

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Chapter I

INTRODUCTION

Soil Erosion has become a serious global problem with systems of intensified agriculture. In tropical countries where conditions of intense rainfall prevail, the importance of soil conservation is recognized but little is being done to implement it. Soil erosion results in the physical removal of soil and deterioration of soil fertility causing low productivity.

Tea cultivation plays an important role in the economy of Sri Lanka in terms of foreign exchange earnings and employment. Soil erosion in tea land has always been considered to be immense as tea is nearly always grown on sloping land in areas of intense rainfall under less than ideal management methods.

The importance of soil erosion has been recognized qualitatively for many years in the tropics but the availability of quantitative research data is not satisfactory.

The present research was conducted at the Tea Research Institute of Sri Lanka as a preliminary study leading to more intensive research that would provide a more deeper understanding of the soil erosion problem with a view of adopting a suitable system of soil conservation in the tea lands of Sri Lanka.

Chapter II

LITERATURE REVIEW

2.1 SOIL EROSION - A GLOBAL PROBLEM.

Studies of the effect of erosion on early civilizations have shown that a major cause of the downfall of many flourishing empires was soil degradation (Lowdermilk, 1953). Several Greek philosophers have mentioned land improvement. Homer advocates fallows to rest the soil and Plato associates floods and erosion with destruction of forests. Earlier Roman literature mentions what we would today call conservation farming (quoted by Hudson, 1981a).

Hudson (1981a) attributes the reluctance of our ancestors to appreciate the significance of erosion to be due to the fact that all the earlier civilizations have arisen on irrigated alluvial plains which depend upon flood deposits of silt for continued fertility. Therefore, the civilizations of the valleys of the Nile, the Tigris and the Euphrates, which owed their existence to erosion, could hardly be expected to be concerned about erosion in the head waters in the same light as a modern agricultural community.

Today soil erosion is universally recognized as a serious threat to man's well being, if not his very existence. This is shown by the fact that many governments in all parts of the world actively promote programmes of soil conservation.

Much erosion research has been conducted and information is available now from researchers all over the world. In the United States erosion research stations were established over five decades ago and these formed the beginning of the present federal erosion research effort in the United States (Moldenhauer, 1978). Estimating erosion losses from fields by using empirical equations was mainly developed in the United States and one developed by Wischmeier (1965), the Univeral Soil Loss Equation (USLE), is used in many parts of the world today.

Morgan and Morgan (1981) from their studies conducted in Great Britain, claim that the use of the above model requires high quality data which may not be attainable with field experiments. However, Becher et al. (1977), in their studies in Southern Bavaria, where erosion under hops is severe, have used this equation and the Wischmeier nomograph to estimate soil losses and erodibility of soils.

In recent years, tracers have been used in several countries to estimate long term erosion losses. Cesium-137 is produced by nuclear explosions. Radioactive fall-out from nuclear tests has occurred since 1945 and about 80 percent of the total fall-out had occurred by the end of 1964. The fall-out pattern changes according to the season with maximum values occurring in spring. Cesium-137 carried from the atmosphere with rain is strongly adsorbed to soil particles. In undisturbed soil profiles it is concentrated mostly in the surface layers. The current distribution of the isotope in a soil profile is used to reflect the degree of erosion since the 1960's when most of the fall-out occurred (McCallan et al., 1980).

Mitchell et al. (1976) have used fall-out Cesium-137 levels in soil to identify areas of soil loss and deposition. Jenkins et al. (1984) have used Cesium-137 as a tracer to estimate erosion in Manitoba, Canada. McCallan et al. (1980) have conducted extensive research in Australian soils using Cesium-137.

In Germany, Schwertmann et al. (1980) used copper as a tracer to measure the annual soil losses in a hop cultivation. Copper has been used as a fungicide for as long as 50 years in this area and it was used as a tracer to measure the annual soil losses during 13-46 years of hop cultivation. The copper concentration of the plough layer was measured and the dilution and accumulation of copper at the time of study were used to identify sites of erosion and deposition.

In humid tropics several workers have carried out extensive research into the estimation of erosion losses. Elwell (1981) has proposed a method of soil loss estimation which he claims to be suited particularly to countries unable to support expensive research programmes but which urgently require a decision making aid to combat soil erosion. One such model, SLEMSA (Soil Loss Estimator for Southern Africa) has been described by Elwel (1978). The SLEMSA consists of several stages. The first stage, soil erosion environment, is divided into 4 systems: climate, soil, crop and topography. Each system is treated as a separate entity. This differs from the concept of the USLE. The second stage, control variables, consists of the major overriding factors determining soil losses within each of the above mentioned systems. The factors identified are seasonal rainfall energy, amount of rainfall energy intercepted by the vegetation, soil erodibility, slope length and slope percentage. The control variables are expressed in terms of soil loss at the next level submodels. The submodels interact as simple products in the main model to estimate the mean annual soil loss from a specific crop type, climate, soil type and slope conditions.

Othieno (1975) in Kenya has recorded the runoff and erosion losses from young tea fields. Small runoff plots with collection tanks have been constructed at the Coffee Research Station in East Africa as early as 1934 and the erosion under several cover crops has been compared (Anonymous, 1935). Bonsu (1981) has compared erosion losses under several traditional mixed cropping systems in Ghana and reported that mulching is superior to other practices in the control of erosion, and that most of the traditional mixed cropping can be very effective in the control of erosion by providing close soil cover.

Soil conservation programmes have been conducted in India for nearly four decades. Das and Singh (1981) have reported case studies of sixteen conservation structures established in different parts of India. They found these to be economically viable for protecting the national resources of land and the investment on the multi-purpose river valley project.

2.2 TYPES OF EROSION.

2.2.1 Geological and accelerated erosion.

Removal of soil is a natural geological process which has always taken place and which always will. Geological erosion takes place only as a result of the action of nature's forces. Accelerated erosion is caused by the action of man. Rates of geological as well as acclerated erosion are governed by climatic and topographical conditions of a location.

2.2.2 Agents of Erosion.

Erosion is mainly caused by the action of wind, water or temperature changes and in some cases biological action. Except for a few locations, wind erosion is of relatively little significance to Sri Lanka. On the other hand, water erosion causes loss of soil and degradation of soil fertility in valuable agricultural lands of the island.

2.3 WIND EROSION.

Factors that affect the likelihood of wind erosion are the soil conditions, the rainfall and the vegetation (Hudson, 1981a).

The nature of soil will affect the vulnerability of the aggregates to disintegration but the more important fact to consider is that wind erosion occurs only in dry soil. As a rule, wind erosion is more common in dry areas where the annual rainfall is less than 300 mm or in wet areas subjected to long dry spells. Soil is practically non-erodible by wind if it is covered by adequate vegetation.

For any particular soil condition, the extent of erosion depends upon the wind velocity and the roughness of the surface over which the wind blows. para

A formula that describes the inter-relationship of factors which affect wind erosion was described by Schwab et al. (1966).

$$S \propto (V - Vo)^3 d^{1/2}$$

where S - quantity of soil moved

V - Wind Velocity

Vo- Minimum wind velocity which can move particles of this size

d - diameter of soil particles

Measures to control wind erosion are directed towards changing these factors by increasing soil moisture, reducing wind velocity and increasing the soil roughness.

Depending upon the size of soil particles, wind erosion occurs by three types of movement: suspension, surface creep and saltation. Particles less than 0.1 mm in diameter may be carried in suspension, intermediate particles (0.05 - 0.5 mm) by saltation, and the largest (0.5 - 1 or 2 mm) by surface creep. Saltation is considered to be the most important (Stallings, 1957; Hudson, 1981a; Morgan, 1979).

The physical parameters of wind erosion are measured using wind tunnel experiments. It is not easy to differentiate the amounts of soil moved by the different types of movement (Chepil, 1945).

Unlike water erosion, it is difficult to estimate the extent of wind erosion. Chepil and Woodruff (1963) have defined an equation to estimate it. This equation shows that the annual soil loss caused by wind erosion is a complicated function of several other factors.

$$E = f(I,C,K,L,V)$$

where E - Annual soil loss caused by wind erosion

I - Erodibility of soil to wind erosion

C - Factor representing local climatic conditions

K - Surface roughness

L - Width of field in direction of prevailing winds

V - Factor accounting for the degree of vegetative cover

However, it must be remembered that in contrast to the Universal Soil Loss Equation, a direct multiplication of factors will not give the amount of wind erosion. This is caused by the interactions of the mathematical relationships between factors.

2.3.1 Preventive methods to control Wind Erosion.

Methods of controlling wind erosion can be divided into two groups:

a) Routine practices that are used every year to prevent the commencement of drifting. Strip cropping, rotation of crops, trash cover farming or leaving of stubble, use of cover crops and providing shelter belts are categorized as routine practices.

Strip cropping provides erosion control by reducing wind velocity across the strip, by localizing drifting that starts from a focal point and by reducing the cumulative effect of soil movement. Strips should be arranged at right angles to the prevailing wind. The width of strips depend on the soil structure, the degree of erosion in the recent past and the wind conditions of the area.

Trash cover reduces wind velocity at the soil surface and traps soil particles to reduce the intensity of drifting once it starts. The quantity of trash that is required to protect the field varies with the wind velocity, erodibility of soil and other factors.

Wind breaks and shelter belts provide physical barriers and reduce the wind velocity.

b) Emergency control measures which are used to reduce or stop erosion once a drift has started. Several methods of tillage, such as chiselling, strip listing or complete listing or ridging etc. can be used as emergency measures of controlling a drift (Hudson, 1981a; Morgan, 1979). These measures should be taken before too much soil has been lost and started on the windward side of the field.

Most of these emergency measures are aimed at producing a rougher, cloddy surface, thus reducing the intensity of a drift. Ploughing or discing can be used to turn soil to provide such a surface. Straw or manure is also used to cover the soil at focal points to stop the spreading of a drift.

2.4 WATER EROSION.

Water erosion can be caused by rainfall or by spring runoff as a result of snow melting. The latter is of significance only in temperate regions. Rainfall erosion is more significant and is wide spread in all parts of our planet.

Factors that affect water erosion are rainfall characteristics, the erodibility of soil, topography and the crop and management practices used. Rainfall intensity, raindrop size, terminal velocity of rain drops and their momentum and kinetic energy can be grouped into rainfall characteristics.

Erosivity of rainfall The ability or potential of rain to cause erosion is termed the erosivity of rainfall. It is a function of the physical characteristics of rainfall (Hudson, 1981a).

Erodibility of soil - The erodibility of soil is its vulnerability or susceptibility to erosion. Erodibility of a soil is governed by several factors such as the physical composition of a soil, the slope of land and the kind of crop cover it has.

The process of erosion starts when the rainfall intensity exceeds the rate at which water is infiltrated into the soil. First, the soil particles are detached from the main soil mass and then they move to a channel in which they may be transported for the rest of their journey by the runoff flowing on the surface (Linsley et al. 1958).

Water erosion can be of three types: sheet erosion - the removal of a relatively uniform layer of soil from the surface; rill erosion - formation of rills or rivulets along which water will move; and finally gully erosion - the formation of gulleys.

The discovery of rain drop splash by Ellison in 1952 and further developments in this area opened a new line of investigation in soil erosion research (quoted by Hudson, 1981a). His theory showed that the falling rain drop was a complete erosive agent within itself and that the protective effect of plant cover was due to the transfer of kinetic energy of the falling raindrops to the plant cover (quoted by Stallings, 1957). Although some of the pioneer workers on soil erosion did not agree with Ellison at the time (Bennett et al., 1951), today rain drop splash is recognized as the most important factor in the process of erosion.

2.5 MEASUREMENT AND PREDICTION OF WATER EROSION.

The measurement of water erosion can be made by using several different techniques. Several workers have suggested different methods (Jackson, 1964; Wischmeier and Smith, 1965; Hudson, 1981a). Most techniques use runoff plots, field observations and rainfall simulators.

Runoff plots - Runoff plots probably are the most widely used for measuring soil erosion. They could range from small plots of 40.47 m^2 or one hundredth of an acre (Jackson, 1964) to several acres. In early studies conducted in the United States plots 1.83 m (6 feet) wide and 22.13 m (72.6 feet) in length (40.47 m^2 or 1/100th of an acre) were used. Wischmeier (1964) has made measurements using plots 0.91 meters by 1.83 meters (3 feet by 6 feet) and Hudson (1981a) has used some micro plots in Malawi. In field scale operations, much larger plots are required.

Plot boundaries can be made out of metal or concrete. Collection troughs, tanks, etc. for both small and large plots are installed at the lower end of the plots and usually made out of concrete or metal. In microplots the collection systems may be simple tanks but for larger plots, measuring devices and divisors such as Geib multislot divisors (Jackson, 1964; FAO, 1965) are used for accurate measurement.

To determine the rates of runoff, especially in large plots measuring flumes are used. H-flumes (USDA, 1962) and Parshall flumes (Parshall, 1950) are two types commonly used worldwide. The measurement of runoff water and soil can be completed using measuring sticks, etc. and the concentration of soil in the runoff water can be determined by taking representative samples after vigorous stirring. Determination of the soil content in the suspension is normally conducted in a laboratory.

Field Observations - Field observations are used to assess or investigate the control of erosion in a qualitative manner by observing the effects of various treatments on erosion. This can be achieved by identification of the effects of erosion by experienced observers. A multitude of factors can be used for identification. The factors used are the presence of rills, gullies, washes, areas of exposed subsoil, deposition of coarse sediments where the velocity of the runoff water is slowed on the more level areas, decreasing depth of top soil compared to protected areas of the same type and other phenomena (FAO, 1965).

Methods to control erosion have been developed by trying various procedures in the field and observing the most effective.

Rainfall Simulators - Use of rainfall simulators has advantages because research work can be accelerated and results are no longer dependent upon weather. Any type of rain can be created artificially and the results tested repeatedly. These simulators have varying drop sizes or spraying nozzles.

The type of simulator used depends upon the plot size used. Simulators can vary from the Purdue Sprinkling Infiltrometer (Bertrand and Parr, 1961) for small plots to larger complicated systems such as the Rainulator (Meyer and McCune, 1958) or the Rotating Boom Rainfall Simulator (Swanson, 1965 - quoted by FAO, 1965).

2.5.1 Estimation of Water Erosion.

Attempts have been made over a long period of time to estimate the erosion loss under given conditions. A team from the United States have succeeded in achieving this objective with the Universal Soil Loss Equation (Wischmeier and Smith, 1965).

This equation isolates each variable that is responsible for erosion and reduces it to a numerical value and the product of these values gives the amount of soil loss under given circumstances. The equation is as follows:

$$A = R \times K \times L \times S \times C \times P$$

where A - computed soil loss per unit area

R - Rainfall factor based on the EI_{30} index (the product of the kinetic energy of the storm and the greatest average intensity experienced in any 30 minute period during the storm). The kinetic energy is calculated from rainfall intensity using the equation: $KE = 11.9 + 8.73 \log I \ J\ m^{-2}\ mm^{-1}$ of rain (where, I is the average intensity of the storm).

K - Soil Erodibility factor. The erodibility factor in numerical values represents the actual loss of soil from a standard slope of standard length, with a standard crop cover, rainfall, etc. Soil erodibility depends upon the soil properties such as texture, infiltration rate, etc. For example, soils with high silt content are more susceptible to erosion, and extremes in particle size such as large gravel or very small clay particles can reduce erosion. Wischmeier et al. (1971) have produced a nomograph which is used to obtain erodibility values for soils with known soil properties. The information needed is percentage of silt plus very fine sand, percentage sand particles larger than 0.1 mm, organic matter content, soil structure and permeability to water (Appendix M).

L - Slope length factor. Ratio of soil loss which is comparable to that from a field of specified length of 22.13 m (72.6 feet).

S - Slope gradient factor. Ratio which compares the soil loss from a field with a given gradient with that from a field with 9 percent slope.

Wischmeier and Smith (1965) have combined slope and gradient into one term (LS) in the USLE using the equation: $LS = l^{1/2} (0.0076 + 0.0053s + 0.00076s^2)$ to calculate it. In this equation l is the slope length in feet and s is the gradient in percent. LS factor can also be estimated using a graphical relationship (Hudson, 1981a) (Appendix L).

C - Crop Management Factor. A ratio which compares soil loss from a crop at a specific stage of development with that from a field under a standard treatment (cultivated bare fallow).

P - Conservation practice factor. Ratio compares the soil loss with that from a field with no conservation practices.

Details of the use of the equation and an evaluation of the factors used in the equation are given by Wischmeier and Smith (1965) and Wischmeier et al. (1978). The USLE has been used by reserarch workers of several countries: Morgan and Morgan (1981) in the United Kingdom, Lal (1981) in Nigeria, and Krishnarajah (1982) in Sri Lanka.

2.6 EFFECT OF SOIL EROSION ON SOIL FERTILITY.

All types of erosion contribute to the loss of soil and applied nutrients from cultivated land. The soil layers most readily removed (top soil) are generally the richest in plant nutrients and the most favourable physically for water storage and transmission, as well as the most suitable structurally for rapid root growth. Deeper soil layers exposed by erosion are less able to support healthy vegetative growth (El-Swaify et al., 1982).

Lal (1975) attributes the limited or complete lack of response to applied fertilizer in tropical soils to leaching losses and partially to losses in water runoff and eroded sediments. There is little doubt that the removal of solutes and the loss of applied fertilizers are important factors in the depletion of soil fertility.

Estimating the quantity of solutes lost from soils has occupied several research workers. A loss of 0.322 Mg ha^{-1} $year^{-1}$ (82 Ton mi^{-2} $year^{-1}$) of solutes from US soils and 0.175 Mg ha^{-1} $year^{-1}$ (44.5 Ton mi^{-2} $year^{-1}$) from USSR soils have been reported by Drum et al. (1960). Several workers have reported the amounts of nitrogen losses in runoff water (Moe et al., 1967; Bryant and Slater, 1948; Mattyasovszky and Duck, 1954; Barnett et al., 1972; Kowal, 1972).

Studies conducted at the International Institute of Tropical Agriculture in Nigeria shows that the total nutrient losses in runoff water were proportional to the surface runoff and were, therefore, affected both by slope and soil management treatments.

From the considerable amount of data available on the losses of phosphorus in runoff water and eroded sediment, it is evident that the major loss of P in runoff water was through eroded sediments (Dudley, 1926; Ryden et al., 1973; Munn et al., 1973). Very little information is reported in literature regarding the losses of potassium in runoff. Lal's results show that the concentration of K in runoff from bare plots was significantlly higher than that from plots under cover crops.

It has been suggested by many research workers that most of the nutrients lost in runoff water is associated with eroded sediments. A large fraction of the lost nutrients are associated with the finer fraction of the eroded sediments.

An average annual loss of 192 kg of organic matter, 10.6 kg of N and 1.8 kg of exchangable K per ha was reported by Massey et al. (1973) from an 11 percent Wisconsin slope. Several others (Chandler, 1938; Volk, 1945; Ensminger, 1952; Gupta and Singh, 1967; Lal, 1975) have agreed that one major nutrient lost in eroded sediment is applied P. Extensive losses of N in eroded sediments have also been reported by Rogers (1944), Kowal (1952), Massey et al. (1953) Osburn and Mathews (1955) and others.

As the amount of nutrients lost in runoff water and eroded sediment is directly proportional to the amount of soil eroded it is clear that it is possible to control the resulting degradation of soil fertility by controlling erosion.

2.7 SOIL EROSION IN SRI LANKA (CEYLON).

The importance of soil erosion has been stressed for a considerable number of years in Ceylon. As early as 1919 in a report made by W.L. Strange, an officer seconded from India, recommendations were made to prevent soil erosion (quoted by Norris,1936).

One of the earliest references to the problem of soil erosion in Ceylon was made by J.D. Hooker in 1873 who is quoted in the Report of the Committee on Soil Erosion, 1931 (Sessional Paper No. III of 1931). He pointed out that the faulty opening up of land for extensive cultivation of plantation crops resulted in soil erosion and irregular water supplies. The report of the Committee was based on evidence placed before it by scientists, planters and others interested in agriculture. This report held the estate sector responsible for the greater part of soil erosion, particularly tea estates and to a lesser extent rubber and coconut estates.

The only available reference in earlier Ceylon of an attempt to quantify the extent of erosion dates back to 1930. This study showed that 132,000 to 833,000 tonnes of soil per year was carried by the Mahaweli river (Joachim and Pandithasekera, 1930).

Although the recommendations of the Committee on Soil Erosion resulted in the estate sector adopting soil conservation measures, the situation with respect to all areas was not satisfactory. A survey made four years later showed that new soil conservation measures were adopted in 45,000 ha of tea and 3,800 ha of rubber land.

The Soil Conservation Act, enacted in 1953 was aimed at taking suitable preventative methods to minimize soil erosion applicable to the entire island in general, and to adopt specific measures in certain areas declared as 'erodible areas' (Manipura, 1971). Although much progress has been made in adopting suitable soil conservation measures, soil erosion continues to be a problem of varying magnitude in certain types of agricultural land today.

2.8 SOIL EROSION RESEARCH IN SRI LANKA.

Soil erosion research in Sri Lanka was in its very rudimentary stage until a few years ago. Very few studies have been reported. Hasselo and Sikurajapathy (1965), Manipura (1975) and Kandiah (1975) have reported the results of erosion studies conducted in tea lands using small scale runoff plots.

Alles (1971) evaluated the effectiveness of a chemical spray against splash erosion which was effective for several weeks after application (quoted by Manipura, 1972). Manipura (1972) evaluated the influence of mulch and cover crops on runoff and sediment yield on tea during early growth of replanted tea.

An intergrated research study on water erosion was started by the Land Use Division of the Department of Agriculture in Sri Lanka in the Mahaweli river watersheds. The results have been reported by Krishnarajah et al. (1981), Hudson (1981b) and El-Swaify et al. (1982).

2.9 SOIL EROSION IN TEA LANDS.

Many of the tea plantations in the mid country and up country of Sri Lanka were planted nearly 100 years ago. Planting was done by using seed material from selected mother bushes of high quality. However, the seedling tea fields lack uniform good growth due to genetic variabilities. This results in inferior crop cover. Planting was almost always done up and down the slope, with the result that the inter-row spaces became channels for surface runoff. In most of the old tea fields, lateral drains are either not available or when present are constructed at gradients varying from 1 in 7 to 1 in 30 (14 to 35 percent), i.e. they were designed to carry the water away from the land rather than for soil conservation. The leader drains when present were not paved by stones or stabilized by planting of grasses to check the flow of water. They have been transformed into ravines and gullies with considerable washing away of the side walls, exposing the tea roots. Vacant patches are quite common in seedling tea due to the dieback of tea bushes from exposed roots, old age, drought, pests and diseases. When these patches are not replanted they become subject to the action of rain. The use of an implement called a scraper for weed control further aggravates the problem by not only exposing appreciable land surface but also by leaving behind a loose layer of soil which is susceptible to removal by the runoff water. This situation prevails on nearly 80 percent of the total tea area of the country.

The replacement of poor yielding seedling tea fields by high yielding VP (vegetatively propogated or clonal) tea, which also gives a good crop cover, reduces soil erosion to a minimum. However, during early stages of replanting (during land preparation and until a good cover is established) soil erosion may be very serious. The most critical period occurs between the time when the old tea is uprooted and the rehabilitation grass has grown to cover the soil. Depending on the type of soil management, soil loss can occur to varying degrees following the planting of young tea and until the tea has covered the ground. Hasselo and Sikurajapathy (1965) have estimated a soil loss of 250 tonnes of top soil per hectare during a four year replanting period.

Depending on the elevation at which it is grown, it is a common practice for the tea plant to be pruned every 3-4 years to a height of about 45 cm. As pruning reduces crop cover, the soil is susceptible to erosion in the period after pruning until the tea covers the soil.

2.10 METHODS OF SOIL CONSERVATION IN TEA PLANTATIONS.

Soil erosion in tea land is caused mainly by rain drop splash and surface runoff. Rainfall in tea growing areas vary from 1500-5000 mm per year and storms, especially inter-monsoonal storms of very high intensity, are experienced in all tea growing districts. The soil conservation methods adopted should aim to absorb as much as the incident rainfall as possible and to lead any excess away from the fields at non-erosive velocities to prevent loss of soil (Manipura, 1971).

Soil erosion losses from tea plantations could be minimized by implementing certain management practices (Krishnarajah, 1982). Mulching, leaving of prunings in the field, adopting chemical weed control, growing of cover crops are examples.

2.10.1 System of drainage.

A very effective system of drainage to control the flow of water with a view of reducing soil erosion was designed in 1928 by a proprietor-planter in the up country (Felsinger, 1928). The present day drainage system could be called a modification of his work. Felsinger based his system on the idea that by trapping the soil that is being washed away by runoff water in a series of locks to collect silt deposits, one can reduce the amount of soil carried away from fields.

The Felsinger system consisted of paved leader drains to carry away excess water and lock and spill type of lateral drains with silt pits, cut on the contour. The distance between the lateral drains depends on the steepness of the land.

The present day recommendations for the spacing of drains is given in Table 1.

TABLE 1

Recommended spacing of contour drains in tea plantations.

Slope in percent	Spacing between two drains(m)
0 - 10	15
11 - 20	12
21 - 30	9
31 - 40	6

The lips of drains and road banks should be planted with a stabilizing grass such as Eragrostis curvula (African Love grass). The drains should be cleaned regularly and the silt collected should be spread above the drain. Although neglected by many of today's planters, this procedure is very important as the extent of silt deposits in lateral drains can become very large (Krishnarajah, 1982).

Unless properly constructed, the leader drains can turn into gullies where considerable washing away of side walls occurrs (Manipura, 1971). It is recommended that leader drains be constructed stepwise, paved with stones and strengthened by the planting of a suitable grass.

2.10.2 Selective Weed Control

Encouraging the growth of non-competitive indegenous weed species provides protective soil cover in tea fields (Manipura,1971). Manipura (1971) has recommended Oxalis sp.(Oxalis corymbosa, Oxalis latiifolia and Oxalis coniculata) and Drimaria cordata for this purpose. These are currently recommended by the Tea Research Institute of Sri Lanka. Huntley-Wilkinson (1940), although disagreeing with the leaving of several weed species, favoured the use of Justicia procumbens, Biophytum proliferum and Fragaria indica (a type of wild strawberry) in addition to the present day recommendations.

Replacing manual weed control, using implements, with chemical weed control is clearly desirable for the reducing of soil erosion in tea.

2.10.3 Cover Crops

Over the years several research workers and planters have demonstrated the effectiveness of cover crops for reducing soil erosion. Holland and Joachim (1935) demonstrated the use of cover crops to minimize erosion. Manipura's experiments conducted at the Tea Research Institute of Sri Lanka in 1972 showed a drastic difference of 51.09 Mg ha^{-1} $year^{-1}$ soil loss between a bare plot and a plot with a cover crop. Eden (1931) has advocated the use of cover crops as the best way to control erosion by preventing soil movement on steep slopes by immobilizing the soil. Huntley-Wilkinson (1940) has also recommended the use of cover crops to minimize erosion in tea fields.

There are various objections raised to the use of cover crops in tea fields: such as competing for moisture, harbouring of weeds, interference with the plucking table, increasing costs, etc. Regarding the objections raised on competition by cover crops for moisture Norris (1936) argues that, if it does occur, it has only a temporary nature and is not significant. He recommends the use of varieties which die back to some extent with the commencing of hot weather. He has strongly recommended the use of legumes as cover crops. The use of legumes is also the choice of Eden (1931), Manipura (1971) and Krishnarajah (1984). Manipura (1971) has recommended cover crops with a low creeping habit such as *Desmodium ovalifolium* and *Stylosanthus gracilis* rather than tall bushy varieties such as *Crotolaria anagyroides* or *Tephrosia vogelli*.

At the present time, cover crops are used by most tea planters in newly planted tea fields as an inter crop. These are cut at the onset of a drought to prevent competition for soil moisture and the cuttings are used to mulch the soil.

2.10.4 Contour Planting of Tea.

At present many estates are replacing uneconomical old seedling tea fields with clonal tea. Contour planting of tea definitely reduces soil erosion and is recommended. The dense tea cover when it is established itself covers the soil well and protects it. Krishnarajah's (1982) results from the mid country where the rainfall is very intense, showed that runoff and soil loss from a tea field with adequate cover is negligible.

2.10.5 Terraces as a measure of soil conservation.

The construction of stone terraces help to conserve the soil. This is practiced in several high rainfall areas but the practice is limited by the availability of stones and funds as terracing can be an expensive operation. Norris (1936) mentions that success depends more upon the frequency of the terraces than on their height and provisions must be made to prevent spilling of water over the edges.

2.10.6 Shade trees.

Shade trees are recommended in tea plantations. These can be indirectly involved in reducing erosion. Rain drop velocity can be reduced by the interception of rain by shade trees, especially if several canopies of high and low shade exists. In addition, the tea cover itself will reduce the terminal velocity of raindrops thus minimizing the raindrop impact on soil (Sandanam, 1981). Shade trees can also provide leaf fall and mulch which can have a long term benefit in increasing the organic matter content of soil. However, the use of shade trees by themselves is not an adequate soil conservation measure (Norris and Eden, 1930).

2.10.7 Contour Hedges.

Huntley-Wilkinson (1940)) has suggested the establishment of green manure shrubs planted on the contour in tea as a measure of soil conservation. He recommends that to prevent soil loss the second sowing of seed take place a few months before the eradication of the original plants. However, this method is not practiced in the present day tea plantations.

Tea hedges have been known to be used as permanent terraces above roads and drains. Huntley Wilkinson (1940) notes that their effect in trapping silt deposits carried away by runoff is evident.

2.11 SOIL CONSERVATION DURING THE REPLANTING OF TEA.

As mentioned earlier most of the estates are now undertaking the large scale replanting of uneconomical old seedling tea with clonal tea. In this period of replanting the soil is extremely vulnerable to erosion and extra precautions must be taken for the operation to succeed.

Once the old tea is uprooted and until a good cover of clonal tea is established, much of the replanted area is exposed and the loss of soil may be very high. The replanting programme includes the planting of a soil rehabilitating or reconditioning grass for a period of 18-24 months or more. These grasses are cut periodically and are used to mulch the soil.

Experiments carried out by the Tea Research Institute have shown that the soil loss from a mulched plot was only 0.073 Mg ha^{-1} (0.03 tons $acre^{-1}$) when compared to that of 43.775 Mg ha^{-1} (18 tons $acre^{-1}$) from a bare, clean weeded plot during the month of April when most of the high intensity storms occur (Manipura et al., 1969). Their results also showed superior soil structure in the mulched plots than in the clean weeded plot.

Sandanam (1981) has recommended the following procedure to be adopted in tea plantations as soil conservation measures during replanting:

a) Avoid land preparation during high intensity storms that occur during April and October monsoons.

b) Uproot in smaller blocks rather than uprooting a field and complete all cultural practices up to the planting of grass in each block.

c) Mechanical soil conservation measures such as the construction of a drainage system, terracing etc. should be in place before the planting of the reconditioning grass.

d) Uprooting and planting of grass should be started from the top of the slope downwards and not vice versa, since the tea bushes on lower slopes act as a barrier to any soil wash that may occur.

Once the young tea is planted the soil should be kept covered with cover crops or mulch until such period that the clonal tea has established its cover to protect the soil.

2.12 SOIL EROSION RESEARCH IN TEA.

Tea is grown as a major cash crop in India, Sri Lanka, Indonesia, Kenya, East Africa, the USSR, China and several other countries. However, the extent of information available on soil erosion studies in tea seems to be minimal. A few studies conducted in Sri Lanka have been reported by Hasselo and Sikurajapathy (1965) and Manipura (1971, 1972). Krishnarajah (1981, 1982 and 1984) has published the results of studies conducted in tea as part of an intergrated catchment study in the mid country of Sri Lanka. El-Swaify et al. (1982) have reported on soil erosion in tea land as part of a research study conducted in South East Asia. In this study the information on tea was only limited to the mid country of Sri Lanka.

In Kenya, tea is grown in high rainfall areas which are mainly located in the highlands with gentle to steep slopes and the erosion losses encountered in tea are high. Othieno (1975) and Othieno and Laycock (1977) have reported the results of runoff plot experiments in young and mature tea fields under different management practices such as mulching, manual and chemical weed control and intercropping. Their results show that rainfall intensity, runoff and canopy cover strongly correlate with soil erosion and that the soil and water losses were greatest in the 1st year. In the 2nd and 3rd years, when the cover developed from about 30 to 70 percent there were marked reductions in both runoff and soil loss.

In India, which is the leading tea producing country of the world, tea is grown mainly on steep slopes in high rainfall areas and erosion is expected to be high. Although a few catchment studies have been reported (Das and Singh, 1985), no reports on soil erosion in tea were found in the literature.

Tea is grown extensively in the Southern USSR in the Krasnodar region and in Georgia. However, as most of the tea in this country is grown on flat land, erosion is not a problem facing the tea industry of USSR.

In general, the amount of information presently available on soil erosion in tea, especially quantification of erosion, is minimal.

Chapter III

MATERIALS AND METHODS.

3.1 OBJECTIVES

Soil Erosion has always been recognized as a hazard in Sri Lanka and the tea plantation sector has been accused of and held responsible for the greater part of the problem. Out of the island's 2.2 million ha of continuous farmland, 0.24 million ha is under tea plantations and they have no doubt been contributing greatly to the serious erosion problems of the country over the years. However, other land uses have equally contributed their share to the problem.

Although many were aware of the hazards of erosion in the tea plantations qualitatively, little was known about the extent of erosion from a tea plantation quantitatively. The present studies were undertaken as preliminary research to study the soil erosion problem facing the tea industry of Sri Lanka. The objectives of the study were:

1) Quantitative measurement of runoff and soil loss using macro plots from existing clonal and seedling tea fields which are representative examples of the present land use of the up country.

2) Study the relationships between runoff and soil loss and different rainfall and soil parameters.

3) Study the changes of physical properties of soil and the depletion of soil nutrients caused by runoff and erosion.

4) Study the extent of soil erosion from other tea growing areas (such as the Uva) with a view of expanding the current research programme.

3.2 DESCRIPTION OF STUDY AREAS

Sri Lanka has a land area of 66.6 million ha which is divided into 3 climatic zones: wet, dry and intermediate (Figure 1). These zones are subdivided into 7 major agro-ecological regions. Both the wet and the intermediate zones include the Low Country (0-300 m a.m.s.l.), Mid Country (300-600 m a.m.s.l.) and Up Country (over 1000 m).

The rainfall in Sri Lanka has a distinctive bi-modal pattern with monsoonal rains occurring from April to August and October to December as a regional phenomenon and intermonsoonal rains as a local phenomenon. The mean annual rainfall ranges from 1250 mm to about 5000 mm in wet regions. Intermonsoonal thunder storms of short duration may have intensities up to 100 mm h^{-1}.

The maximum and minimum air temperatures are commonly 20°C and 10°C respectively, in the up country wet zone, and 32°C and 25°C in the low country dry regions.

The soil map shows 17 great soil groups and subgroups (Panabokke and Kannangara, 1975). Nine out of the ten soil orders from the US Soil Taxonomy are encountered on the island; Alfisols, Ultisols and Oxisols being the more widespread.

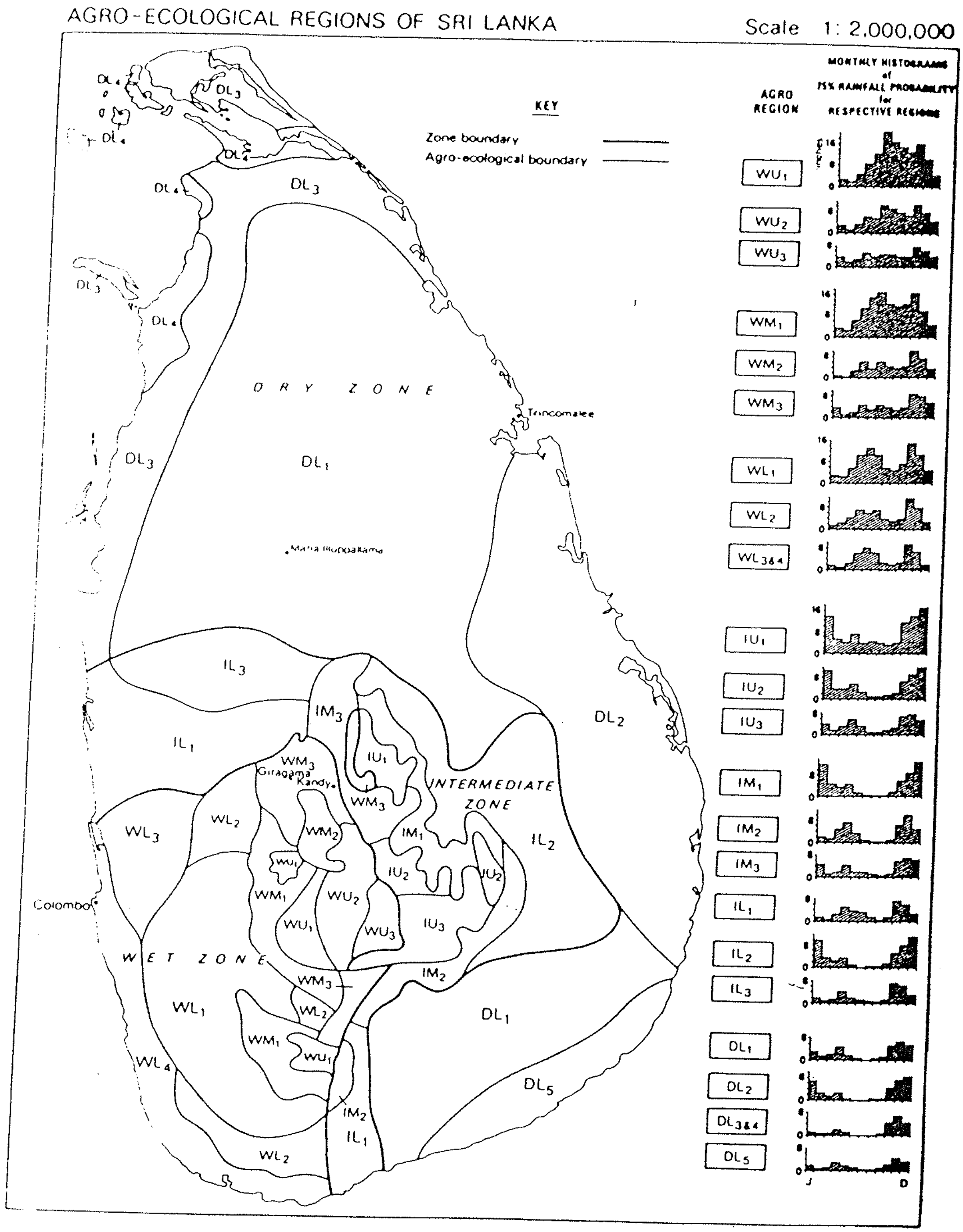

Figure 1: Agroecological Regions of Sri Lanka.

3.3 STUDIES AT ST. COOMBS ESTATE

The present study was conducted at the St. Coombs Estate of the Tea Research Institute of Sri Lanka, Talawakelle, Sri Lanka. The experimental sites, consisting of 4 macro plots appproximately 0.5 ha in area are situated in the fields No. 7 and 13 of the St. Coombs Estate at an elevation of 1310 - 1495 m a.m.s.l. Talawakelle is situated in the Nuwara Eliya District in the Up Country wet zone of Sri Lanka. This area receives rain from the two major monsoons - the South-West in April to July and the North-East from October to December. The annual rainfall is approximately 2300 mm.

Macro scale plots were used, since smaller plots, although quite inexpensive to construct, are not practical when accurate experimental results are required. Smaller plots have been successfully used elsewhere for preliminary studies of soil erosion (Jackson, 1964) but for a more detailed field scale study larger plots are preferred. Two macro plots were constructed in each of two types of tea grown in Sri Lanka i.e. old seedling tea and clonal tea. The seedling tea area was planted in 1935 and the mixed clonal tea field was planted in 1962. The slopes in the clonal tea plots range from 22 - 65 percent and the seedling tea from 20 - 50 percent (Figures 2 and 3). Ideally, the sites should have had the same slope conditions. However, it was not possible to find such sites of sufficiently large area close to the Institute. Since close and constant attention and supervision are needed throughout the rainy season, it was essential for the staff to have easy access to the experimental sites. The closeness of the two sites, accessibility to the site by vehicle, transportation of construction materials, distance from the laboratory were also taken into account when selecting the experimental sites.

The clonal and seedling tea macro plots in St. Coombs were started in 1981 and the construction work continued from April to July 1981. Sampling was started from October 1981 with the onset of the North East monsoon.

Figure 2: Runoff plots in clonal tea - St. Coombs.

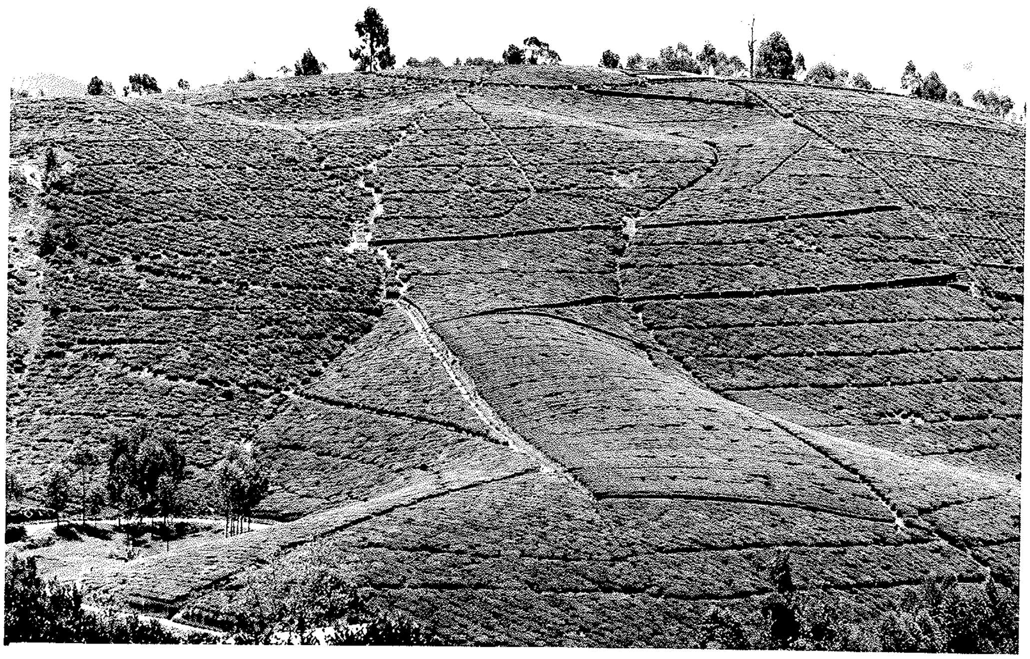

Figure 3: Runoff plots in seedling tea - St. Coombs.

3.3.1 Soil Properties.

The soils in both the selected fields are classified as Red Yellow Podzolic soils which correspond to Rhodudults, Tropudults, Rhodustults or Tropustalts great groups of the order Ultisols in the US Soil Taxohomy (Krishnarajah, 1981). The soil of the clonal tea field is known as that belonging to the Mattakele series and the seedling tea field soil is classified as that of the Waltrim series (Soil map of St. Coombs).

The Waltrim series soils have a 0-48 cm Ap horizon of Munsell colour 10 YR/3/3, a friable loamy structure, free of gravel and a pH of 4.25. The B horizon, 48 - 80 cm,is rather clayey with a blocky structure and a pH of 4.45. The C horizon was below 80 cm, colour corresponding to 7.5 YR/5/6 with streaks of 5 YR/8/1 and had a sandy texture.

The Mattakele soil has an Ap horizon of approximately 60 cm, Munsell colour of 7.5 YR/4/4 , with a considerable amount of gravel present, a pH of 4.3; a clayey B horizon, 60 - 80 cm, with a colour of 5 Yr/5/6 and a C horizon of colour 10R/4/6 with mottles of 7.5 YR/3/4 and a clayey texture.

Physical properties of the soils are given in Table 2.

TABLE 2

Physical properties of St. Coombs soils.

	Clonal Tea	Seedling Tea
Soil Series	Mattakele	Waltrim
Soil Texture (surface)		
Sand %	32.91	31.81
Silt %	23.77	20.33
Clay %	43.77	47.87
Bulk Density (surface) $g\ cm^{-3}$	0.96	0.98
Total pore space (surface) %	64.18	63.02
Infiltration rate $cm\ h^{-1}$	5.80	6.80
Water retention (% by weight)		
1 bar	48.41	43.92
15 bar	28.54	28.44

3.3.2 Plot boundaries.

The plots were completely isolated from the rest of the field by brick and cement walls to a height of approximately 45 cm above and 15 cm below the soil surface. The construction of brick and cement walls is preferable but as the construction of these is extremely expensive, earth bunds strengthened by the planting of African Love grass - Eragrostis (*Eragrostis curvula*) were used for some side bunds.

3.3.3 Collection Systems.

Both the seedling and clonal fields have well constructed lateral drains of the lock and spill type and paved leader drains constructed according to the recommendations of the Tea Research Institute. The collection systems are capable of collecting runoff water for a maximum continuous rainfall of 25 cm h^{-1} sustained for 20 minutes for a 100 percent runoff. This system is designed to suit the rainfall and slope conditions of the tea area in Sri Lanka (Krishnarajah et al. 1982). Design of the system is given in Figure 4.

The runoff from each leader drain is led into a paved approach channel and then it flows through a 30 cm (1 foot) H- flume. An automatic water level recorder (Type Munro IH 89) with 24 hour charts, records a hydrograph of the flow from each plot. The runoff water flows into the first collection tank which is divided into two subtanks by a concrete wall. This reduces splash and enables an even water flow during intense storms. If and when both the subtanks are full of water, a tenth portion of the excess water will be led into the second tank through a multi slot device which connects the two tanks. This slot device consists of ten 7.6 cm (3.0 inch) pipes built into the tank wall at the same level (Figure 5). The excess water from the second tank is led into the third tank through a similar device. Each tank has fitted drainage outlets to drain the tanks of water after taking samples.

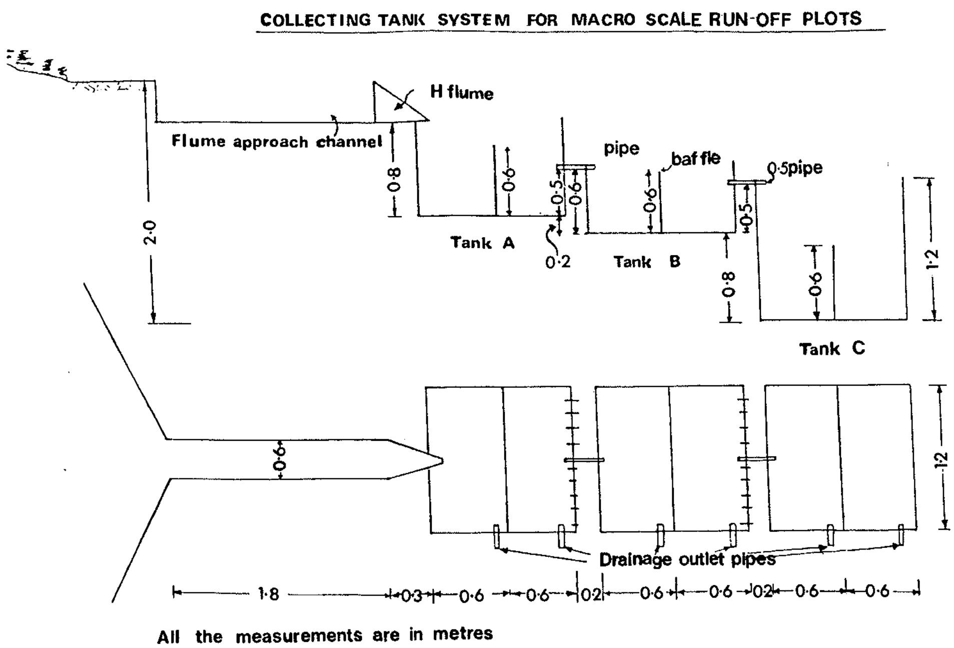

Figure 4: Design of the collection systems.

Figure 5: Collection systems at St. Coombs.

3.3.4 Recording of rainfall.

Each site has a 24 hour recording raingauge installed on the crest of the hill. The recording raingauge charts are used to compute the maximum 30 minute intensity EI_{30} (Wischmeier), KE>25 (Hudson) and AIm (Lal) indexes.

3.3.4.1 EI_{30} index.

Wischmeier et al. (1958) states that the best estimator of soil loss is a compound parameter which consists of the product of the kinetic energy of a storm and its maximum 30 minute intensity. This parameter is called the EI_{30} index.

I_{30} is the greatest average intensity experienced in any 30 minute period during a storm. This may be computed from recording raingauge charts by locating the greatest amount of rain which falls in any 30 minutes and converting the units to mm h^{-1} (or inch h^{-1}).

The following equations are used to calculate the kinetic energy values:

$$KE = 916 + 331 \log_{10} I \quad \text{(foot-tons acre inch}^{-1}\text{)}$$

$$KE = 11.9 + 8.73 \log I \quad (\text{J m}^{-2}\ \text{mm}^{-1} \text{ of rain})$$

The energy values obtained are multiplied by I_{30} to compute the EI_{30} index in foot-tons $acre^{-1}$ or J m^{-2}. EI_{30} values may be computed for individual storms and the storm values could be added over a period of time to give weekly, monthly or annual values of erosivity.

3.3.4.2 KE>25 or KE>1 index.

This index was derived for the use under tropical conditions as it was proposed that there exists a threshold value of intensity at which rain becomes erosive. This value for Africa was found to be about 1 inch h^{-1} or 25 mm h^{-1} (Hudson, 1971). KE>25 is an estimator of erosivity which is the total kinetic energy of rain falling at intensities over 25 mm h^{-1}. This index is computed using the same method as the previous EI_{30} index but by omitting the energy of the non-erosive rain i.e. with intensities less than 25 mm h^{-1}.

3.3.4.3 AIm index.

This new and relative unknown erosivity index was first used in Nigeria by Lal (1975). He proposes it to have many advantages over the use of EI_{30} and KE>25 indices. Tropical rainstorms can be associated with high wind velocities and this together with the drop size distribution of rain can cause errors in the computations of kinetic energy (Lal, 1975). The use of this index is proposed by Lal to reduce these errors.

The AIm is relatively simple to compute and is calculated using the following equation:

AIm = Amount of rainfall x maximum intensity over a 7.5 minute period (cm^2 h^{-1})

The AIm was computed and used for comparison in the present study to investigate its use under Sri Lankan conditions.

3.3.5 Methods of sampling.

Runoff was measured by taking dip stick measurements in all the tanks. The dip stick measurements were required for calculations as the automatic recorders often did not record runoff caused by low intensity storms, or when measurements were incorrect due to the slight disturbance caused by leaves, twigs etc.

When taking samples, the eroded material from the approach channel was washed into the first tank by using water from the same tank and the soil and water mixed thoroughly to obtain a uniform suspension. Three samples of 250 mL each were taken from each tank. The sediment yields were calculated by evaporating these samples at a temperature of 105°C until a constant weight was obtained. A separate set of samples were taken for analysis of nutrients (N, P, K).

Daily measurements were used to estimate the runoff in mm, runoff percentage and soil loss (Appendix A).

Since the tanks were open to rain, a correction factor was used to deduct the amount of rainfall when estimating the runoff in mm and runoff percentage. Covering the collection systems to reduce error was found to be practically impossible due to frequent thefts.

In addition to measuring the soil that was eroded away from the plots, an effort was made to estimate the amount of eroded soil that accumulated in the lock and spill drains. This was achieved by lining the lock and spill drains at random with polythene sheets and scraping the eroded material along a length of one meter after the monsoon was over and weighing it. The length of each drain, as well as the average soil collected in one metre of the particular drain were measured and the total amount of soil collected in the drain was calculated by multiplying the two values. The amount of total soil collected in the field was calculated by the sum of soil in all drains. The soil collected from drains was used for the determination of texture and organic matter content to calculate an erosion ratio and an enrichment ratio for organic carbon.

$$\text{Erosion Ratio} = \frac{(\text{silt} + \text{clay})\% \text{ of eroded soil} \;/\; \text{sand}\% \text{ of eroded soil}}{(\text{silt} + \text{clay})\% \text{ of field soil} \;/\; \text{sand}\% \text{ of field soil}}$$

Thus, an erosion ratio > 1 would indicate that fine separates (silt + clay) were preferentially eroded.

Enrichment ratios were calculated using the ratio of organic carbon percentages in eroded soil to field soil. Several samples were taken from each drain and the average values taken to estimate the loss of nutrients for each drain and then the sum of the values taken as the total value.

Soil samples were also taken to a depth of 15 cm at random from all 4 plots to assess the change of soil properties caused by erosion.

3.3.6 Prediction of Erosion using the Universal Soil Loss Equation (USLE)

An attempt was made to predict the soil losses for St. Coombs using the Universal Soil Loss Equation and to compare the predicted values with the actual values measured. The study was a limited one as actual soil loss data was available only for this location.

An isoerodent map is not available for Sri Lanka to obtain the Erosivity factor (R) values. Annual totals of kinetic energy values and maximum 30 minute intensity averaged for all storms for 5 years have been used by Krishnarajah (1982) to compute an average R value for Talawakelle. This value and the R values calculated from rainfall data from each site were used for prediction of soil losses.

Measured soil erodibility (K) values were also not available for Sri Lanka and the K values from the nomograph (Appendix M) were used. However, the K values for ultisols appear to be high although these soils have a relative high stability and the K values determined by Krishnarajah (1982) have been used. These values are presently being used in Sri Lanka. The LS factor, the crop factor (C) and the conservation measures factor (P) have been estimated using the Appendices L, K and J, respectively.

3.4 SOIL EROSION EXPERIMENTS IN THE UVA TEA REGION.

In late 1984 it was decided to carry out a short term assessment on the extent of soil erosion in tea in the Uva region during the Northeast monsoon of 1984 and early 1985. The climate in the Uva region is characterized by a long drought and monsoons consisting of high intensity storms. Erosion losses in this region can be very high. Therefore, it was decided to carry out some preliminary studies in this region with a view of conducting a more detailed research programme in the near future.

Seven sites were selected in two adjoining estates of the Uva region on average 30 percent slopes and the approximately 21.3 x 6.1 m plots were demarkated using stone walls in existing tea fields. Due to the short time in which the assessment was to be conducted and the preliminary nature of the study, no construction of collection tanks to collect sediment was attempted. Only the soil collected in the lateral drains was estimated. A method similar to that used in estimating the sediment yield from lateral drains at St. Coombs was used, i.e. the lateral drains were lined with polythene sheets at random and soil from 0.5 m lengths were sampled and samples were transported to the laboratory for analysis. The treatments assessed in the two sites are shown in Table 3.

TABLE 3

Treatments of the soil erosion experiments in Uva.

Site/location	Treatment
1. Gonakelle Group, Passara Division	Young tea with a cover crop, mulched with grass.
2. Gonakelle Group Passara Division	Young tea with a cover crop, no mulch.
3. Gonakelle Group, Mortlake Division	100 year old seedling tea, well maintained (Replicated twice)
4. Gonakelle Group, Blarneywatte Division	40 year old seedling tea, poorly maintained (Replicated twice)
5. Ury Group	Seedling tea infilled with clonal tea, pruned in 1984 (Replicated twice)
6. Ury Group	New clearing planted with Mana grass after taking soil conservation measures (Replicated twice)
7. Ury Group	Well maintained clonal tea (Replicated twice).

The drains in all the plots were lined on November 1, 1984 with the onset of the monsoon and the final sampling was completed on January 31, 1985. Rainfall in each site was monitored daily but due to the non-availability of recording raingauges only the total amount of rainfall was measured.

The total soil loss collected in lateral drains was estimated and the soil analyzed for nutrient losses.

3.5 METHODS OF ANALYSES.

1.) Sediment Analysis - The soil loss was determined using 250 mL (0.25 L) samples of suspension from each of the collection tanks. The sediment was transferred to beakers and evaporated at 105^{0}C for 24 hours or until a constant weight was obtained and weighed. Three samples from each sub tank were used and the average used to calculate the total soil loss.

2.) Particle size analysis - This was determined using the standard pipette method (Day, 1965). A few mL of 30 percent H_2O_2 and 200 mL H_2O were added to 20 g of sieved soil and digested overnight and heated until all the organic matter was oxidized. Then the samples were dried overnight and then cooled. To 10 g of the sample 10 mL of dispersing agent Calgon was added and shaken for 10 min. The suspension was diluted to 1 litre and the amount of sand, silt and clay particles were determined using the pipetted samples.

3.) Organic Carbon

was determined using the Walkley-Black Method (1934). Soil samples were digested using H_2SO_4 and $K_2Cr_2O_7$ and back titrated against $FeSO_4$ with phosphoric acid and barium diphenylamine sulphonate present. The organic carbon content was multiplied by the Van Bemmelen factor of 1.724 to obtain the total organic matter content (Allison, 1965).

4.) Total Nitrogen

was determined using the standard Kjeldahl method. Five g of sieved soil were placed in a 300 mL Kjeldahl flask and 10 g of the catalyst and 20 mL of concentrated H_2SO_4 were added, mixed well and digested in a fume cupboard. The digestion was continued for 1 hour after the soil decolourized. After cooling the flask, 25 mL of distilled water were added and the flask was heated for 5 minutes.

The digestant was transferred into a 1 L flat bottomed flask and 90 mL of 40 percent NaOH were added. A distillation flask containing 25 mL of 4 percent Boric acid and 2 drops of indicator was attached and the ammonia evolved into the collection solution was titrated with HCl.

5.) <u>Phosphorus</u> - Borax extractable phosphorus was determined colourimetrically. To 10 g of sieved soil 100 mL of Borax (pH 1.5) were added and shaken for 30 minutes and filtered using a No. 50 Whatman filter paper. A 2 mL aliquot from the filtrate was pipetted and 4 mL of a single colour reagent (scr) and the volume made up with distilled water. The spectrophotometer reading was taken after 30 minutes.

6.) <u>Potassium</u> - Ammonium Chloride extractable potassium was determined in the soil samples using the flame photometer. To 10 g of sieved soil 100 mL of 1 N NH_4Cl (adjusted to the pH of the soil) were added, shaken overnight and filtered. Five mL aliquots were taken from the extract into 25 mL flasks and volume made up with distilled water. From 100 ppm working standards, a range of standards from 0-20 ppm K were obtained. Five mL of NH_4Cl solution were added and made to volume from each standard was used for determining K.

Chapter IV

RESULTS AND DISCUSSION.

4.1 EXPERIMENTS IN ST. COOMBS

4.1.1 Runoff and soil loss from seedling and clonal tea plots.

The runoff in mm, runoff percentage (as a percentage of rainfall) and the soil loss estimated from clonal and seedling tea plots for the period 1981 - 1984 are given in Table 4.

The runoff from the clonal plots with an excellent cover of tea during the entire period of study was minimal. The highest, occurring in April 1984 and was 0.77 mm which was only 2 percent of the rainfall received. Even the runoff from the well managed seedling tea plots did not exceed 1.76 mm for a month, that occurring in September 1984.

The maximum soil loss measured during any one year during the period of study was 756.9 kg ha^{-1} in 1982 from clonal tea and 773.9 kg ha^{-1} in the same year from seedling tea. However, it must be noted that this is only the soil carried away from the field while a greater part of the eroded soil was trapped in the lateral drains. This will be discussed in section 'Soil loss in lateral drains.'

The high soil losses obtained in 1981 during the 3 month period of sampling may be due to the soil disturbance caused by tank construction and the de-silting of lateral drains before the commencement of the experiment.

Table 4. Monthly Rainfall, Run off and Soil Loss in Tea from October 1981 - 1984.

Year/Month	Rainfall (mm)		Run off (mm)		Soil Loss (kg ha⁻¹)		Run off (%)	
	Seed	Clonal	Seed	Clonal	Seed	Clonal	Seed	Clonal
1981								
October	71.7		0.01	0.16	1.3	1.8	0.05	1.30
November	71.7		0.77	0.44	352.2	401.5	3.14	2.10
December	46.9		0.07	0.07	155.1	118.9	0.53	0.59
TOTAL	190.3		0.85	0.67	508.6	522.2	3.72	3.99
1982								
January								
February								
March	96.5	110.2	0.20	0.24	284.2	202.9	1.26	0.69
April	150.9	138.6	0.18	0.25	356.9	68.9	0.82	0.99
May	247.6	272.2	1.22	0.60	85.8	403.9	2.69	2.94
June	305.3	316.4	0.73	0.78	3.5	16.6	2.11	3.10
July	262.7	248.4	0.19	0.32	1.7	2.6	1.05	1.93
August	148.8	159.2	0.63	0.20	3.5	1.4	1.54	0.93
September	64.8	65.9	0.03	0.08	0.6	1.6	0.35	0.80
October	116.8	117.5	0.07	0.12	2.9	3.7	0.65	1.25
November	235.2	216.3	0.20	0.54	30.6	46.6	1.24	3.27
December	99.7	101.5	0.13	0.23	2.4	8.6	0.56	1.21
TOTAL	1728.3	1746.2	3.68	3.36	772.1	756.8	12.27	17.11
1983								
January	0.3							
February	12.7	5.1	0.02	0.02	15.6	5.9	0.16	0.45
March	27.5	33.2	0.02	0.04	18.5	21.4	0.07	0.12
April	2.5	2.1						
May	158.4	154.1	0.50	0.15	210.3	118.4	1.35	0.64
June	110.6	100.8	0.04	0.08	1.6	1.9	0.48	0.97
July	174.3	162.6	0.04	0.11	0.6	6.6	0.37	0.86
August	179.6	169.0	0.08	0.14	1.0	2.9	0.32	0.67
September	118.5	114.4	0.06	0.09	0.4	1.6	0.55	0.93
October	142.8	148.2	0.02	0.03	154.9	60.6	0.65	1.06
November	209.1	214.9	0.18	0.21	12.2	15.1	1.20	0.73
December	222.5	198.1	0.39	0.23	88.1	13.8	1.29	1.15
TOTAL	1358.8	1302.5	1.35	1.10	503.2	248.2	6.44	7.58
1984								
January	127.5	122.8	0.13	0.14	10.7	18.3	0.89	0.80
February	147.3	142.5	0.25	0.24	128.9	21.9	1.63	1.80
March	202.2	178.7	0.17	0.24	84.8	13.4	1.11	1.59
April	293.5	288.9	0.22	0.77	4.1	243.6	0.59	2.01
May	108.5	106.0	0.07	0.06	1.4	4.6	0.48	0.32
June	319.2	298.0	0.22	0.14	5.2	6.2	1.03	1.28
July	445.8	423.8	0.48	0.57	23.8	20.5	1.45	1.72
August	154.5	125.4	0.62	0.29	28.1	15.9	1.32	1.49
September	325.5	315.5	1.76	0.58	410.6	49.2	2.68	1.65
October	128.6	113.8	0.04	0.05	0.8	1.2	0.28	0.41
November	162.8	158.4	0.09	0.16	2.0	1.3	1.43	13.39
December	64.6	55.0	0.01	0.02	0.4	0.3	0.04	0.30
TOTAL	2480.0	2329.2	4.15	3.26	700.8	396.4	12.93	26.76

The minimum runoff and the minimum soil loss from clonal tea was measured in December 1984 and from seedling tea in October 1984.

The runoff percentage calculated was low at below 8 percent on an average per rainy season in clonal tea and 5.1 percent in seedling tea. This may seem low but it must be noted that this data was obtained from existing fields with a high standard of management and that due to the adequate soil conservation measures taken, the extent of runoff water and soil that was carried away from the field were minimal.

The average runoff from clonal tea was higher. This may be due to both the clonal plots having higher slope conditions. Slopes in the seedling tea fields changed gradually although the average slopes in both sites were the same.

4.1.2 Estimating the soil loss in lateral drains.

The estimation of the amount of eroded soil in the lateral drains was conducted in the seedling and clonal plots for the periods October 1981 to December 1982 (3 rainy seasons) and June 1984 to December 1984 (1 rainy season). The results for 1983 were not available as sampling was not conducted. The results for 1981/1982 and for the second rainy season in 1984 are given in Table 5.

The soil losses in lateral drains were 36 percent higher in seedling tea than from clonal tea in the first 3 seasons. However, in the one rainy season in 1984 a difference in erosion losses was visible in only one of the clonal plots and the difference amounted to only 21 percent on an average.

TABLE 5

Soil loss in lateral drains from tea plots.

Plot no.	Treatment	Weight of soil $Mg\ ha^{-1}$
Period: October 1981 to December 1982.		
C1	Clonal tea	8.50
C2	Clonal tea	6.30
S1	Seedling tea	11.85
S2	Seedling tea	11.85
Period: June to December 1984.		
C1	Clonal tea	0.24
C2	Clonal tea	0.18
S1	Seedling tea	0.32
S2	Seedling tea	0.23

The higher soil loss in the first 3 seasons could be due to the fact that in 1981 the fields were in the 1st year after pruning and in 1984 the 2nd year after pruning. The year 1984 was also considered to be a year with low intensity rainfall and the rainfall conditions could also have reduced sediment yields.

The higher soil loss in the first clonal plot, C1 in the second season of 1984 could be attributed to the deterioration of plant cover in part of this plot due to the root disease Poria. This disease caused the dieback of several bushes and as a result the affected part of the plot was uprooted and fumigated before replanting in early 1985. The exposure of soil caused by the diebacks may have caused the higher soil loss, particularly in this plot.

In general, the soil that is trapped in lateral drains is considerably high. This soil which is rich in nutrients should not be allowed to be carried away from the fields. When lateral drains are cleaned or de-silted in most plantations the soil is spread below the drain. This will cause this soil to be washed off into the next drain within a short duration. This emphasizes the importance of adhering to the recommended practice of spreading the de-silted soil from drains above the drains.

4.1.3 Total soil loss from tea plots.

The total soil loss from tea plots was taken as the amount of soil in water runoff plus the quantity that was collected in the lateral drains. The total soil loss during the periods for which soil loss in lateral drains are available is given in Table 6.

The data presented indicates that for the 3 rainy seasons the maximum total soil loss was 13.95 Mg ha^{-1} from seedling tea. The average soil loss for a year from clonal tea ranged from 5.6 to 8.24 Mg ha^{-1} and from seedling tea 9.64 to 11.16 Mg ha^{-1}. Thus, the seedling tea areas lost more soil than the estimated tolerance limits for tropical countries, viz. 9 Mg ha^{-1} $year^{-1}$ (Thompson, 1957).

However, the extensive soil losses in the first years of data collection may have been due to the fact that during construction the collection systems, especially plot boundary walls, top soil disturbance was unavoidable. Since the construction work continued till September 1981, most of the loosened top soil may have been washed into the collection tanks with the high intensity rains of the next monsoon. It

TABLE 6

Total soil loss from tea plots.

Plot No.	Treatment	Weight of soil in drains Mg ha^{-1}	Weight of soil in runoff Mg ha^{-1}	Total soil loss Mg ha^{-1}
Period: October 1981 to December 1982.				
C1	Clonal tea	8.50	1.80	10.30
C2	Clonal tea	6.30	0.70	7.00
S1	Seedling tea	11.85	2.10	13.95
S2	Seedling tea	11.85	0.20	12.05
Period: June to December 1984.				
C1	Clonal tea	0.24	0.05	0.29
C2	Clonal tea	0.20	0.14	0.34
S1	Seedling tea	0.32	0.45	0.77
S2	Seedling tea	0.23	0.49	0.72

must also be noted that the lateral and leader drains of all the plots were cleaned and desilted before the commencement of the data collection in June to September. This could also have contibuted to the high soil losses obtained in the first 3 seasons.

The data collection in 1984 (Table 6) shows that the total soil loss from seedling tea was 58 percent higher than that from clonal tea. This was to be expected due to the comparatively poor cover of the seedling fields. Although this particular seedling field has been well maintained with all the recommended soil conservation measures adopted, the soil loss was much higher than that from the clonal tea field, though the seedling field was situated on more gently sloping land.

From the results obtained, it is evident that under high standards of management, tea, especially clonal tea, could be grown without causing significant erosion hazards, even on steep slopes in high rainfall areas. As mentioned earlier, soil erosion is a natural process which cannot be prevented completely. Even though a seemingly large amount of soil was carried away by runoff from tea land, the data presented confirm that under careful manipulation of topography and management practices these losses could be brought well under the limits of soil loss tolerance.

The experimental results also demonstrate that the amount of soil collected in the lateral drains by far exceeds that carried away by runoff. Measures should be taken to retain this soil in the tea fields. This could have been achieved by spreading the soil above the drains during the desilting and cleaning out of lateral drains.

4.1.4 Relationship between runoff and soil loss in runoff.

To test for a relationship between runoff and soil loss in tea plots, the daily runoff and soil loss data for 1984 were correlated and linear regression equations for clonal and seedling tea computed.

In both plots, a positive relationship was found to exist between runoff and soil loss, i.e. soil loss increased with the increasing of runoff (Table 7). The correlation between runoff and soil loss in seedling tea was high compared to that from clonal tea. Although the relationship between runoff and soil loss seem to be good, it may not always be possible to estimate soil loss from runoff data alone.

TABLE 7

Correlation coefficients and linear regression equations for soil loss and runoff from tea plots.

Treatment	Independent variable (X)	Dependent variable (Y)	Correlation coefficient r	Linear Regression equation
Seedling tea	Runoff (mm)	Soil Loss	0.921	Y = -1.469 + 241.76X
Clonal tea	Runoff (mm)	Soil Loss	0.426	Y = -0.526 + 188.08X

units for soil loss - kg ha^{-1} $year^{-1}$

4.1.5 <u>Rainfall erosivity and soil erosion</u>.

EI_{30} index is the most widely used rainfall index to calculate rainfall erosivity. However, this has been found to be less effective under tropical conditions. Therefore, kinetic energy was calculated using the KE>25 or KE>1 index (Hudson, 1981a; Lal, 1975). Rainfall intensity values were calculated for St. Coombs for each rainy day using the automatic daily recording raingauge charts from 1982 to 1984. In addition, an index used by the International Institute of Tropical Agriculture in Nigeria called the AIm (which is based on the amount of rainfall multiplied by the maximum intensity over a 7.5 minute period) was also calculated to investigate its use under Sri Lankan conditions (Appendix D). A summary of results obtained for each month during the period of studies is given in Table 8.

Simple linear regressions between each of runoff and soil loss from individual plots and the erosivity indices were run. There were similar trends between the clonal and seedling tea in all cases. The interac-

TABLE 8

Rainfall Indices calculated for St. Coombs.

Year	EI_{30} $J\ m^{-2}$	KE>25 $J\ m^{-2}$	AIm $mm^2\ h^{-1}$
1982			
January			
February			
March	1.96×10^4	1.56×10^2	1.34×10^3
April	3.06×10^4	4.57×10^2	3.25×10^3
May	2.85×10^4		1.99×10^3
June	4.33×10^4		5.49×10^3
July	2.21×10^4		2.11×10^3
August	0.07×10^4		0.08×10^3
September	1.09×10^4		1.06×10^3
October	1.26×10^4		1.06×10^3
November	5.96×10^4		2.68×10^3
December	1.24×10^4		1.45×10^3
Total	24.03×10^4	6.13×10^2	20.16×10^3
1983			
January			
February	1.63×10^4	2.50×10^2	0.90×10^3
March	4.30×10^4	5.60×10^2	2.60×10^3
April	0.01×10^4		0.01×10^3
May	6.17×10^4		3.03×10^3
June	1.033×10^4	3.65×10^2	2.97×10^3
July	1.64×10^4		1.29×10^3
August	1.31×10^4		1.07×10^3
September	1.79×10^4		1.25×10^3
October	7.65×10^4		2.53×10^3
November	3.09×10^4		3.45×10^3
December	4.64×10^4		2.85×10^3
Total	33.26×10^4	11.75×10^2	21.99×10^3
1984			
January	2.39×10^4		1.18×10^3
February	3.39×10^4		0.43×10^3
March	4.97×10^4	2.50×10^2	1.14×10^3
April	9.08×10^4		4.83×10^3
May	1.82×10^4		0.90×10^3
June	0.81×10^4		0.59×10^3
July	1.37×10^4		4.35×10^3
August	3.05×10^4		2.06×10^3
September	7.99×10^4		1.32×10^3
October	1.02×10^4		0.83×10^3
November	0.39×10^4		0.56×10^3
December	0.85×10^4		0.49×10^3
Total	37.15×10^4	2.50×10^2	18.68×10^3

tions of factors causing runoff and soil erosion may be responsible for the apparent lack of significant correlation between runoff and soil erosion, and the erosivity indices. For example, the extraodinarily high loss during a low intensity storm may have been due to a particular management practice, such as cleaning of drains a few days before that particular storm.

The use of the KE>1 (or KE>25) index has been favoured by many scientists in the tropics. Therefore, the possibility of using this in present and future studies was explored.

Tropical rainstorms of intensities greater than 25 mm h^{-1} are considered to be erosive (Hudson, 1981a). The occurrence of such storms is given in Table 9.

According to the data obtained during the period of study, out of the total 169 rainy days in 1982 only 3.6 percent or 6 days had storms with intensities of over 25 mm h^{-1}. In 1983 only 8 storms or 5.5 percent of the total 145 days, and in 1984 only 1 storm or 0.5 percent of the total 219 rainy days, had such intensities.

From Table 9 it is evident that soil loss occurred even though there were no so called 'erosive' storms. In 1982 visible soil loss occurred on 67 days, even though such 'erosive'storms occurred only on 7 occasions. Similar data were obtained in all the other years. However, it should be noted that in most of the days during which visible soil loss occurred, the soil loss measured was usually lower than 1 kg ha^{-1}. From the data it is evident that most of the large soil losses were encountered during the few days in which intense storms have occurred. This may lead to future investigations of the use of KE>25 index.

TABLE 9

Rainfall Characteristics - St. Coombs (1982 -1984).

Year/Month	Rainy days	Days with KE>25 storms	Days with visible soil loss	Days with > 5 kg ha^{-1} soil loss.
1982				
March	7	1	5	1
April	9	2	7	2
May	20	2	13	2
June	24	0	5	1
July	20	0	8	0
August	18	0	1	0
September	15	1	4	0
October	22	0	8	0
November	20	0	12	2
December	14	0	14	0
TOTAL	169	6	67	8
1983				
February	2	1	1	1
March	1	1	1	1
April	2	1	0	0
May	13	1	6	1
June	19	3	3	0
July	15	0	8	0
August	20	0	6	0
September	22	0	6	0
October	17	0	5	2
November	12	1	5	1
December	22	0	8	1
TOTAL	145	8	49	7
1984				
January	15	0	4	1
February	17	0	7	2
March	15	1	7	1
April	19	0	10	2
May	13	0	6	0
June	28	0	13	1
July	26	0	8	1
August	17	0	3	1
September	20	0	6	0
October	21	0	2	0
November	19	0	2	0
December	9	0	1	0
TOTAL	219	1	69	9

4.1.5.1 <u>The relationship between runoff and erosivity indices</u>.

Correlation coefficients were computed between runoff from clonal and seedling tea and the three rainfall indices calculated daily (Table 10).

TABLE 10

Correlation coefficients and linear regression equations for runoff from tea plots with rainfall erosivity indices.

Treatment	Independent variable (X)	Dependent variable (Y)	Correlation coefficient r	Linear Regression equation
Clonal	EI_{30}	runoff (mm)	0.938	$Y = 0.0074 + 8.69 \times 10^{-6}X$
Seedling	EI_{30}	runoff (mm)	0.230	$Y = 0.0121 + 6.32 \times 10^{-6}X$
Clonal	KE>25	runoff (mm)	0.007	$Y = 0.031 + 2.1 \times 10^{-6}X$
Seedling	KE>25	runoff (mm)	0.805	$Y = -0.043 + 3.029 \times 10^{-4}X$
Clonal	AIm	runoff (mm)	0.502	$Y = 0.0115 + 1.132 \times 10^{-4}X$
Seedling	AIm	runoff (mm)	0.347	$Y = 0.0031 + 2.136 \times 10^{-4}X$

Note: Units for Independent variable are given in Table 8.

All three erosivity indices used were positively correlated with runoff in both seedling and clonal tea. In clonal tea the EI_{30} index was highly correlated with runoff compared to KE>25 and AIm indices. The correlation between runoff and AIm was higher than KE>25 in clonal tea but in seedling tea KE>25 had the best correlation with runoff. In seedling tea, EI_{30} index had the lowest correlation with runoff. The variation in results could be caused by the interaction of the cover effect in clonal tea.

KE>25 was a good index of measuring runoff under seedling tea but it was not related with runoff in clonal tea. Although the seedling tea field is comparatively well managed, it still has a poorer cover than the dense cover of clonal tea. In the clonal field, the raindrop velocity will be reduced by the interception of the plant cover to a higher degree than in the seedling tea field. As a result, the rain drop impact on soil in the clonal tea could be much less when compared to the seedling tea which could be the cause of the large difference of correlation coefficients obtained between the two treatments.

Due to the variations obtained from tea plots it may not be possible to use erosivity indices to estimate runoff. Further investigations in this area are necessary.

4.1.5.2 Relationship between soil loss and erosivity indices.

The correlation coefficients and linear regression equations which were computed to relate soil loss from tea plots to erosivity indices are given in Table 11.

The correlation coefficients between erosivity indices and soil loss were lower or equal to those between runoff and erosivity indices. However, KE>25 index shows a very high correlation with soil loss in clonal tea. For seedling tea the lowest correlation was obtained for soil loss with this index. This is difficult to explain. Both EI_{30} and AIm indices correlate well with soil loss in clonal tea but the correlation is comparatively low in seedling tea. The variablility in using the KE>25 index could be due to using data for all three years of study unlike with the other indices as there was only one rainy day with intensities over 25 mm h^{-1} in 1984 (Table 9). Another reason for the

TABLE 11

Correlation coefficients and linear regression equations for soil loss from tea plots with rainfall erosivity indices.

Treatment	Independent variable (X)	Dependent variable (Y) kg ha^{-1}	Correlation coefficient r	Linear regression equation
Clonal	EI_{30}	Soil loss (kg ha^{-1})	0.526	Y = -3.99 + 0.00217X
Seedling	EI_{30}	Soil loss (kg ha^{-1})	0.254	Y = 1.19 + 0.001856X
Clonal	KE>25	Soil loss (kg ha^{-1})	0.960	Y = -2.39 + 0.059X
Seedling	KE>25	Soil loss (kg ha^{-1})	0.015	Y = 47.02 + 0.00729X
Clonal	AIm	Soil loss (kg ha^{-1})	0.051	Y = -3.11 + 0.0512X
Seedling	AIm	Soil loss (kg ha^{-1})	0.257	Y = 1.70 + 0.0422X

Note: Units for Independent variable are given in Table 8.

low correlation obtained could be the seedling fields having gradually changing slopes compared to clonal tea,.

The possibilities of using EI_{30}, KE>25 and AIm indices should be investigated further. The introduction of AIm with a wind velocity factor incorporated has been suggested by Lal (1975) to give the kinetic energy of windy storms and this could be more useful as an erosivity index for the tropics.

4.1.6 Properties of eroded sediments.

The change of soil properties as a result of erosion has been discussed by many research workers in the past. The change in soil physical and chemical properties due to erosion takes place gradually over a long period of time and in a study like the present one, an assessment of these changes is practically not possible. However, an attempt was made to compare the texture and organic matter content of soil from the field with the eroded soil in lateral drains immediately below.

Erosion ratios for eroded soil were calculated using the procedure given in Materials and Methods. The erosion ratios calculated for clonal and seedling tea are given in Table 12. Average values from a multitude of samplings for each plot were used.

The average erosion ratio obtained from plot C1 was 1.802 which shows that fine particles are preferentially eroded. This was confirmed by the results obtained from both the seedling plots. But the erosion ratio from C2 was slightly lower than 1 although the average erosion ratios in both treatments were greater than 1 which leads to the conclusion that finer particles are preferentially eroded.

TABLE 12

Erosion Ratios calculated for eroded soil from tea plots.

Plot No.	Erosion Ratio
Clonal tea C1	1.802
Clonal tea C2	0.906
Average for Clonal tea	1.350
Seedling tea S1	1.140
Seedling tea S2	1.650
Average for Seedling tea	1.140

Erosion ratios have been used to relate erodibility to soil composition. Several soil properties are involved in assessing its erodibility. Some properties influence the soil's infiltration capacity and others will be important in determining the soils resistance to detachment and transport of particles by rainfall erosion.

Soils high in silt content but low in clay and organic matter have been found to be the most vulnerable to erosion (Wischmeier and Mannering, 1969). Extremes in particle size were also found to reduce the erodibility of soils.

The erosion ratios obtained from seedling and clonal tea plots were analyzed statistically using the unpaired t- test to compare the difference (Huntsberger and Billingsley, 1981). Although a large number of samples compared showed an erosion ratio greater than 1, there was no significant difference between the two treatments at 95 percent confidence interval. The t value obtained was 0.368.

Enrichment ratios for organic carbon were calculated using the following equation:

$$\text{Enrichment ratio} = \frac{\text{\% organic carbon in eroded soil}}{\text{\% organic carbon in field soil}}$$

Enrichment ratios for organic carbon content were calculated for each plot. Average enrichment ratios from both treatments are given in Table 13.

The average enrichment ratios from seedling plots show an enrichment in organic carbon in eroded soil. In the clonal tea plots there is no enrichment in organic carbon which is not possible to explain. The

TABLE 13

Enrichment ratios for organic carbon in eroded soil.

Plot No.	Enrichment Ratio
Clonal tea C1	0.80
Clonal tea C2	1.16
Average for Clonal tea	0.98
Seedling tea S1	1.26
Seedling tea S2	0.98
Average for Seedling tea	1.12

values obtained were analyzed using the unpaired t- test to compare the differences, if any, that existed between the seedling and clonal plots. An enrichment ratio above unit value signifies that the eroded soil was enriched with organic carbon when compared to the field soil.

Although there was an enrichment in organic carbon in the eroded sediment there was no significant difference between the two treatments at 95 percent confidence level. The t value calculated was 0.898.

4.1.7 Nutrient Loss in runoff.

The suspension from collection tanks was analyzed during the early part of the study to estimate the nutrient losses in runoff. Three samples of 250 mL were taken from each tank, filtered and analyzed using the procedures mentioned in Chapter 3. The data for the months May-July and November-December for 1982 were available. The analysis of runoff water was not continued from 1983. The total amounts of nutrients in runoff water from tea plots are given in Table 14.

TABLE 14

Nutrient losses in runoff water from tea plots - 1982.

period: May - December

Month	Treatment	Nutrient loss (kg ha^{-1}) N	P	K	Runoff (mm)
May	Clonal	0.090	0.020	0.110	0.599
	Seedling	0.070	0.0004	0.060	1.223
June	Clonal	0	0.010	0.030	0.775
	Seedling	0	0.005	0.040	0.725
July	Clonal	0.020	0.003	0.010	0.323
	Seedling	0.080	0.006	0.060	0.188
November	Clonal	0.050	0.001	0.010	0.543
	Seedling	0.01	0.001	0.003	0.196
December	Clonal	0.01	0.005	0.008	0.225
	Seedling	0.003	0.080	0.005	0.125

From the results obtained during the short duration of sampling the nutrient loss estimated in runoff was not high. The loss of nitrogen ranged from 0 to 0.09 kg ha^{-1} per month in clonal tea and 0 to 0.08 in seedling tea. Phosphorus losses were low as well, ranging from 0.0004 to 0.08 kg ha^{-1} in seedling tea and 0.0001 to 0.01 kg ha^{-1} in clonal tea. Potassium losses varied from 0.008 to 0.1 kg ha^{-1} in clonal tea and 0.003 to 0.006 kg ha^{-1} in seedling tea. These amounts could not be called significant when compared with the application rates of fertilizer for tea (360 kg N, 30 kg P and 120 kg K per hectare were applied for 1982 for both plots).

It can be seen that the loss of applied nutrients in runoff from tea plots was not high.

4.1.8 Nutrient Loss in eroded soil.

The eroded soil sampled from the lock and spill drains during June to December 1984 was analyzed for N, P, K and organic carbon to estimate the amount of nutrients lost in eroded soil.

TABLE 15

Amount of Nutrients lost in eroded soil - June to December 1984.

Plot No.	Amount of soil in drains (kg ha^{-1})	Amount of Nutrients lost (kg ha^{-1}) N	P	K	O.M.	Ratio O.M.: eroded soil
Clonal Tea C1	236.21	0.224	0.09	0.005	11.77	0.049
Clonal Tea C2	179.337	0.414	0.08	0.004	11.89	0.066
Average for Clonal Tea	207.774	0.319	0.085	0.0045	11.83	0.058
Seedling Tea S1	317.31	0.364	0.110	0.003	14.40	0.045
Seedling Tea S2	226.06	0.447	0.07	0.006	16.30	0.072
Average for Seedling tea	271.685	0.406	0.09	0.0045	15.35	0.058

The results indicate that the total nitrogen and organic matter losses from seedling tea were higher when compared to clonal tea (Table 15). The P and K losses were identical from both plots. The organic carbon losses were high for both plots and about 47 percent higher in seedling than in clonal tea.

Although phosphorus has been found to be one major nutrient which is lost through eroded sediment (Dudley, 1926; Ryden et al., 1973; Munn et al., 1973), this was not true in the present study. This could be due to the lower P amounts in soil as well as lower application rates of P fertilizers in tea. The soil N, P, K levels at 0-15 and 15-30 cm depths of the tea plots before and after a fertilizer application are given in Appendix P. The lower application rates of P fertilizer, i.e. 30-40 kg ha^{-1} P_2O_5 as compared to 360-400 kg of N, is based on the lower percentage of P (0.15-0.25) in the harvested product of tea when compared to N (3-5 percent) (Sandanam et al., 1980).

The ratios of organic carbon lost in eroded soil to soil loss were identical (0.058) in both seedling and clonal tea (Table 15). Therefore, the higher amount of organic carbon lost in eroded soil from the seedling tea plot could not be caused by the higher soil loss from seedling tea.

It is evident that the majority of the nutrient loss in tea is contained in eroded sediment and not in runoff water.

4.2 SOIL EROSION EXPERIMENTS IN THE UVA TEA REGION.

4.2.1 Soil loss in lateral drains.

An assessment of the extent of soil erosion in the Uva region was carried out during the 3 month Northeast monsoon period of 1984-1985. The results of the estimation of eroded soil in lateral drains are given in Table 16. The data from treatment 7 (well maintained clonal tea) are not included as the sampling was interrupted and the data collection was incomplete.

TABLE 16

Soil loss in lateral drains from tea plots in the Uva during the northeast monsoon period of 1984-1985.

Treatment	Soil Loss Mg ha^{-1}
1. Young tea, with mulch	2.470
2. Young tea, without mulch	2.899
3. 100 year old seedling tea, well maintained	0.505
4. 40 year old seedling tea, poorly maintained	1.280
5. Well maintained seedling tea, pruned in 1984	2.030
6. New clearing, planted with grass	6.105

Total rainfall = 606 mm

The results show that in the Uva region erosion losses could be much higher than in the up country. During a 3 month monsoon period the amount of soil collected in lateral drains ranged from 0.5 to 6.1 Mg ha^{-1} from tea in different stages of growth and standards of management.

In the Uva, rainstorms are often preceded by strong winds and this may definitely have an effect on the high erosion losses in this region. Wind driven rain is known to increase soil losses considerably (Lyles et al., 1969).

It was evident that the erosion losses were higher in unmulched young tea. In the experimental site where both the young tea plots had a fairly well established cover crop, the difference in soil loss was

17.4 percent between the mulched and unmulched plots but losses could be much higher in less protected fields.

In the extremely well managed 100 year old seedling tea the soil losses amounted to only 0.5 Mg ha^{-1} when compared to a 1.3 Mg ha^{-1} loss from a much younger tea field with poor management and cover. This result emphasized the value of good management, especially in erosion prone areas such as the Uva.

The soil losses from the pruned seedling tea plots, treatment 5, indicate the dependence of soil losses upon stage of growth in tea. This field had a plant cover as good as that of treatment 3 but the soil losses were four times as high due to the exposure caused by pruning.

The soil losses from the new clearing planted with grass and after having an adequate system of drainage was 6.105 Mg ha^{-1}. This is extremely high for a period of 3 months when we compare it with the tolerable limits of soil loss predicted for Sri Lanka (9 Mg ha^{-1} $year^{-1}$). It must also be noted that this amount is less than the total soil loss from the field, as soil carried away from the field by run off was not monitored. Therefore, the total soil loss from this field was likely much higher. This emphasizes the importance of soil conservation measures, especially during the replanting of tea. This field had lost practically all the soil it could afford to lose in one year, even before it was planted.

From the experimental results, it is evident that the maintenance of a good tea cover can be used to minimize soil erosion even in erosive prone, high rainfall areas. During the stages of growth of tea which are vulnerable to erosion, i.e. young tea, pruned tea, replanting period, soil should be kept covered as much as possible by means of cover crops, mulching etc. In mature tea fields, the most efficient soil conservation measure would be the maintenance of a good tea cover. This will naturally increase the yields as well. Infilling of vacancies is a must in maintaining a good cover.

The importance of a good system of drainage, consisting of well constructed lateral and leader drains should not be under estimated. However, this should be combined with the maintenance of a good soil cover for it to be effective. It must be noted that the new clearing (Treatment 6) had an excellent system of drainage. However, its poorly established grass cover was not sufficient to reduce erosion in this particular field.

4.2.2 Nutrient loss caused by erosion in the Uva Region.

The eroded soil obtained from each drain in the experimental sites in Uva was analyzed for total N, P, K and organic carbon.

The highest N losses were measured in the new clearing where the erosion was very high (Table 17). Losses were high in the pruned tea plots. Nitrogen losses were higher in the mulched young tea plots when compared to the unmulched but all other nutrient losses were higher from unmulched tea. Compared to all other treatments the losses from the well maintained 100 year old seedling tea were the lowest.

The organic matter losses from all plots were high. In the up country the highest loss in organic matter was 16.3 kg ha^{-1} in seedling tea but in the Uva organic matter losses and N losses were much higher. These high losses could be due to the higher application rates of N fertilizers in this region due to obtaining higher tea yields. The

TABLE 17

Nutrient loss from tea plots in the Uva region during the northeast Monsoon.

Treatment	Soil loss Mg ha^{-1}	Nutrient loss in eroded sediments ($kg\ ha^{-1}$)				Ratio O.M: soil loss
		N	P	K	O.M.	
1. Young tea, with mulch	2.470	1.76	0.08	0.26	76.13	0.031
2. Young tea, without mulch	2.899	1.32	0.96	0.29	165.3	0.057
3. 100 year old Seedling tea well managed	0.505	0.83	0.09	0.14	29.77	0.059
4. 40 year old Seedling tea, poorly managed	1.28	1.37	0.07	0.29	49.15	0.038
5. Well managed Seedling tea pruned in 1984	2.030	9.09	0.15	0.43	100.32	0.049
6. New clearing, planted with grass	6.105	26.19	0.34	0.79	156.32	0.026

higher soil losses could not have caused higher organic matter losses as the ratio of organic matter loss to soil loss in Uva on an average was lower when compared to same of St. Coombs.

The lowest nutrient losses were encountered from the well managed old seedling tea plots. This clearly shows that maintaing tea fields with a good cover not only reduces soil erosion but leads to lower losses of applied nutrients.

4.3 ESTIMATION OF SOIL EROSION USING THE UNIVERSAL SOIL LOSS EQUATION(USLE)

The USLE was used to estimate the average soil loss for a year at St. Coombs and from clonal and seedling tea. The tables in Appendices L, K and J were used respectively to estimate the LS, C and P factors and actual rainfall data for estimating the R values for each year of study. Both seedling and clonal tea were on an average slope of 30 percent planted on the contour with well constructed lateral drains. The soil loss measured was taken as the amount of soil that was carried away by runoff.

TABLE 18

Soil losses for St. Coombs- actual and estimated using the USLE.

Year/ Treatment	Parameters in the USLE R	K	LS	C	P	Soil Estimated Mg ha^{-1} year^{-1}	Loss Measured Mg ha^{-1} year^{-1}
1982							
Clonal	2404	0.09	6	0.01	0.1	1.3	0.8
Seedling	2404	0.09	8	0.05	0.1	8.7	0.8
1983							
Clonal	3326	0.09	6	0.01	0.1	1.8	0.25
Seedling	3326	0.09	8	0.05	0.1	11.97	0.5
1984							
Clonal	3715	0.09	6	0.01	0.1	2.0	0.4
Seedling	3715	0.09	8	0.05	0.1	13.4	0.7
Average/yr							
Clonal	694	0.09	6	0.01	0.1	0.15	0.48
Seedling	694	00.09	8	0.05	0.1	14.99	0.67

Actual soil losses measured in all cases (except the average for a year) are lower than soil losses estimated using the the USLE (Table 18).

Chapter V

SUMMARY AND CONCLUSIONS

The current study conducted from October 1981 to December 1984 in St. Coombs shows that the runoff recorded from clonal tea was low. The highest monthly value, 0.77 mm was obtained in April 1984. The maximum runoff from seedling tea was 1.76 mm recorded in September 1984.

The maximum soil loss for a year was recorded in 1982 from both plots, i.e. 773.9 kg ha^{-1} from seedling tea and 756.9 kg ha^{-1} from clonal tea.

The eroded soil collected in lateral drains in tea plots for a period of 15 months (October 1981 - December 1982) showed losses of 6.3 - 8.5 Mg ha^{-1} from clonal tea and 11.85 Mg ha^{-1} from seedling tea. For seedling tea the total soil losses measured exceeded the tolerable limits of soil loss estimated for the country. These excessive losses may be due to the top soil disturbance caused during the construction of plots and collection systems. Such excessive losses were not encountered in subsequent years of study.

From the experiments conducted in Uva, the effect of stages of growth of tea and soil management practices on soil erosion was evident. A soil loss of 0.5 Mg ha^{-1} was measured from well managed seedling tea for 3 months while the losses from a poorly managed plots were 1.3 Mg ha^{-1} for the same period. From a young tea field without mulch the soil losses were 2.9 Mg ha^{-1} while a similar plot with grass mulch lost 2.5

Mg ha^{-1} for the same period. A well managed seedling field in the year of pruning lost 2.03 Mg ha^{-1} for the same period. The losses recorded in a new clearing with poorly established grass cover were as high as 6.1 Mg ha^{-1} for 3 months during a monsoon period.

Three erosivity indices were calculated for St. Coombs and all three of these were found to correlate positively with runoff in both seedling and clonal tea. However, the degree of correlation with each index varied from seedling to clonal tea. Due to the variations obtained, it may not be possible to use erosivity indices to estimate runoff. The relationship between rainfall indices and soil loss showed that KE>25 index was highly correlated with soil loss in clonal tea but not in seedling tea. The possibility of using these rainfall indices should be investigated in future studies.

The present study demonstrates the importance of practising correct management practices with good timing in the reduction of soil erosion in tea estates. Contrary to common belief, tea is not a crop that will increase erosion. Cultural practices can be used to minimize erosion on high sloping lands. Even in old seedling tea fields with a good cover and adequate soil conservation measures, soil erosion can be very low. Clonal tea, when well established, by itself reduces runoff by protecting the soil by its cover.

It is evident that erosion causes the depletion of soil and applied nutrients and the amounts lost are proportional to the amount of erosion.

The importance of constructing an efficient system of soil conservation, especially in the construction of a good system of drainage was evident from the results obtained. The desilting of drains should be taken as an opportunity not to aid the already eroded valuable soil to be washed away but to conserve it in the fields. This can be achieved by the spreading of soil removed during the de silting process, above lateral drains and not below them as done commonly. This is a practice neglected by most present day tea planters and more attention in this regard is absolutely necessary.

In future reseach work, rainfall erosivity studies in tea should be continued for many years and the introduction of a more suitable rainfall index may be necessary. The use of rainfall simulators in erosivity studies could be of great benefit in reducing the duration of such studies. Future erosivity studies should be expanded into different tea growing districts to ensure a wider data base.

More detailed analysis of runoff water and eroded sediments, preferably from the collection tanks, should be introduced. It would be suitable to conduct experiments in high erosivity tea growing areas such as the Uva and the Mid country. The effect of cultural practices on runoff and erosion could be monitored using smaller plots in future studies. Rainfall simulators could be used in these studies to expedite the collection of data.

Estimation of erosivity of rainfall and erodibility of soil on an island wide basis is absolutely necessary. The preparation of iso-erodent maps even on a regional basis could be put to good use in Sri Lanka.

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Appendix A

CALCULATION PROCEDURES.

1.) Calculations for runoff in mm:

Runoff volume in tanks = (h-R) x A x 1000 / 1000

where h = water level in tank(mm)

R = rainfall in mm

A = tank area in m^2

(Note : Rainfall is deducted when calculating runoff volume.)

If total runoff volume is = V

V = A1 + A2 + 10B1 + 10B2 + 100C1 + 100C2

(where A1, A2, B1 etc. are volume of water collected in respective tanks.)

2.) Calculation procedure for runoff percentage:

Runoff Percentage = Runoff in mm/R x 100

3.) Calculation procedure for Runoff in mm:

Runoff in mm = Total runoff in m^3 x 1000 / Plot area m^2

4.) Calculation procedure for Soil loss:

If total volume of water in tanks = V litres

sample volume = 250 mL = .25 litres

Average mass of soil in a sample = w g

Mass of soil in volume V = w/1000 x V /0.25 (kg/plot)

Soil loss = w/1000 x V /0.25 x 10000 /Ap (kg ha^{-1})

(Ap = Plot area in m^2)

(Note : To calculate the tank volume rainfall is not deducted.)

Total volume of water in tanks A1 and A2 = h x tank area

Total volume of water in tanks B1 and B2 = 10 x h x tank area

Total volume of water in tanks C1 and C2 = 100 x h x tank area

where, h - water level in tank

(Note: Values were multiplied by 10 and 100 as 1/10th and 1/100th of the total volume is collected in tanks B and C.)

Appendix B

DAILY RECORDS OF RAINFALL, RUNOFF AND SOIL LOSS FROM CLONAL TEA - ST. COOMBS.

Date	Rainfall mm	Runoff in mm		Runoff %		Soil loss kg ha^{-1}	
		C1	C2	C1	C2	C1	C2
Year : 1982							
3/3	28.4	0.1	0.03	0.4	0.1	342.8	50.1
21/3	31.4	0.04	0.03	0.13	0.09	5.3	0.03
22/3	24.6	0.04	0.2	0.2	0.09	2.2	0.6
23/3	6.8	0.01	0.01	0.1	0.1	0.02	0.1
30/3	7.7	0.008	0.005	0.1	0.06	0.11	4.45
Total	98.9	0.198	0.275	0.93	0.44	350.43	55.55
11/4	13.0	0.01	0.01	0.09	0.1	0.11	1.6
12/4	23.0	0.03	0.02	0.1	0.1	0.25	0.98
13/4	10.0	0.01	0.01	0.1	0.1	0.2	0.001
14/4	18.8	0.05	0.02	0.3	0.1	104.4	16.5
16/4	8.0	0.01	0.01	0.1	0.1	0.004	0.03
28/4	40.5	0.05	0.04	0.1	0.1	1.2	1.2
30/4	21.0	0.08	0.05	0.4	0.2	6.4	4.8
Total	134.3	0.24	0.16	1.19	0.8	112.4	25.1
1/5	5.0	0.005	0.004	0.1	0.008	0.02	0.04
10/5	12.5	0.02	0.01	0.14	0.08	0.25	0.6
12/5	8.75	0.01	0.01	0.15	0.11	0.6	0.19
13/5	9.2	0.02	0.01	0.02	0.014	1.4	11.2
14/5	21.4	0.11	0.14	0.5	0.6	392.4	381.15
18/5	8.4	0.01	0.01	0.15	0.09	0.4	0.9
19/5	24.4	0.07	0.06	0.29	0.23	2.9	4.2
22/5	17.9	0.02	0.02	0.11	0.09	0	0
22/5	17.5	0.02	0.02	0.11	0.09	0	0
23/5	3.5	0.003	0.001	0.07	0.04	0	0
24/5	8.2	0.01	0.01	0.1	0.1	0.2	0.4
25/5	16.2	0.02	0.01	0.02	0.06	0.1	0.1
26/5	3.1	0.003	0.002	0.1	0.006	0	0
27/5	71.7	0.2	0.2	0.3	0.3	2.4	4.9
28/5	13.5	0.02	0.02	0.17	0.13	0.1	0.2
30/5	9.0	0.02	0.01	0.2	0.15	0.06	0.5
31/5	12.0	0.05	0.05	0.4	0.4	0.2	0.5
Total	262.25	0.611	0.587	3.091	2.78	401.03	406.89

1/6	54.0	0.2	0.23	0.4	0.4	2.3	0.03
2/6	23.0	0.07	0.06	0.3	0.3	0.8	1.7
3/6	19.0	0.02	0.02	0.1	0.1	0	0
4/6	42.5	0.14	0.1	0.3	0.3	2.97	0.9
5/6	46.7	0.2	0.2	0.3	0.3	2.97	11.3
6/6	5.2	0.005	0.003	0.01	0.06	0	0
7/6	6.5	0.007	0.005	0.1	0.08	0	0
8/6	43.0	0.08	0.07	0.2	0.2	0	0
9/6	21.3	0.04	0.03	0.17	0.15	0.08	0.2
10/6	6.0	0.008	0.007	0.14	0.11	0	0
19/6	4.0	0.004	0.003	0.09	0.07	0	0
20/6	3.1	0.003	0.002	0.11	0.7	0	0
21/6	4.0	0.004	0.002	0.09	0.04	0	0
23/6	2.9	0.003	0.001	0.05	0.04	0	0
24/6	4.5	0.004	0.003	0.09	0.06	0	0
25/6	5.3	0.005	0.09	0.08	0.08	0	0
26/6	3.5	0.003	0.002	0.08	0.06	0	0
27/6	5.8	0.007	0.005	0.1	0.09	0	0
Total	300.3	0.803	0.743	2.96	3.24	9.15	24.13
5/7	18.0	0.02	0.01	0.09	0.08	0.2	0.2
6/7	11.7	0.01	0.01	0.14	0.11	0.1	0.1
7/7	23.0	0.05	0.05	0.2	0.22	0.4	0.45
8/7	32.0	0.03	0.03	0.1	0.09	0	0
9/7	8.4	0.01	0.01	0.1	0.14	0	0
10/7	12.0	0.02	0.01	0.1	0.12	0	0
11/7	10.0	0.01	0.01	0.1	0.09	0	0
14/7	8.0	0.02	0.01	0.2	0.1	0.2	0.4
15/7	5.0	0.006	0.004	0.12	0.07	0	0
16/7	35.5	0.05	0.05	0.14	0.14	0.3	0.4
17/7	25.0	0.04	0.04	0.16	0.15	0.3	0.4
18/7	22.0	0.03	0.04	0.15	0.17	0.2	0.4
19/7	5.0	0.005	0.004	0.11	0.08	0	0
20/7	5.8	0.01	0.006	0.15	0.11	0	0
31/7	16.7	0.02	0.03	0.15	0.18	0.5	0.7
Total	238.1	0.331	0.314	2.01	1.8	2.2	3.05
6/8	96.6	0.16	0.14	0.2	0.14	1.2	1.6
7/8	3.6	0.003	0.002	0.08	0.05	0	0
9/8	8.8	0.007	0.004	0.08	0.04	0	0
10/8	3.5	0.002	0.002	0.08	0.05	0	0
11/8	5.7	0.007	0.006	0.12	0.11	0	0
13/8	12.0	0.02	0.02	0.2	0.2	0	0
16/8	0.7	0.002	0	0.3	0	0	0
24/8	8.0	0.008	0.008	0.1	0.1	0	0
Total	138.9	0.209	0.184	1.16	1.69	1.2	1.6
11/9	6.0	0.005	0.002	0.08	0.03	0.4	0.4
12/9	4.2	0.004	0.002	0.09	0.05	0	0
13/9	8.0	0.001	0.005	0.09	0.06	0	0
14/9	2.8	0.002	0.002	0.07	0.07	0	0
17/9	1.7	0	0.006	0	0.09	0	0
18/9	6.8	0.007	0.007	0.1	0.09	0.1	0.25
19/9	7.5	0.004	0	0.12	0	0.5	0

24/9	17.9	0.03	0.022	0.17	0.12	0.3	0.7
25/9	2.7	0.04	0.022	0.15	0.07	0	0
27/9	2.0	0.002	0.001	0.1	0.05	0	0
Total	57.9	0.106	0.049	0.97	0.63	1.3	1.85
4/10	9.0	0.004	0.01	0.4	0.12	0.2	0.2
8/10	6.0	0.006	0.008	0.1	0.1	0.3	0.2
9/10	9.5	0.014	0.013	0.15	0.1	0.7	0.2
10/10	4.0	0.003	0.005	0.08	0.1	0.07	0.06
13/10	7.0	0.006	0.01	0.09	0.14	0	0.2
14/10	4.6	0.003	0.005	0.07	0.01	0	0
17/10	3.6	0.002	0.003	0.06	0.08	0	0.1
22/10	6.7	0.001	0.002	0.01	0.03	0	0
23/10	10.5	0.01	0.014	0.1	0.1	0.2	0.2
24/10	7.0	0.007	0.008	0.1	0.1	0.1	0.07
25/10	25.7	0.03	0.03	0.1	0.1	0.9	0.7
26/10	10.5	0.02	0.02	0.2	0.19	2.03	0.4
Total	107.6	0.107	0.131	1.13	1.37	4.97	2..33
1/11	6.0	0.005	0.003	0.08	0.05	0.3	0.3
2/11	8.5	0.01	0.007	0.12	0.008	0.1	0.4
3/11	4.5	0.005	0.003	0.1	0.07	0	0
6/11	8.0	0.009	0.007	0.01	0.09	0.1	0.2
8/11	10.5	0.02	0.015	0.016	0.014	2.04	0.5
9/11	26.7	0.1	0.05	0.4	0.2	25.6	23.0
10/11	6.2	0.02	0.012	0.24	0.2	0.2	1.3
15/11	26.5	0.07	0.03	0.2	0.13	3.0	1.03
19/11	8.8	0.01	0.01	0.1	0.08	0	0
20/11	9.5	0.04	0.03	0.4	0.3	3.2	1.6
23/11	15.5	0.07	0.07	0.5	0.4	3.8	5.6
24/11	18.5	0.1	0.1	0.6	0.5	11.8	4.8
26/11	12.0	0.03	0.02	0.3	0.2	0.7	0.4
27/11	38.0	0.12	0.1	0.3	0.2	1.6	1.6
28/11	12.0	0.02	0.01	0.2	0.1	0	0
Total	211.1	0.629	0.457	3.8	2.74	52.44	40.73
1/12	1.6	0.0002	0	0.02	0	0	0
2/12	7.8	0.008	0.006	0.1	0.07	0	0
4/12	15.8	0.06	0.06	0.4	0.4	6.11	7.3
8/12	16.0	0.04	0.04	0.2	0.2	0.4	0.4
9/12	39.0	0.1	0.1	0.3	0.3	0.6	1.9
11/12	4.0	0.006	0.005	0.2	0.11	0	0
17/12	8.5	0.01	0.003	0.1	0.1	0.4	0.13
18/12	1.7	0.003	0.001	0.1	0.07	0	0
29/12	3.0	0.003	0	0.1	0	0	0
Total	97.4	0.23	0.22	1.52	0.89	7.5	9.73

Year : 1983

21/2	4.6	0.024	0.016	0.53	0.36	6.25	5.54
28/2	0.5	0	0	0	0	0	0

Total	5.1	0.024	0.016	0.53	0.36	6.25	5.54
2/3	0.2	0	0	0	0	0	0
28/3	33.0	0.045	0.029	0.136	0.09	5.14	37.7
Total	33.2	0.045	0.029	0.136	0.09	5.14	37.7
5-9/5	55.4	0.05	0.04	0.09	0.07	30.9	129.4
16/5	7.2	0.008	0.008	0.1	0.1	0.4	0.6
17/5	23.5	0.03	0.03	0.14	0.15	0.3	4.5
18/5	40.0	0.04	0.04	0.11	0.1	4.8	64.0
22/5	13.5	0.02	0.01	0.15	0.07	0.5	0.6
27/5	6.4	0.01	0.004	0.13	0.07	0.3	0.4
Total	146.0	0.16	0.13	0.72	0.56	37.2	199.5
7/6	8.5	0.01	0.003	0.12	0.03	0.2	0.4
8/6	4.3	0.005	0.0004	0.12	0.01	0	0
14/6	5.3	0.01	0.003	0.23	0.05	0.72	0.2
15/6	7.7	0.009	0.004	0.12	0.05	0	0
18/6	17.7	0.02	0.014	0.112	0.08	0	0
24/6	4.0	0.02	0.003	0.47	0.09	0	0
27/6	15.5	0.02	0.01	0.12	0.08	0.3	0.2
28/6	8.0	0.01	0.002	0.11	0.03	0	0
29/6	5.2	0.004	0.001	0.08	0.03	0	0
Total	76.2	0.11	0.04	1.48	0.45	1.22	2.6
13/7	7.8	0.009	0.005	0.13	0.06	0.3	0.2
14/7	12.2	0.01	0.01	0.11	0.07	0.02	0.03
15/7	13.5	0.02	0.01	0.13	0.07	0.08	0.07
16/7	18.0	0.025	0.015	0.14	0.05	0.09	0.05
17/7	18.0	0.007	0.004	0.04	0.02	0	0
18/7	7.7	0.009	0.003	0.11	0.06	0.07	0.2
19/7	8.5	0.01	0.007	0.13	0.09	0	0
20/7	6.5	0.006	0.002	0.1	0.04	0.2	0.2
24/7	8.0	0.01	0.004	0.13	0.05	0.07	0.5
27/7	23.8	0.032	0.008	0.13	0.03	0.07	10.4
Total	124.0	0.14	0.07	1.15	0.57	1.53	11.65
13/8	20.5	0.027	0.017	0.13	0.08	0.7	1.85
14/8	6.5	0.007	0.001	0.11	0.02	0.04	0.01
16/8	17.5	0.032	0.12	0.18	0.07	0.2	0.2
17/8	13.0	0.016	0.007	0.13	0.005	0.13	0.06
18/8	39.5	0.037	0.024	0.1	0.06	0.4	0.6
19/8	35.5	0.047	0.031	0.13	0.1	0.1	0.8
20/8	12.5	0.015	0.008	0.12	0.06	0	0
Total	144.5	0.18	0.1	0.9	0.44	2.17	3.52
4/9	15.5	0.024	0.016	0.16	0.1	0.3	0.6
7/9	0.3	0.001	0.0004	0.1	0.	0.06	0.01
18/9	4.3	0.003	0.004	0.1	0.11	0	0
20/9	12.0	0.017	0.008	0.14	0.07	0.2	0.7
21/9	8.3	0.01	0.008	0.12	0.1	0.2	0.4
22/9	28.6	0.29	0.21	0.103	0.07	0.2	0.2

23/9	7.9	0.013	0.009	0.17	0.12	0.07	0.2
24/9	5.8	0.006	0.003	0.11	0.06	0	0
25/9	3.0	0.003	0.003	0.11	0.12	0	0
Total	85.7	0.11	0.07	1.11	0.75	1.03	2.11
10/10	12.0	0.023	0.005	0.2	0.05	0.7	8.1
11/10	7.8	0.009	0.002	0.12	0.03	0.1	0.06
12/10	41.5	0.208	0.142	0.5	0.34	6.2	91.3
20/10	5.7	0.007	0.002	0.18	0.04	0	0
21/10	10.0	0.011	0.001	0.11	0.01	0.3	0.1
28/10	9.0	0.008	0.006	0.1	0.07	0	0
31/10	44.3	0.08	0.069	0.2	0.16	2.2	12.1
Total	130.3	0.35	0.23	1.41	0.7	9.5	111.66
2/11	29.2	0.045	0.027	0.16	0.1	0.2	3.0
3/11	12.7	0.005	0.005	0.04	0.04	0	0
4/11	25.8	0.028	0.018	0.11	0.07	0	0
6/11	54.5	0.075	0.046	0.14	0.08	5.75	2.6
18/11	27.5	0.062	0.037	0.23	0.13	1.1	15.4
19/11	28.3	0.035	0.027	0.012	0.01	1.0	0.8
29/11	12.8	0.012	0.003	0.1	0.03	0.2	0.16
Total	190.8	0.26	0.16	0.9	0.55	8.25	21.96
2/12	26.3	0.02	0.01	0.07	0.05	0.2	0.75
10/12	17.0	0.01	0.01	0.07	0.05	0.1	0.3
14/12	32.0	0.06	0.06	0.19	0.2	1.4	4.1
15/12	12.0	0.01	0.004	0.08	0.03	0.3	0.3
17/12	5.0	0.006	0.005	0.11	0.1	0.14	0.24
20/12	13.0	0.01	0.004	0.1	0.03	0	0
21/12	25.7	0.08	0.1	0.3	0.3	5.65	1.35
24/12	9.5	0.005	0.002	0.01	0.02	0	0
25/12	15.0	0.03	0.03	0.2	0.2	0.3	10.6
29/12	10.8	0.01	0.01	0.01	0.08	0.1	1.83
Total	166.3	0.29	0.23	1.23	1.06	8.2	19.47

Year : 1984

3/1	2.4	0.0003	0.001	0.01	0.06	0	0
10/1	7.8	0.001	0.012	0.01	0.015	0	0
11/1	14.2	0.01	0.01	0.008	0.01	0	0
14/1	11.3	0.02	0.02	0.2	0.1	2.17	0.41
17/1	11.8	0.01	0.01	0.1	0.1	22.51	9.43
18/1	32.1	0.08	0.08	0.2	0.2	0.98	0.94
20/1	14.0	0.01	0.015	0.08	0.1	0.10	0.07
25/1	4.7	0.003	0.002	0.06	0.05	0	0
Total	98.3	0.1343	0.15	0.74	0.86	25.75	10.85
4/2	11.8	0.004	0.005	0.04	0.04	0	2.72
5/2	9.4	0.01	0.007	0.1	0.07	0.21	0
9/2	7.5	0.01	0.009	0.1	0.1	0.12	0.37
11/2	11.5	0.01	0.008	0.1	0.7	0.08	0.11

12/2	8.8	0.003	0.003	0.04	0.03	0	0
13/2	15.2	0.08	0.08	0.5	0.5	3.44	17.44
14/2	11.5	0.017	0.016	0.15	0.14	0	0
15/2	24.5	0.027	0.045	0.11	1.18	0.3	2.12
17/2	13.5	0.013	0.009	0.07	0.06	0.09	0.3
18/2	17.5	0.028	0.06	0.16	0.34	0.49	16.2
28/2	1.1	0.005	0.003	0.5	0.2	0	0
Total	132.3	0.243	0.245	1.87	1.73	4.65	39.26
2/3	20.2	0.01	0.01	0.09	0.06	0.23	0.24
4/3	15.6	0.012	0.11	0.08	0.07	0.08	0.13
5-9/3	53.8	0.08	0.093	0.16	0.17	0.18	3.5
17/3	8.2	0.06	0.07	0.8	0.8	0.6	13.53
26/3	27.0	0.05	0.04	0.2	0.1	2.47	5.64
28/3	6.8	0.006	0.01	0.09	0.1	0.05	0.12
29/3	10.3	0.01	0.005	0.1	0.05	0.07	0.055
30/3	4.9	0.009	0.006	0.18	0.13	0	0
Total	146.8	0.237	0.245	1.7	1.48	3.68	23.21
2/4	16.7	0.006	0.003	0.03	0.02	0	0
4/4	39.3	0.18	0.19	0.45	0.48	79.33	255.09
12/4	13.3	0.01	0.004	0.08	0.03	0.41	0.08
14/4	12.7	0.034	0.037	0.27	0.29	0.33	2.33
15/4	27.0	0.13	0.13	0.4	0.4	67.62	67.62
16/4	10.2	0.02	0.03	0.2	0.3	0.2	0.94
17/4	23.0	0.04	0.03	0.1	0.1	0.49	0.53
18/4	21.7	0.04	0.05	0.1	0.2	0.4	3.54
19/4	21.8	0.04	0.03	0.1	0.1	0.28	2.5
22/4	17.6	0.01	0.01	0.06	0.06	0	0
23/4	57.0	0.09	0.07	0.1	0.1	0.74	4.96
24/4	15.3	0.02	0.009	0.1	0.05	0.08	0.08
Total	275.62	0.62	0.926	1.99	2.03	149.48	337.64
16/5	15.0	0.01	0.01	0.06	0.08	1.98	1.25
17/5	10.0	0.01	0.01	0.1	0.1	0.89	0.2
18/5	14.0	0.02	0.009	0.1	0.006	0.27	1.31
19/5	4.5	0.003	0.003	0.08	0.06	0.17	0.27
28/5	24.6	0.005	0.006	0.02	0.02	0.21	0.96
31/5	26.8	0.03	0.01	0.03	0.02	0.33	1.1
Total	95.4	0.078	0.048	0.29	0.34	3.85	5.4
1/6	21.8	0.01	0.004	0.08	0.02	0.09	0.07
2/6	15.2	0.01	0.002	0.08	0.01	0.05	0.56
3/6	21.6	0.03	0.01	0.1	0.07	0.26	0.78
6/6	7.6	0.006	0.004	0.08	0.05	5.59	0.08
7/6	43.1	0.03	0.001	0.09	0.004	3.04	0.29
10/6	11.5	0.005	0.008	0.04	0.07	0	0
11/6	11.1	0.005	0.007	0.05	0.07	0.07	0.7
12/6	12.9	0.007	0.01	0.05	0.07	0.02	0.02
13/6	11.7	0.006	0.003	0.05	0.02	0.02	0.04
16/6	7.0	0.008	0.004	0.12	0.06	0.02	0.03
17/6	16.7	0.008	0.009	0.05	0.05	0.06	0.08
23/6	6.5	0.006	0.009	0.1	0.01	0.05	0.11

24/6	7.3	0.007	0.007	0.09	0.09	0.02	0.2
25/6	8.7	0.004	0.004	0.05	0.04	0	0
26/6	20.8	0.008	0.001	0.03	0.007	0.04	0.03
27/6	11.5	0.007	0.002	0.06	0.02	0	0
28/6	8.6	0.007	0.003	0.08	0.03	0	0
30/6	29.5	0.01	0.01	0.06	0.06	0	0
Total	273.1	0.174	0.841	1.71	0.841	9.33	2.99
1/7	31.1	0.03	0.02	0.1	0.07	0	0
3/7	22.5	0.01	0.02	0.1	0.1	0	0
4/7	46.9	0.09	0.09	0.2	0.2	1.53	17.5
5/7	62.0	0.2	0.21	0.3	0.3	1.537	3.097
6/7	32.4	0.02	0.0007	0.002	0.002	0.07	0.13
9/7	20.6	0.01	0.02	0.09	0.09	0.83	0.67
11/7	65.7	0.11	0.07	0.1	0.1	3.98	5.37
12/7	17.2	0.08	0.09	0.5	0.5	3.26	2.1
13/7	18.0	0.006	0.001	0.007	0.007	0	0
14/7	9.2	0.01	0.008	0.1	0.1	0.25	0.44
19/3	3.0	0.006	0.006	0.2	0.2	0	0
20/7	22.4	0.02	0.01	0.04	0.04	0.13	0.14
Total	362.4	0.592	0.546	1.74	1.709	11.587	29.443
5/8	32.5	0.01	0	0.03	0	0.09	0
9/8	50.7	0.06	0.05	0.11	0.09	0.71	1.37
10/8	2.7	0.004	0.005	0.14	0.18	0	0
24/8	18.1	0.2	0.24	1.104	1.325	6.06	23.61
Total	104.0	0.274	0.295	1.384	1.595	6.86	24.98
3/9	1.9	0.008	0.001	0.42	0.05	0	0
15/9	8.3	0	0	0	0	0	0
20/9	6.7	0.01	0.0006	0.14	0.008	0.04	0
21/9	38.6	0.09	0.24	0.23	0.62	2.82	36.18
23/9	15.9	0.16	0	0.1	0	0	0
24/9	10.5	0.009	0.08	0.08	0.76	0	0
26/9	16.8	0.01	0	0.05	0	0.11	0
27/9	76.0	0.08	0.07	0.10	0.09	13.78	8.72
28/9	86.0	0.18	0.18	0.2	0.2	3.89	31.97
29/9	12.0	0.009	0.005	0.075	0.04	0.24	0.06
30/9	16.3	0.01	0.001	0.06	0.006	0	0
Total	289.0	0.566	0.584	1.455	1.846	20.88	77.49
1/10	18.0	0.01	0.004	0.05	0.02	0	0
2/10	5.5	0.006	0.006	0.1	0.1	0	0
8/10	9.4	0.005	0.003	0.05	0.03	0	0
22/10	5.7	0.01	0.01	0.17	0.17	0.31	1.82
28/10	14.2	0.02	0.01	0.14	0.07	0.06	0.14
29/10	8.5	0.008	0.008	0.0009	0.0009	0	0
Total	61.3	0.059	0.041	0.5109	0.3009	0.37	1.96
3/11	10.8	0.02	0.04	0.18	0.37	0	0
5/11	11.9	0.007	0.002	0.05	0.01	0	0
12/11	6.3	0.01	0.009	0.15	0.14	0	0

13/11	7.5	0.008	0.006	0.1	0.08	0	0
14/11	25.0	0.06	0.06	0.24	0.24	0	0
17/11	0.5	0.004	0.004	8.0	8.0	0	0
19/11	14.0	0.01	0.007	0.07	0.05	0	0
20/11	19.7	0.02	0.01	0.01	0.05	0	0
22/11	0.9	0.01	0.007	1.11	1.11	0.6	0.24
28/11	40.0	0.03	0.003	0.075	0.0075	1.52	0.27
Total	136.6	0.179	0.1453	9.785	10.0575	2.12	0.51
23/12	20.0	0.02	0.01	0.1	0.5	0.41	0.2
Total	20.0	0.02	0.01	0.1	0.5	0.41	0.2

Appendix C

DAILY RECORDS OF RAINFALL, RUNOFF AND SOIL LOSS FROM SEEDLING TEA - ST. COOMBS.

Date	Rainfall mm	Runoff in mm S1	Runoff in mm S2	Runoff % S1	Runoff % S2	Soil loss kg ha^{-1} S1	Soil loss kg ha^{-1} S2
Year : 1982							
3/3	20.3	0.07	0.02	0.35	0.09	398.9	0.6
21/3	32.0	0.03	0.02	0.9	0.05	15.3	1.5
22/3	17.3	0.03	0.02	0.15	0.09	126.96	0.03
23/3	8.4	0.01	0.02	0.07	0.2	23.7	0.2
30/3	8.2	0.008	0.0009	0.1	0.01	0.6	0.5
Total	96.5	0.148	0.0809	1.57	0.44	565.46	2.83
11/4	9.2	0.003	0	0.004	0	0.3	0
12/4	19.5	0.02	0	0.1	0	106.8	0
13/4	12.5	0.02	0	0.1	0	71.8	0
14/4	18.3	0.06	0	0.3	0	322.7	0
16/4	8.8	0.02	0	0.2	0	68.7	0
18/7	7.7	0.02	0	0.26	0	85.57	0
28/4	40.5	0.03	0.03	0.07	0.07	0.5	0.4
30/4	32.5	0.07	0.09	0.2	0.3	5.3	51.7
Total	149.0	0.243	0.12	1.27	0.37	661.67	52.1
1/5	4.5	0.003	0.003	0.06	0.06	0.03	0.04
11/5	4.0	0.001	0.002	0.03	0.04	0.3	0.5
12/5	8.75	0.008	0.008	0.09	0.09	0.2	0.3
13/5	9.5	0.007	0.007	0.08	0.09	0.8	0.2
14/5	21.4	0.1	0.2	0.4	1.3	130.61	25.51
18/5	8.0	0.003	0.004	0.04	0.05	0.4	0.4
19/5	20.0	0.02	0.02	0.1	0.1	0.5	0.2
21/5	15.5	0.006	0.009	0.04	0.05	0.01	0
22/5	17.5	0.009	0.01	0.05	0.06	0	0
23/5	5.1	0.002	0.002	0.03	0.03	0	0
25/5	10.0	0.007	0.01	0.07	0.1	0.1	0.2
26/5	2.1	0.0008	0.001	0.04	0.05	0	0
27/5	71.7	0.5	0.7	0.7	1.02	2.5	8.5
28/5	13.5	0.02	0.01	0.11	0.08	0.1	0.1
30/5	9.0	0.006	0.007	0.07	0.08	0.05	0.03
31/5	12.0	0.03	0.03	0.25	0.21	0.01	0.05
Total	232.55	0.723	1.723	2.16	3.22	135.61	36.03

1/6	54.0	0.4	0.43	0.7	0.8	2.5	1.4
2/6	23.0	0.04	0.03	0.16	0.12	0.3	0.2
3/6	16.5	0.01	0.01	0.08	0.08	0.1	0
4/6	39.2	0.07	0.04	0.18	0.09	0.5	0.1
5/6	40.0	0.2	0.5	0.2	0.4	0.7	0.6
6/6	6.3	0.003	0.003	0.05	0.07	0	0
7/6	5.9	0.003	0.004	0.05	0.06	0	0
8/6	43.8	0.05	0.04	0.12	0.09	0.3	0.2
9/6	14.8	0.015	0.012	0.1	0.08	0	0
10/6	7.0	0.004	0.005	0.05	0.07	0	0
19/6	4.2	0.002	0.003	0.04	0.07	0	0
21/6	4.4	0.002	0.002	0.04	0.04	0	0
23/6	3.2	0.001	0.001	0.05	0.05	0	0
24/6	5.1	0.002	0.003	0.04	0.06	0	0
25/6	6.0	0.002	0.004	0.03	0.06	0	0
26/6	3.7	0.001	0.002	0.04	0.05	0	0
27/6	6.0	0.001	0.004	0.02	0.07	0	0
Total	283.1	0.806	0.643	1.95	2.26	4.4	2.5
5/7	18.0	0.005	0.01	0.03	0.08	0.06	0.15
6/7	9.0	0.004	0.006	0.04	0.07	0	0
7/7	25.0	0.02	0.04	0.07	0.17	0.1	0.3
8/7	32.0	0.02	0.02	0.06	0.07	0	0
9/7	10.0	0.005	0.008	0.05	0.08	0	0
10/7	12.7	0.009	0.01	0.07	0.09	0	0
11/7	12.0	0.006	0.008	0.05	0.06	0	0
14/7	9.0	0.004	0.008	0.05	0.08	0.15	0.13
15/7	5.8	0.002	0.003	0.04	0.06	0	0
16/7	36.5	0.03	0.03	0.08	0.09	0.5	0.6
17/7	25.5	0.03	0.02	0.12	0.096	0.3	0.2
18/7	21.8	0.02	0.02	0.09	0.09	0.2	0.15
19/7	6.2	0.003	0.001	0.05	0.01	0	0
20/7	4.5	0	0.004	0	0.08	0	0
31/7	16.7	0.01	0.02	0.12	0.12	0.3	0.3
Total	247.9	0.168	0.208	0.86	1.246	1.61	1.83
6/8	96.6	0.5	0.7	0.6	0.7	4.3	4.3
7/8	3.5	0.002	0.002	0.05	0.04	0	0
9/8	8.8	0.004	0.001	0.05	0.007	0	0
10/8	3.6	0.002	0.002	0.05	0.05	0	0
11/8	7.5	0.004	0.005	0.05	0.07	0	0
13/8	4.2	0.18	0.2	0.4	0.6	0.2	0.2
24/8	8.0	0.004	0.004	0.05	0.05	0	0
Total	132.2	0.696	0.914	1.25	1.517	4.5	4.5
11/9	7.25	0.002	0.003	0.03	0.05	0.25	0.3
12/9	4.8	0.001	0.002	0.02	0.04	0	0
13/9	7.4	0.003	0.004	0.04	0.05	0.03	0.03
14/9	4.5	0.001	0.001	0.02	0.02	0	0
18/9	5.5	0.004	0.003	0.07	0.05	0.1	0.1
19/9	3.5	0.001	0.001	0.03	0.03	0	0
24/9	15.8	0.01	0.02	0.06	0.01	0.2	0.2
27/9	2.0	0.001	0.001	0.03	0.03	0	0

Total	50.75	0.023	0.035	0.3	0.37	0.58	0.63
4/10	7.2	0.003	0.005	0.04	0.07	0.1	0.06
6/10	2.2	0.0002	0.001	0.01	0.01	0	0
8/10	7.7	0.003	0.005	0.04	0.07	0.2	0.2
9/10	9.5	0.005	0.007	0.05	0.07	0.2	0.2
10/10	4.0	0.002	0.002	0.05	0.05	0.04	0.03
13/10	5.5	0.001	0.003	0.02	0.06	0.1	0.06
17/10	3.6	0.001	0.001	0.02	0.03	0.03	0.02
22/10	6.0	0.0035	0.001	0.06	0.02	0	0
23/10	13.5	0.003	0.007	0.02	0.052	0.1	0.1
24/10	6.8	0.003	0.003	0.04	0.04	0.05	0.03
25/10	25.7	0.019	0.023	0.07	0.09	0.2	0.3
26/10	12.0	0.015	0.021	0.13	0.18	0.6	3.1
Total	103.7	0.059	0.079	0.55	0.744	1.62	4.1
1/11	6.0	0.001	0.002	0.013	0.03	0.1	0.1
2/11	9.0	0.004	0.006	0.044	0.07	0.3	0.08
3/11	4.0	0.001	0.002	0.03	0.05	0	0
6/11	13.0	0.006	0.009	0.046	0.07	0.3	0.2
8/11	14.0	0.011	0.12	0.08	0.09	1.0	0.5
9/11	26.5	0.035	0.045	0.13	0.2	15.1	37.0
10/11	13.5	0.007	0.009	0.06	0.07	0.3	0.3
15/11	26.5	0.03	0.02	0.1	0.1	0.4	0.2
16/11	3.3	0.001	0.0005	0.03	0.05	0	0
19/11	8.3	0.003	0.01	0.03	0.07	0	0
20/11	13.0	0.01	0.01	0.06	0.09	1.4	0.2
23/11	15.2	0.01	0.01	0.09	0.09	0.8	0.5
24/11	18.5	0.01	0.01	0.07	0.08	0.5	0.2
26/11	12.0	0.006	0.008	0.05	0.07	0.5	0.05
27/11	38.0	0.05	0.04	0.1	0.1	0.9	0.2
28/11	11.0	0.01	0.01	0.1	0.1	0	0
Total	231.8	0.195	0.197	1.033	1.21	21.6	39.53
2/12	7.5	0.003	0.002	0.04	0.03	0	0
4/12	16.0	0.02	0.01	0.1	0.1	0.6	0.4
8/12	16.3	0.02	0.02	0.1	0.1	2.0	0.2
9/12	39.0	0.1	0.06	0.2	0.16	0.8	0.4
11/12	4.0	0.001	0.003	0.035	0.08	0	0
17/12	8.5	0.005	0.006	0.059	0.065	0.1	0.2
18/12	1.7	0.0002	0	0.01	0	0	0
Total	95.2	0.15	0.1	0.544	0.575	3.5	1.2

Year : 1983

21/2	12.5	0.02	0.02	0.15	0.16	16.8	14.4
Total	12.5	0.02	0.02	0.15	0.16	16.8	14.4
28/3	27.3	0.02	0.02	0.08	0.06	36.4	0.6
Total	27.3	0.02	0.02	0.08	0.06	36.4	0.6

5-9/5	55.7	0.056	0.036	0.1	0.07	94.6	71.7
16/5	14.0	0.006	0.007	0.05	0.05	0.2	0.4
17/5	21.8	0.06	0.02	0.26	0.1	211.5	1.0
18/5	44.2	0.26	0.53	0.6	1.22	33.3	7.6
22/5	6.5	0.002	0.003	0.04	0.05	0.03	0.6
27/5	5.8	0.002	0.005	0.04	0.1	0.07	0.06
Total	148.0	0.39	0.6	1.1	1.6	339.7	80.96
4/6	3.2	0.001	0.002	0.05	0.07	0.1	0.1
7/6	9.2	0.001	0.006	0.02	0.06	0.1	0.3
8/6	4.3	0.001	0.003	0.02	0.07	0	0
14/6	5.5	0	0.005	0	0.1	0	0.1
15/6	8.5	0	0.004	0	0.05	0	0
18/6	17.7	0.009	0.012	0.05	0.07	1.5	0
24/6	4.4	0	0.006	0	0.15	0	0
27/6	18.7	0.007	0.012	0.04	0.07	0.4	0.6
28/6	7.7	0.001	0.005	0.01	0.06	0	0
29/6	5.0	0	0.003	0	0.06	0	0
Total	84.2	0.02	0.06	0.2	0.76	2.1	1.1
13/7	8.8	0.0003	0.01	0.004	0.11	0	0
14/7	12.6	0	0.01	0	0.08	0	0.02
15/7	11.6	0	0.01	0	0.08	0	0.4
16/7	17.7	0	0.01	0	0.08	0	0.06
17/7	18.3	0	0.004	0	0.02	0	0
18/7	10.6	0.004	0.004	0.04	0.02	0.13	0
19/7	9.0	0	0.007	0	0.08	0	0
20/7	6.5	0	0.004	0	0.06	0	0.1
24/7	7.5	0	0.005	0	0.07	0	0.04
27/7	23.8	0	0.01	0	0.06	0	0.24
Total	75.9	0.0043	0.08	0.044	0.07	0.13	1.06
13/8	24.0	0.02	0.02	0.08	0.08	0.8	0.3
14/8	5.5	0	0.003	0	0.06	0	0.03
16/8	21.8	0.003	0.02	0.1	0.07	0.04	0.2
17/8	14.8	0.001	0.01	0.004	0.04	0.01	0.05
18/8	36.0	0.01	0.03	0.03	0.08	0.2	0.01
19/8	36.0	0	0.03	0	0.08	0	0.3
20/8	14.0	0.001	0.008	0.01	0.06	0	0
Total	152.1	0.035	0.12	0.134	0.5	1.05	0.99
4/9	17.5	0.02	0.02	0.13	0.09	0	0
6/9	5.6	0	0.007	0	0.13	0	0.1
18/9	4.8	0.003	0.004	0.01	0.08	0	0
20/9	13.0	0.001	0.01	0.01	0.09	0.02	0.06
21/9	8.3	0.002	0.005	0.03	0.06	0.14	0.03
22/9	27.2	0.001	0.02	0.01	0.07	0.02	0.1
23/9	7.3	0.01	0.01	0.12	0.1	0.23	0.03
24/9	6.8	0.002	0.005	0.03	0.07	0	0
25/9	3.5	0.0005	0.001	0.02	0.04	0	0
Total	94.0	0.04	0.08	0.36	0.73	0.43	0.32

10/10	8.0	0	0.007	0	0.09	0	0.15
11/10	6.5	0	0.006	0	0.08	0	0
12/10	41.5	0.14	0.17	0.35	0.4	265.5	41.0
20/10	6.4	0	0.004	0	0.06	0	0
21/10	11.5	0	0.006	0	0.05	0	0.04
28/10	9.6	0.004	0.006	0.05	0.06	0	0
31/10	42.4	0.03	0.03	0.08	0.08	0	1.2
Total	125.9	0.174	0.23	0.48	0.82	267.4	42.4
2/11	29.2	0.01	0.02	0.05	0.08	3.0	0.2
3/11	12.7	0.002	0.008	0.01	0.07	0	0
4/11	25.7	0.006	0.02	0.02	0.01	0	0
6/11	54.5	0.1	0.1	0.18	0.18	3.6	15.1
18/11	20.8	0.02	0.02	0.1	0.1	1.2	0.15
19/11	28.0	0.02	0.02	0.07	0.07	0.6	0.5
29/11	12.8	0.002	0.007	0.02	0.05	0.04	0.06
Total	183.7	0.16	0.2	0.45	0.56	8.44	16.01
2/12	27.3	0.01	0.02	0.04	0.04	0.8	0.1
10/12	17.3	0.01	0.02	0.04	0.1	0.4	0.2
14/12	35.2	0.14	0.2	0.4	0.5	59.1	2.5
15/12	12.3	0.01	0.01	0.08	0.1	0.3	1.8
17/12	4.5	0.002	0.005	0.05	0.11	0.03	0.03
20/12	17.7	0.004	0.012	0.07	0.07	64.5	35.3
21/12	30.5	0.13	0.15	0.5	0.5	0	0
24/12	7.8	0.001	0.003	0.02	0.05	0	0
25/12	20.8	0.02	0.02	0.08	0.09	1.0	0.1
29/12	10.8	0.007	0.009	0.07	0.08	2.0	3.0
Total	184.2	0.33	0.45	0.9	0.67	133.13	43.03

Year : 1984

3/1	8.3	0.01	0.006	0.17	0.07	2.06	0.8
10/1	8.7	0.004	0.011	0.05	0.12	0.13	0.17
11/1	14.7	0.006	0.071	0.04	0.48	0	0
14/1	10.4	0.017	0.01	0.16	0.09	9.23	0.11
17/1	12.4	0.004	0.007	0.03	0.06	0.09	0.07
18/1	32.3	0.06	0.03	0.21	0.09	6.88	0.15
20/1	13.7	0.017	0.007	0.12	0.05	2.44	0.03
25/1	5.0	0	0.002	0	1.0	0	0
Total	105.5	0.118	0.144	0.78	1.0	20.83	0.61
4/2	10.5	0.0013	0.017	0.012	0.066	0	0
5/2	9.9	0.006	0.012	0.06	0.12	1.98	0.41
9/2	8.7	0.0015	0.0079	0.0172	0.091	0.1	0.45
11/2	11.5	0.007	0.002	0.068	0.017	0.22	0.06
12/2	8.6	0.004	0.0031	0.046	0.036	0	0
13/2	15.0	0.072	0.031	0.48	0.2	94.96	0.35
14/2	8.2	0.01	0.005	0.122	0.067	0.13	0.04
15/2	26.0	0.106	0.069	0.4	0.26	118.99	0.6
17/2	13.5	0.005	0.007	0.04	0.05	0.21	0.03
18/2	22.5	0.075	0.048	0.33	0.21	30.66	4.58

28/2	1.1	0.003	0.004	0.29	0.36	0	0
Total	135.5	0.291	0.206	1.8652	1.394	251.25	6.52
2/3	20.2	0.014	0.014	0.06	0.06	0.21	0.17
4/3	15.6	0.01	0.01	0.06	0.06	0.23	0.12
5-9/3	74.1	0.18	1.06	0.24	1.4	16.45	147.75
17/3	8.2	0.03	0.03	0.3	0.3	4.21	0.29
Total	118.1	0.034	1.114	0.39	1.82	21.1	148.33
22/4	16.0	0.01	0	0.07	0	0	0
23/4	57.0	0.25	0.09	0.44	0.16	3.99	3.51
24/4	15.3	0.02	0.07	0.1	0.4	0.49	0.1
Total	88.3	0.28	0.16	0.61	0.2	4.48	3.61
16/5	14.5	0.007	0.008	0.04	0.05	0.22	0.18
17/5	4.0	0.01	0.01	0.1	0.1	0.45	0.29
18/5	11.9	0.013	0.009	0.11	0.07	0.58	0.27
19/5	4.5	0.009	0.0011	0.2	0.02	0.58	0.03
28/5	23.0	0.005	0.028	0.02	0.04	0.09	0.11
31/5	28.0	0.029	0.028	0.1	0.1	0.21	0.17
Total	85.9	0.073	0.0661	0.57	0.38	1.82	1.05
1/6	23.0	0.01	0.012	0.04	0.05	0.05	0.04
2/6	16.0	0.01	0.013	0.006	0.08	0.06	0.06
3/6	22.0	0.012	0.016	0.07	0.07	0.15	0.16
6/6	9.0	0.003	0.005	0.03	0.06	0.04	0.1
7/6	46.3	0.04	0.03	0.09	0.06	0.03	0.31
10/6	13.0	0.007	0.008	0.05	0.06	0	0
11/6	15.3	0.007	0.008	0.05	0.06	8.36	0.01
12/6	13.0	0.007	0.006	0.05	0.04	0.01	0.01
13/6	12.6	0.007	0.007	0.05	0.06	0.01	0.04
16/6	10.0	0.007	0.009	0.07	0.09	0.3	0.08
17/6	17.3	0.006	0.007	0.03	0.04	0.05	0.06
23/6	7.9	0.008	0.004	0.1	0.05	0.06	0.02
24/6	8.1	0.003	0.006	0.04	0.07	0.02	0.02
25/6	7.6	0.005	0.003	0.07	0.05	0	0
26/6	20.8	0.012	0.011	0.06	0.05	0.06	0.03
27/6	12.0	0.006	0.005	0.05	0.04	0	0
28/6	9.1	0.006	0.005	0.06	0.06	0	0
30/6	29.5	0.11	0.019	0.03	0.06	0	0
Total	292.3	0.266	0.174	1.0	1.05	9.52	0.94
1/7	36.7	0.01	0.02	0.03	0.05	0	0
3/7	24.0	0.02	0.02	0.09	0.08	0	0
4/7	50.4	0.08	0.08	0.16	0.17	9.48	1.51
5/7	70.0	0.07	0.23	0.11	0.33	3.56	21.0
6/7	22.4	0.01	0.02	0.04	0.11	0.04	0.1
9/7	20.6	0.01	0.01	0.05	0.06	0.62	0.63
11/7	70.3	0.08	0.08	0.1	0.1	3.28	4.92
12/7	17.2	0.06	0.07	0.3	0.4	0.88	0.67
13/7	18.4	0.003	0.006	0.03	0.032	0	0
15/7	8.5	0.012	0.011	0.15	0.13	0.37	0.16

19/7	5.0	0.007	0.006	0.14	0.13	0	0
20/7	23.1	0.009	0.015	0.03	0.06	0.16	0.23
Total	366.6	0.371	0.579	1.23	1.672	17.83	29.72
5/8	25.0	0.0005	0.03	0.02	0.12	0.6	0.33
9/8	50.7	0.08	0.16	0.15	0.31	1.07	2.0
10/8	2.7	0.002	0.002	0.07	0.07	0	0
24/8	54.0	0.07	0.96	0.12	1.77	2.45	49.64
Total	132.4	0.153	1.125	0.36	2.27	4.12	51.97
3/9	8.0	0.006	0.003	0.26	0.13	0	0
15/9	15.1	0.01	0.02	0.06	0.13	0.02	0.28
20/9	5.8	0.003	0	0.05	0	0.017	0
21/9	32.7	0.08	0.15	0.24	0.45	55.25	53.18
23/9	14.4	0.01	0.01	0.06	0.06	0	0
24/9	10.5	0.006	0.005	0.05	0.04	0	0
26/9	18.0	0.007	0.01	0.03	0.05	0.11	0.22
27/9	81.0	0.11	0.13	0.13	0.16	1.51	1.46
28/9	87.5	1.47	1.46	1.68	1.66	361.33	347.69
29/9	14.0	0.007	0.01	0.05	0.07	0.03	0.02
30/9	18.7	0.009	0.008	0.04	0.04	0	0
Total	309.5	1.718	1.806	2.57	2.79	418.27	402.85
1/10	19.0	0.007	0.01	0.03	0.05	0	0
2/10	8.8	0.004	0.002	0.04	0.02	0	0
8/10	10.7	0.002	0.004	0.01	0.03	0	0
22/10	6.0	0.005	0.008	0.08	0.07	0.19	0.53
28/10	18.3	0.019	0.014	0.1	0.07	0.09	0.87
29/10	11.6	0.005	0.002	0.04	0.01	0	0
Total	74.4	0.042	0.04	0.3	0.25	0028	1.4
3/11	18.0	0.02	0.02	0.11	0.11	0	0
5/11	13.0	0.01	0.005	0.07	0.03	0.49	0.19
13/11	7.3	0.006	0.003	0.08	0.04	0.31	0.18
14/11	21.4	0.008	0.004	0.03	0.01	0.39	0.23
17/11	1.9	0.004	0.002	0.2	0.1	0	0
19/11	9.5	0.007	0.005	0.07	0.05	0.02	0.06
20/11	17.6	0.006	0.003	0.03	0.01	0	0
22/11	0.9	0.007	0.007	0.7	0.7	0.28	0.21
28/11	40.7	0.03	0.02	0.04	0.04	0.7	0.98
Total	139.9	0.096	0.075	1.71	1.15	2.19	1.85
23/12	24.0	0.01	0.01	0.04	0.04	0.37	0.36
total	24.0	0.01	0.01	0.04	0.04	0.37	0.36

Appendix D

DAILY RAINFALL INDICES FOR ST. COOMBS FOR THE PERIOD 1982-1984.

Date	EI_{30}	KE>25	AIm
Year : 1982			
21/3	8.820 x 10^3	-	-
22/3	8.766 x 10^3	1.560 x 10^2	12.000 x 10^2
23/3	1.194 x 10^3	-	0.068 x 10^2
24/3	0.020 x 10^3	-	0.003 x 10^2
25/3	0.003 x 10^3	-	0.001 x 10^2
26/3	0.015 x 10^3	-	0.007 x 10^2
30/3	0.778 x 10^3	-	0.062 x 10^2
11/4	5.299 x 10^3	-	6.030 x 10^2
12/4	0.440 x 10^3	-	5.900 x 10^2
13/4	2.050 x 10^3	-	2.100 x 10^2
14/4	10.780 x 10^3	2.500 x 10^2	8.404 x 10^2
15/4	0.002 x 10^3	-	0.001 x 10^2
16/4	0.859 x 10^3	-	0.800 x 10^2
18/4	0.006 x 10^3	-	0.960 x 10^2
28/4	9.459 x 10^3	-	7.980 x 10^2
30/4	1.693 x 10^3	-	1.246 x 10^2
1/5	0.235 x 10^3	-	0.018 x 10^2
6/5	0.002 x 10^3	-	0.045 x 10^2
10/5	4.440 x 10^3	-	3.936 x 10^2
11/5	0.032 x 10^3	-	0.036 x 10^2
12/5	3.030 x 10^3	1.125 x 10^2	3.276 x 10^2
13/5	3.726 x 10^3	1.690 x 10^2	5.148 x 10^2
14/5	2.282 x 10^3	-	2.132 x 10^2
17/5	0.662 x 10^3	-	1.120 x 10^2
18/5	2.175 x 10^3	-	1.968 x 10^2
20/5	0.023 x 10^3	-	0.024 x 10^2
21/5	2.540 x 10^3	-	1.580 x 10^2
22/5	1.388 x 10^3	-	1.368 x 10^2
23/5	0.208 x 10^3	-	0.128 x 10^2
24/5	1.270 x 10^3	-	1.740 x 10^2
25/5	1.690 x 10^3	-	1.920 x 10^2
26/5	0.716 x 10^3	-	0.096 x 10^2
27/5	26.600 x 10^3	-	17.900 x 10^2
28/5	1.387 x 10^3	-	1.053 x 10^2
29/5	0.001 x 10^3	-	0.008 x 10^2
31/5	0.471 x 10^3	-	0.848 x 10^2
1/6	7.900 x 10^3	-	15.300 x 10^2
2/6	4.500 x 10^3	-	4.990 x 10^2
3/6	1.590 x 10^3	-	2.400 x 10^2

4/6	6.399 x 10³	–	8.220 x 10²
5/6	15.300 x 10³	–	11.389 x 10²
6/6	0.172 x 10³	–	0.990 x 10²
7/6	0.490 x 10³	–	0.488 x 10²
8/6	7.840 x 10³	–	5.080 x 10²
9/6	2.801 x 10³	–	2.320 x 10²
10/6	0.285 x 10³	–	0.294 x 10²
11/6	0.002 x 10³	–	0.003 x 10²
12/6	0.059 x 10³	–	0.142 x 10²
15/6	0.150 x 10³	–	0.368 x 10²
16/6	0.006 x 10³	–	0.005 x 10²
18/6	1.860 x 10³	–	1.920 x 10²
19/6	0.074 x 10³	–	0.126 x 10²
20/6	0.078 x 10³	–	0.062 x 10²
21/6	0.062 x 10³	–	0.180 x 10²
22/6	0.004 x 10³	–	0.005 x 10²
23/6	0.040 x 10³	–	0.052 x 10²
24/6	0.241 x 10³	–	0.132 x 10²
25/6	0.059 x 10³	–	0.120 x 10²
26/6	0.043 x 10³	–	0.060 x 10²
27/6	0.197 x 10³	–	0.285 x 10²
4/7	0.013 x 10³	–	0.020 x 10²
5/7	0.959 x 10³	–	1.017 x 10²
6/7	1.070 x 10³	–	1.550 x 10²
7/7	5.800 x 10³	–	3.570 x 10²
8/7	0.978 x 10³	–	0.510 x 10²
9/7	0.799 x 10³	–	0.567 x 10²
10/7	1.110 x 10³	–	1.390 x 10²
11/7	0.330 x 10³	–	0.552 x 10²
12/7	0.023 x 10³	–	0.056 x 10²
13/7	0.156 x 10³	–	0.188 x 10²
14/7	0.196 x 10³	–	0.156 x 10²
15/7	0.113 x 10³	–	0.147 x 10²
16/7	5.490 x 10³	–	3.750 x 10²
17/7	3.917 x 10³	–	2.020 x 10²
18/7	4.770 x 10³	–	4.840 x 10²
19/7	0.237 x 10³	–	0.102 x 10²
20/7	0.101 x 10³	–	0.092 x 10²
21/7	0.061 x 10³	–	0.144 x 10²
29/7	0.067 x 10³	–	0.350 x 10²
30/7	0.004 x 10³	–	0.066 x 10²
1/8	0.119 x 10³	–	0.070 x 10²
2/8	0.084 x 10³	–	0.088 x 10²
3/8	0.004 x 10³	–	0.004 x 10²
4/8	0.002 x 10³	–	0.003 x 10²
5/8	0.038 x 10³	–	0.030 x 10²
6/8	35.900 x 10³	–	18.300 x 10²
7/8	0.086 x 10³	–	0.096 x 10²
8/8	0.005 x 10³	–	0.004 x 10²
9/8	1.100 x 10³	–	2.3 x 10²
10/8	0.132 x 10³	–	0.132 x 10²
11/8	0.369 x 10³	–	0.290 x 10²
12/8	0.494 x 10³	–	0.500 x 10²
13/8	3.323 x 10³	–	1.460 x 10²
14/8	0.022 x 10³	–	0.013 x 10²

16/8	0.005×10^3	–	0.014×10^2
17/8	0.029×10^3	–	0.096×10^2
20/8	0.016×10^3	–	0.020×10^2
24/8	0.680×10^3	–	0.470×10^2
11/9	0.317×10^3	–	0.386×10^2
12/9	0.536×10^3	–	1.600×10^2
13/9	0.316×10^3	–	0.144×10^2
14/9	0.118×10^3	–	0.160×10^2
15/9	0.029×10^3	–	0.036×10^2
17/9	0.023×10^3	–	0.048×10^2
18/9	1.010×10^3	–	0.410×10^2
19/9	1.340×10^3	1.100×10^2	2.700×10^2
21/9	0.049×10^3	–	0.115×10^2
23/9	0.084×10^3	–	0.030×10^2
24/9	6.910×10^3	–	4.680×10^2
25/9	0.096×10^3	–	0.232×10^2
26/9	0.011×10^3	–	0.028×10^2
27/9	0.049×10^3	–	0.060×10^2
28/9	0.003×10^3	–	0.008×10^2
1/10	0.007×10^3	–	0.005×10^2
2/10	0.001×10^3	–	0.004×10^2
3/10	0.008×10^3	–	0.004×10^2
4/10	1.990×10^3	–	0.890×10^2
6/10	0.924×10^3	–	0.180×10^2
8/10	1.600×10^3	–	0.960×10^2
9/10	3.800×10^3	–	1.300×10^2
10/10	0.214×10^3	–	0.234×10^2
11/10	0.003×10^3	–	0.006×10^2
13/10	1.840×10^3	–	0.760×10^2
14/10	0.320×10^3	–	0.120×10^2
15/10	0.002×10^3	–	0.120×10^2
17/10	0.162×10^3	–	0.074×10^2
18/10	0.008×10^3	–	0.016×10^2
19/10	0.012×10^3	–	0.005×10^2
20/10	0.007×10^3	–	0.008×10^2
22/10	0.376×10^3	–	0.195×10^2
23/10	0.914×10^3	–	0.930×10^2
24/10	0.580×10^3	–	0.340×10^2
25/10	5.652×10^3	–	2.710×10^2
26/10	4.990×10^3	–	2.760×10^2
27/10	0.113×10^3	–	0.056×10^2
1/11	0.602×10^3	–	0.410×10^2
2/11	0.465×10^3	–	0.364×10^2
3/11	0.120×10^3	–	0.602×10^2
5/11	0.005×10^3	–	0.004×10^2
6/11	1.400×10^3	–	0.640×10^2
8/11	4.400×10^3	–	2.600×10^2
9/11	9.300×10^3	–	4.140×10^2
10/11	0.220×10^3	–	0.126×10^2
13/11	0.019×10^3	–	0.012×10^2
15/11	5.600×10^3	–	4.700×10^2
16/11	0.046×10^3	–	0.840×10^2
19/11	1.200×10^3	–	0.960×10^2
20/11	1.476×10^3	–	0.990×10^2

23/11	10.000×10^3	–	4.030×10^2
24/11	19.000×10^3	–	4.100×10^2
25/11	0.007×10^3	–	0.010×10^2
26/11	3.110×10^3	–	1.400×10^2
27/11	1.400×10^3	–	0.882×10^2
28/11	1.180×10^3	–	0.702×10^2
29/11	0.006×10^3	–	0.005×10^2
1/12	0.027×10^3	–	0.022×10^2
2/12	0.173×10^3	–	0.074×10^2
3/12	0.004×10^3	–	0.024×10^2
4/12	4.710×10^3	–	0.604×10^2
5/12	0.006×10^3	–	0.005×10^2
6/12	0.027×10^3	–	0.003×10^2
8/12	4.200×10^3	–	5.340×10^2
9/12	7.298×10^3	–	8.580×10^2
11/12	0.004×10^3	–	0.080×10^2
12/12	0.095×10^3	–	0.180×10^2
16/12	0.002×10^3	–	0.002×10^2
17/12	0.403×10^3	–	0.240×10^2
18/12	0.011×10^3	–	0.030×10^2
29/12	0.342×10^3	–	0.024×10^2
Year : 1983			
21/2	16.300×10^3	2.500×10^2	9.000×10^2
28/2	0.005×10^3	–	0.004×10^2
28/3	43.000×10^3	5.600×10^2	26.400×10^2
26/4	0.332×10^3	–	0.024×10^2
28/4	0.014×10^3	–	0.024×10^2
2/5	0.007×10^3	–	0.010×10^2
6/5	0.210×10^3	–	0.250×10^2
7/5	10.000×10^3	–	2.100×10^2
16/5	4.400×10^3	–	2.240×10^2
17/5	1.600×10^3	–	3.800×10^2
18/5	47.000×10^3	7.500×10^2	18.000×10^2
20/5	0.022×10^3	–	0.020×10^2
22/5	5.900×10^3	–	3.020×10^2
23/5	0.011×10^3	–	0.026×10^2
24/5	0.230×10^3	–	0.027×10^2
26/5	0.004×10^3	–	0.0001×10^2
27/5	1.200×10^3	–	0.409×10^2
28/5	0.076×10^3	–	0.192×10^2
1/6	0.036×10^3	–	0.086×10^2
3/6	0.041×10^3	–	0.024×10^2
4/6	0.232×10^3	–	0.512×10^2
6/6	0.025×10^3	–	0.058×10^2
7/6	1.720×10^3	1.118×10^2	4.390×10^2
8/6	0.123×10^3	–	0.540×10^2
9/6	0.003×10^3	–	0.008×10^2
11/6	0.170×10^3	–	0.204×10^2
13/6	0.300×10^3	–	0.750×10^2
14/6	0.090×10^3	–	0.750×10^2
15/6	0.288×10^3	–	1.010×10^2

19/6	0.550 x 10^3	–	0.282 x 10^2
22/6	0.140 x 10^3	–	0.350 x 10^2
23/6	0.470 x 10^3	–	0.480 x 10^2
24/6	0.480 x 10^3	–	1.200 x 10^2
25/6	0.099 x 10^3	–	0.270 x 10^2
27/6	4.300 x 10^3	2.350 x 10^2	20.500 x 10^2
28/6	2.500 x 10^3	–	2.600 x 10^2
29/6	1.400 x 10^3	1.300 x 10^2	2.200 x 10^2
1/7	0.007 x 10^3	–	0.029 x 10^2
12/7	0.173 x 10^3	–	0.242 x 10^2
13/7	0.301 x 10^3	–	0.234 x 10^2
14/7	0.598 x 10^3	–	1.400 x 10^2
15/7	2.500 x 10^3	–	1.620 x 10^2
16/7	2.200 x 10^3	–	1.440 x 10^2
17/7	1.190 x 10^3	–	0.960 x 10^2
18/7	0.640 x 10^3	–	0.462 x 10^2
19/7	1.400 x 10^3	–	0.833 x 10^2
20/7	0.430 x 10^3	–	0.562 x 10^2
21/7	0.023 x 10^3	–	0.043 x 10^2
22/7	0.034 x 10^3	–	0.072 x 10^2
24/7	1.300 x 10^3	–	0.077 x 10^2
27/7	5.600 x 10^3	–	4.270 x 10^2
28/7	0.026 x 10^3	–	0.020 x 10^2
2/8	0.096 x 10^3	–	0.058 x 10^2
3/8	0.017 x 10^3	–	0.008 x 10^2
4/8	0.030 x 10^3	–	0.025 x 10^2
6/8	0.067 x 10^3	–	0.079 x 10^2
7/8	0.034 x 10^3	–	0.042 x 10^2
8/8	0.021 x 10^3	–	0.060 x 10^2
12/8	0.049 x 10^3	–	0.055 x 10^2
13/8	6.150 x 10^3	–	3.440 x 10^2
14/8	0.302 x 10^3	–	0.420 x 10^2
15/8	0.051 x 10^3	–	0.080 x 10^2
16/8	1.500 x 10^3	–	3.570 x 10^2
17/8	0.776 x 10^3	–	0.670 x 10^2
18/8	5.200 x 10^3	–	4.290 x 10^2
19/8	5.999 x 10^3	–	2.272 x 10^2
20/8	0.836 x 10^3	–	3.140 x 10^2
21/8	0.159 x 10^3	–	0.180 x 10^2
22/8	0.001 x 10^3	–	0.001 x 10^2
24/8	0.082 x 10^3	–	0.115 x 10^2
31/8	0.001 x 10^3	–	0.001 x 10^2
2/9	0.005 x 10^3	–	0.013 x 10^2
4/9	5.599 x 10^3	–	2.980 x 10^2
5/9	0.002 x 10^3	–	0.009 x 10^2
6/9	0.113 x 10^3	–	2.240 x 10^2
7/9	0.001 x 10^3	–	0.001 x 10^2
8/9	0.117 x 10^3	–	0.097 x 10^2
9/9	0.001 x 10^3	–	0.006 x 10^2
10/9	0.514 x 10^3	–	0.488 x 10^2
11/9	0.011 x 10^3	–	0.021 x 10^2
12/9	0.002 x 10^3	–	0.004 x 10^2
16/9	0.006 x 10^3	–	0.004 x 10^2
18/9	0.419 x 10^3	–	0.230 x 10^2

19/9	0.255 x 10^3	-	0.169 x 10^2
20/9	2.190 x 10^3	-	0.667 x 10^2
21/9	1.380 x 10^3	-	0.996 x 10^2
22/9	4.761 x 10^3	-	1.980 x 10^2
23/9	1.712 x 10^3	-	1.270 x 10^2
24/9	0.745 x 10^3	-	1.140 x 10^2
25/9	0.129 x 10^3	-	0.112 x 10^2
26/9	0.0054 x 10^3	-	0.012 x 10^2
27/9	0.028 x 10^3	-	0.073 x 10^2
2/10	0.002 x 10^3	-	0.004 x 10^2
3/10	0.019 x 10^3	-	0.072 x 10^2
4/10	0.081 x 10^3	-	0.090 x 10^2
9/10	0.107 x 10^3	-	0.097 x 10^2
10/10	5.668 x 10^3	-	1.840 x 10^2
11/10	0.939 x 10^3	-	0.460 x 10^2
12/10	47.720 x 10^3	-	10.160 x 10^2
15/10	0.001 x 10^3	-	0.003 x 10^2
17/10	0.002 x 10^3	-	0.001 x 10^2
18/10	0.032 x 10^3	-	0.026 x 10^2
19/10	0.072 x 10^3	-	0.042 x 10^2
20/10	0.249 x 10^3	-	0.492 x 10^2
21/10	1.183 x 10^3	-	0.495 x 10^2
28/10	1.313 x 10^3	-	0.963 x 10^2
29/10	0.030 x 10^3	-	0.023 x 10^2
30/10	0.202 x 10^3	-	0.326 x 10^2
31/10	18.924 x 10^3	-	10.540 x 10^2
1/11	0.637 x 10^3	-	0.263 x 10^2
2/11	9.398 x 10^3	-	8.410 x 10^2
3/11	0.917 x 10^3	-	0.330 x 10^2
4/11	2.853 x 10^3	-	1.730 x 10^2
5/11	0.591 x 10^3	-	0.382 x 10^2
6/11	0.091 x 10^3	-	0.534 x 10^2
16/11	0.010 x 10^3	-	5.340 x 10^2
18/11	10.800 x 10^3	2.215 x 10^2	9.350 x 10^2
19/11	4.517 x 10^3	-	1.880 x 10^2
20/11	0.019 x 10^3	-	0.336 x 10^2
29/11	0.108 x 10^3	-	0.563 x 10^2
30/11	0.966 x 10^3	-	0.824 x 10^2
2/12	3.768 x 10^3	-	2.270 x 10^2
6/12	0.345 x 10^3	-	1.646 x 10^2
7/12	0.054 x 10^3	-	0.036 x 10^2
8/12	0.016 x 10^3	-	0.024 x 10^2
9/12	0.007 x 10^3	-	0.005 x 10^2
10/12	0.499 x 10^3	-	2.176 x 10^2
13/12	1.008 x 10^3	-	0.352 x 10^2
14/12	2.313 x 10^3	-	0.109 x 10^2
15/12	4.878 x 10^3	-	0.197 x 10^2
16/12	0.136 x 10^3	-	0.089 x 10^2
17/12	0.089 x 10^3	-	0.060 x 10^2
18/12	0.026 x 10^3	-	0.030 x 10^2
19/12	0.135 x 10^3	-	0.043 x 10^2
20/12	0.228 x 10^3	-	1.115 x 10^2
21/12	26.510 x 10^3	-	7.350 x 10^2
22/12	0.023 x 10^3	-	0.034 x 10^2

23/12	0.935×10^3	–	0.439×10^2
24/12	0.969×10^3	–	0.298×10^2
25/12	4.088×10^3	–	1.539×10^2
26/12	0.005×10^3	–	0.003×10^2
28/12	0.152×10^3	–	7.250×10^2
29/12	0.212×10^3	–	0.690×10^2
Year : 1984			
3/1	2.604×10^3	–	0.259×10^2
5/1	0.029×10^3	–	0.075×10^2
6/1	1.359×10^3	–	1.760×10^2
10/1	0.514×10^3	–	0.835×10^2
11/1	0.610×10^3	–	0.829×10^2
12/1	0.003×10^3	–	0.016×10^2
13/1	0.007×10^3	–	0.009×10^2
14/1	3.793×10^3	–	1.809×10^2
16/1	0.029×10^3	–	0.014×10^2
17/1	1.589×10^3	–	1.304×10^2
18/1	10.030×10^3	–	2.148×10^2
19/1	0.061×10^3	–	0.024×10^2
20/1	1.741×10^3	–	0.435×10^2
25/1	0.444×10^3	–	0.101×10^2
29/1	1.046×10^3	–	0.141×10^2
4/2	1.720×10^3	–	0.829×10^2
5/2	0.781×10^3	–	0.214×10^2
6/2	0.022×10^3	–	0.003×10^2
7/2	0.028×10^3	–	0.027×10^2
8/2	0.249×10^3	–	0.058×10^2
9/2	0.469×10^3	–	0.136×10^2
10/2	0.493×10^3	–	0.105×10^2
11/2	0.840×10^3	–	0.250×10^2
12/2	0.528×10^3	–	0.074×10^2
13/2	5.616×10^3	–	0.480×10^2
14/2	1.239×10^3	–	0.377×10^2
15/2	13.260×10^3	–	0.965×10^2
17/2	0.780×10^3	–	0.156×10^2
18/2	7.847×10^3	–	0.588×10^2
19/2	0.005×10^3	–	0.064×10^2
20/2	0.034×10^3	–	0.390×10^2
28/2	0.010×10^3	–	0.096×10^2
1/3	0.432×10^3	–	0.026×10^2
2/3	2.052×10^3	–	0.700×10^2
3/3	0.027×10^3	–	0.011×10^2
4/3	1.060×10^3	–	0.257×10^2
5/3	3.369×10^3	–	0.612×10^2
6/3	1.789×10^3	–	0.489×10^2
7/3	0.007×10^3	–	0.004×10^2
8/3	5.845×10^3	–	1.659×10^2
9/3	1.576×10^3	–	0.664×10^2
20/3	0.002×10^3	–	0.003×10^2
21/3	5.000×10^3	2.500×10^2	3.990×10^2
26/3	26.120×10^3	–	0.980×10^2
28/3	0.644×10^3	–	0.804×10^2
29/3	1.193×10^3	–	0.183×10^2
30/3	1.015×10^3	–	1.021×10^2

2/4	0.846 x 10^3	–	0.498 x 10^2
3 /4	0.017 x 10^3	–	0.002 x 10^2
4/4	28.776 x 10^3	–	11.995 x 10^2
5/4	0.829 x 10^3	–	0.860 x 10^2
6/4	1.588 x 10^3	–	0.304 x 10^2
12/4	3.136 x 10^3	–	0.372 x 10^2
13/4	0.006 x 10^3	–	0.053 x 10^2
14/4	5.343 x 10^3	–	2.295 x 10^2
15/4	20.872 x 10^3	–	4.507 x 10^2
16/4	7.079 x 10^3	–	3.499 x 10^2
17/4	5.347 x 10^3	–	4.756 x 10^2
18/4	6.458 x 10^3	–	1.411 x 10^2
19/4	5.664 x 10^3	–	0.619 x 10^2
20/4	0.032 x 10^3	–	0.034 x 10^2
21/4	0.012 x 10^3	–	0.016 x 10^2
22/4	3.636 x 10^3	–	0.990 x 10^2
24/4	0.700 x 10^3	–	0.210 x 10^2
30/4	0.005 x 10^3	–	0.004 x 10^2
1/5	0.082 x 10^3	–	0.051 x 10^2
8/5	0.024 x 10^3	–	0.009 x 10^2
9/5	0.002 x 10^3	–	0.001 x 10^2
10/5	0.034 x 10^3	–	0.002 x 10^2
16/5	3.766 x 10^3	–	0.690 x 10^2
17/5	1.291 x 10^3	–	0.349 x 10^2
18/5	7.602 x 10^3	–	3.422 x 10^2
19/5	0.696 x 10^3	–	0.477 x 10^2
21/5	1.151 x 10^3	–	0.030 x 10^2
28/5	3.941 x 10^3	–	1.033 x 10^2
29/5	0.104 x 10^3	–	0.360 x 10^2
30/5	0.230 x 10^3	–	0.022 x 10^2
31/5	3.219 x 10^3	–	2.573 x 10^2
1/6	2.693 x 10^3	–	1.432 x 10^2
2/6	1.222 x 10^3	–	1.930 x 10^2
3/6	4.884 x 10^3	–	0.936 x 10^2
5/6	0.009 x 10^3	–	0.014 x 10^2
6/6	0.773 x 10^3	–	2.340 x 10^2
7/6	4.282 x 10^3	–	3.698 x 10^2
8/6	0.203 x 10^3	–	0.111 x 10^2
10/6	0.459 x 10^3	–	0.230 x 10^2
11/6	0.797 x 10^3	–	0.352 x 10^2
12/6	0.889 x 10^3	–	0.390 x 10^2
13/6	1.138 x 10^3	–	1.304 x 10^2
14/6	0.118 x 10^3	–	0.090 x 10^2
15/6	0.161 x 10^3	–	0.513 x 10^2
16/6	0.509 x 10^3	–	0.497 x 10^2
17/6	1.376 x 10^3	–	1.453 x 10^2
18/6	0.005 x 10^3	–	0.134 x 10^2
19/6	0.057 x 10^3	–	0.288 x 10^2
20/6	0.004 x 10^3	–	0.089 x 10^2
21/6	0.007 x 10^3	–	0.022 x 10^2
22/6	0.020 x 10^3	–	0.050 x 10^2
23/6	0.388 x 10^3	–	0.514 x 10^2
24/6	0.635 x 10^3	–	1.752 x 10^2
25/6	0.249 x 10^3	–	0.312 x 10^2

26/6	2.039 x 10^3	–	1.343 x 10^2
27/6	1.008 x 10^3	–	0.299 x 10^2
28/6	2.644 x 10^3	–	2.256 x 10^2
29/6	0.009 x 10^3	–	0.076 x 10^2
30/6	2.183 x 10^3	–	1.580 x 10^2
1/7	6.329 x 10^3	–	2.187 x 10^2
2/7	0.689 x 10^3	–	0.302 x 10^2
3/7	1.106 x 10^3	–	1.593 x 10^2
4/7	18.640 x 10^3	–	15.950 x 10^2
5/7	20.932 x 10^3	–	3.905 x 10^2
6/7	0.438 x 10^3	–	0.888 x 10^2
7/7	0.044 x 10^3	–	0.055 x 10^2
8/7	0.219 x 10^3	–	0.083 x 10^2
9/7	6.140 x 10^3	–	1.420 x 10^2
10/7	1.200 x 10^3	–	0.504 x 10^2
11/7	2.160 x 10^3	–	0.660 x 10^2
12/7	5.834 x 10^3	–	2.098 x 10^2
13/7	0.479 x 10^3	–	0.499 x 10^2
14/7	1.301 x 10^3	–	0.626 x 10^2
15/7	0.752 x 10^3	–	0.851 x 10^2
16/7	0.340 x 10^3	–	0.106 x 10^2
18/7	0.447 x 10^3	–	0.630 x 10^2
19/7	0.229 x 10^3	–	0.195 x 10^2
20/7	3.290 x 10^3	–	2.030 x 10^2
21/7	0.557 x 10^3	–	0.235 x 10^2
24/7	0.171 x 10^3	–	8.120 x 10^2
25/7	0.116 x 10^3	–	0.2583 x 10^2
27/7	0.001 x 10^1	–	0.019 x 10^2
28/7	0.091 x 10^3	–	0.050 x 10^2
29/7	0.068 x 10^3	–	0.077 x 10^2
30/7	0.053 x 10^3	–	0.120 x 10^2
2/8	0.002 x 10^3	–	0.002 x 10^2
3/8	0.004 x 10^3	–	0.004 x 10^2
4/8	0.225 x 10^3	–	0.159 x 10^2
5/8	5.099 x 10^3	–	2.405 x 10^2
6/8	0.017 x 10^3	–	0.051 x 10^2
7/8	0.034 x 10^3	–	0.083 x 10^2
8/8	0.548 x 10^3	–	0.320 x 10^2
9/8	13.662 x 10^3	–	2.839 x 10^2
10/8	0.005 x 10^3	–	0.051 x 10^2
15/8	0.054 x 10^3	–	0.026 x 10^2
16/8	0.007 x 10^3	–	0.012 x 10^2
17/8	0.004 x 10^3	–	7.800 x 10^2
24/8	10.740 x 10^3	–	6.750 x 10^2
26/8	0.027 x 10^3	–	0.062 x 10^2
27/8	0.006 x 10^3	–	0.001 x 10^2
28/8	0.001 x 10^3	–	0.001 x 10^2
29/8	0.003 x 10^3	–	0.002 x 10^2
1/9	0.265 x 10^3	–	0.164 x 10^2
2/9	0.282 x 10^3	–	0.216 x 10^2
3/9	0.042 x 10^3	–	0.044 x 10^2
4/9	0.001 x 10^3	–	0.001 x 10^2
5/9	0.001 x 10^3	–	0.001 x 10^2
9/9	0.001 x 10^3	–	0.001 x 10^2

15/9	9.388×10^3	-	4.394×10^2
16/9	0.129×10^3	-	0.035×10^2
19/9	0.829×10^3	-	0.056×10^2
20/9	0.566×10^3	-	0.139×10^2
21/9	31.440×10^3	-	5.650×10^2
22/9	32.380×10^3	-	0.207×10^2
23/9	2.835×10^3	-	0.827×10^2
24/9	1.675×10^3	-	0.420×10^2
25/9	0.242×10^3	-	0.182×10^2
26/9	1.067×10^3	-	1.003×10^2
27/9	30.600×10^3	-	14.990×10^2
28/9	9.466×10^3	-	7.613×10^2
29/9	0.375×10^3	-	0.673×10^2
30/9	1.292×10^3	-	0.729×10^2
1/10	2.272×10^3	-	0.863×10^2
2/10	0.461×10^3	-	0.334×10^2
3/10	0.082×10^3	-	0.084×10^2
4/10	0.00001×10^3	-	0.061×10^2
5/10	0.915×10^3	-	0.428×10^2
6/10	0.149×10^3	-	0.002×10^2
7/10	0.043×10^3	-	0.102×10^2
8/10	0.929×10^3	-	0.770×10^2
9/10	0.053×10^3	-	0.064×10^2
10/10	0.007×10^3	-	0.008×10^2
11/10	0.002×10^3	-	0.001×10^2
12/10	0.280×10^3	-	2.145×10^2
13/10	0.200×10^3	-	0.176×10^2
17/10	0.005×10^3	-	0.047×10^2
20/10	0.027×10^3	-	0.017×10^2
21/10	0.048×10^3	-	0.143×10^2
22/10	0.753×10^3	-	0.306×10^2
26/10	0.637×10^3	-	0.762×10^2
27/10	0.081×10^3	-	0.168×10^2
28/10	2.538×10^3	-	1.335×10^2
29/10	0.747×10^3	-	0.244×10^2
5/11	3.512×10^3	-	0.507×10^2
8/11	0.238×10^3	-	0.109×10^2
9/11	0.012×10^3	-	0.096×10^2
10/11	0.752×10^3	-	0.230×10^2
12/11	2.093×10^3	-	0.720×10^2
13/11	1.832×10^3	-	0.518×10^2
14/11	6.339×10^3	-	0.984×10^2
15/11	0.081×10^3	-	0.090×10^2
16/11	0.003×10^3	-	0.003×10^2
17/11	0.009×10^3	-	0.213×10^2
18/11	0.003×10^3	-	0.001×10^2
19/11	0.400×10^3	-	0.199×10^2
20/11	3.652×10^3	-	0.510×10^2
21/11	0.005×10^3	-	0.005×10^2
23/11	0.006×10^3	-	0.008×10^2
25/11	0.001×10^3	-	0.001×10^2
26/11	0.072×10^3	-	0.128×10^2
27/11	0.076×10^3	-	0.128×10^2
28/11	3.907×10^3	-	1.221×10^2

9/12	0.252×10^3	-	0.132×10^2
10/12	0.016×10^3	-	0.019×10^2
21/12	1.678×10^3	-	1.488×10^2
23/12	4.457×10^3	-	1.248×10^2
24/12	0.891×10^3	-	0.223×10^2
26/12	0.171×10^3	-	0.122×10^2
27/12	0.738×10^3	-	1.504×10^2
28/12	0.001×10^3	-	0.001×10^2
31/12	0.285×10^3	-	0.175×10^2

Appendix E

ESTIMATION OF SOIL LOSS IN LATERAL DRAINS (ST. COOMBS) FOR THE PERIOD SEPTEMBER 1981 TO DECEMBER 1982.

Plot No.	Plot area	Soil Loss	
	m^2	kg/plot	Mg ha^{-1}
C1	3343	2831.1	8.5
C2	3166	2003.1	6.3
S1	5071	6009.8	11.85
S2	4377	5186.6	11.85

Appendix F

ESTIMATION OF SOIL LOSS IN LATERAL DRAINS (ST. COOMBS) FOR THE PERIOD JUNE TO DECEMBER 1984.

Plot No.	Plot area	Soil Loss	
	m^2	kg/plot	Mg/ha
C1	3343	78.97	0.24
C2	3166	56.78	0.18
S1	5071	160.91	0.32
S2	4377	98.95	0.22

Appendix G

SOIL TEXTURE AND ORGANIC MATTER OF ERODED SOIL AND FIELD SOIL - ST. COOMBS.

Period: June to December 1984

Plot No.	Sample No.	sand %	silt %	clay %	O.M %	Erosion ratio	Enrichment ratio
C1	1 Field	58.75	16.65	24.60	2.185		
	Drain	34.50	20.01	45.49	1.725	2.704	0.793
C1	2 Field	38.75	28.33	42.92	2.775		
	Drain	25.25	24.64	50.11	-	1.610	-
C1	3 Field	58.75	16.65	24.60	2.250		
	Drain	43.75	27.00	29.25	1.725	1.8312	0.767
C1	4 Field	28.75	28.33	42.92	2.775		
	Drain	25.25	24.64	50.11	1.125	1.1945	0.405
C1	5 Field	48.75	37.44	13.81	2.220		
	Drain	25.00	37.42	37.58	2.250	2.8536	1.013
C1	6 Field	20.00	53.00	27.05	1.800		
	Drain	28.75	17.00	54.25	1.875	0.619	1.042
C2	1 Field	27.50	21.22	51.28	-		
	Drain	26.25	26.30	52.45	1.200	1.138	-
C2	2 Field	33.75	13.64	52.56	1.875		
	Drain	38.75	21.20	40.05	2.475	0.8058	1.320
C2	3 Field	21.25	21.06	57.69	2.625		
	Drain	32.50	15.83	51.67	1.125	0.560	0.428
C2	4 Field	21.25	21.06	57.69	2.625		
	Drain	30.00	16.50	53.50	1.875	0.6296	0.714
C2	5 Field	27.50	20.47	52.03	1.800		
	Drain	26.25	19.50	54.25	2.625	1.066	1.458
C2	6 Field	25.00	20.28	54.72	1.800		
	Drain	28.75	17.75	53.50	2.250	0.826	1.280
C2	7 Field	26.25	20.88	52.87	2.025		
	Drain	21.25	26.93	51.82	3.525	1.319	1.741
S1	1 Field	37.00	23.45	39.55	5.175		
	Drain	38.00	9.97	52.03	2.625	0.958	0.507

S1	2 Field	32.00	21.16	46.84	1.125		
	Drain	32.50	19.66	47.84	4.425	0.977	3.933
S1	3 Field	45.75	21.73	32.52	4.425		
	Drain	26.25	21.46	52.29	2.100	2.3693	0.474
S1	4 Field	35.75	32.74	31.51	4.425		
	Drain	23.75	34.27	39.48	3.225	1.728	0.729
S1	5 Field	37.50	37.30	25.20	4.425		
	Drain	33.75	19.75	46.51	2.925	1.178	0.661
S1	6 Field	22.50	48.28	29.24	-		
	Drain	51.25	21.39	27.34	-	0.276	-
S1	7 Field	62.00	6.81	31.19	-		
	Drain	55.00	21.24	23.76	-	1.335	-
S1	8 Field	32.50	43.94	23.56	-		
	Drain	65.00	19.91	15.09	-	0.259	-
S2	1 Field	47.50	29.99	22.51	5.750		
	Drain	37.50	34.20	28.31	3.900	1.508	0.678
S2	2 Field	47.50	29.99	22.51	5.750		
	Drain	21.25	55.21	23.54	3.300	3.353	0.574
S2	3 Field	37.50	47.15	21.35	3.900		
	Drain	40.00	20.32	39.68	3.525	0.8211	0.904
S2	4 Field	38.50	35.60	26.90	4.175		
	Drain	51.25	12.80	29.70	3.750	0.511	0.898
S2	5 Field	33.73	46.15	20.09	2.625		
	Drain	41.25	47.73	11.02	3.750	0.726	1.43
S2	6 Field	57.50	19.83	22.67	2.625		
	Drain	32.52	22.82	44.62	3.225	2.806	1.230
S2	7 Field	42.50	15.80	41.70	3.788		
	Drain	23.75	30.76	27.92	4.275	1.826	1.129

Appendix H

NUTRIENT ANALYSIS IN ERODED SOIL - ST. COOMBS.

(Data used for Table 9) Period: June to December 1984

Plot No.	Drain No.	Soil Loss kg ha^{-1}	N %	P ppm	K ppm	Org. C %
C1	1L	6.52	0.13	440	20.84	3.45
	1L	1.54	0.04	440	12.90	3.07
	3L	7.56	0.09	440	16.87	3.26
	1R	25.55	0.15	180	8.13	2.70
	2R	3.71	0.10	370	19.95	2.78
	3R	34.09	0.05	560	31.76	2.85
C2	1L	2.80	0.31	460	20.25	4.42
	2L	8.65	0.31	460	20.25	4.42
	3L	13.65	0.31	460	20.25	4.42
	1R	2.38	0.17	200	4.96	3.15
	2R	7.94	0.19	340	23.82	4.72
	3R	21.36	0.16	480	22.63	2.92
S1	1L	9.75	0.05	380	9.38	3.37
	2L	11.84	0.05	380	9.38	3.40
	3L	6.78	0.04	420	12.11	3.52
	4L	12.27	0.05	380	9.38	3.37
	5L	10.63	0.50	380	9.38	3.40
	6L	29.90	0.06	340	6.65	3.22
	7L	20.81	0.13	300	18.36	4.50
	1R	6.50	0.30	300	9.60	2.98
	2R	6.42	0.03	280	8.73	2.89
	3R	6.03	0.30	300	9.60	2.98
	4R	8.09	0.08	320	10.42	3.07
	5R	9.43	0.03	280	8.73	2.89
	6R	22.46	0.08	320	10.42	3.07
S2	1R	6.85	0.25	400	65.50	2.85
	2R	8.81	0.25	400	65.50	2.85
	3R	8.63	0.25	240	14.88	4.35
	4R	13.87	0.25	240	14.88	4.35
	5R	10.54	0.08	260	6.95	5.10
	6R	10.47	0.08	480	67.88	4.42
	1L	5.6	0.28	300	15.88	5.66
	2L	4.86	0.28	300	15.88	5.66
	3L	6.40	0.28	300	15.88	5.66
	4L	5.23	0.08	200	5.06	3.67
	5L	6.55	0.08	200	5.06	3.67

6L	5.01	0.24	430	5.95	2.92
7L	6.13	0.24	430	5.95	2.92

Appendix I

NUTRIENT ANALYSIS OF ERODED SOIL - UVA EXPERIMENTS.

Period: 1st November 1984 - 31st January 1985.

Location/ plot No.	Drain No.	Soil loss kg	N %	P ppm	K ppm	C %
Young tea no mulch	1L	179.19	0.06	28.78	100	4.20
	2L	124.83	0.01	40.69	100	2.55
	3L	103.67	0.06	28.78	100	2.47
Young tea with mulch	1R	111.63	0.10	35.73	100	1.42
	2R	96.69	0.02	19.85	100	2.47
	3R	158.91	0.08	35.73	112.50	1.57
100 year old seedling tea	1L	24.96	0.17	142.92	250	3.30
	2L	14.05	0.02	174.68	362.5	3.37
	3L	10.86	0.06	230.26	312.00	2.88
	1R	35.15	0.28	259.24	212.50	3.37
	2R	8.60	0.12	63.52	337.50	4.65
	3R	9.3	0.11	142.92	337.50	3.00
40 year old seedling tea	1L	72.33	0.01	70.37	312.50	2.92
	2L	42.89	0	91.31	275.00	2.32
	3L	105.41	0.16	45.65	237.50	2.02
	1R	80.02	0.14	24.81	112.50	1.20
	2R	75.95	0.12	75.43	212.50	2.25
	3R	62.89	0.16	32.75	150.00	2.51
New Clearing	1L	57.32	0.55	50.67	75.00	2.02
	2L	123.81	0.43	33.85	87.50	1.09
	3L	103.31	0.48	65.01	100.00	2.19
	4L	80.20	0.42	83.37	100.00	1.81
	1R	46.09	0.50	40.50	75.00	2.10
	2R	48.93	0.26	27.79	50.00	0.60
	3R	84.18	0.28	72.46	100.00	1.05
	4R	93.87	0.52	62.53	350.00	1.27
Seedling tea, pruned	1L	31.95	0.44	94.29	275.00	3.00
	2L	29.15	0.42	99.45	250.00	3.60
	3L	113.33	0.39	48.63	125.00	1.50
	1R	92.50	0.48	88.82	238.00	3.30
	2R	150.99	0.46	66.49	225.00	3.30

3R	62.12	0.51	111.16	250.00	3.40

Appendix J

CONSERVATION SUPPORT PRACTICE FACTOR (P) USED IN THE USLE.

(source: Hamer, 1980)

No.	Conservation Practice	P value
1.	Bench terraces:	
	- high standard design/construction	0.04
	- medium standard design/construction	0.15
	- low standard design/construction	0.35
2.	Traditional terrace	0.40
3.	Hillside trenches (silt pit)	0.30
4.	Contour cropping:	
	- 0-8% slope	0.50
	- 9-20% slope	0.75
	- higher than 20% slope	0.90

Appendix K

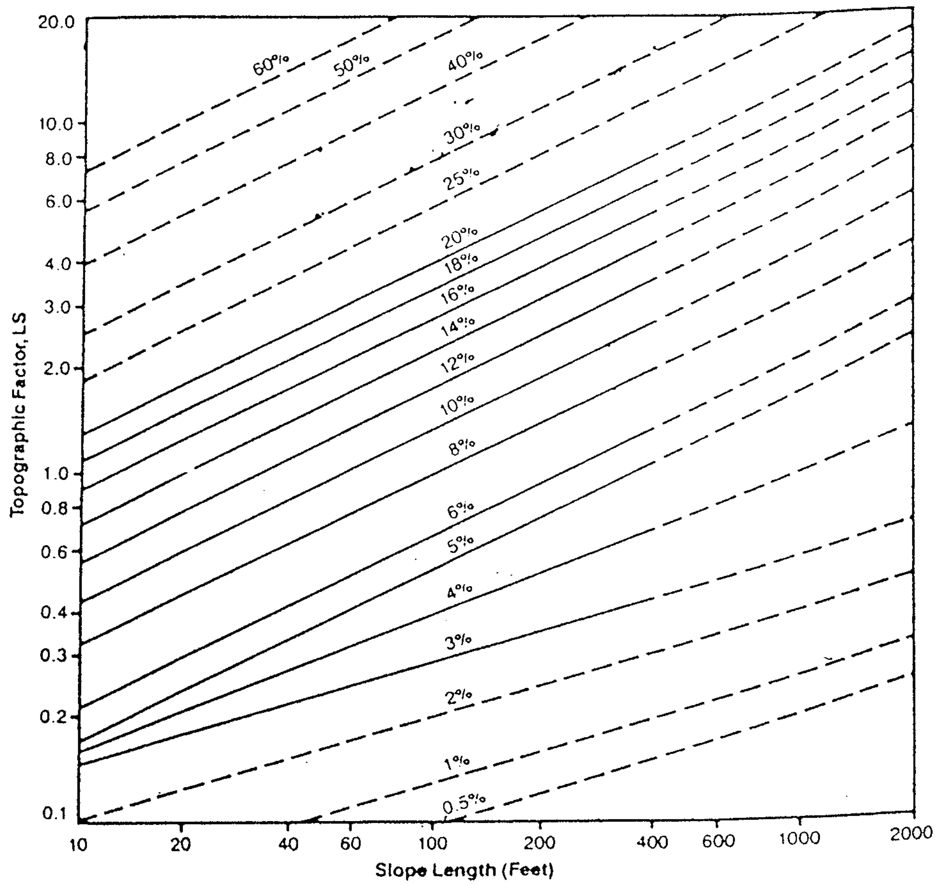
THE CROP COVER FACTOR (C) USED IN THE USLE.

(source : Krishnarajah 1984)

Practice	Annual Average C factor
Bare soil	1
Forest or dense shrub, high mulch crops	0.01
Savannah, prairie in good condition	0.01
Over-grazed savannah or prairie	0.1
Crop cover of slow development/late planting (1st year)	0.3 - 0.8
Crop cover of rapid development/early planting (1st year)	0.01- 0.1
Crop cover of slow development/late planting (2nd year)	0.01- 0.1
Corn, sorghum, millet (as a function of yield)	0.4 - 0.9
Rice (intensive fertilization)	0.1 - 0.2
Cotton - tobacco (second cycle)	0.5 - 0.7
Peanuts (as a function of yield and date of planting)	0.4 - 0.8
First year cassava and yam (as a function of date of planting	0.2 - 0.8
Palm tree, coffee, cocoa with crop cover	0.1 - 0.3
Pinapple on contour (as a function of slope)	
(burned residue)	0.2 - 0.5
(buried residue)	0.1 - 0.3
(surface residue)	0.01

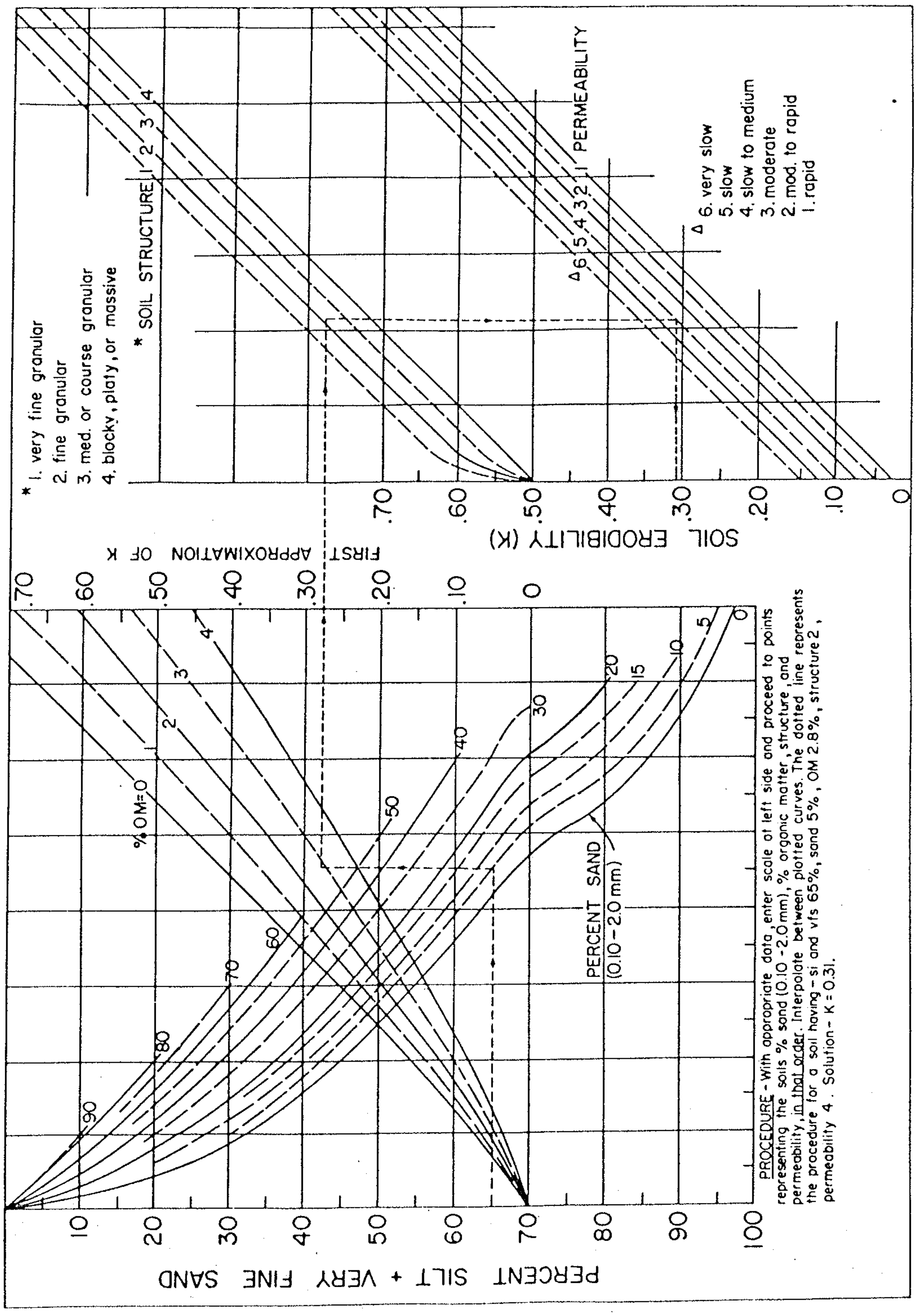
Appendix L

TOPOGRAPHY CHART FOR ESTIMATING THE LS FACTOR IN THE USLE.



Appendix M

NOMOGRAPH FOR ESTIMATING THE ERODIBILITY FACTOR (K) IN THE USLE.



Appendix N

SOIL NUTRIENT CONTENT IN TEA PLOTS BEFORE AND AFTER A FERTILIZER APPLICATION - ST. COOMBS.

Plot	Depth	N		P		K	
		before	after	before	after	before	after
C1	0-15 cm	0.157	0.227	4.8	44.1	64.0	207.5
	15-30 cm	0.150	0.217	12.9	25.7	104.0	133.8
C2	0-15 cm	0.165	0.292	15.2	52.8	103.3	143.5
	15-30 cm	0.165	0.204	11.2	21.6	106.3	120.0
S1	0-15 cm	0.217	0.218	13.9	18.0	125.0	136.8
	15-30 cm	0.207	0.213	7.0	8.0	91.3	112.5
S2	0-15 cm	0.159	0.247	8.0	9.9	92.5	105.8
	15-30 cm	0.180	0.185	5.7	16.2	64.0	92.5

units : ppm

Appendix O

NUTRIENT CONCENTRATIONS IN RUN OFF FROM TEA PLOTS - 1982.

Treatment : Clonal tea

Date	C1				C2			
	Runoff	Nutrient conc.(ppm)			Runoff	Nutrient conc.(ppm)		
	volume (l)	N	P	K	volume (l)	N	P	K
1/5	21.55	14.45	2.5	4.0	16.35	14.45	2.0	3.3
10/5	67.85	15.0	t	14.3	42.58	15.0	t	11.71
12/5	49.79	15.0	t	34.0	38.1	15.0	t	58.25
13/5	65.40	14.45	t	11.25	47.8	14.45	t	9.38
14/5	382.23	14.45	t	8.75	467.66	14.45	t	10.75
18/5	47.04	14.45	3.5	5.2	30.7	14.45	5.5	4.0
19/5	252.9	15.0	t	9.25	192.3	15.0	t	8.13
21/5	79.0	14.45	t	5.0	66.9	14.45	t	4.75
22/5	75.06	14.45	t	3.10	467.66	14.45	t	10.75
23/5	11.67	14.45	t	8.3	7.2	15.0	t	11.3
24/5	33.7	14.45	t	8.2	26.8	14.45	2.0	8.3
25/5	68.6	14.45	t	5.0	57.4	15.0	t	4.5
27/5	788.1	14.00	3.7	1.75	794.75	14.0	3.6	2.0
28/5	85.5	14.0	t	2.25	66.7	14.0	t	2.5
30/5	66.0	14.0	3.8	5.5	48.8	14.0	0	6.1
31/5	173.4	14.0	0	3.6	167.4	14.0	0	2.5
1/6	785.3	t	3.9	1.9	812.6	t	4.4	2.25
2/6	244.0	t	0	2.4	206.0	t	0	2.25

3/6	66.8	0	0	3.5	77.8	0	0	4.25
4/6	524.3	0	0	2.7	375.8	0	0	2.9
5/6	707.9	0	0	2.6	670.7	0	0	4.3
6/6	21.32	0	0	4.75	13.9	0	0	4.6
7/6	28.9	0	0	6.0	21.0	0	0	5.5
8/6	315.1	0	0	2.6	254.4	0	0	2.6
9/6	139.4	0	0	2.6	118.2	0	0	2.6
10/6	31.7	0	0	5.4	25.3	0	0	4.9
19/6	15.3	0	0	11.5	11.7	0	0	13.0
20/6	13.4	0	0	11.25	9.7	0	0	9.75
21/6	16.06	0	0	10.3	8.4	0	0	9.65
23/6	11.4	0	0	14.1	5.4	0	0	15.75
24/6	17.3	0	0	12.0	11.4	0	0	9.75
25/6	21.0	0	0	10.6	18.1	0	0	10.6
26/6	12.1	0	0	12.0	18.1	0	0	11.0
27/6	26.2	0	0	9.25	20.6	0	0	9.25
5/7	73.4	0	t	11.1	59.9	0	t	8.75
6/7	58.5	14.0	1.09	6.25	53.3	14.0	0.77	6.6
7/7	173.5	14.0	2.5	4.75	179.1	14.0	1.25	4.25
8/7	136.7	14.0	3.1	4.25	124.1	14.0	1.4	3.9
9/7	44.07	14.0	0.93	5.75	44.6	14.0	0.93	4.5
10/7	64.6	0	0	5.1	55.7	0	0	4.75
11/7	47.8	0	0	5.75	38.4	0	0	6.0
10/11	53.5	14.0	t	4.4	42.0	14.0	t	3.75
15/11	235.48	14.0	t	4.5	124.9	14.0	t	4.1
23/11	260.86	14.0	t	t	196.7	14.0	t	t
24/11	354.5	14.0	t	3.75	279.4	14.0	t	4.6
26/11	117.4	14.0	t	3.5	83.2	14.0	t	4.25

27/11	414.5	t	0.93	2.5	313.6	t	0.93	3.0
1/12	2.0	14.0	1.4	7.6	0.6	14.0	0.93	8.5
2/12	31.2	14.0	0.93	5.9	22.8	14.0	0.09	5.75
4/12	203.4	14.0	1.25	3.5	206.6	14.0	0.93	4.7
8/12	141.4	t	2.8	3.6	121.4	t	1.4	4.25
9/12	282.9	t	2.8	1.75	345.1	t	1.56	2.0
11/12	23.5	t	2.18	2.75	17.3	t	0.93	3.7
17/12	141.3	t	2.2	7.25	30.5	t	0.93	5.4
18/12	9.9	t	1.7	7.25	5.2	t	0.93	12.15
29/12	11.1	t	1.56	16.1	2.2	t	0.93	16.6

Treatment : Seedling tea

Date	C1				C2			
	Runoff volume(l)	Nutrient conc.(ppm) N	P	K	Runoff volume(l)	Nutrient conc.(ppm) N	P	K
1/5	17.09	14.45	1.5	5.5	14.6	14.45	1.5	7.2
10/5	8.7	t	t	t	10.63	t	t	t
12/5	46.6	t	t	t	40.65	t	t	t
13/5	44.4	14.45	t	7.5	36.7	14.45	t	9.4
14/5	475.42	14.45	t	6.5	1413.6	14.45	t	6.3
18/5	23.3	14.45	2.0	6.0	24.5	14.45	t	8.1
19/5	115.7	14.45	t	12.0	94.39	14.45	t	18.0
21/5	43.85	14.45	t	7.3	48.83	14.45	t	10.2
22/5	57.75	14.45	t	5.2	57.23	14.45	t	10.2
23/5	11.89	14.45	t	10.2	10.93	14.45	t	16.0

25/5	43.33	14.45	t	7.3	56.7	14.45	t	8.75
27/5	1029.33	14.0	t	7.25	1115.3	14.0	t	3.25
28/5	86.95	14.0	t	4.6	58.0	14.0	t	4.5
30/5	36.8	14.0	t	9.0	37.4	14.0	t	12.0
31/5	158.3	14.0	t	5.0	119.1	14.0	t	4.0
1/6	968.2	t	3.5	5.5	923.4	t	3.5	2.6
2/6	198.7	t	t	4.0	134.5	t	t	3.5
3/6	81.2	t	t	4.1	73.6	t	t	4.6
4/6	377.8	t	t	4.5	198.0	t	t	4.0
5/6	1362.8	t	t	4.0	706.8	t	t	1.5
6/6	18.6	t	t	6.0	230.0	t	t	7.5
7/6	19.5	t	t	7.0	20.8	t	t	9.95
8/6	309.0	t	t	3.5	202.0	t	t	3.255
9/6	64.0	t	t	4.75	63.7	t	t	4.75
10/6	23.3	t	t	6.5	2.6	t	t	7.8
19/6	11.9	t	t	13.1	15.4	t	t	12.7
21/6	12.4	t	t	12.25	11.9	t	t	17.5
23/6	10.0	t	t	14.55	8.7	t	t	19.75
24/6	15.4	t	t	11.3	16.4	t	t	12.3
25/6	15.0	t	t	11.75	20.3	t	t	10.75
26/6	9.4	t	t	11.5	11.1	t	t	13.5
27/6	11.4	t	t	10.9	23.0	t	t	9.8
5/7	36.4	14.0	0.93	8.75	72.6	14.0	0.93	9.75
6/7	26.5	14.0	1.09	7.5	34.7	14.0	1.09	7.25
7/7	101.1	14.0	0.93	4.6	204.38	14.0	0.93	5.0
9/7	33.4	14.0	0.93	5.75	42.9	14.0	0.93	5.775
10/7	57.4	t	t	5.1	56.7	t	t	5.75
11/7	37.9	t	t	5.75	42.5	t	t	6.1

10/11	46.8	14.0	t	3.5	48.1	14.0	t	4.25
15/11	146.6	14.0	t	3.6	116.9	14.0	t	3.6
23/11	77.06	14.0	t	t	76.5	14.0	t	t
24/11	80.3	14.0	t	3.75	78.26	14.0	t	3.5
26/11	38.6	14.0	t	3.75	46.07	14.0	t	4.6
27/11	299.5	t	0.93	2.6	190.7	t	0.93	3.0
2/12	19.1	14.0	1.25	6.1	15.9	t	1.25	6.6
4/12	89.6	14.0	1.09	3.3	71.3	14.0	0.93	3.5
8/12	104.3	t	0.93	3.4	81.5	t	0.93	4.1
9/12	440.2	t	1.25	3.25	305.5	t	0.93	4.1
11/12	10.4	t	0.93	3.75	17.3	t	0.93	3.9
17/12	32.0	t	0.93	5.6	30.7	t	0.93	15.3

(where: t - trace only)