SOIL AND WATER CONSERVATION IN YOUNG TEA FIELDS IN USAMBARA MOUNTAINS, TANZANIA

BY

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (SOIL SCIENCE AND LAND MANAGEMENT) OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2003

ABSTRACT

A socio-economic survey was conducted in the Usambara Mountains to study the failure of smallholder tea growers to adopt recommended soil and water conservation practices, particularly in young tea. Results from the socio-economic survey indicated that most smallholder tea growers were not aware of splash and sheet erosion and, hence, needed education on the subject. Mulching in young tea fields was also not widely done by the tea growers in the steep slopes (15- 50%) of Usambara Mountains. Lack of enough mulching materials was found to be a reason for the poor adoption of the practice. Recommended mulching materials (Guatemala grass) were found to have another important function of feeding stall-fed livestock. It was, therefore, recommended to address the use of mulches in young tea fields. A field experiment to study the effectiveness of high density tea rows as live barrier in young tea fields was conducted at Marikitanda Tea Research Station (MTRS), Amani, Tanga. Initial results of this experiment indicated that there was a significant difference in canopy cover development and yield across the treatments ($P < 0.01$). During the first year of establishment, canopy cover was highest in high density tea rows (52%) and lowest in Guatemala mulch (31%). Control (no soil and water conservation practice) and vetiver grass had 32.2 and 31.7% canopy cover, respectively, during the first year of tea growth. Yield recorded was 44.9 ($P=0.01$), 20.1, 17.7 and 14.0 kg made tea ha^{-1} for Guatemala mulch, high density tea rows, control and vetiver grass, respectively, during the first year of growth. Soil erosion was highest in vetiver grass (28.6 Mg ha^{-1}) followed by the control, high density tea rows and Guatemala mulch (26.0, 23.4 and 7.8 Mg ha^{-1}, respectively). However, vetiver grass trapped 52.0 Mg ha^{-1} of soil, which was significantly higher ($P < 0.01$) than in any other practice. The control and the high density tea live barrier practices lost 20.8 and 15.6 Mg ha^{-1} of soil instead of deposition. No deposition was observed on Guatemala mulch plots.

Generally, initial results showed that high density tea rows when used as live barrier showed low positive effects, however, there was an indication of fast development of its canopy cover.

DECLARATION

I, BADAN NAHAMANI SANGA do hereby declare to the Senate of Sokoine University of Agriculture that the work presented here is my own original work, and has not been submitted for a degree award in any other University.

Signature: ______________________

Date: 10/07/2003

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ACKNOWLEDGEMENTS

I am grateful to the Tea Research Institute of Tanzania (TRIT) for offering me sponsorship and granting me a leave to undertake MSc studies at the Sokoine University of Agriculture (SUA). I also thank TRIT for allowing me to use their soil and water conservation strategy for my research project. I am grateful to Prof. Bruno J. Ndunguru, TRIT Executive Director, for his efforts on initiating and making this study possible.

I am also grateful to all TRIT staff for their endless support. Special thanks go to Dr. Julius M. Kigalu and Mr. Emmanuel F. Simbua, who worked very close to me in field experiment and socio-economic survey, respectively. Dr. Kigalu also took care of my family when I was at SUA. Their support is highly acknowledged.

I would like to express my sincere gratitude to my supervisor, Dr. Peter W. Mtakwa, whose untiring guidance and encouragement throughout the period of this study is very much appreciated. I would like to thank all staff and students of the Department of Soil Science, SUA, who were always ready to help during my study period. My only classmate, Deusdedit P. Mlay, with whom I worked as twin is also thanked for his co-operation.

Finally, I would like to gratefully acknowledge the patience and moral support showed by my wife Alice, my children Agness, Diana, Ezekiel and Alexander who was born during the course of this study!

DEDICATION

This work is dedicated to the late Pascal T. Sanga, my uncle who sent me to school on the first day. I believe without him it would have been impossible for me to reach this academic level.

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LIST OF ABBREVIATIONS AND SYMBOLS

AHI	-African Highlands Initiative
a.s.l.	-Above sea level
BBK	-Brooke Bond Kenya
CEC	-Cation Exchange Capacity
CV	-Coefficient of variation
DALDO	-District Agricultural and Livestock Development Officer
DEO	-District Extension Officer
df	-Degrees of freedom
FAO	-Food and Agricultural Organization of the United Nations
ISWC	-Indigenous Soil and Water Conservation
LSD	-Least Significant Difference
MOP	-Muriate of Potash
MTRS	-Marikitanda Tea Research Station
N	-North
NPK	-Nitrogen, Phosphate and Potash
S	-South
SECAP	-Soil Erosion Control and Agroforestry Project
s.e.d.	-Standard error for the difference between means
SPSS	-Statistical Package for Social Sciences
SUA	-Sokoine University of Agriculture
SWC	-Soil and Water Conservation
TRF(CA)	-Tea Research Foundation of Central Africa

TRFK	-Tea Research Foundation of Kenya
TRIEA	-Tea Research Institute of East Africa
TRIT	-Tea Research Institute of Tanzania
TSP	-Triple Superphosphate
TTU	-Technology Transfer Unit (of TRIT)
cm	-Centimetre
°C	-Degrees Celsius
Eo	-Water evaporation
Et	-Evapotranspiration rate
ha	-Hectare
H_2O	-Water molecule
KCl	-Potassium Chloride
kg	-Kilogramme
Mg	-Megagramme
m	-Metre
mm	-Millimetre
%	-Percent
$>$	-Greater than
$<$	-Less than

CHAPTER ONE

1. INTRODUCTION

Soil erosion is the physical removal of topsoil by agents of erosion mainly water and wind (Morgan, 1986; Lal, 1998a). There are two types of soil erosion, namely: geological and accelerated erosion. Accelerated erosion is influenced by human activities and is a serious global problem (Lal, 1998a). According to the United Nations Environmental Program (1980), cited by Ahn (1981) crop productivity on about 20 million hectares each year is reduced to zero or becomes uneconomic because of soil erosion and soil-induced degradation while in India 6000 million and 6.2 million megagrammes of soil and nutrients are estimated to be eroded by sheet erosion only in 80 million ha per year (Das, 1977). No other soil phenomenon is more destructive world-wide than soil erosion (Hudson, 1995). Accelerated erosion comprises two processes. First, the detachment of soil particles from their positions in the soil mass, and second the movement to a channel in which they may be transported for the rest of their journey by the excess running water on the surface (Othieno and Laycock, 1977; Davies *et al.*, 1993). The amount of soil lost during an erosion event is directly related to the erosive stresses placed on the soil surface and the susceptibility of the surface to erosion (Eldridge and Kinnell, 1977).

According to Wischmeier and Smith (1961; 1978) land slope and cover are among the major factors of soil erosion. Soil erosion is more serious in bare soils whereby raindrops directly hit the soil particles. On steep slopes water has inadequate time to infiltrate, hence, it moves on the surface down the slope with high velocity (Hudson, 1981; Davies *et al.*, 1993; Kinnell, 1998).

The tea growing areas in the Usambara Mountains in Tanzania are characterized by very steep slopes, sometimes above 50 per cent (Assenga, 1993) (Plate 1). During land preparation, planting and early development of young tea plants, almost bare soil is left exposed to direct rain drops hence splash and run-off usually occur leading to soil, water and nutrient losses by erosion.

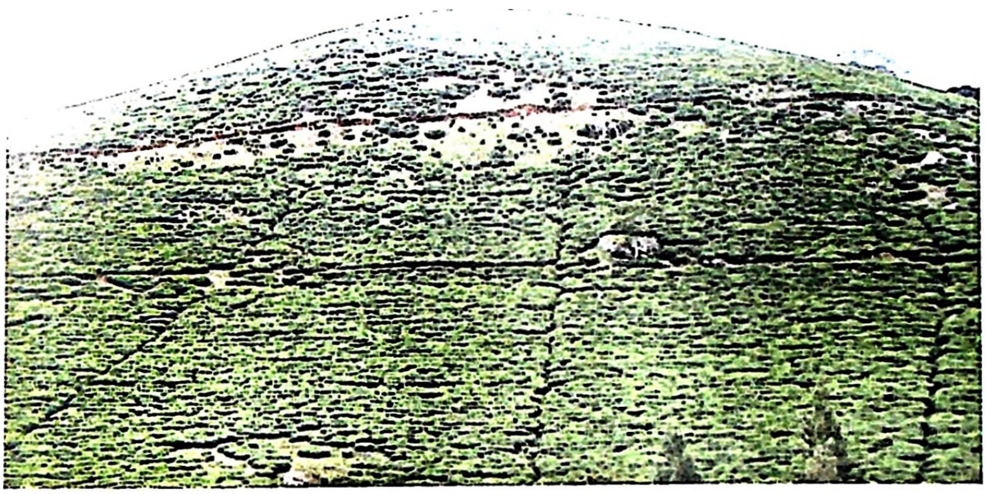

Plate 1: Mature tea in the steep slopes of East Usambara. "Vacancies" are seen near the top of the hill on both sides of the road. Care needs to be taken during establishment and "infilling" of tea in such slopes so as to reduce soil loss by erosion.

Young tea fields are prone to erosive agents as the spacing of tea is usually wide, at a minimum of 0.6 m × 1.2 m, leaving the field almost not covered. People in steep slope areas will go on using land of low productivity for crop production because the population increases and sometimes this is the only land they have (Hudson, 1992). This is the typical case of Usambara Mountains crop growing area.

Soil and water conservation measures are important in young tea with little ground cover as well as in mature tea fields with dead plants gaps (also called vacancies) between the bushes, particularly on steep slopes where run-off can easily occur. The issue of conserving soil in tea fields with 16-20% vacancies (Plate 1) in East Usambara is perceived by stakeholders to be critical (Amritanand, A. personal communication, 1999).

Various methods have been identified world-wide that can reduce soil erosion. Performance of these methods in tea fields has been tested and reported elsewhere (Templer, 1971; Othieno, 1973a; 1975a; 1975b; 1979; Aono *et al.*, 1974; Othieno and Laycock, 1977; Rajasingham, 1980; Sandanam and Rajasingham, 1981; Sivapalan, 1983; Krishnarajah, 1985; Nyasulu, 1995; 1996; 1999; 2000; Sanga and Kigalu, 2002a).

Despite research recommendations, soil and water conservation practices are not widely adopted in East and West Usambara where torrential rainfall usually occurs creating potential run-off and soil erosion hazards, for reasons not obviously known. A socio-economic study was needed so that factors limiting the implementation of soil and water conservation practices are addressed and rectified. Also the use of high density tea rows (an economic crop) as crop barrier needed to be tested and compared with other soil and water conservation methods for the ability of reducing soil loss without causing detrimental effects to normal spaced tea bushes in the field and environment.

The general objective of this work was to identify cost-effective and appropriate methods of controlling run-off and soil erosion in young tea grown on steep slopes. The specific objectives included:

1. To identify the social and economic constraints to the adoption of recommended soil and water conservation practices in the Usambara tea-growing area.
2. To test the effectiveness of dense planting of tea as a means of controlling soil erosion.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Soil Loss in Young Tea Fields

A number of studies on soil loss through soil erosion in tea have been reported in Kenya (Othieno, 1975a; Othieno and Laycock, 1977), Sri Lanka (Sivapalan, 1983; Krishnarajah, 1985) and Uganda (Templer, 1971). The findings from Othieno (1975a) over three years at 10% slope indicated that run-off was lowest under mulched plots at 2.6 per cent of the total rainfall, compared with 8.7, 7.7 and 3.1 per cent from manual and herbicide weeding and oats live barriers treatments, respectively. The experiment was on land with 10% slope. Total soil loss was also the lowest at 0.46 Mg ha^{-1} from plots which were mulched compared with 161.3, 168.1 and 34.9 Mg ha^{-1} from manual weeding, herbicide and oats treatments, respectively. Similar results have been reported from Sri Lanka (Sivapalan, 1983; Sandanam and Rajasingham, 1981).

In another study from Sri Lanka, Krishnarajah (1985) reported soil erosion and control measures on tea land. In that study, application of 25 Mg of fresh cuttings of Guatemala grass (*Tripsacum laxum*) ha^{-1} was very effective in controlling soil erosion on land with 14% slope, almost completely eliminating surface run-off and soil loss. Over a period of nearly four years (January 1980 to September 1983) the results from well-managed vegetative propagated clonal tea indicated a maximum soil loss of only 0.33 Mg ha^{-1} per year. Run-off was also minimal averaging less than one per cent of the total annual rainfall. Thus in Sri Lanka, and in some other tea growing areas, vacancies in tea fields are usually planted with grasses including Guatemala grass, Love grass (*Eragrostis curvula*) and Mana grass (*Cymbopogon confertiflorus*). These grasses have been reported to renovate or rehabilitate the soil and to help in establishment of new tea plantings (Krishnarajah, 1985). Somaratne and Jayasooriya (1980) also found that soil reconditioning by pre-planting Guatemala and Mana grasses increased yield of replanted tea in a poor soil with low (2.73%) carbon content but did not influence yield in good soil with high (4.38%)carbon content.

In Uganda, Templer (1971) reported that tied ridges as a method of soil and water conservation in tea are expensive to construct and their maintenance coincided with heavy plucking (tea harvesting by hand) period in the estate. He further pointed out that tied ridges on steep slopes are impossible to maintain and they probably increase erosion by their frequent breaking. Tied ridges should not be recommended as an erosion control measure in tea.

2.2 Soil-Water Loss in Young Tea Fields

The effect of water conservation measures on soil water-loss in young tea fields has also not been systematically studied and reported. The Tea Research Institute of East Africa (TRIEA) stated that application of any form of mulch resulted in better soil moisture conservation even under prolonged drought periods than no mulch (TRIEA, 1966, 1976). Leaching by long rainfall was reduced by the mulch, enhancing and increasing the response of tea to all types of fertilizers compared to when fertilizers were used without mulching (TRIEA, 1966).

Dagg (1970) found that in fields of young tea with less than 50 per cent canopy cover, much of the water loss was by direct evaporation from the soil. However, this loss was subject to rapid reduction in evaporation rate as surface soil dried and presented a strong barrier to diffusion of water vapour out of, and to heat flow into, the soil. Based on lysimeter studies on evapotranspiration rates (Et) of tea and the Penman estimate of open-water evaporation (Eo), Dagg (1970) established an inverse correlation of the rate of water use, Et/Eo, ratio with the potential water evaporation Eo in the early stages of growth of young tea in East Africa. There is still very limited information on the water use of tea and the extent of water loss by surface evaporation and run-off at different growth stages.

2.3 Factors Influencing Soil and Water Losses in the Tea Fields

Sivapalan (1983) listed rainfall, topography and ground cover as the three main factors influencing soil and water losses in Sri Lanka. Othieno and Laycock (1977) reported that rainfall intensity, run-off and ground cover were the major factors affecting soil erosion in a tea estate in Kenya. Using multiple regression and correlation analyses, Othieno and Laycock (1977) found that these three factors accounted for about 86 per cent of the variability in soil erosion.

2.3.1 Rainfall

Rainfall contributes to soil loss by inducing splash transportation and surface run-off in areas with un-mulched and loosened soil (Hainsworth, 1969; Sivapalan, 1983). Results reported by Othieno (1975a) and those reviewed above suffice to demonstrate the variations of run-off and soil erosion under various soil and water conservation measures for a given rainfall intensity. According to Othieno (1977), in the wet months when the soil moisture content was at or above field capacity, the rate of infiltration depended on the rainfall intensity. Storms of greater intensity exceeded the rate of infiltration and therefore, run-off occurred. Torrential rainfall usually occurs in Usambara Mountains creating potential run-off and soil erosion hazards.

2.3.2 Topography

Soil erosion increases with increasing land slope. The slopes of Usambara Mountains most cropping land vary from 40 to 60% (Assenga, 1993; Kaswamila, 1995). There is, however, less information to quantify the performance of soil erosion control measures at varying land slopes in tea fields. Hence, this needs further research.

2.3.3 Canopy cover (vegetation)

The effect of canopy cover on soil erosion, soil moisture status and yield of young tea was reported in Sri Lanka (Rajasingham, 1980). Soil loss was estimated to be 88 and 51 Mg ha^{-1} in the first and second year, respectively, after field planting when tea was young. In the first year, soil loss was lower (5 to 7 Mg ha^{-1}) in mulched plots than plots which were selectively weeded or under crop barriers (11 to 31 Mg ha^{-1}). In the second year, soil loss from plots with Crotalaria as crop barrier was higher (4.7 Mg ha^{-1}) than that from plots with mulching, selective weeding and bare soil (1.2 to 2.5 Mg ha^{-1}). In the third and fourth years, soil loss from the plots was very much reduced (range: 0.9 to 2.0 Mg ha^{-1}) in various treatments. This was attributed to achievement of large canopy cover by the tea bushes. Blackie (1972), cited by Carr and Stephens (1992) found that in tea with full canopy cover, surface run-off from an estate in Kenya represented only 1% of the annual rainfall, a value similar to that of the forest it replaced. Similar results were reported in Kenya by Othieno and Laycock (1977) and Othieno (1992) whereby there was minimum soil erosion when the canopy cover provided by the tea bushes exceeded 65 per cent. This suggests that there is little or no soil erosion under mature tea with full canopy cover. This emphasizes the importance of constant replanting new young tea in areas with dead plants, a process referred to as "infilling" in fields with vacancies. It also shows the importance of good management practices so that young tea attains 65 per cent ground cover early.

It was reported in Sri Lanka that mulching conserved more soil moisture than did crop (live) barriers, suggesting that crop barriers competed with tea for water (Rajasingham, 1980). There was a trend to indicate that the yield of tea from the mulched plots was higher than that from plots with crop barriers. However, Okigbo and Lal (1977) indicated that it is difficult to use mulch in relatively large areas under arable or row crop farming.

2.4 Performance of Some Soil and Water Conservation Measures in Tea Fields

2.4.1 Effects of mulching

Effects of mulching on the control of soil loss and run-off in young tea have been reported by several researchers. For example, reviews have shown that mulching, as a method of soil erosion control, suppressed weed growth between tea bushes and helped to improve the soil organic matter content, hence, improving soil physical properties leading to improved water infiltration and retention in soil (Bates, 1975; Othieno, 1980; Sandanam, 1986; Nyasulu, 2000). Very low amounts of run-off and soil loss were recorded from mulched fields of young tea with 1 to 30 per cent canopy cover. These values were much reduced when the canopy cover rose to more than 65 per cent (Othieno, 1975a; 1975b; Nyasulu, 1995; 1996; 1999; 2000). It was found that mulched tea developed a bigger top canopy than root system resulting in a narrower root to shoot ratio (0.43:0.46) compared to un-mulched tea (root to shoot ratio 0.50:0.67). Mulched tea also produced better plant growth with higher yield than un-mulched tea. It was reported in Malawi by Nyasulu (1999; 2000) that yield of tea in mulched plots was higher for three years after stopping mulching as compared to that under crop barriers. It was further reported in Malawi and India that mulching protected the tea field in early years from the raindrops' erosive action and significantly reduced run-off, besides conserving moisture and suppressing weeds. Therefore, mulch keeps the soil on land (Tea Research Foundation of Central Africa, 1990; Hudson *et al.*, 1997). Similar findings were reported in Uganda by Templer (1973). At Marikitanda, in East Usambara where soils are shallow and have very little humus, tea responded well to mulching than to chemical fertilizer applications (Othieno and Machaga, 1977).

2.4.2 Effects of crop barriers

Results on the effect of crop (live) barriers on reducing soil and water loss in tea estates have also been reported. For example, positive effects of crop barriers for controlling soil loss (erosion) have been reported to include reduction of run-off from between 0.9 and 24.9 per cent of rainfall during the first year after field planting to between 0.8 and 11.4 per cent in the second year (Othieno, 1975a). Soil loss was also reduced from 0.03 and 33.5 Mg ha^{-1} to 0.01 and 2.2 Mg ha^{-1} in the first and second years, respectively. When well managed, crop barriers also helped quick establishment of young plantings in new tea fields and replaced plants "infills" between mature tea in Sri Lanka (Krishnarajah, 1985). Obaga and Othieno (1989) mentioned other benefits of crop barriers as improving organic matter of soil, water infiltration, aeration and air nitrogen fixation for leguminous crops.

Elsewhere, crop barriers have been reported to compete with tea for water and nutrients providing a deleterious effect on tea growth and yield in drought periods (Othieno, 1975a; Nyasulu, 1995; 1996; 1999; 2000). Thus, it was recommended that crop barriers must be cut down or killed with herbicides towards the end of the rainy season to minimize competition with tea for water (Sandanam, 1986). No significant improvements of soil nutrients resulting from planting crop barriers have been found (Mwakha, 1994). Soil physical properties, however, were found to be improved by planting dadaps (*Erythrina lithosperma*) as crop barrier in mature tea fields in Sri Lanka (Ananthacumaraswamy *et al.*, 1988). At Marikitanda, in East Usambara, pre-planting tea land to Guatemala grass was found beneficial as it improved soil physical properties and increased soil fertility (Machaga, 1973; Templer, 1973; Templer and Machaga, 1978).

2.4.3 Effects of mechanical structures

Cut-off drains and micro-catchments have been described by Kilavuka (1975) as practical and effective means of controlling soil erosion in tea fields at Kericho, Kenya with a land slope of 10 per cent. Somaratne (1986), cited by Willson (1992), reported that lateral drains were recommended in Sri Lanka for the control of soil erosion in tea fields. Lateral drains were supported by crop barriers to trap water and encourage the deposition of entrained soil. Similar results were reported in Malawi whereby methodologies on how to make bunds, micro-catchments and waterways were outlined (Tea Research Foundation of Central Africa, 1990). However, the use of bunds, drains and tied ridges in young tea fields has been criticized as being just a form of organizing erosion in themselves, involving a lot of soil disturbance and loosening (Field, 1970; Templer, 1971; Krishnarajah, 1985). Cut-off drains and other mechanical structures have been applied successfully for annual crops and pasture land in Lushoto district, Tanzania (SECAP, 1997; Lyamchai and Mowo, 2000; Johansson, 2001).

2.5 Studies of Soil Erosion and Its Control in Other Crops

As part of land degradation, effects of soil erosion on yield of crops has widely researched as erosion-induced loss in soil productivity (Stocking and Murnagham, 2000). Erosion decreases soil productivity by removing nutrients and organic matter and by thinning and modifying the zone where the plant roots grow (Kim, 1998).

A number of studies on soil loss through soil erosion and conservation practices in various crops have been reported. In Tanzania, Temple (1973) reported that banana mulch reduced soil loss to negligible amounts in coffee fields at Lyamungu Research Station while clean weeded coffee plots lost the highest amounts. Ridges, unless closely spaced, were ineffective. In Nigeria, Lal (1976) reported that straw as a mulch at the rate of 4 to 6 Mg ha^{-1} effectively prevented run off and soil loss from tilled plots on slopes ranging from 1 to 15%. Further studies conducted in Nigeria indicated that the number of days required for 50% canopy cover development were approximately 38, 46 and 63 for soya beans, pigeon peas and cassava, respectively. Run off and erosion losses which occurred under these crops were proportional to the time required for full canopy cover to develop (Aina *et al.*, 1979).

The use of hedgerows of fodder grass (Napier grass; *Pennisetum purpureum*) and legume tree (*Gliricidia sepium*) as live barriers was tested and trained to farmers in Philippines (Fujisaka, 1993). The mean heights of trapped soil in this trial were 36, 44 and 49 cm after first, second and third year, respectively, in a field with 22% slope.

Farmers adopted the method, replacing the former practices of using competitive grasses and trees. Bunting and Milsum (1928), Wingley (1929), Whyte and Trumble (1953) and Webster and Wilson (1966), all cited by Okigbo and Lal (1977) reported that further to soil erosion control, live barriers have other advantages including reducing temperature fluctuations, maintaining adequate levels of organic matter, improving soil physical properties, reducing leaching and, for deep rooted and leguminous crops, enhancing nutrients recycling and contributing nitrogen to soil, respectively.

Findings of Herweg and Grunder (1991), cited by Liniger (1995) indicated that in Ethiopian Nitosols, on a bare soil with a 16% slope, surface run-off amounted to 28% of the total rainfall, while on a much steeper slope of 42% with grass cover, surface run-off was only 1%. In Lixisols, a vegetated soil under a maize crop on a 42% slope had surface run-off amounting to 84% of the rainfall, while only 3% run-off was recorded on a similar soil on the same slope under a coffee forest with a dense grass cover.

Agus *et al.* (1998) reported results of the comparison of the effect on soil erosion and crop yields of level terracing, outward sloping bench terracing, ridge terracing and alley cropping with double hedgerows of *Flemingia congesta*, spaced 50 cm apart. In the three terracing treatments, the terrace lips were planted to *Setaria sphacelata* and the terrace raisers to *Brachiaria ruziziensis*. The experiment was conducted for six years on slopes of between 15 and 40% in Indonesia. Under rainfall of 2515 mm in the first year, level bench terracing had a surface runoff coefficient of 0.20, while for outward sloping bench terracing, ridge terracing and alley cropping it was 0.39, 0.34 and 0.38, respectively. In the same treatment order, the amount of soil loss was 26, 45, 51 and 110 Mg ha^{-1}, respectively (Agus, *et al.*, 1998). Agus *et al.* (1998) further reported that the run-off and soil loss decreased with time. Soil loss below the tolerable limit of 13.5 Mg ha^{-1} year^{-1} was reached in the second year for all but the alley cropping treatment. The alley cropping treatment reached the tolerable limit in the fourth year. No difference was observed in the crop yield.

Studies on the effect of cumulative soil loss on maize fields were conducted in Kenya in fertilized and non-fertilized plots (Gachene *et al.*, 1998). In the fertilized plots maize grain yield in most eroded plots was 83% less than that in the least eroded plots. No grain yield was obtained from most eroded plots when fertilizer was not applied. Soil erosion and control studies in maize fields in China showed that the straw mulch sustained a soil loss of 0.91 Mg ha^{-1} and was appropriate for soil conservation as compared with intercropping, no tillage, polythene mulch and conventional tillage methods with 2.91, 3.29, 4.15 and 4.16 Mg ha^{-1} soil loss respectively (Fullen *et al.*, 1999).

Stones collected during land rehabilitation were used to make boundaries and piles as soil conservation measures in Bolivia (Clark *et al.*, 1999). Net loss of sediment from fields with piles of stones was 164 and 118 Mg ha^{-1} year^{-1} for potatoes and oats respectively. However, the net loss of sediment was low in the fields with stone boundary bunds whereby 100 and 58 Mg ha^{-1} year^{-1} of sediments were recorded in potatoes and oats fields respectively. Other findings from Bolivia were on the use of crop residues cover in wheat fields (Wall, 1999). Crop residues were reported as an appropriate way of increasing rainfall infiltration, hence reducing run-off and increasing yield. Results showed that yield of wheat grain increased from 0.98 Mg ha^{-1} in fields without cover to 1.86 Mg ha^{-1} in fields with 4 Mg crop residue ground cover ha^{-1}. The fields with 2 Mg ground cover ha^{-1} obtained 1.45 Mg of grain ha^{-1}. However, Tengberg *et al.* (1999) reported that crop residues must be used with care to avoid the encouraged spread of insect pests and disease pathogens. Unfortunately, very little is reported on erosion studies in tea.

2.6 Effects of Farm and Crop Management on Soil Loss Control

Field practices aiming to control erosion have been applied in various crops. Ahn (1981) reported the use of grass strips in sorghum fields in Mpwapwa, Tanzania. Sorghum cultivated in plots without grass strips lost between 6 and 86 m^3 of soil ha^{-1} per season over eight seasons as compared with only 0.3 to 0.9 m^3 soil loss ha^{-1} from plots with grass strips. According to Ahn (1981) mixed cropping gives better cover and protection. Similar findings were reported in Lyamungu and Tengeru, Tanzania, where mixing coffee with banana trees greatly reduced water and soil losses (Ahn, 1981).

Crops and field management practices which help produce an early ground cover are certainly more useful in controlling run off and erosion than those which take longer time for full canopy cover development (Aina *et al.*, 1976; Lal, 1981a). Lal (1981a) mentioned plant population as one of the effective field practices used to control erosion. Similar explanations were reported by Kigalu (1997) whereby high density tea plants of clone S15/10 with spreading growing habit and K35 with upright growing habit planted at spacing of 0.2 × 0.6 m reached 90 and 70% canopy cover, respectively, after only two years from planting. In low density at spacing of 1.0 × 1.2 m only 20 and 10% canopy cover, respectively, were observed in the same period. Irrigation had an added advantage on crop cover development in both clones. Hudson (1971), cited by Celestino (1985) reported that cultural practices that support good crop growth go a long way towards reducing soil erosion. These practices included optimum plant population, fertiliser application and adequate crop protection against pests and diseases. Chandra and De (1982) reported that the proper use of cattle manure in India was effective in checking soil erosion. Lal (1998b) reported that increase in crop yields due to widespread use of improved agricultural technology like improved genotypes, tillage methods, fertilizers, water management systems, past erosion control measures and harvesting techniques mask the increasing severity of soil erosion.

Okigbo (1981) reported that farm practices and operations determine the extent of soil erosion hazards. Farmers in sugar cane areas in Australia adopted several soil conservation practices with different reasons other than soil conservation. Loch and Freebairn (1985) reported that tillage was a major cost in high rainfall sugar cane areas. Trash retention in the fields also reduced the operation costs. Farmers, therefore, easily adopted this practice in their fields not for purposes of reduction of soil loss but reduction of operational costs.

Lal (1981b) reported the advantage of no-tillage practice against ploughing in Nigeria, under cowpeas field. Results obtained after two weeks from planting showed that run-off was 69.8 and 87.6% at 1 and 15% slope, respectively, in bare ploughed plots as compared with 1.3 and 2.7% run-off in no-till plots. Similarly, soil loss was 1.0 and 33.3 Mg ha^{-1} at 1 and 15% slope in bare ploughed plots as compared to no soil loss in no-till plots. He further mentioned other advantages of no-till as reduced weed growth, improved moisture conservation in the soil profile and reduced operational costs.

In plantation crops, soil erosion has been serious in the initial stages of field establishment when forests are cleared and the crop is still young. This happened in Sri Lanka in the nineteenth century whereby native forests were cleared for tea plantations

(Lal, 1981c). Therefore, as far as erosion is concerned, important than what to grow is how to grow the crop (Lal, 1981d).

2.7 Application of Soil and Water Conservation Measures in the Usambara Mountains

Soil loss in young tea fields in Usambara Mountains is caused by raindrop action and run-off in the steep slopes leading to splash and sheet erosion. Soil mass slide in the edges of mature tea fields is also common (Plate 2).

Plate 2: Soil mass slide in mature tea field in East Usambara. Sometimes, tea bushes that move with soil manage to survive in their new locations as their roots clump soil particles together as seen in the plate

Although the soil and water losses problem is serious in the Usambara Mountains, very few people apply soil and water conservation measures in their fields particularly in young tea. Lack of application of these measures leads to very big losses, not only in tea but also in other crops fields (Shelukindo, 1996). Immediate efforts need to be taken to make sure people apply the soil and water conservation practices. The efforts include understanding the problems leading to not applying these practices and solving them and identifying proper practices based on the real farmers conditions in the Usambara Mountains. This study tried to address this question.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Factors Limiting Adoption of Recommended Soil and Water Conservation Practices in Young Tea Fields in Usambara Mountains

3.1.1 Data collection

A socio-economic survey to study the constraints limiting tea growers to adopt the recommended soil and water conservation practices was held in all three districts in Usambara (Muheza, Lushoto and Korogwe). The survey was conducted from 8 - 16 March 2001. At district level, personal interviews were conducted to District Agriculture and Livestock Development Officers (DALDOs) and District Extension Officers (DEOs). At village level, individuals were requested to complete a prepared questionnaire (Appendix I). Questionnaires covered broad aspects of tea production and marketing with specific interest on the understanding and management of soil erosion. Testing of questionnaire was done at one village in Muheza district before modifications were made to cover the rest of the intended survey area.

3.1.2 Choice of villages and respondents

The number of villages and respondents depended on the level at which the tea crop was grown (Nyanga *et al.*, 2000). In East Usambara tea is grown in Amani Division. The area was divided into two parts, north and south. Two villages were selected, one from each part. A large number of tea smallholders farmers is found in West Usambara. Three villages were chosen in Lushoto District. Only one village was chosen in

Korogwe District, making a total of four villages in the West Usambara Mountains. The tea producing area in Korogwe that sells green leaf to factories in Lushoto (New Mponde, Balangai and Herkulu factories) was regarded as part of the Lushoto tea growing area. Respondents from the villages were randomly chosen from amongst farmers who attended the meeting. Table 1 summarizes the locations, districts, villages and number of respondents visited during the study period.

Table 1: Districts, villages and number of respondents interviewed in a socio-economic survey in East and West Usambara

	Location	District	Village	Number of Respondents
	East Usambara	Muheza	Antakae (North Amani)	10
			Mlesa (South Amani)	6
	West Usambara	Lushoto	Mpalalu	12
			Kwehangala	10
			Dule	11
		Korogwe	Ngulu	9
Total	**2**	**3**	**6**	**58**

3.1.3 Data analysis

Data obtained from the questionnaires were summarized, coded and analysed by the Statistical Package for Social Sciences (SPSS) software (SPSS Inc., 1998).

3.2 Effects of High Density Tea Rows on Soil Erosion Control in Young Tea Fields in Usambara Mountains

3.2.1 Site, soils and climate

3.2.1.1 Site and history

Marikitanda Tea Research Station located at 5° 08' S, 38° 35' E, with altitude of 970 m a.s.l. is a northern station of the Tea Research Institute of Tanzania (TRIT). It is located along the tea growing area of East Usambara Mountains about 80 km North-west of Tanga municipalty and 45 km from Muheza following the route described by Ellman *et al.* (1995). The area was planted to coffee after the First World War, followed by cinchona before being cleared for tea in 1958 (TRIEA, 1967; Carr *et al.*, 1992). Currently the area is planted with both seedling and clonal tea.

3.2.1.2 Soils and climate

Landform is characterized with hills having non-uniform steep slopes leading to several watersheds. According to TRIEA (1966) the soils at Marikitanda consist of a weathered laterised red clayey loam, which varies in depth from a few centimetres to three metres or more before a basement complex rock, chiefly gneiss, is encountered. According to Assenga (1993) the soil at Marikitanda is classified as Haplic Ferralsol (FAO, 1988) or Typic Haplustox (Soil Survey Staff, 1990). Results of soil physico-chemical properties at 0-0.15 and 0.4-0.5 m, from the experimental area are presented in Table 2. The available soil water capacity averages about 100 mm m^{-1} depth of soil (Othieno, 1973b).

Table 2: The physico-chemical properties of soils at Marikitanda Tea Research Station measured in May 2001

Soil property		Depth (m)	
		0-0.15	0.40-0.50
Bulk density (Mg m^{-3})		1.04	1.24
pH (in 1:2.5 H_2O)		5.80	5.30
pH (in 1:2.5 KCl)		4.60	4.50
Organic carbon (%)		2.64	1.25
Total nitrogen (%)		0.19	0.10
C/N ratio		14	13
Bray-1 P (mg P kg^{-1})		2.23	1.54
Cation Exchange Capacity (CEC)	(Cmol/kg soil)	4.63	2.46
Exchangeable bases	(Cmol/kg soil)	2.92	1.07
Base saturation (%)		63.00	46.00

Marikitanda has a bimodal type of rainfall with short rains *"vuli"* falling from October to November and long rains *"masika"* from March to May. There is little rainfall from June to September and a dry spell that lasts from December to February. The average long-term annual rainfall is 1792 mm (35 years, 1967-2001). Monthly mean temperature ranges from 16.0 °C in cold months (June to August) to 23.0 °C in warm months (September to May). Table 3 summarizes rainfall and temperature regimes at Marikitanda Tea Research Station for the reporting period of this work from June 2001 to May 2002.

3.2.2 Site preparation

In 2001, an area of approximately 0.2 ha was identified as the site for a new soil and water conservation experiment. The area has a slope of 15% with a West-east direction. Previously the area was used for annual crops production, mainly maize and cassava. It was left with secondary vegetation for four years before the experiment was established.

Table 3: Rainfall and temperature regimes at Marikitanda Tea Research Station from June 2001 to May 2002

Month	Total Rainfall (mm)	Monthly mean of daily values Temperature Maximum (°C)	Minimum (°C)	Mean (°C)
June	126.2	21.2	15.8	18.5
July	25.1	20.7	14.0	17.4
August	36.9	21.6	13.5	17.6
September	3.7	23.5	13.4	18.5
October	41.4	24.6	15.2	19.9
November	4.4	27.2	16.5	21.9
December	71.0	28.4	18.2	23.3
January	16.4	28.0	17.9	23.0
February	9.8	29.0	17.2	23.1
March	110.2	27.0	18.2	22.6
April	382.9	23.6	18.0	20.8
May	143.9	23.0	15.9	19.5

Source: Marikitanda Tea Research Station, Amani, Tanzania

Land clearing and cultivation of the selected experimental area were done in March 2001. This involved grass cutting and felling of secondary growth, including shrubs and trees. The soil was repeatedly dug to a depth of 0.6 m using hand hoes. All thick roots and stems were collected and removed from the area in order to prevent the area from fungal infection by *Armillaria melea*. *Armillaria* causes tea root rot disease (Rattan, 1992; Onsando, 1997; Otieno, 1998). The area was then levelled and staked (lined) at a spacing of 0.6 m × 1.2 m. (Plate 3).

Plate 3: Staking (lining) of the soil and water conservation experiment site ready for plots demarcation and planting, at Marikitanda Tea Research Station, East Usambara, May 2001

An upright growth habit clone K35 (also known as BBK35) was selected and planted in May 2001. Clones with erect growth habits cover the ground slowly hence taking longer time than the spreading types clones to reach 65% canopy cover which is required to reduce soil erosion to a minimum in young tea fields (Othieno, 1975a). Clone K35 originated from Kenya highlands. Triple super phosphate (TSP) fertilizer at a rate of 30 g per plant (= 190 kg P_2O_5 ha^{-1}) was applied by mixing with soil during planting.

3.2.3 Experimental design and layout

The tea was planted in a Randomized Complete Block Design experiment comprising four blocks, each containing four plots representing each treatment (Figure 1), (Sanga and Kigalu, 2002b).

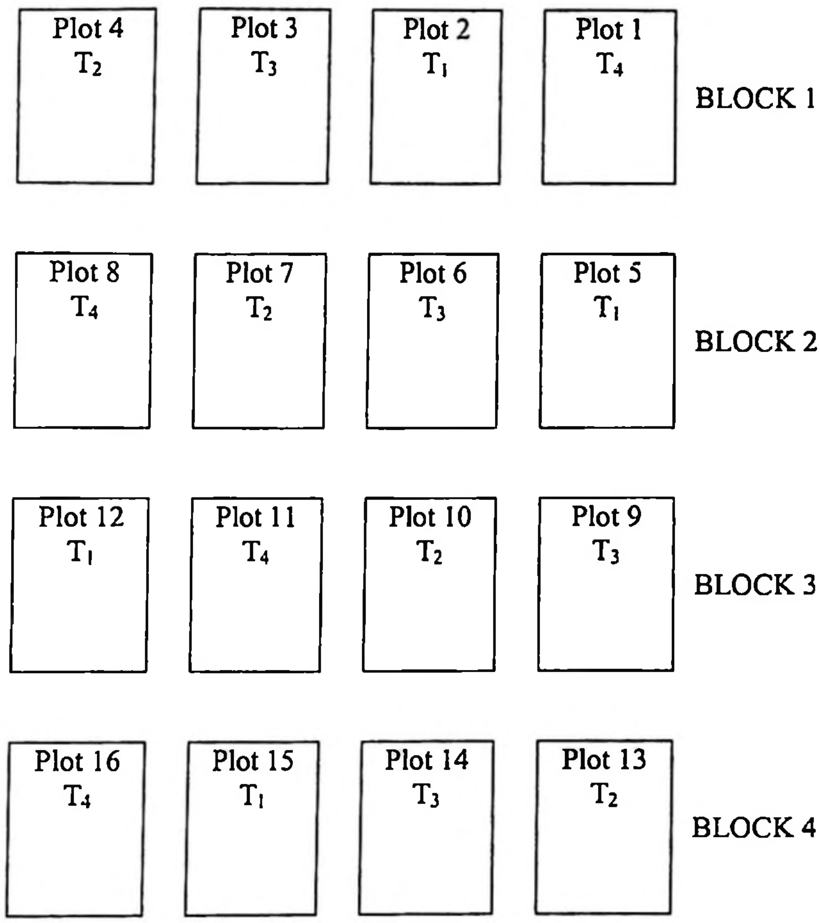

Figure 1: Soil and water conservation experiment layout at Marikitanda Tea Research Station in East Usambara, May 2001

Where:

T_1 = Control; no soil and water conservation practice applied

T_2 = High density tea (*Camellia sinensis*) rows as crop barrier

T_3 = Dry Guatemala (*Tripsacum laxum*) grass as mulch

T_4 = Vetiver grass (*Vetiveria zizanioides*) as crop barrier

Each plot contained nine rows each row measuring 4.2 m. Length of net plot was 10.8 m, giving a net plot area of 45 m^2. Each plot was surrounded by a single guard row in all sides, giving a gross plot area of 71 m^2.

Straight logs of wood were laid on the soil surface in all sides except the lower side of a net plot as boundary barrier to prevent water from running into other plots. Three guard rows mulched with Guatemala grass separated adjacent blocks along the slope. Waterways were constructed in the guard area across the experiment to collect and lead water away from entering the bottom plots. In treatment T_1 no soil and water conservation practice was applied (Plate 4).

Plate 4: The control treatment plot whereby no soil and water conservation practice was applied with young tea plants soon after planting in May 2001. Notice the logs demarcating the plot

In treatment T_2, the first, fifth and ninth rows under normal planting were replaced by high dense tea rows planted at a spacing of 0.2 m apart (Plate 5). This spacing covered the soil very fast in Southern Tanzania (Kigalu, 1997). In treatment T_3 air-dry Guatemala grass was evenly spread at a rate of 35 Mg ha^{-1}. From literature, Guatemala mulch rates varied from 12 t ha^{-1} (Othieno and Ahn, 1980) to 38 t ha^{-1} (Sandanam and Rajasingham, 1981). In treatment T_4, vetiver grass was planted at a spacing of 0.1 m apart (National Research Council, 1993), 0.6 m above the first, fifth and ninth rows. Each plot contained 63 tea plants (net) except for treatment T_2, which had 105 tea plants per plot.

Plate 5: The high density tea row (left) soon after planting in May 2001. Erosion pins row is seen below the tea row (right) and the plot with Guatemala mulch is seen at the far side.

3.2.4 Recording of data

3.2.4.1 Soil loss or deposition

To indicate the loss or deposition of soil, iron rods (pins) are usually employed. They are widely used in estimation of seasonal or annual sediment loss or yield. Usually they are used in hillslopes, large plots and watersheds (Temple and Murray-Rust, 1973; Loch and Freebairn, 1985; Mtakwa *et al.*, 1987; Hudson, 1995; Kaswamila, 1995; Swete Kelly and Gomez, 1998). However it was chosen due its simplicity and accuracy of using it.

For security purposes, instead of iron rods, small strong bamboo sticks were used. These sticks were installed 0.5 m apart and the same distance on the lower and upper sides of top and bottom barrier rows, respectively and on both sides of the middle barrier in each plot. In bare and mulch plots, sticks were installed in similar locations as in plots with tea rows as crop barrier treatment. (Plates 5 and 6). The sticks were used to measure the increase or decrease in height (using a normal office ruler) of soil surface as the lower part of the live barrier rows was expected to be eroded, hence increasing the height of the sticks (Plate 6).

Plate 6: A technical staff taking erosion pins measurements using a ruler in soil and water conservation experiment at Marikitanda Tea Research Station in May 2002

The eroded soil was expected to be trapped by the close spaced bushes and vetiver grass, therefore decreasing the height of sticks on the upper area of the rows. Bulk density was measured before land preparation using metallic core procedure. Measurements were taken at the end of each month. Amount of soil deposited or lost was calculated by multiplying the change of sticks height by the bulk density of soil and area using the following equation:.

$$A = \Delta h \times \beta d \times a \qquad \text{(Equation 1)}$$

Where A = Amount of soil gained or lost in kg

Δh = Change of height of erosion pins in m

βd = Bulk density, kg m^{-3}

a = Area in m^{-2}

3.2.4.2 Canopy cover

The canopy cover (also referred to as ground or crop cover) development of tea bushes was measured at the end of each month using a wooden rectangular grid with an area of 0.72 m^2 (= area of a tea bush). The grid was subdivided into small grids of 0.01 m^2 by a polythene thread. Canopy cover was measured on two bushes in each plot located at the middle of each normal spaced row between the crop barriers and in similar locations in other treatments (Plate 7).

In each close spaced row three bushes (= 0.72 m^2) were measured using the same grid. The wooden grid was placed horizontally on top of a bush without pressing it. Small grids were observed vertically. Those fully covered by bush leaves scored two while those partially covered scored one, counted by using a tally count machine. The proportion covered by a bush was calculated by relating the number of counts and total number given by small grids expressed in per cent (Burgess, 1992; Kigalu, 1997).

Plate 7: Technical staff at Marikitanda Tea Research Station taking canopy cover measurements in one of the soil and water conservation plots in May 2002

3.2.4.3 Stem diameter

Stem diameter was measured to monitor the increase in stem diameter of bushes, which is related to structural material formation of the tea plant. Stem diameter of two bushes each located at the middle of each normal spaced row was measured monthly using a vernier calliper. Measurements were taken in millimetres and the average represented the stem diameter of bushes in a plot.

3.2.4.4 Green leaf yield

As an economic crop, tea live barrier in young tea field was expected to benefit the main crop by increasing yield in the early stages of production. It was important, therefore, to monitor yield differences in the different treatments. The fresh weight of the harvested shoots (green leaf yield) in kilogrammes per plot was measured at every harvest. Plucking was done at normal plucking rounds (at two *phyllochrons*) (Burgess, 1992; 1993). A conversion factor of 0.225 obtained as a mean of long-term outturn of made tea was used to compute kilogrammes made tea from kilogrammes green leaf (TRIEA, 1979).

3.2.5 Data analysis

Data collected were statistically analyzed using GENSTAT software (GENSTAT 5 Committee, 1987). Other parameters were computed following procedures explained by Mead *et al.* (1993). To analyse the effect of different treatments on soil loss, the following model was used;

$$Y_{ij} = \beta_i + t_j + \varepsilon_{ij} \qquad \text{(Equation 2)}$$

Where Y_{ij} = observed soil loss or gain

β_i = mean soil loss or gain for block

t_i = treatment effect on soil loss or gain

ε_{ij} = random unit variation within a block

3.2.6 Management of young tea after planting

3.2.6.1 Weed control in the experiment

Planting was followed by application of *pre-emergence* herbicide (primagram) at a rate of 150 ml in 15 l of water using a knapsack sprayer. This was followed by regular hand weeding. In March 2002, the experiment obtained high rainfall, reaching 383 mm (Table 3). This resulted into high weeds infestation leading to herbicide application. Round-up (*Glyphosate*) at a rate of 50 ml in 15 l of water was applied in April 2002 using a knapsack sprayer followed by regular hand weeding.

3.2.6.2 Fertiliser application

Fertilizer was applied five weeks after planting at a rate of 60 kg N ha^{-1} as NPK 25:5:5 mixed from straight fertilizers urea, TSP and muriate of potash (MOP). The pH of the soil (in water) at 5.3-5.8 (Table 2) was at the upper end of the optimum range for tea of 5.3-5.6 (Landon, 1991) or 5.0-5.6 (Othieno, 1992). Therefore, the source of nitrogen was changed from urea to sulphate of ammonia in other fertilizer applications in order to lower the pH to optimum range. According to Gokhale (1957) and Tolhurst (1966), cited by Boheure and Willson (1992) sulphate of ammonia has the effect of acidifying the soil, hence, lowering the pH. However, fertilizer was not applied during the short rains due to the low rainfall that was obtained. A second fertilizer application at the rate of 60 kg N ha^{-1} was done in March 2002 after the onset of long rains.

3.2.6.3 Drought problem and infilling

Young tea plants suffered severe drought problem from July 2001 to March 2002. This was caused by lack of the short rains from October to November. A death rate of 11.8%

was recorded across the experiment in March 2002 after the onset of long rains. Dead plants from May 2001 to March 2002 were 16, 62, 13 and 38 for the control, high density tea rows, mulch and vetiver grass treatments, respectively ($P < 0.05$) (Fig. 2; Plate 8). Infilling to replace dead plants was done in March 2002.

Plate 8: Live barrier (vetiver grass) growing in March 2002, one month after being lopped. Vacancies are seen in the tea row below the vetiver grass row at the end of the prolonged drought period. The Amani Nature Reserve forest is seen at far side

3.2.6.4 Bringing tea into bearing

Cutting of the middle stem of the tea bushes at 30 cm (decentering) in order to hasten the development of lateral shoots was done in February 2002. Vetiver grass in live barrier plots was first lopped (cut down to 10 cm above ground) at the same time and spread on adjacent tea area to protect the severely drought affected tea bushes.

The second vetiver grass lop was done in April 2002, the lopped grass was weighed to get fresh weight and a sample collected and weighed to determine the air dry mass. The lopped grass was spread in the guard rows. Light pruning of tea at 40 cm height was done in late March 2002 to establish the flat harvesting surface "plucking table".

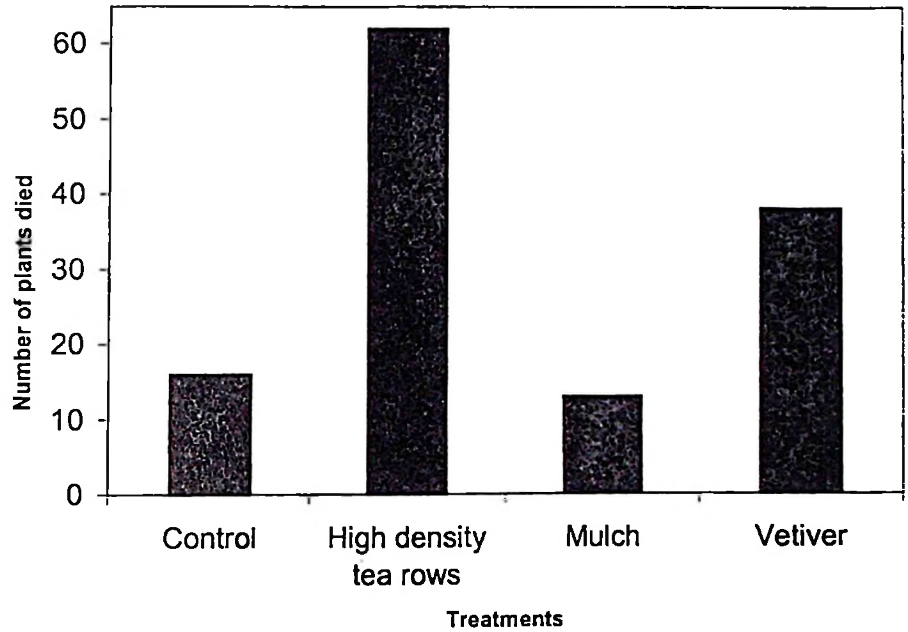

Figure 2: Dead plants in each treatment from planting in May 2001 to March 2002 in the soil and water conservation experiment at Marikitanda Tea Research Station, East Usambara. $P < 0.05$, LSD ($P=0.05$) = 2.12

The first plucking was done in late March 2002 at 40 cm height. The second and third pluckings were done at 45 cm height from the ground surface. Thereafter plucking was done at 50 cm. Care was taken not to pluck the shoots growing side-ways as these were leading to an increase in canopy cover.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Factors Limiting Adoption of Recommended Soil and Water Conservation Practices in Young Tea Fields in Usambara Mountains

4.1.1 Land availability and ownership

Sixty nine per cent of the people interviewed in Usambara Mountains owned between one half and four hectares of land, followed by 19% owning between four and eight hectares and 12% with eight hectares and above (Table 4).

Table 4: Farm size and proportion of ownership by the population, March 2001

Farm size (hectare)	Proportion of ownership (%)
0.5-4.0	69
4.0-8.0	19
>8.0	12
Total	**100**

The owned land is used for growing field crops, livestock keeping, as fallow land as well as for erecting residence houses. The study revealed that in the Usambara Mountains land was acquired by inheritance, buying from other people, hired from other people and allocated by the government during the "*Ujamaa*" policy (Table 5). By March 2001, the government had allocated twenty four per cent of the land owned by people in Usambara.

Table 5: Mode and proportion of land acquisition in tea growing areas in Usambara Mountains

Mode of land acquisition	Korogwe (%)	Lushoto (%)	Muheza (%)	Mean (%)
Inherited	78	54	0	44
Bought	22	34	38	31
Allocated	0	10	62	24
Hired	0	2	0	1
Total	**100**	**100**	**100**	**100**

The proportion of land obtained by buying from individual farmers and allocation by district authorities is high in Muheza (38% and 62%, respectively). This group includes people called "*Manamba*" who came from other areas searching for employment in coffee and tea estates. Thereafter they decided to settle. Sixty seven per cent of the residents of Amani, where employment in tea estates was available, immigrated from other areas (Table 6).

Table 6: Origin of residents in tea growing areas in the Usambara Mountains, March 2001

District	Indigenous to the area (%)	Migrated from other areas (%)	Total (%)
Korogwe	89	11	100
Lushoto	100	0	100
Muheza	33	67	100

Increasing population and prices of land were cited as the main factors restricting people from increasing the size of their farms. In East Usambara the National Forest Reserve surrounding the upper plateau where tea is grown has imposed regulations that hinder people from clearing the forests for cultivation. This means that the increasing population will entirely depend on and concentrate within the existing opened up agriculture land (Sanga and Simbua, 2003). Similar results were reported in Kenya whereby land pressure was cited as a problem limiting tea production (M'Imwere, 1997; Seurei, 1997)

Tea is a crop that requires a reasonably large area to realize profits and thus faces problems of area expansion due to limited land availability. Tea in Usambara Mountains (and in most tea growing areas in Tanzania) is grown as a sole crop. Therefore, any land set aside for tea will not be used for any other crop. Competition of tea with other crops for land and labour was observed in Usambara Mountains. In East Usambara tea competes with spices (cardamom, cinnamon, cloves and ginger), sugarcane and tomatoes. In West Usambara production of tomatoes, vegetables and fruits trees competes with tea farming. Sometimes these crops replace tea in priority by the farmers, and, in the past, this was intensified by low prices and unreliable market for the green leaf.

Results from land availability and ownership, tea cropping system and the by-laws imposed by the National Forest Reserve indicate that the current land pressure will go on increasing as the population increases. The optimum use of the current land owned by people by improving agronomic cultural practices (Owuor, 1997; 2001) is an important solution to the expected land pressure problem. It is apparent, therefore, that proper land use is required (Ndamugoba *et al.*, 2000). This will include application of recommended soil and water conservation practices in young tea and other crops fields.

4.1.2 Soil erosion in young tea fields in Usambara Mountains

Only 7% of the population in the Usambara Mountains understood that sheet is one of the erosion types while splash erosion was not known. Rill and Gully erosion accounted for 27 and 66%, respectively (Table 7).

Table 7: Types of soil erosion and proportion of the population understanding them in Usambara Mountains during the survey, March 2001

Type of soil erosion	Proportion of population understanding (%)
Sheet erosion	7
Rill erosion	27
Gully erosion	66
Soil mass slide	3
Splash erosion	0
Total	**100**

Few people in Usambara Mountains regard sheet erosion as an important type of soil erosion. Most of them relate erosion to gullies and rills (or water ways on the surface of soil). This is caused by the long time lag between occurrence of sheet erosion and observation of its effects, which include poor nutritional status and low water holding capacity of soil, hence low soil productivity. This reason is found to affect most soil erosion control measures, not only in tea but also in other crops (Rauschkolb, 1971; Sanga and Simbua, 2001).

The current study indicated that mechanical structures, which include terraces, ridges and major drains were the main soil and water conservation methods practised by people in the Usambara Mountains. This accounted for 69% of the total soil erosion practices applied in the area, followed by live barrier (59%) and agroforestry (16%). The use of mulching (12%) was the least (Table 8). Most of the methods were applied in annual or seasonal crops. Few methods were applied in tea, particularly young tea. High level of application of mechanical structures and live barriers "*makinga maji*" may be influenced by the high level of erosion in the lowlands of Korogwe and some parts of Lushoto where SECAP and the African Highland Initiative (AHI) projects are based. Mulching, which is usually used to control splash and sheet erosion, is not widely applied (Table 8).

Table 8: Soil and water conservation practices and proportion of the population applying them in Usambara Mountains during the survey, March 2001

SWC practices	Proportion of population applying (%)
Mechanical structures	69
Live (crop) barriers	59
Agroforestry	16
Mulching	12
Total	**156***

*Some respondents were using more than one practice

Unless people are educated on the hazards brought by sheet erosion and benefits from controlling these problems, their habit of neglecting this important step in the farming system will not change. Similar findings were reported in Kenya by Tengberg *et al.* (1999) in their studies on using indigenous soil and water conservation (ISWC) practices in land management. According to Keregero *et al.* (1977), Keregero (1992) and Ekpere and Shetto (1992) this problem may be reduced by strengthening linkages through adaptive research between research stations, farmers and extension workers.

Dissemination of information to farmers through extension and other channels need to be improved. It was also advised by Falck (1992) and Mussei and Shiyumbi (1992) that it is important to have flow of information in the opposite direction as well as regular training of the extension staff with focus on smallholder farmer's real needs. Carr *et al.* (1990) listed various reasons leading to poor adoption of research findings by farmers. These included lack of contact of research workers with each other, with extension staff and with farmers. Similar observations were given by Hatibu *et al.* (1999). Malley and Temu (2001) reported the success obtained when partnership between researchers, farmers and extensionists were used to improve indigenous soil and water conservation projects (ISWCPs) in the Southern Highlands of Tanzania. The Technology Transfer Unit (TTU) of the Tea Research Institute of Tanzania must find ways of filling this gap in tea growing areas.

4.1.3 Mulching in young tea fields

Few smallholder tea growers in Usambara Mountains apply mulch in their newly established tea farms. However, this study revealed that trash obtained from weeding was left in the field as mulch and accounted for 83% of total mulching materials used compared to 7% for Guatemala grass. Other grasses contributed only 10% of the mulching materials (Table 9).

Table 9: Mulching materials and their proportion of use in smallholder young tea fields in Usambara Mountains prior to the survey, March 2001

Type of Material	Proportion of use (%)
Trash from weeding	83
Guatemala grass	7
Other grasses	10
Total	**100**

However, various research findings have recommended mulching mostly using Guatemala grass as the most effective method of soil and water conservation in young tea fields (Field, 1970; Rauschkolb, 1971; Templer, 1973; Tolhurst, 1973; Aono, *et al.*. 1974; Bates, 1975; Othieno, 1975a 1975b; Othieno, 1979; Sandanam and Rajasingham. 1981; Sandanam, 1986 and Nyasulu, 1995; 1996; 1999; 2000).

The farmers reported that leaving trash in the field was not related to soil erosion control. Trash from weeding was said to conserve moisture and add manure upon decomposition. However, according to Rauschkolb (1971) the use of mulches, primarily crop residues and weed trash, is an effective way to prevent soil perturbation by rainfall. Similar recommendations were given by Okigbo and Lal (1977) and the Tea Research Foundation of Kenya (TRFK, 1986). Extension staff and farmers in Usambara Mountains need to be educated on types of erosion (splash, sheet, rill gully and soil mass slide) and their appropriate control measures. In young tea, mulching should be part and parcel of extension staff package of skills to be delivered to farmers. Mulching should be regarded as essential as planting materials, particularly in the large slopes of the Usambara Mountains.

In Amani and parts of Lushoto, the recommended mulching material (Guatemala grass) has an alternative use. It is used for feeding stall-fed livestock. Furthermore, large amounts of Guatemala grass are required for mulching large areas of young tea and, therefore, need substantial land to be grown. This, in turn, increases the pressure on land requirement. Therefore, alternative grasses to supplement or replace Guatemala grass as mulching material need to be investigated and recommended.

4.2 Effects of High Density Tea Rows on Soil Erosion Control in Young Tea Fields in Usambara Mountains

4.2.1 Experimental plants death rate

Field observations and analysis of data revealed that young tea death rate was higher in high density as well as in vetiver treatments than in control and mulch plots ($P < 0.01$). Death was lowest in mulch-treated followed by control plots (Figure 2). Dead plants in high density rows accounted for 88% of the total dead plants in their plots while plants died in rows adjacent to vetiver live barriers accounted for 92% of total dead plants in the plots with vetiver live barrier. High death rate of plants in vetiver grass and high density tea plots might have been contributed by competition between tea plants and vetiver grass and between tea plants themselves, respectively, for water during extended dry spell. Similar observations were reported by Othieno (1975a) and Nyasulu (1999; 2000) whereby competition between tea plants and live barriers were reported.

Vetiver grass roots have downward growth, hence, reducing competition with the crops close to the line (National Research Council, 1993; Mtakwa, P.W. personal communication, 2002). However, under prolonged drought spells like the one that happened in the Usambara Mountains in the 2001/02 growing season, competition may occur and affect the adjacent plants. Vetiver grass grew very fast producing a big canopy and therefore large biomass within a very short time, e.g. one row of 16 m produced 18 kg air-dry grass in two and a half months after the first cut in February 2002. Fast growth of vetiver grass can be useful if the interval between the grass rows can be widened to reduce the risk of competition during prolonged droughts. Additionally, the canopy can be lopped and mulched in the intermediate space between the rows, hence, getting the benefits of both practices: the live barrier and mulch. This will also effectively replace Guatemala grass that is used as fodder for cattle.

4.2.2 Canopy cover, yield and stem diameter

Initial results of soil and water conservation field experiment (Table 10) indicated that in the first year from planting there was an average canopy cover of 52.2% for bushes in plots with high density tea rows.

Table 10: Canopy cover, Yield and Stem diameter measurements from the soil and water conservation experiment at Marikitanda Tea Research Station, East Usambara from June 2001 to May 20002

Treatment	Canopy cover (%)	Yield (made tea) (kg ha^{-1})	Stem diameter (mm)
Control	32.2a	17.8a	16.7a
High density tea rows	52.2b	20.1a	13.9a
Guatemala mulch	31.0a	44.9b	15.1a
Vetiver grass rows	31.7a	14.0a	15.3a
Mean	36.8	24.2	15.0
LSD (P=0.05)	11.7	15.4	4.8
CV%	20.2	32.4	16.1

Means with the same letter in the same column do not differ significantly (P=0.05) according to Duncan's New Multiple Range Test. LSD = Least Significant Difference between means; CV = Coefficient of variation over the means.

This was significantly higher than 32.2%, 31.0% and 31.7% of control, Guatemala mulch and vetiver grass plots, respectively ($P < 0.01$) (Table 10; The same result is depicted in Figure 3). Fast growth of canopy cover is important in the control of raindrop splash erosion and run-off, especially in young tea fields on steep slopes where time limits infiltration of rain water (Othieno, 1975a; Krishnarajah, 1985). It is also important in early high yield production in a newly established tea field (Kigalu, 1997).

Guatemala mulch plots yielded significantly (P = 0.01) more than other treatments, with 44.9 kg made tea ha^{-1}. This could be attributed to the ability of the mulch to encourage better moisture infiltration and reduced evaporation. The control, high tea density and vetiver grass live barriers produced 17.8, 20.1 and 14.0 kg made tea ha^{-1}, respectively.

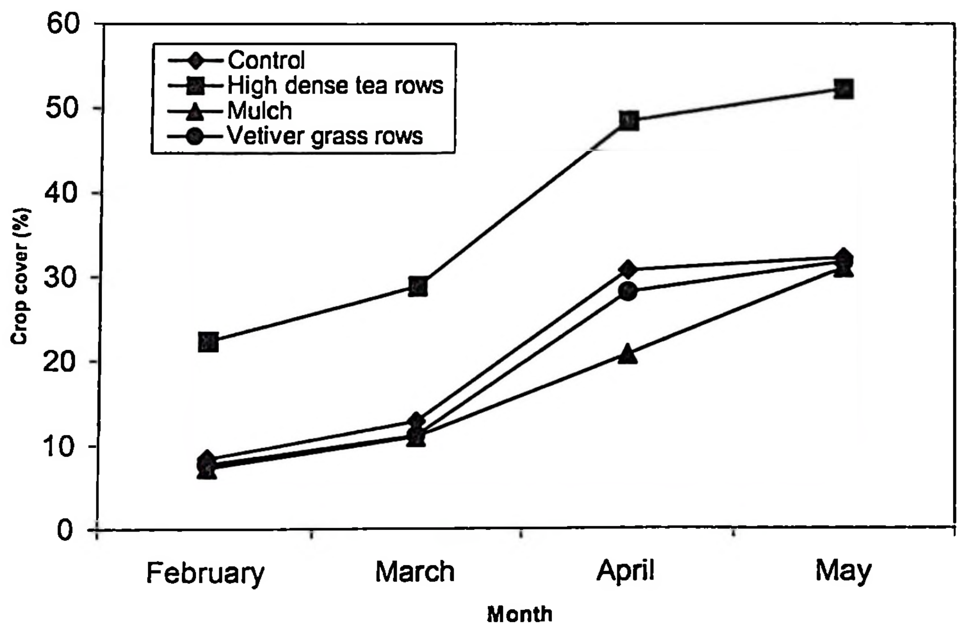

Figure 3: Canopy cover development in soil and water conservation experiment at Marikitanda Tea Research Station, East Usambara from February to May 2002.

Low yield in vetiver grass treatment may be attributed to high death rate of plants caused by the extended drought and competition of tea bushes with the grasses during the year. Similar results were reported by Sandanam and Rajasingham (1981) in the first year of plucking a young tea trial conducted in Sri Lanka. There was insignificant difference in stem diameter within the treatments. Rajasingham (1980) observed similar results in Sri Lanka.

4.2.3 Soil erosion or deposition

Low rainfall with poor distribution during the year resulted into poor response of treatments to soil loss or deposition in the first nine months from planting. Measurements were taken during the long rains from March to May 2002 which had low rainfall compared to the previous years. Initial results of soil erosion showed that there was lower soil loss in Guatemala grass mulched plots with soil loss of 7.8 Mg ha^{-1} ($P < 0.05$; Table 11). Vetiver grass had the highest soil loss of 28.6 Mg ha^{-1} while control and high tea density treatments had 26.0 and 23.4 Mg ha^{-1} soil loss, respectively.

Table 11: Soil erosion and deposition in soil and water conservation experiment at Marikitanda, in East Usambara between February and May 20002

Treatment	Soil erosion	Soil deposition
	(Mg ha^{-1})	
Control	26.0ab	-20.8a
High density tea rows	23.4b	-15.6a
Guatemala mulch	7.8c	0.0a
Vetiver grass rows	28.6a	52.0b
Mean	21.5	3.9
LSD (P=0.05)	2.9	31.8
CV%*	156.3	414.6

Means with the same letter in the same column do not differ significantly (P=0.05) according to Duncan's New Multiple Range Test. LSD = Least Significant Difference between means; CV = Coefficient of variation over the means.
*High coefficient of variation was caused by large range of data from negative to positive figures.

Although a large amount of soil was eroded on the upper part of plots with live barrier of vetiver grass, more soil was trapped by vetiver grass rows, hence, deposition ($P < 0.01$).

A total amount of 52.0 Mg ha^{-1} of soil was deposited in vetiver grass plots as compared with -20.8, -15.6 and 0.0 Mg ha^{-1} soil deposition in the control, high density tea rows and Guatemala mulch treatments, respectively.

Good soil surface cover, which reduced both raindrop splash and surface run-off, contributed to the low movement of soil particles in Guatemala grass mulch. Low soil loss in Guatemala mulches was also reported in Kenya by Othieno (1975a), in Sri Lanka by Sandanam and Rajasingham (1981) and Krishnarajah (1985) and in Malawi by Nyasulu (1996; 2000), also reported by the Tea Research Foundation of Central Africa (1990).

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this study, lack of understanding of the presence and hazards of soil erosion, particularly raindrop splash and sheet erosion types, was found to be the major factor limiting farmers from carrying out erosion control measures, not only in tea but also in other crops. Land pressure and increasing population in the Usambara Mountains hinder the farmers from growing grasses such as Guatemala grass for mulching. It was also found difficult for farmers to use the little available Guatemala grass for mulching since this grass has a priority use in stall-fed livestock.

Initial results of testing high density tea rows as live barriers have shown low effect of this practice in the control of soil loss as well as in trapping eroded soil particles. Although it was less effective in the control of soil erosion, high density tea had fast canopy cover growth, which is a very useful component in minimizing both raindrop splash erosion and run-off.

Most soil particles were trapped by vetiver grass rows, enabling the eroded soil particles to remain within the plots. Guatemala mulch was effective in the control of raindrop splash erosion and run-off, hence affording minimum soil disturbance.

5.2 Recommendations

1. Farmers need to be made aware of the different types of soil erosion, especially the insidious ones. The Technology Transfer Unit (TTU) of TRIT and other extension officers must be well equipped with this knowledge and be able to effectively communicate it to the farmers.

2. Mulching in young tea fields should be regarded as a necessary practice.

3. The growth rate of vetiver is very high producing a lot of dry matter within a short time. Farmers may use vetiver grass as live barrier in relatively wider row spacing. The lopped grass may be used as mulching material within the same tea field. This will eventually replace Guatemala grass mulch.

4. Tea Research Institute of Tanzania is recommended to continue with the trial and get more information to be added to the available results. Economics of using high density tea rows as live barrier in terms of cost of planting materials and the early high yield obtained from the plants should also be worked out.

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APPENDICES

7. APPENDIX I

Questionnaire for Soil and Water Conservation in Young Tea Fields in Usambara Mountains, Tanga Region, Tanzania

7.1. Introduction

Questionnaire No.		Date	

District		Code		Village		Code	

Name of respondent			
Gender of respondent	1. Male 2. Female	Code	
Age of respondent			
Marital status	1.Single 2.Married 3.Divorced 4. Widowed 5. Separated	Code	
Family size			

Name	Gender	Age	Relation to househead

Education of respondent	1.None 2.Primary 3.Secondary 4. Post secondary 5. Adult education	Code	
Occupation	1.Agriculture 2.Non-farming 3.Others (specify)	Code	
Is the respondent indigenous to the area?	Yes/No	Code	

7.2. Field /Biophysical information

What is the size of your farms ______________________________

7.2.2. How did you acquire the land

Mode of acquisition	Area
Bought	
Inherited	
Allocated	
Leased	
Borrowed	
Other means (specify)	
Total	

7.2.3 Which crop do you grow and for what purposes (cash/food)

Cash crop	Farm size	Rank	Food	Farm size	Rank

7.2.4. Describe the main cropping patterns you practice in tea based on farming systems?

Cropping pattern	Crops grown	Topography	Distance	Implements
1.Sole crop (monocropping)				
2. Mixed cropping				
3. Intercropping				
4. Fallow cropping				
5. Others (specify)				

7.2.5. Do you have any access to information on improved cropping systems? Yes/No
If Yes what are the sources and which type of information

Source	Institution	Type of information
1. Field Extension Officer		
2. TRIT staff		
3. Neighbours		
4. Others (specify)		

7.2.6. Do you use mulch in newly planted tea? ....yes/no.
If yes, why, what type of mulching material do you use, and where do you obtain them?

Material	Source	Availability Adequate/inadequate	Reason for use

If Not, why?

____

____

____

If inadequate, how do you counteract the deficit?

____

____

7.2.7. What other measures do you use to protect young tea plants during establishment phase?

____

____

____

7.2.8. Are there any problems related to tea farming? Mention them

Category	Problems	Coping strategy
2.8.1 Establishing of tea field	1	
	2	
	3	
	4	
Crop husbandry	1	
	2	
	3	
	4	
Marketing	1	
	2	
	3	
	4	

7.3. Soil Erosion Management

7.3.1. What do you know about soil erosion?

____

____

7.3.2. Is any part of your field affected by soil erosion ....yes/no

Describe how the erosion affects you field

____

____

____

____

7.3.3. Do you know any soil erosion control measures ....yes/no
If YES mention them

____

____

____

7.3.4. Do you use any of the soil erosion control measures on your field .. yes/no
If NOT why?

____

____

____

7.3.5. What factors determine the adoption of soil conservation measures?

____

____

____

7.3.6. Where did you learn about the control measures?

____

____

____

7.3.7. What problem do you encounter during soil conservation measures?

____

____

____

7.3.8. What is your suggestion on the effective and convenient soil erosion control measures for smallholder tea growers

____

____

____

7.4. Labour utilization

7.4.1. Who is responsible for the farming operations conducted in your household

Farming operation	Crop 1	Crop 2	Crop 3	Crop 4
Field preparation				
Cultivation				
Planting				
Weeding				
Fertilizer application				
Pruning				
Plucking/harvesting				
Marketing				
Conservation				

AM-Adult male	
AF-Adult female	
CH-Children	
HC-Hired labour	

7.4.2. Is the available manpower adequate for the above mentioned activities? Yes/no.

If NO, how do you compensate for the deficit

____

____

____

____

____

____

7.5. Tea Marketing

7.5.1. Where is your main green leaf market ____________________

7.5.2. How accessible is the market ________________________

7.5.3. Type of the buyer________________________________

7.5.4. Mode of payment ________________________________

7.5.5. Price level ___________________________________

7.5.6. What should be done to improve green leaf market ____________

____

____

7.6. Use of revenue from tea

7.6.1. What are the main use by proportion of revenue from tea

Use	Proportion	Rank
Domestic needs		
Farm inputs (specify)		
School fees		
Social obligations		
Recreation		
Others		

7.6.2. Is the revenue adequate to sustain your family needs? ……. Yes/no

If NO how do you overcome the deficit

____

____

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____

____