SOCIO-ECONOMIC AND AGRONOMIC FACTORS INFLUENCING SOIL EROSION IN THE MASINGA DAM CATCHMENT, KENYA

DORTHY NDUKU MUTISYA

DEPARTMENT OF GEOGRAPHY

KENYATTA UNIVERSITY

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DECLARATION

This PH.D thesis is my original work except where acknowledged by reference or citation and has not been presented either wholly or in part, for a degree in this or any other university.

DOROTHY NDUKU MUTISYA

This thesis has been submitted with the approval of my university supervisors.

DR. S.K. MUTISO

DR. W.N. WAMICHA

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ABSTRACT

This research examines agronomic and socio-economic factors influencing soil erosion in the Masinga dam catchment. The study addresses soil erosion from a human point of view as opposed to the common and widespread "physical approach" that has in the past been used by many scientists.

The following two null hypothesis formed the basis of this research:(i) There is no significant difference in the amount of soil loss between farms under different agronomic practices; and (ii) There is no significant difference in socio-economic status between farmers whose farms are experiencing less and severe soil erosion in the study.

Three sets of data including socio-economic, agronomic and soil loss were collected from Kaihungu and Mathauta Sub-catchments in the Upper and Lower parts of the Masinga Dam Catchment. A questionnaire was used in the collection of the socio-economic data and part of the agronomic data. Crop cover was estimated by visual observation while crop density was calculated from crop spacing measurements taken in the field.

Soil loss data was collected using 26 soil traps during the Long and Short Rainy Seasons of 1992. Composite top soil samples were collected from the upper decimeter of 26 sites. These were used in the determination of soil texture and fertility.

Two non-parametric tests namely, Chi-square (X^2) and Mann-Whitney U test were used as the main statistical tools for data analysis. These analyses reveal that accelerated soil erosion is a major environmental problem experienced in the study area. For instance, according to the Mann-Whitney U test analysis, there was not a significant difference in the amount of soil loss between farms under different crops and cropping patterns. That is, soil loss was high in farms where monocropping or intercropping were practised. Similarly, soil loss was high in farms with medium crop density as well as in those with low and medium crop densities. The explanation for these findings is that none of the sampled farmers practised a combination of all the required appropriate agronomic measures. Many of them adopted one or a few of the good agronomic measures thus making soils vulnerable to agents of erosion.

The Chi-square (X^2) results reveal that a large number of the farmers (88%) whose farms had a severe soil erosion problem experienced numerous intricate socio-economic problems hindering them from practising the recommended soil conservation measures. These results indicate that there is a significant difference in socio-economic status between farmers whose farms experienced less severe and severe soil erosion in the Masinga dam catchment. On one hand, farmers experiencing severe soil erosion were poverty stricken and resource poor. They owned small and fragmented farms, and had little or no access to extension services and credit and had little or no on-farm and off-farm income.

On the other hand, however, the few farmers who did not experience severe soil erosion had relatively high on and off-farm incomes, relatively large farms, access to agricultural extension services and were generally highly educated. The implication here is that the progressive farmers have surpluss land and working capital. These can be contrasted with the "resource poor" farmers who can hardly invest on soil and water management in their farms.

Based on the findings of this study, it is recommended that sustainable short and long term solutions to soil and water management problems among the resource poor farmers be sought. These should initially take the form of increased subsidies and incentives among the farmers. Also, it is paramount for academicians to conduct more research in order to monitor and quantify the rate of soil erosion in the entire catchment. The magnitude of soil erosion emanating from bare grounds should also be determined.

DEDICATION

To my children Musembi and Nthenya

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CHAPTER ONE

INTRODUCTION

1.1 The problem of soil erosion: an overview

Soil erosion is one of the major land management problems threatening the economic productivity of the agricultural land in the tropics (Stocking, 1984; Lal, 1990). Many of the tropical countries characterized by high and rapidly growing population are facing a critical population - agricultural land resource imbalance which is aggravated by mismanagement, and over exploitation of the available arable land resource. Further, a scarcity of high potential agricultural land and the unavailability of and costly essential farm inputs compound the problem of dwindling land resource in the tropics, resulting in reduced productivity.

There is already an imbalance between population and the supporting land resource in Kenya. Out of the country's 56.9 million hectares (Ha) of land, only about 17% can be classified as of medium and high potential.These support about 80% of the population and over half of the livestock (Kenya, 1981; 1994). The concentration of the majority of the population in such a small portion of the country has resulted to: land subdivision, land fragmentation,over-cultivation, over-grazing, landlessness, deforestation,and migration of some of the people to the fragile marginal zone. These are clear manifestations of the population - land problem whose effects result in soil erosion. The latter has a negative implication on the efforts geared towards the achievement of sustainable agriculture in Kenya.

Besides soil formation being extremely slow (Stewart, Lal & El-swaify,1991) soil erosion is of a great global concern because: first,it leads to the removal of top soil and consequently to the loss of both applied and native plant nutrients.The result is reduced agricultural land productivity per unit area (Kilewe, 1989; Lal, 1990). Rehabilitation of the farm land usually increases the cost of production to a level which is beyond the financial means of the ordinary farmer.

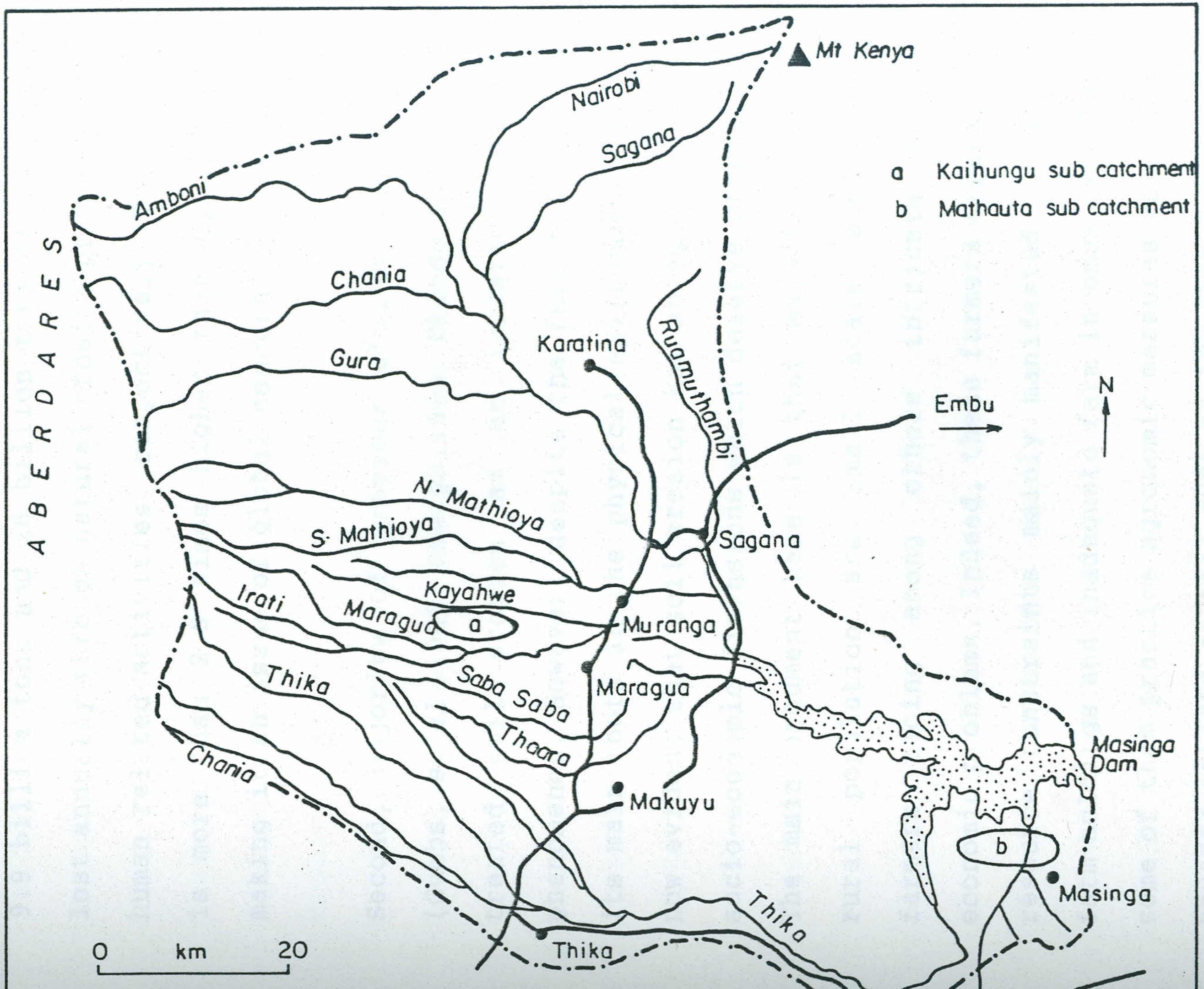
Second, soil erosion also contributes to the siltation of reservoir and irrigation channels. A large proportion of the sediments produced in the agricultural land, bare grounds and footpaths are transported downstream and deposited into the rivers and dams causing a serious siltation problem (Barber,1982; Edwards, 1979 and Dunne, Dietrich and Brunengo, 1978).

Solutions to the problems associated with soil erosion are very costly both at the household and national levels. At the former, the farmers are forced to spend their low incomes in the purchase of additional food and farm inputs while at the national level, the government has to spend its foreign exchange in food imports and on equipment for dredging the silted dams and channels. Mellor & Brennam (1986) estimated the damage resulting from soil erosion at $ 26 billion annually in Africa. The damage is likely to be worse in Kenya where there is a pressing demand for agricultural land but limited resources to combat the problem (Wolde & Thomas, 1989). This, therefore, calls for immediate investigation into the soil erosion problem because its socio-economic effects are costly, widespread and long lasting.

Thus, the aim of this study was to investigate the causes of soil erosion in the Masinga dam catchment in Kenya (Fig.1.1). Much emphasis was placed on the agronomic practices and socio-economic aspects of soil erosion. These were hypothesized to play a crucial role in accelerating the natural soil erosion processes.

1.2 STATEMENT OF THE PROBLEM

The aim of this research was to investigate agronomic and socio-economic factors contributing to soil erosion in the Masinga dam catchment. The basis of the study was to address soil erosion from a human point of view; hence giving it a "humanistic approach". This involved an investigation of the man-related activities as they contribute to the soil erosion problem. Such an approach is vital because man has previously been found capable of modifying nearly all the physical factors causing soil erosion including: soils, topography, and vegetation except climate, either to reduce or to accelerate the erosion process (Morgan,1986), thus, making him a key agent in the soil erosion problem.



Source: Atkin (1984)

Fig·1·1: The Study Area

Two reasons were put forward to justify the study. First, human induced erosion is increasing at an alarming rate. Lal and Pierce (1991) estimated that 9.9 billion tons and 26 billion tons of soil are lost annually through natural erosion processes and human related activities respectively. The latter is more than 2.5 times higher than the former, making it an issue of global concern.

Second, majority of previous studies including; (Gumbs, *et al* 1985; Omwega,1989; Obando,1990) have treated soil erosion as an isolated physical phenomenon. However, despite the fact that it has its main roots in the physical environment, it is now evident that soil erosion has an agronomic and socio-economic dimensions which deserve attention. The main argument here is that majority of the rural population are small scale subsistence farmers facing among others intricate socio-economic problems. Indeed, these farmers experience resource constraints mainly manifested in small farm holdings and inadequate farm incomes. Further, some of them practice agronomic measures which have adverse effects on soil such as low crop densities, late planting, crops and cropping patterns that are prone to soil erosion, use of inadequate farm inputs *etc*. The result has been mismanagement and over-exploitation of the available land resource base; the ultimate consequence being soil erosion, reduced land productivity, food shortages and desertification.

Therefore, there was need to investigate the agronomic and socio-economic aspects of soil erosion.

1.3 Objectives and scope of the Study.

The broad objective of this study was to investigate both agronomic and socio-economic factors and their potential contribution to soil erosion in the Masinga Dam Catchment. The specific objectives are stated as follows;

(1) To examine the agronomic factors contributing to soil erosion;

(2) To investigate the socio-economic factors contributing to soil erosion;

(3) To investigate the farmers awareness of the soil erosion problem; and,

(4) To identify the types of soil conservation measures practiced by the farmers and the problems

hindering their successful implementation.

1.4 Research Hypotheses.

The following two hypotheses were investigated.

(1) H_0: There is no significant difference in the amount of soil loss between farms under different agronomic practices;

H_1: ALTERNATIVE

(2) H_0: There is no significant difference in socio-economic status between farmers whose farms are experiencing less and severe soil erosion in the study area.

H_1: ALTERNATIVE

1.5 JUSTIFICATION OF THE STUDY AND CHOICE OF STUDY AREA

This study was carried out as part of nationwide campain to conserve soil and water as a strategy to protect the environment from further degradation. The Kenya Government's effort to reduce soil erosion had clearly underscored the importance and the seriousness of the problem. This concern emanated from the fact that soil erosion has many negative and costly consequences for human ecology and economics (Dunne,1976). In addition to soil losses, large amounts of soil nutrients are removed through run off, resulting in a decrease in the productivity of the affected areas, the siltation of reservoirs and clogging of irrigation channels. Erosion also, results in reduced water quality and clogging of river channels, thus increasing flood hazards.

Therefore, this study was justified in the sense it drew attention of the academicians, and policy makers to the agronomic and socio-economic factors causing soil erosion. Second, the study proposes several ways through which soil erosion can be controlled.

It was hoped that the findings would be useful mainly to policy makers in devising and formulating relevant land and crop management strategies aimed at sustainable development of the available resources.

The Masinga Dam Catchment area was chosen for this study because it suffers from a serious soil erosion problem (Atkins, 1984; Kenya, 1989). According to Wooldrige (1984) the catchment sediment yield was estimated to be increasing in the rate of; 305 M^3/km^2/year in the period between 1968 and 1974; 357 M^3/Km^2/year between 1974 and 1981 and 1099 M^3/Km^2/year in the period 1981 and 1983. This has two important implications for the Kenya Government: first, a lot of sediments brought into the Masinga dam are likely to cause siltation of the dam thus affecting the aquatic life and Hydro-Electric Power production. Second the catchment particularly the upper areas form one of the most productive regions of the country and if this potential is lost through soil erosion then, food shortages are bound to occur and the government's objective of achieving food self sufficiency will be difficult to achieve.

1.6 Operational definitions

<u>A Household</u> comprises a person or group of persons bound by ties of kinship who normally reside together under a single roof or under several roofs within the same compound such persons who share a community life in that they are answerable to the same head and have a common source of food (Kenya,

1981a). Under this definition, polygamous wives living within a single compound are included in the same household regardless of the cooking arrangements. Those in separate homesteads are considered as two households.

Humanistic approach to the soil erosion problem: In this study it is considered as the social dimension of soil erosion. It views man as part and parcel of the soil erosion problem. This approach involves an understanding of man's contribution to soil erosion and/ his effort to combat it.

Land degradation is the reduction or loss in arid and, semi-arid and dry sub-humid areas of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland or range, pasture, forest and woodlands resulting from land uses or from a process or combination of procceses, including processes arising from human activities and habitation patterns such as:

(i) soil erosion caused by wind and /or water;

(ii) deterioration of the physical, chemical and biological or economic properties of soil and

(iii) long term loss of natural vegetation (UNEP, 1995).

Physical approach to the soil erosion problem: it is here defined as the physical dimension of soil erosion. The approach views soil erosion as a purely physical problem.

Population pressure suggests an imbalance between human beings together with their needs and the natural as well as the human resources which leads to a long term deterioration of the ecosystem and the human conditions in a given area (Kisovi, 1989 and Sindiga, 1989). In this work it is defined as a state of imbalance between human beings and the available physical resources resulting from too many people and inadequate techonology.

Soil erosion is a process of land denudation which involves the removal of surface material by wind or water (Kirkby, 1980). In this study, it is defined as the loss of soil by water or wind ultimately leading to low land productivity. The latter is what is referred to here as "the soil erosion problem" which includes reduced land productivity and the associated financial implication.

Sustainable agriculture is the succeessful management of resources to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources (Lal and Pierce, 1991). It is here used to refer to a proper resource management with a view to minimising soil erosion thereby achieving high farm productivity.

CHAPTER TWO

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.0 Introduction

This chapter examines literature related to the socio-economic and agronomic aspects of soil erosion with particular reference to the Tropics. The literature is reviewed under two sub headings, namely; "socio-economic aspects of soil erosion" and "agronomic dimension of soil erosion".

2.1 Socio-economic aspects of soil erosion

Soil erosion is a function of climate, soils, relief, vegetation cover and land use management (Hudson and Jackson, 1959; Morgan, 1986; and Lal,1990). Many researchers on soil erosion such as Hudson (1971) Mitchel and Bubenzer (1980) Evans (1980), Obando (1990), and Omwega (1989) have concentrated mainly on the physical factors, some of which are difficult to alter, ignoring completely or briefly mentioning the very important role played by human beings in the problem. It is well established that with man's interference, topography, soil characteristics and vegetation cover can be modified thereby reducing or accelerating soil erosion.

Two groups of scholars on soil erosion can be cited. The first major group of researchers have associated population growth with land degradation and soil erosion. The second but smaller group associate soil erosion with population growth hence farm intensification Tiffen, Mortmore, and Gichuki, (1994) and Boserup (1965). Tiffen et.al (1994) are of the view that population growth leads to less environmental degradation. Quoting extensively from Machakos district, they assert that due to population growth, soil erosion has been eliminated or greatly reduced in both arable and pasture land. Their work, however, fails to show exactly how population growth leads to less erosion. Instead it comes out clearly that improved land management depends on the availability of capital and labour which do not necessarily increase with population growth.

Similarly, according to Boserup (1965), population growth is not a developmental problem but a major determinant of technological change in agriculture. She asserts that high population growth leads to shortages of arable land, leaving the affected farmer with no alternative but to adopt farm intensification practices including the use of fertilizers, manure, high yielding seed varieties, insecticides and pesticides as well as appropriate soil conservation measures. Such practises would consequently result in high farm yields. To a large extent, the latter argument does not however, reflect the reality in developing countries where poverty is a major constraint towards the achievement of sustainable economic development. Indeed, farm intensification is a costly exercise which may not be easy to achieve particularly in farming systems where subsistence farming dominates. In the less developed countries, this technology is usually adopted by a few financially well-off farmers . For instance, a few farmers in the Masinga Dam Catchment are practising farm intensification and through this, french beans among other horticultural crops are grown.

On the other hand, cases of adverse effects of population growth are numerous and conspicuous. According to Pereira (1973, 1981), Bernard and Anzagi (1979), Martin (1984), Hauck (1985), Blaikie and Brookfield (1987) Sindiga (1989), and Ngugi and Kabutha (1989) soil erosion is particularly a result of increasing human interference in the natural ecological balance, over exploitation and mismanagement of the available land resource. Examples of such interference are; over cultivation, over grazing, deforestation, and use of marginal lands.

2.1.1 The use of marginal land

Pereira (1973, 1981) explains that population growth has created a severe shortage of arable land in South East Asia, India and Kenya. As a result farmers have encroached on steep unconserved slopes exceeding 45^0 in search of land for cultivation and grazing purposes. In some places crops, are grown and large numbers of livestock are grazed on steep slopes stripping the vegetation and trampling the exposed soils; thus, increasing the erosion risk of these fragile areas. Soil erosion on steep land is further aggravated by use of wrong farming methods such as cultivating straight down the hill slopes hence, creating path ways for the running water. These mal-practises have contributed to the high amounts of silt in the reservoirs behind the Mangla and Tasrbella dams in the Indus Basin and in Thika and Chania rivers in Kenya (Pereira, 1973). In the latter case, soil erosion is not as conspicous in the tea farms as it is in the food crop farms. This is particularly noticeable where maize is planted on steep unprotected slopes. The tea is usually well conserved and has a good plant cover which checks the impact of falling rain drops; thus reducing soil loss (Othieno, 1978).

According to Martin (1984) the pressure of rapidly increasing population has forced farmers to cultivate the steep slopes of the hilly Phillipines. Grasslands and forests have been opened up for agricultural production. This has exposed them to the hazard of accelerated soil erosion due to poor farming methods and unsuitable cropping patterns.

Temple (1972) observes that some over-populated areas of Tanzania especially the Uluguru Mountains are experiencing serious soil erosion problems. Arable land shortage has forced farmers to migrate into steeply slopping land characterised by highly erodible soils. Sheet erosion and land slides are the most notable forms of soil erosion in these mountainous area. According to Rapp (1975) a single rain storm (100mm) that fell in two hours in the same area triggered more than 1,000 landslides and mud flows which caused damage to human life, property, and crops.

Hurni (1985, 1988, 1989) reports the existence of soil erosion problem in Ethiopia. Here population growth, and scarcity of arable land have forced farmers to encroach on steep slopes. These, coupled with inappropriate farming techiniques have resulted to serious soil erosion in the northern and eastern high mountain areas, and along all highlands escarpments, and in the deep valleys. According to the results of a research conducted by Hurni (1985) in Ethiopia, high amounts of soil loss are evident where long and steep slopes are cultivated (Table 2.1). For instance, soil loss amounting to 179 $t.ha^{-1}.yr^{-1}$ was obtained in a 70% and 50m slope. This author further asserts that about 5 million acres of present crop land in the highlands is so much eroded that it has reached the "point of no return". This is attributed to the continuing soil erosion processes and land degradation which have reduced much of the land to bare rock after less than two decades of farming. Sheet and rill are by far the most notable forms of erosion and are mainly a consequence of deforestation especially in the highlands where indigenous forests have been reduced from 40% to 2.8% before and after human occupation respectively.

Table 2.1 Predicted mean annual soil losses from a traditional Ethiopian cultivated field

Mean Annual soil Loss (t/ha) by Slope percentage							
Slope length (m)	10	20	30	40	50	60	70
10	12	35	54	61	68	74	81
20	16	50	76	86	95	105	115
30	20	62	92	104	115	127	138
40	24	70	108	122	134	148	162
50	26	78	119	135	148	164	179

Source: Hurni, 1985.

Land movements are also a common occurrence in the present study area especially in Kangema (Kamau, 1981; Davis and Nyambok, 1992). Kamau (1981) recorded 40 mass movements in a 300 km^2 area within the Mathioya and Maragua catchments. These movements mobilised about 1,000,000M^3 of soils, equivalent to 3,000 $t.km^2$ in the sample area.

Similarly, Milas and Asrat (1985); Benard and Azangi (1979) attribute land degradation and soil erosion problems in Kenya to population pressure. These scholars contend that high population growth has led to a critical population- resource imbalance in Kenya where only 17% of the country's land is suitable for rainfed agriculture. As a result, severe shortage of cultivable land is forcing farmers in the high and medium potential areas such as Central, Western and Nyanza Provinces to migrate into marginal regions. The immmigrants clear vegetation in search of cultivable land and speacilize in annual crops some of which leave the soils exposed to the agents of soil erosion. Consequently, the erosional risk of these fragile zones is increased. Sindiga (1989) expresses similar ideas as he argues that population pressure is a critical constraint to development especially that of Semi-arid areas. He explains that shortage of agricultural land in the high potential areas of Maasailand has forced people to migrate to the drier and more fragile areas therby destabilising the natural resource base mainly through over-grazing.

Bernard and Azangi (1979) also note, the use of marginal land for agricultural practises in densely populated areas of Kenya. Basing their study in four densely settled districts of Kiambu, Kakamega, Kisii and Machakos, they explain that population pressure has triggered human migration from these "population stricken spots" to the marginal areas. About 50 % of their respondents acknowledged that they used at least one or more types of marginal lands for agricultural production due to lack of good agricultural land elsewhere. They also observed cases of monocropped maize on steep slopes without any soil conservation measures. Similar poor agricultural practises are noted in Murang'a district which forms a large portion of the present study area (National Environment Secretariat, 1982). Yet according to the Agriculture Act Cap. 318 no cultivation of land is allowed on slopes exceeding 35% in Kenya!

2.1.2 Land tenure and farm size

Apart from human population migrating into marginal areas, Grigg (1984) and Hudson (1987) contend that in the areas of dense and increasing agricultural population, farms are subdivided into small units some of which are "too small to provide sufficient food for the family". For example in Sri Lanka in 1971, 65% of all farms were less than 1 ha and 96% less than 5 ha, and in Bangladesh in 1974, 95% of all farms were less than 3 ha. In Kenya, about 80% of the farmers occupy holdings that are less than 2 Ha. (Kenya, 1989a). However, these authors point out that high population density is not entirely responsible for the smallness of farms in the tropics. They argue that some forms of land tenure such as those encouraging land sub division through land inheritance also lead to small farms. This is attributed to the fact that in many tropical countries there is the central ethic that every one has an automatic right to own land, particularly in the situation where there has in the past been both sufficient land for every one and little alternative employment other than in the agricultural sector. With a constantly expanding population, this ethic results in increasing pressure on the land and hence, more land sub-divisions. Further, the problem of farm sub-division is aggravated by land-fragmentation which is uneconomic in that farmers spend much time walking from plot to plot and land is wasted in a plethora of field boundaries and plant disease are hard to control.

According to Ahn (1977) and Clayton (1964) population growth has increased pressures on the agricultural land and shortened fallows markedly in tropical Africa. This is attributed to the fact that rising population means less land per family hence a decline in the fallow period. Cropping is now on a continuous basis and as a result organic and inorganic fertilizers have to be used to add nutrients to the already depleted soils. Similar observations are made in Kenya where over-cultivation resulting from lack of fallow land is seen as a serious problem contributing to land degradation (Kenya, 1989a).

According to the report of the Joint Kenya Sweden soil conservation review mission of 1988, the combination of lack of alternative opportunities and customary principles of inheritance through which sons are entitled to equal shares of their fathers land implies a continous sub-division of the small farms (Joint Kenya/Sweden Soil Conservation Review, 1989). This cultural practice has resulted to small, fragmented and uneconomic farm holdings characterised by low yields in the high and medium potential areas of Kenya such as Kisii. Further, in this report it is argued that small farms are to an extent a constraint towards soil conservation efforts since some conservation measures are associated with loss of valuable land. A similar opinion is expressed by Millington, Mutiso, Kirby, and O'Keefe (1989) who note that terracing, grass strips, contour bunding and stick/stone bunding lead to loss of land unlike contour cultivation and conservation tillage.

The above studies (Joint Kenya/Sweden Soil

Conservation Review (1989) and Millington *et al* (1989) raise important issues worth consideration in this study. But they do not show whether land loss associated with certain conservation measure is a factor influencing farmers' choice of soil conservation measures.

Besides the problem of small fragmented farm holdings, Hudson (1981, 1983) and Millington *et al* (1989) contend that majority of African subsistence farmers are poverty striken as they are characterised by low farm incomes. This fact implies that these farmers lack sufficient capital particularly "risk capital" which precludes them from adopting intensive soil conservation measures. Citing examples from Malawi, Millington *et al* (1989) explain that only a few progressive famers who have sufficient capital are able to invest in the construction and maintenance of the conservation structures. The problem of insufficient capital is compounded by the prevailing labour shortages resulting mainly from male migration to urban centers.

Atkins (1984) explains that soil erosion is a serious land management problem in the Masinga Dam Catchment. He associates it to both physical and socio-economic factors. However the latter are not treated with the same detail as the former. Infact, the socio-economic data was analysed using simple descriptive statistics only. The results do not clearly indicate the specific socio-economic factors contributing to soil erosion in this catchment; but low incomes, labour shortages and lack of technical advice are highlighted as some of the constraints hindering the adoption of soil conservation measures.

2.1.3 Deforestation

Kunkle and Dye (1981) explain that population growth is to blame for the on going deforestation in the tropics. The area under forests in the world is decreasing by about 20 million ha^{-1}.yr-1 especially in moutainous areas following the increased demand for forest products especially fuelwood and agricultural land. Quoting the case of deforestation in Panama, the authors note that over 1/3 of the forests that originally covered the watersheds of Panama canal have been cleared and the land is under agricultural use which has caused serious sedimentation and siltation in the canal.

Roose (1988) asserts that following population increase in tropical Africa, deforestation and cropping have been extended to slopes of 40-80%. Referring to Ivory Coast, he contends that soil loss and run-off under undisturbed rainforest conditions are much lower compared to those from areas where deforestation has taken place. For example on a steep slope (>30%) slope, run-off and soil loss were 0.46 $t.ha^{-1}.yr^{-1}$ and 1.2% respectively. However, replacing the forest with cassava and groundnuts resulted in higher amounts of run-off and soil erosion increased from 0.05 $t.ha^{-1}.yr^{-1}$ to >50 $t.ha^{-1}.yr^{-1}$. Thus, clearing vegetation particularly, on steep slopes increases the erosion risk. Similar opinions are expressed by Holeman (1968) who contends that soil erosion under dense undisturbed forests in the humid Tropics is usually less than 1 $t.ha^{-1}.yr^{-1}$.

In the Kenyan context, population growth is highly associated with increased cases of deforestation in humid areas such as Murang'a and Kiambu districts. Kamau (1981) argues that deforestation not only depletes the forests as valuable watersheds and fuel reserves but also eliminates their vital role of soil protection against water erosion on the steep slopes that are common in these districts.

2.1.4 Overstocking and overgrazing

Another problem associated with human activity and land degradation is that of overstocking and overgrazing. Nnyiti (1981), Maro (1990) and Wangati, Muchena, Gichuki and Sharma (1993) assert that overstocking and overgrazing are serious problems experienced in semi-arid areas resulting in depletion of pastures and vegetation. The destruction of natural vegetation is accelerated by the fact that large numbers of livestock are kept in relatively small areas with a low carrying capacity. Once the vegetation is removed, the soils are then left bare and exposed to the effect of rain drops. They further note that the soil erosion hazard in the overgrazed areas is increased through trampling and the loosening of soils which occur as the livestock cover long distances to the grazing fields and watering places. Such loose soils are easily removed and washed away during the rainy season resulting in increased sedimentation of dams and irrigation channels.

Stocking (1985) observes that cattle which are of great social importance to the Wasukuma people of Tanzania have contributed to the soil erosion problem in the country. Grazing pressure, associated with large numbers of cattle raised per family, has left 15% of the South Eastern Shinyanga region almost bare and eroded beyond use. He, however, points out that the problem is not easy to tackle as the government is using the wrong approach by emphasising destocking which ignores the intricate role played by the cattle in the socio-economic system of the Wasukuma.

Ahn (1977), Thomas (1977), Thomas, Edwards, Barber and Hogg (1981), Muhia (1989) and Dregne (1990) observe that overgrazing is a common problem in the semi-arid areas of Kenya and has resulted in the disappearance of vegetation cover hence the incidence of soil erosion in these marginal and fragile areas. Biamah (1989) and Groot, Field-Juma and Hall (1992) explain that overgrazing, clearing of land for cultivation, and cutting of trees for timber and fuelwood together with the occurrence of long dry spells are to an extent responsible for soil erosion in Baringo district. These human activities lead to extremely low vegetation cover which coupled with high rainfall intensities and high erodible soils have accelerated soil erosion in the district. Similarly, Muhia (1989) asserts that large livestock numbers have resulted in over-grazing, excessive trampling, soil erosion and desert like conditions in Kitui, Machakos, Baringo and Marsabit Districts, Kenya.

Hussain, Landstra, Manda, Medland, Paraico and Schnabel (1982) draw attention to the causal relationship between overstocking, overgrazing and soil erosion in Makueni District, Kenya. About 60% of the population that they interviewed had overstocked pasture land which appeared denudated. These authors assert that poor livestock management aggravated by the traditional attitude of over stocking have resulted in overgrazing and hence soil erosion.

Atkins (1984) reported that overstocking is not a serious problem in the Masinga Dam Cachtment except in areas where livestock concentrate. Such places including watering and common grazing areas, depicted signs of erosion as was indicated by the presence of bare patches and gullies. Similar observations are made by Thomas (1991). However these authors fail to explain why farmers do not extend soil conservation efforts to the grazing fields. Further, the effect of livestock rearing on soil erosion in the humid hilly areas is not discussed.

The literature reviewed so far appears to generally blame population growth for the on going land degradation and soil erosion problems. Rarely do the authors seek to understand the specific factors which cause "man" to interfere with the natural system in an uncontrolled manner. Besides most of it being based on secondary data, the reviewed studies represent sketchy and uncoordinated bits of socio-economic aspects of soil erosion. This creats the need for a systematic and comprehensive study that examines in totality all the socio-economic factors influencing soil erosion. Further, none of the existing studies was conducted in the Masinga Dam Catchment. This study, therefore, aims at investigating some of the underlying socio-economic factors that "push" man to cause land degradation and soil erosion in the Masinga Dam Catchment.

2.2 The agronomic dimension of soil erosion

2.2.1 Crop cover

Vegetation cover plays an important role in protecting soil from the effect of erosive rains (Rogers and Schumm, 1991; Morgan, 1986; Lal,1983; Evans, 1980). These authors share the opinion that soil loss and run off decrease and increase with high vegetation cover and expansive bare grounds respectively. Evans (1980) explains that when rain drops strike the vegetation, their energy is dissipated and there is less direct impact on the soil surface.

The major protective role played by vegetation cover is emphasised in the mosquito gauze experiment of Hudson and Jackson (1959) in which soil loss was compared from two identical bare plots. On one plot a fine wire gauze was suspended which had the effect of breaking the force of the rain drops absorbing their impact and allowing the water to fall to the ground from a low height as a fine spray. The mean annual soil loss over a six year period was 141.3m^3 ha^{-1} for the open plot and 1.2m^3 ha^{-1} for the plot covered by wire gauze.

According to Rogers and Schumm (1990) vegetation cover which is less than 15% is not effective in reducing soil loss. Their study showed that sediment yield increased rapidly as vegetation cover decreased from 43% to 15%. These authors emphasize that efforts to reduce soil loss particularly in the dry lands by slightly increasing vegetation cover to any level below 15% is not an effective measure towards soil conservation.

Zobisch (1986) studied soil erosion in grazing land in Machakos district, Kenya using sites with good, medium and poor vegetation cover on slopes varying from 9m to 15m long and 14% to 42% steep. The results obtained showed that soil loss was closely correlated with ground cover. An increase in vegetation cover from 20 % to 40% led to a major reduction in soil loss. In his work, he emphasises the importance of management strategies which will sustain high vegetation cover in the grazing areas. The question that this work does not address is whether grazing fields are considered a priority compared to the crop farms considering the financial inability of the farmers.

2.2.2 Crops and cropping patterns

The type of crops, cropping patterns and farming practice adopted by farmers have previously been identified to have an important role to play towards the control or acceleration of soil erosion on agricultural land (Lal, 1977a and b; 1983; Hudson, 1971; Hauck, 1985). These authors contend that arable crop farming leads to soil erosion and land degradation in cases where crops and cropping practices adopted require that the land be left bare for part of the year and, thus, exposed to water and wind erosion.

A study carried out in Central Tanzania by Rapp and Dahlin (1975) showed that land use and vegetation cover play an important role in accelerating or controlling soil erosion. This is demonstrated by results obtained from soil erosion tests on grounds under different use and vegetation covers. While no soil loss was obtained on an ungrazed bush thicket and a piece of plot fully covered by grass, 78 $t.ha^{-1}$ and 146 $t.ha^{-1}$ were obtained in a millet farm and a bare plot left on fallow respectively. These demonstration plots were on a 3.5° slope which received about 400-600 mm of rainfall per annum. They noted that soil erosion is a pronounced problem in the overgrazed slopes of the Semi-arid parts of Central Tanzania contributing to the siltation of small sized dams. The dams were found to be "filling up with sediments much faster than earlier thought".

According to Elwell and Stocking (1976) the amount of vegetation cover is an important factor determining the erosion hazard in crops and grazing areas in Zimbabwe (Rhodesia). In some experiments conducted in Zimbabwe, they observed that run off and soil loss rates declined as vegetation cover increased. The results of their study indicated that peak run off and soil loss in a maize farm occurred in December when crop cover was most variable (20 - 85%). Also, during this time soil moisture was high enough to initiate the run off and hence erosion processes. By February, the second month after planting, full canopy had developed which not only protected the soil from rain drop impact, but also conserved soil moisture through transpiration. The overall result was a decrease in run off and soil losses.

Thomas (1988) observes that the type of crops grown by any farming community have an important role to play in as far as soil erosion is concerned. The main argument in his work is that perennial crops including banana and coffee on the slopes of Mt. Meru and Mt. Kilimanjaro in the Northern Tanzania, tea and coffee in Kenya are better in soil conservation than annual crops. This is because they protect the soils throughout the year after the initial cover has been fully established. Citing examples from East Africa, this author also notes that the demand for cereals and pulses for food has resulted in large areas being used for annual crops which have a higher erosional risk during the period between planting at the onset of the rains and the time when crop cover is fully established. According to Moore (1979) and Fisher (1977), this is a critical period when about 70% of the most erosive rains occur and when the surface is sparsely covered with crops or grass. Indeed, most crops including beans are not able to attain a cover of 50% earlier than 20 days from the date of planting.

Besides the type of crops grown by the farmer, cropping patterns also influence the rates of soil erosion. Lal (1977a and b), Fisher (1977) and Hudson (1971) note that cropping patterns and management practices which help to produce an early vegetation cover are better in soil and water conservation than those which take longer for adequate cover to develop. For instance, these authors associate monocropping especially maize or cassava monocrop with high rates of erosion than intercropping. In some experiments done in Nigeria, Lal (1977a) observes that soil loss in a monocropped cassava farm is high (about 109 $t.ha^{-1}.yr^{-1}$ on average) compared to that from cassava intercropped with maize (69 $t.ha^{-1}.yr^{-1}$ on average). This problem is most pronounced where monocropping is practised on steep slopes. In Table 2.2 it is shown that soil loss is high (221 $t.ha^{-1}.yr^{-1}$) on a 15° slope in the monocrop farm while it is low (137 $t.ha^{-1}.yr^{-1}$) on the same slope and in a mixed cropped farm.

Table 2.2 Soil loss from a monoculture (cassava) and mixed cropping of cassava with maize

slope (%)	soil loss ($t.ha^{-1}yr.^{-1}$)	
	monoculture	mixed cropping
1	2.7	2.5
5	87.4	49.9
10	125.1	85.5
15	221.1	137.3

Source: Adopted from Lal, 1977a.

Similarly, Fisher (1977), Omwega (1989) and Obando (1990) assert that soil erosion is less where maize and beans are intercropped; and high in monoculture farms of maize. They argue that maize takes longer than any other crop to establish a good cover. On the same note, Lal (1990) observes that, more important than the crop and the cropping pattern is the soil management practise. He argues that a non soil protective crop for instance, maize grown with good conservation techniques such as mulching could give rise to less run off and soil loss than a soil conserving crop grown with erosion promoting practices. He however, does not discuss the bottlenecks hindering farmers from practising good farm management.

However, Lal (1977), Fisher (1977a), Hudson (1971), Omwega (1989) and Obando (1990) do not show whether the amount of soil loss obtained in farms under different cropping patterns in their study plots are significantly different. Further, these studies were conducted in research stations under controlled conditions and therefore, they do not portray a real on-farm situation.

2.2.3 Date of planting and crop density

Grunder, (1988) observes that early planting and dense crop cover are important factors likely to lead to less soil erosion. In some experiments done in Ethiopia, measured soil loss amounting to 282 $t.ha^{-1}.\ yr^{-1}$ and 1 $t.ha^{-1}.yr^{-1}$ were obtained in a farm cropped with tef and intercropped sorghum and beans respectively. The high amounts of soil loss were obtained in the former case because tef was not only planted late and therefore took long before cover was established but it was monocropped. On the other hand, in the latter case both crops were sown before the rains and a good cover was established, thus protecting the soil from the early erosive rains.

Soil erosion is also influenced by plant density. Gumbs, Lindsay, Nasir and Mohammed (1985) assert that high plant density increase ground cover and thus reduces soil erosion. Assessing soil loss in Northern Trinidad these authors observed that it was; 57.6 $t.ha^{-1}$; 32 $t.ha^{-1}$; and 20.5 $t.ha^{-1}$ in a bare plot and in maize farms with a low (41,000 plants/ha) and high (62,500 plants/ha) plant densities, respectively. The soil losses from the high and low densities were significantly different at P= 0.05. Thus, for increased crop yields and plant cover, a dense plant population for the humid areas is recommended. But while this may be true in a research station, different results could be obtained in a real farm situation where other important farm characteristics such as lack of use of fertilizers may limit cover establishment even with high plant densities.

In Kenya, researchers such as Siambi, Kanampiu, and O'Neil (1991) and Wafula (1989) have addressed the issue of plant density in relation to crop yields rather than soil loss. For instance, while conducting a research at Katumani appropriate soil management system for sub-humid uplands. When applied at 1.3 to 2.5 tons per acre crop residue mulch effectively controled erosion on slopes of upto 15%. The mulch reduced kinetic energy of rainfall and flow rate of run-off.

In Ivory Coast, Roose (1988) shows that soil loss is high on pineapple farms where mulch was not used on slopes between 7 and 20%. However, when mulch was applied run-off and soil loss were reduced to almost negligible levels on slopes upto and including 20%. Bonsu (1985) explains that mulch increases crop yields and reduces soil erosion in the hot Savanna region of northern Ghana. Here when straw was used as surface mulch average soil loss was reduced by more than 90% and the yield of sorghum increased by 2.9%.

Othieno (1978) shows that mulch plays a major role in erosion control in cash crop farms particularly when the planted trees are still young and vegetation cover not fully established. His experiments were done in young tea farm plots in Kericho, Kenya where the measured soil loss 0.68 $t.ha^{-1}.yr^{-1}$ in the farms where mulch was used. This increased to 211 $t.ha^{-1}.yr^{-1}$ where manual tillage was practised without the use of mulch. Similar results have been obtained elsewhere

(Bekele, 1989).

However, as Thomas (1988) and Ngugi and Kabutha (1989) observe, mulch is not easily available. This is attributed to the fact that crop residues which could provide mulch are consumed by livestock and termites while in other places crop residue and cow dung are used as a source of domestic energy (Thapa and Weber, 1991). Eckholm (1979; 1980), notes that firewood scarcity in Eastern Nigeria forces the Tiv people to uproot all crop residues after crop harvesting for use as fuel, instead of re-ploughing them back to the soil. This practice deprives soils of nutrients, deteriorates its structure and diminishes crop productivity.

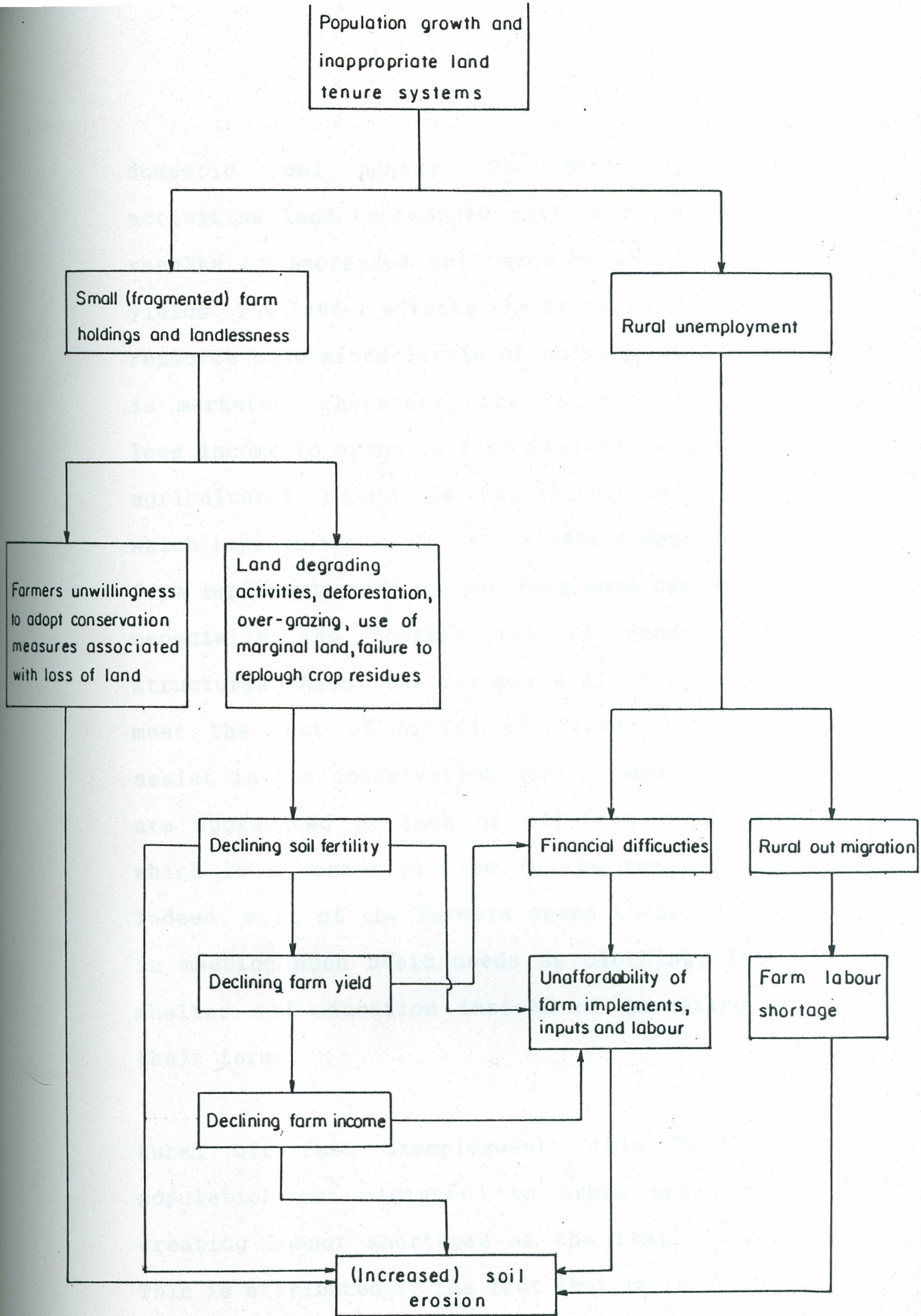
The literature reviewed above emphasises the need for good crop and soil management. This will ensure a quick establishment of crop cover which will consequently lead to a better protection of the soils from the impact of rain drops. However, most of these researches have been conducted in research stations under controlled conditions and do not portray a real on- farm situation. Further, most of the recommendations advanced are not in accordance with the socio-economic status of the majority of the rural farming community.

Therefore, the present study is an on-farm research investigating the process of soil loss on agricultural land from a socio-economic and agronomic point of view.

2.3 Conceptual Frame Work

From the foregoing literature review, a unifying framework showing the contribution of socio-economic and agronomic factors to the soil erosion problem is lacking. Hence, what was required here was a clear conceptual framework which could illustrate the socio-economic and agronomic factors that influence soil erosion. A systems analysis approach (Singh and Dhillon, 1984) was adopted in the conceptualization of the study problem. A system represents a set of interacting and interdependent variables that are used to explain the existence of a given phenomenon. In this work, the interaction and interdependence of agronomic and socio-economic variables was used to explain the existence of soil erosion in the Masinga Dam Catchment.

First and foremost, man was considered very influential in the soil erosion process because, through his activities, the topography, soil physical characteristics and vegetation cover are bound to change resulting to soil in the agricultural land. It was conceptualised that rural population growth coupled with inappropriate land tenure systems characterized by land sub- division and fragmentation through inheritance results in small land holdings or landlessness (Fig.2.1): This has two effects; firstly, as a result of small farm size, some farmers become unwilling to adopt soil conservation measures which are associated with loss of land. Secondly, farmers engage in land degrading activities such as deforestaton, over-grazing, use of marginal land, over-cultivation, and failure to replough crop residues in their farms. Deforestation takes place as people fell down trees in search of land for settlement, cultivation and grazing. Over-grazing results from overstocking in small land holdings. Use of marginal land including arid and semi-arid land, steep slopes, roadsides, and river banks without proper conservation measures is indicative of population pressure on supportive resources. This increases the erosional risk of such fragile areas. Over-cultivation occurs because of continous cultivation of farms without a break or allowing the land to lie on fallow. Failure to replough crop residues or to use them as mulch results from the increased demand for fodder and



Source: Author.

Figure 2·1: A conceptual model of socio-economic and agronomic factors influencing soil erosion in the Masinga Dam Catchment.

domestic fuel energy. The foregoing human activities lead to reduced soil fertility which results to increased soil erosion and low farm yields. The latter affects the farmers' financial resource base since little or no surplus produce is marketed. Therefore, the farmers will have less income to spend on farm implements and such agricultural inputs as fertilizer and manure which improve the soils' fertility. A shortage of farm implements will impede farm work operations especially the construction of conservation structures. Also, the farmers will be unable to meet the cost of hiring additional labour to assist in the conservation work. These problems are aggravated by lack of off-farm employment which is a common problem in the rural areas. Indeed, most of the farmers spend their incomes in meeting such basic needs as clothing, food, shelter and education instead of investing on their farms.

Rural off farm unemployment: this leads to population out migration to urban areas thus creating labour shortages at the family level. This is attributed to the fact that it is usually the able bodied men who migrate to towns to seek gainful employment. The family members left at home, most of them being the old, women and young school attending children are not capable of conserving soil and undertaking other farm operations. Instead, they concentrate on the seemingly more urgent food production activities such as planting, weeding and harvesting.

CHAPTER THREE

PHYSICAL AND HUMAN BACKGROUND OF THE MASINGA DAM CATCHMENT

3.0 INTRODUCTION

The Masinga Dam Catchment is about 7,950 km^2, lying to the east of the Aberdares Mountains and South of Mount Kenya (Fig.1.1). The proportion of the study area found in Central and Eastern Provinces are 70% and 30%, respectively.

Kaihungu Sub-catchment is located in the highlands of the Masinga Dam Matchment, in Murang'a district, Central Province, Kenya. It is approximately 20 km west of Murang'a town and comprises of the upper catchment of the Kaihungu river, and a tributary of the Maragua river. This Sub-catchment covers about 23.85 km^2 (Fig.1.1).

On the other hand, Mathauta Sub-catchment is a low lying semi-arid area in Machakos district, Kenya. It lies south west of Masinga dam and about 17km north of Matuu town. It covers about 26km^2 (Fig.1.1).

In this chapter, both the physical and human characteristics of the whole catchment together with that of Kaihungu and Mathuata Sub-catchments are discussed. These give the basic information required for an indepth understanding of the dynamics of the soil erosion problem in the study area.

3.1 The physical environment of the Masinga Dam Catchment.

3.1.1 Physiography

The land in the Masinga Dam Catchment rises gradually from the East to the West ending in the slopes of the Aberdares Mountains and Mt Kenya (Fig 3.1). Its relief is characterised by:

(i) **Mountain and major scarps:** The Aberdares and Mt Kenya are the dominant relief features in the West and North Eastern of the catchment respectively. These are dissected mountain terrains with steep slopes (greater than 30%) and altitudes of 2400-4000m. A mean annual rainfall of more than 1800mm is received. Human settlements are almost non-existent in this zone because of the severe climate and poor soils associated with such elevations.

(ii) **Highland:** These are found in the uplands and

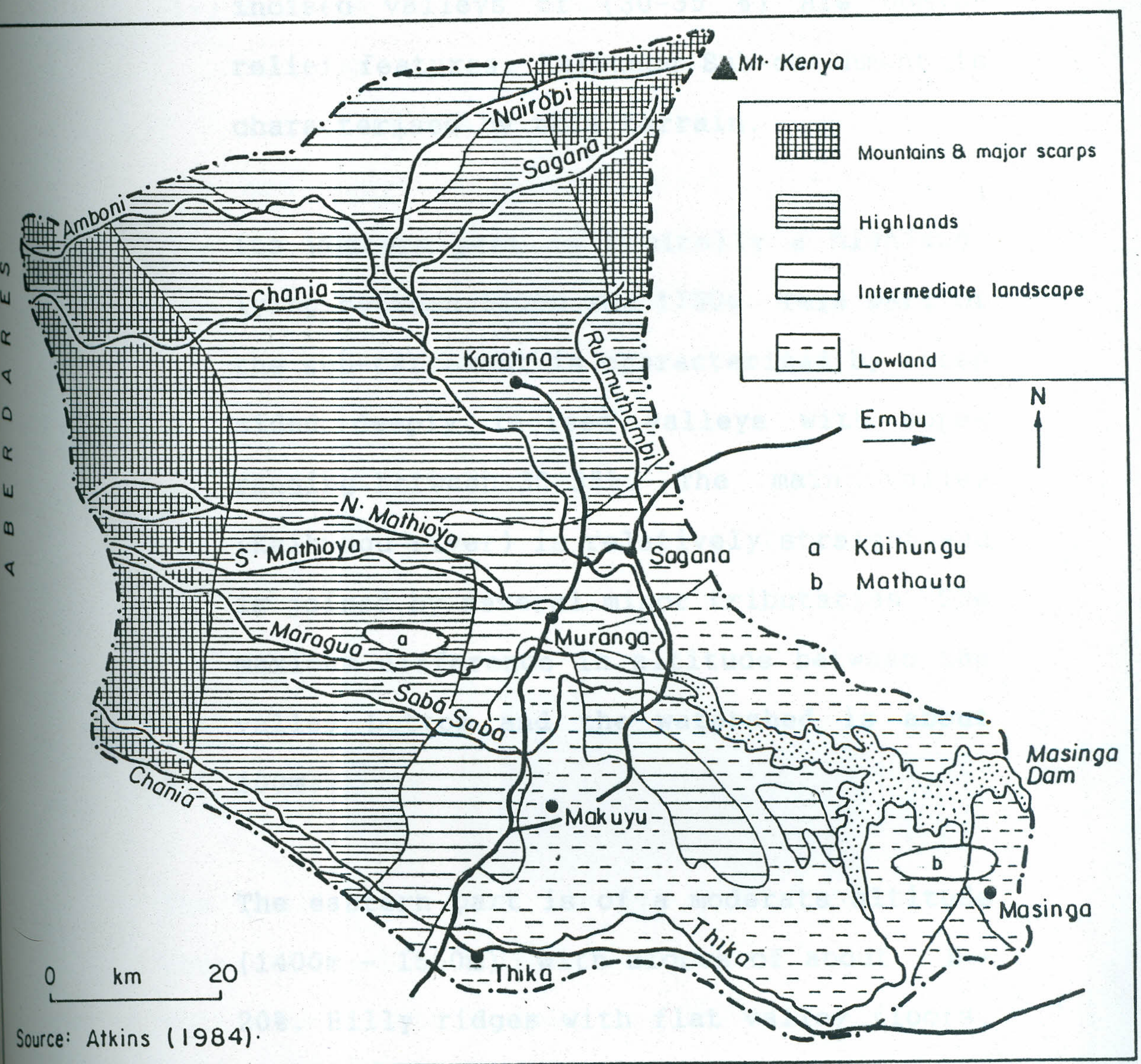


Fig. 3.1: Landforms of the Masinga Dam Catchment Area

Mt. Kenya, between 1500m-2000m and receive a minimum mean annual rainfall of 1400mm - 1800mm. Steeply dissected ranges (slopes of 20-35%) and steep sided deeply incised valleys of (30-35 %) are common relief features. Kaihungu Sub-catchment is characterised by this terrain.

Its western part is basically a highland, lying between 1400m and 1750m. This part of the sub-catchment is characterized by steep sided deeply incised valleys with sopes ranging between 30-35%. The main valley (Kaihungu river) is relatively straight and is joined by several minor tributaries. The maximum difference in altitude between the valley bottom and the watershed is about 100m.

The eastern part is of a moderate altitude (1400m - 1550m) with slopes of about 0 - 20%. Hilly ridges with flat valley floors, mostly with alluvial plains, are conspicuous in the area.

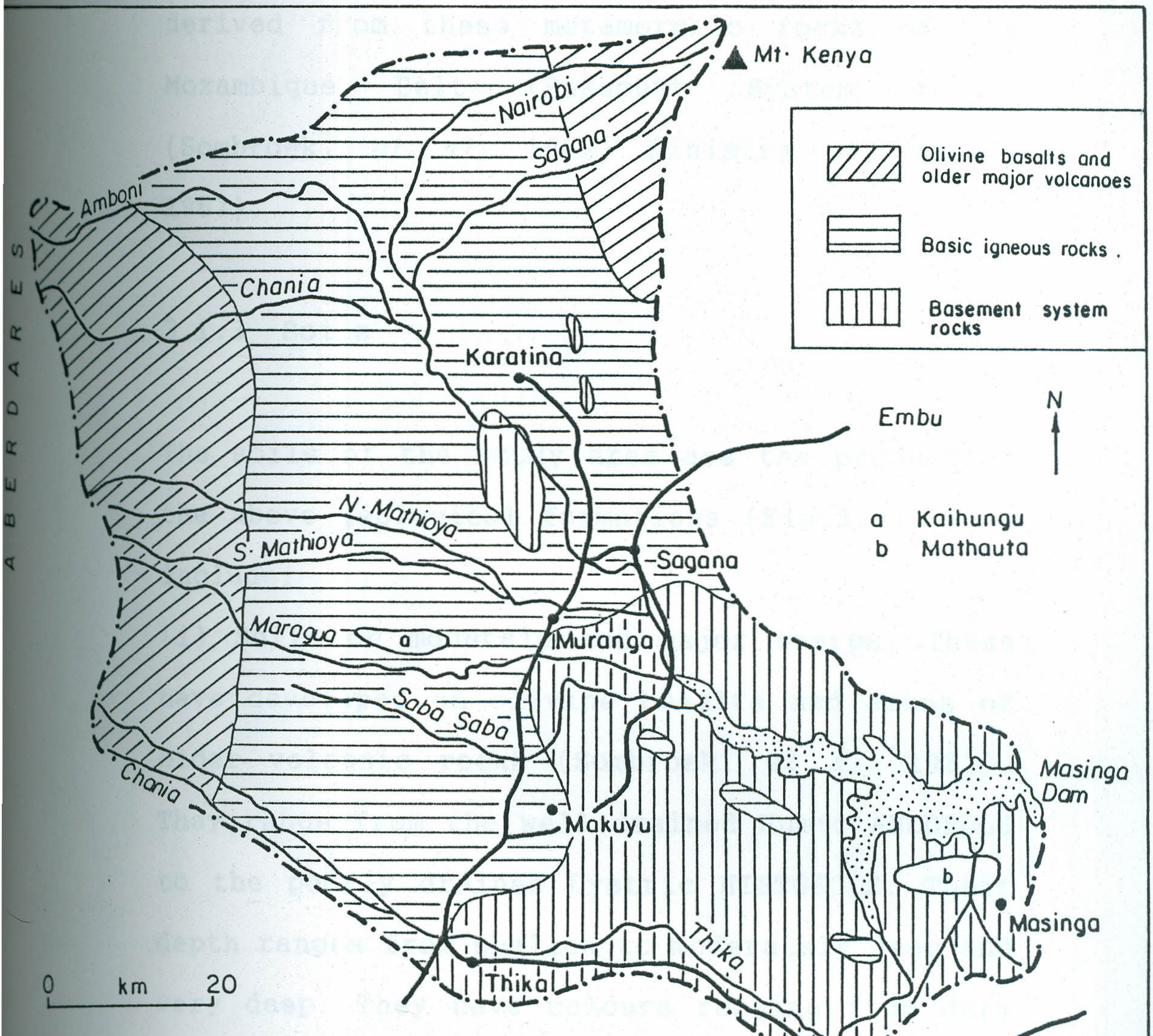
(iii) Intermediate landscape: This consists of the lower footslopes of the Aberdares and Mt kenya, ranging from 1200m-1500m. A mean annual rainfall of 900mm-1400mm is received. The major features include gentle slopes (0-20%) and ridges with flat valley floors.

(iv) **Lowland**: These consist of undulating plains ranging between 900m-1200m. with a mean annual rainfall of 600-900mm. The lowlands are characterized by erosional land surfaces on the Mozambique Belt Rocks (Basement System Complex), upland plains and plateaus.

The Mathauta Sub-catchment which consists of this terrain is generally a low-lying area between 1000 - 1400 m. The terrain is undulating with gentle slopes of less than 5%.

3.1.2 Geology

The geology of the Masinga Dam Catchment is characterised by olivine basalts and older major volcanoes in the Western and North Eastern side (Fig.3.2). The middle part of the catchment where Kaihungu Sub-catchment lies consists of basic igneous rocks. These include tertiary and quartenary basalts, basaltic agglomerates, phonolites and trachytic tuffs (Sombroek, Braun, and Van der Pouw, 1982). Undifferentiated



Source: Developed from Sombroek, et al, 1982·

Fig· 3.2: Geology of the Masinga Dam Catchment Area·

(Basement System) metamorphic rocks consisting mainly of granitic gneisses and gneisses rich in ferromagnesium minerals are dominant in the Mathauta sub catchment and other South Eastern parts of the catchment. There is also colluvium derived from these metamorphic rocks of the Mozambique Belt (Basement System rocks) (Sombroek, *et al*, 1982; Ministry of Energy, 1987).

3.1.3 Soils

The soils of the study area are the product of the above geological formations (Fig.3.3). They include;

(i) **Soils on mountain and major scarps:** These have developed on olivine basalts and ashes of older volcanic rocks (Sombroek, *et al*, 1982). They range from the well drained Humic ANDOSOLS to the poorly drained Dystric HISTOSOLS. Their depth ranges from shallow to moderately deep and very deep. They have colours ranging from dark greyish to dark reddish brown and texture of clay loams to clay.

(ii) **Soils on volcanic footridges:** These are well drained clay soils derived from tertiary basic igneous rocks (basalts) ranging from very deep

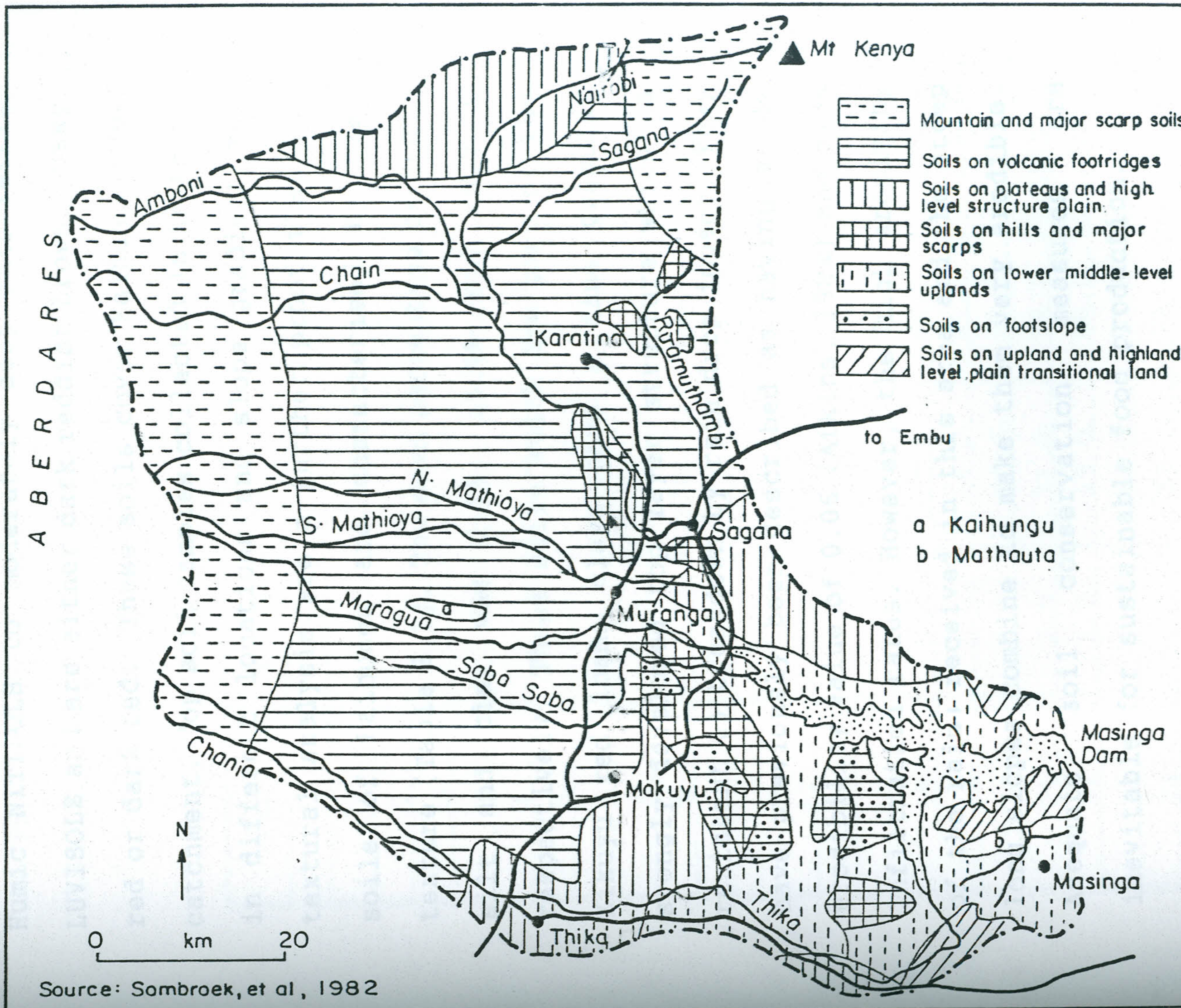


Fig. 3.3: Soils of the Masinga Dam Catchment Area

Humic NITISOLS to moderately deep Nito-ferric LUVISOLS and are either dark reddish brown, dusky red or dark red. These soils cover Kaihungu Sub-catchment. Top soil samples collected in 24 farms in different locations and slope gradient for textural analysis are a further proof that the soils of Kaihungu are characterised by clay texture (Table 3.1). The mean percentage of sand, silt and clay was 2.2%, 20.9% and 76.9 % respectively. These soils which are part of the Kikuyu red loams clays have a fine granular srongly developed top layer structure which is resistant to breakdown by rain drop impact. They have previously been described as having a low erodibility value of 0.06 (Atkins, 1984) and high infiltration rates. However, the high erosivity of the rains received in this area and the steep long slopes combine to make them very erodible. Adequate soil conservation measures are inevitable for sustainable food production.

(iii) **Soils on hills and minor scarps**: These are well drained soils developed on undifferentiated Mozambique Belt, that are predominantly granitic gneisses. They range from the moderately deep red to dark red Ferralic CAMBISOLS; to shallow dark red to brown Dystric REGOSOLS. Their texture varies from sandy clay loam; sandy clay to clay.

The REGOSOLS have fragments coarser than 2mm in diameter.

Table 3.1 Texture of Kaihungu's soils

farm	%sand	%silt	%clay	textural class
1	2.0	19.0	79.0	clay
2	3.0	22.0	74.0	clay
3	7.0	31.0	62.0	clay
3A	1.0	31.0	68.0	clay
3B	2.0	39.0	60.0	clay
4	2.0	8.0	91.0	clay
5	3.0	25.0	72.0	clay
7	2.0	22.0	76.0	clay
8	2.0	7.0	90.0	clay
9	2.0	25.0	73.0	clay
10	2.0	27.0	71.0	clay
11	1.0	14.0	85.0	clay
12	2.0	5.0	93.0	clay
16	2.0	16.0	81.0	clay
17	3.0	6.0	91.0	clay
18	2.0	12.0	86.0	clay
19	1.0	18.0	81.0	clay
20	2.0	31.0	67.0	clay
21	2.0	21.0	76.0	clay
22	2.0	19.0	80.0	clay
23	1.0	24.0	75.0	clay
24	1.0	23.0	76.0	clay
25	2.0	20.0	79.0	clay
26	2.0	23.0	75.0	clay
average %	2.0	20.0	77.0	clay

Source: Author.

(iv) **Soils on plateaus and high level structural plains:** These are clay soils derived from Tertiary basic igneous rocks ranging from well drained Nito-rhodic FERRALSOLS, Verto-eutric

NITISOLS, and IRONSTONE soils to poorly drained Pellic VERTISOLS, verto-luvic PHAEOZEMS and VERTISOLS. Their depth ranges from very deep to shallow and are either, dark reddish brown, dark brown, dark red, dark grey , black, or yellowish red in colour.

(v) **Soils on lower middle-level uplands:** These are well drained sandy clay loam to clay soils developed on undifferentiated Mozambique Belt. They are moderately deep to very deep and are either dark red, dark reddish brown or yellowish red.

(vi) **Soils on upland\high level plain transitional lands:** These are complex of well to imperfectly drained clay soils developed on gneisses rich in feromagnesian minerals. They include Pellic VERTISOLS, Verto-eutric PLANOSOLS and Orthic SOLONETZ and are dark red to black.

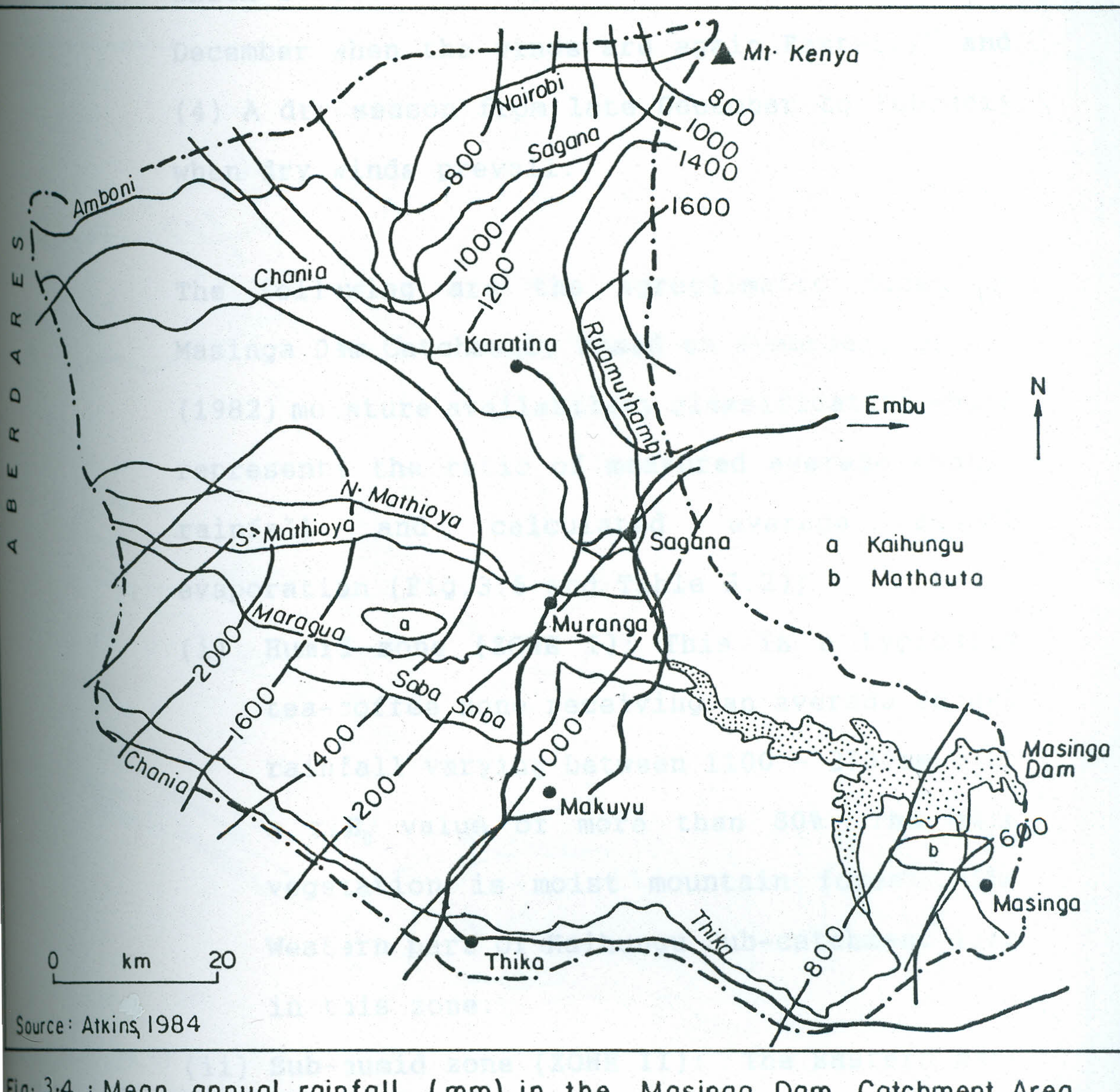
(vii) **Soils on footslopes:** These are well drained, moderately deep to very deep soils developed on colluvium from undifferentiated Mozambique Belt (Basement System) rocks. They include Ferralic ARENOSOLS and Chromic LUVISOLS and are either dark reddish brown or dark red or dark yellowish brown or reddish brown.

(viii) Soils on footplains: These are soils developed on sediments mainly from crystalline (Mozambique Belt (Basement System) rocks. They are very deep, brown to dark brown Eutric FLUVISOLS and are sandy loam to clay loam.

The Mathauta sub catchment consists largely of Nito-rhodic, Chromic CAMBISOLS, Pellic VERTISOLS ACRISOLS and LUVISOLS. The latter cover the southern part of the catchment while the other three cover the northern areas. These soils are prone to capping and sealing under the impact of heavy rainfall which coupled with the low infiltration rates and sparse vegetation cover increases the amounts of run-off and erosion risk.

3.1.4 Climate and vegetation

Rainfall which is strongly influenced by orographic effects varies from 600 mm in the low lying semi-arid areas in the East to over 2,000mm in the high altitude humid areas in the West and North East (Fig.3.4). Four fairly distinct climatic seasons are recognized: (i) Long Rain season which occurs between March and May when the Easterly winds bring



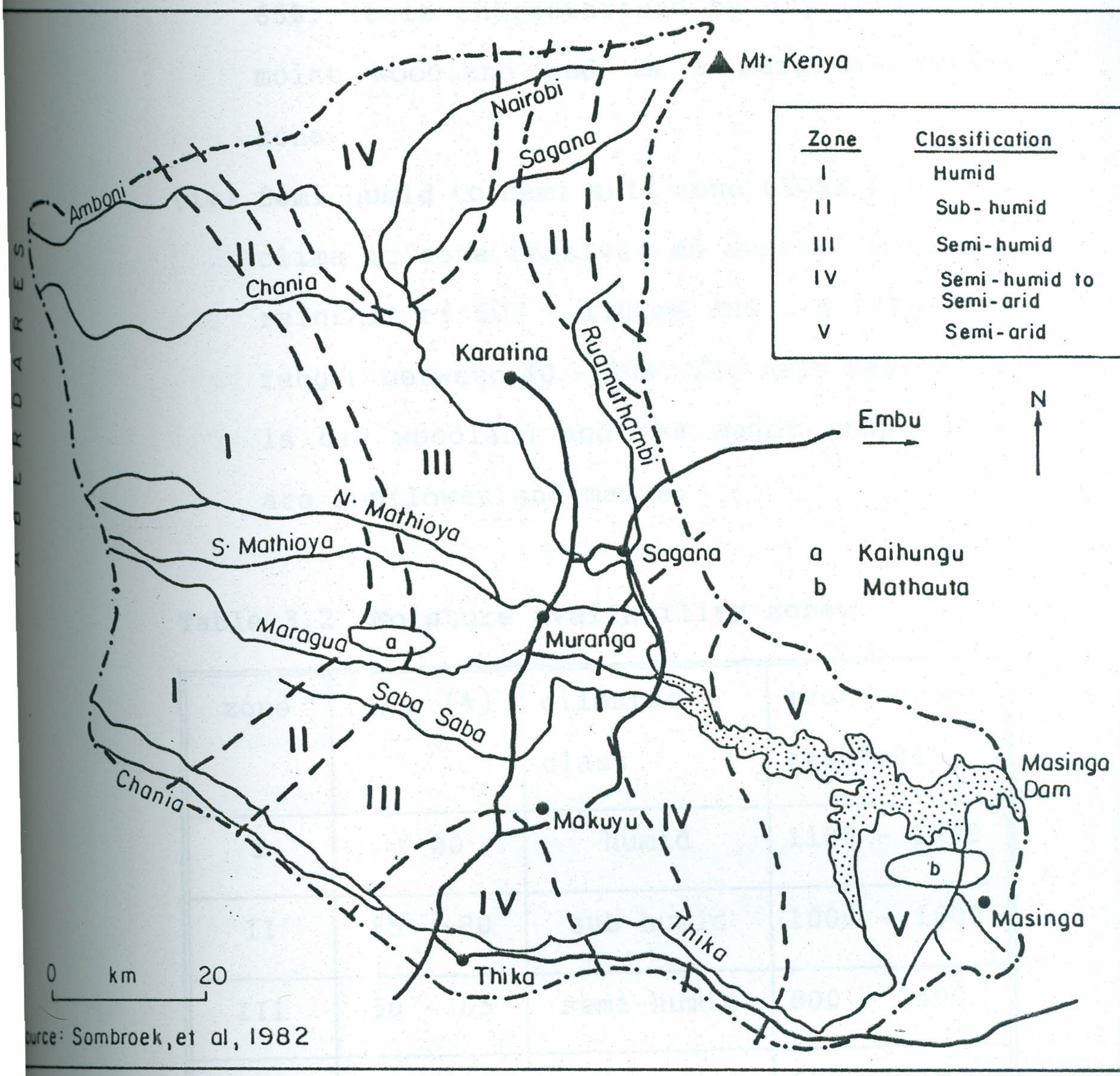
Source: Atkins, 1984

Fig· 3·4 : Mean annual rainfall (mm) in the Masinga Dam Catchment Area heavy rainfall; (ii) A cool and dry season between June and August; (iii) Short Rain season which occurs in the period between mid October-December when the winds are again Easterly; and (4) A dry season from late December to February when dry winds prevail.

The following are the agroclimatic zones in Masinga Dam Catchment, based on Sombroek, *et.al,* (1982) moisture availability classification which represents the ratio of measured average annual rainfall and calculated average annual evaporation (Fig.3.5 and Table 3.2);

(i) **Humid zone (ZONE I)**: This is a typically tea-coffee zone receiving an average annual rainfall varying between 1100 - 2700mm with a r/E_0 value of more than 80%. The main vegetation is moist mountain forest. The Western part of Kaihungu Sub-catchment lies in this zone.

(ii) **Sub-humid zone (ZONE II)**: The Eastern part of Kaihungu Sub- catchment lies in this zone which receives an average annual rainfall of between 1000 - 1600mm with r/E_0 value ranging between 65 - 80%. The main vegetation is moist and dry forest, most of which has been cleared. Coffee is the main crop grown in this zone.



5: Moisture availability zones of Masinga Dam Catchment Area

(iii) Semi-humid zone (ZONE III): This zone receives an average annual rainfall of 800-1400mm with r/E_0 value varying from 50 - 65%. It is characterized by dry forest and moist woodland and is a marginal coffee zone.

(iv) Semi-humid to semi arid zone (ZONE IV): This climatic zone receives an average annual rainfall of 600 - 1100mm and its r/E_0 value ranges between 40 - 50%. The main vegetation is dry woodland and the major crops grown are sunflower and maize.

Table 3.2 Moisture availability zones

zone	r/E_0 (%)	climatic class	mean annual rainfall
I	> 80	humid	1100 - 2700
II	65 - 80	sub-humid	1000 - 1600
III	50 - 65	semi-humid	800 - 1400
IV	40 - 50	semi humid/semi-arid	600 - 1100
V	25 - 40	semi-arid	450 - 900

E_0 =average annual rainfall
r = average annual potential evaporation

Source, Sombroek et.al. (1982:44)

(v) Semi-arid zone (ZONE V): This zone including Mathauta Sub- catchment receives an average annual rainfall of 450 - 900mm and its r/E_0 value varies from 25 - 40%. Its vegetation comprises mainly of bushland. Cotton is the main crop found in this area.

Temperature is also controlled by altitude. In the Estern areas where Mathauta sub catchment lies (semi-arid zone) and where the altitudes range from 900 - 1200m the mean maximum annual temperatures are $26^0 - 30^0$ C while the mean minimum annual temperatures are $14^0 - 18^0$ C. In the high altitude (2450 - 3050m). Western wetter and colder areas, the mean minimum and maximum annual temperatures are 6^0 C or below and 18^0 C or less respectively (Jaetzold & Schmidt, 1983; Sombroek, *et.al*, 1982). Mean minimmum and mean maximum temperatures range between 8^0 C or below and 26^0 C or less respectively in the middle areas lying between 1200 - 2450m. and where Kaihungu sub catchment lies.

Kaihungu has a Sub-humid and Semi-humid climate in the western and eastern areas, respectively (Fig. 3.5). It receives high amount of rainfall with a mean annual of 1575mm. About 75% and 25% of the catchment lies in the moisture availability zone II and III with an average annual rainfall of 1,000-1600mm and 800-1400mm, respectively.

Moisture availability for vegetation growth including Grevillea (*G.robusta*), black wattle (*Acacia mearnsii*) coffee, and fruit trees is high. Although nearly all the original vegetation has virtually been cleared for agricultural purposes, secondary vegetation which include trees and perennial crops provide a reasonable amount of ground cover. The latter offers protection to the soils from the impact of the heavy rains that are characteristic of this sub-catchment.

The mean annual temperatures are between 16-18^{0}C in the higher altitude or western part of the sub-catchment with a mean maximum and mean minimum temperature between 22 - 24^{0}and 10 - 12^{0}C, respectively. Further lower down in the Eastern part of the catchment, the mean annual temperatures increase and range between 18 - 20^{0}C with a mean maximum and minimum temperatures between 24 - 26^{0}C and 12 - 14^{0}C, respectively.

Mathauta Sub-catchment lies entirely in Agro-climatic zone V (Sombroek, *et al*, 1982; Fig. 3.4) which is classified as semi-arid or marginal area, receiving an average annual rainfall of 450 - 900 mm. The rainfall is characterised by small total amounts, and high temporal variations from year to year and from season to season. The minimum of 450 mm is far less than 750 mm considered necessary under a bimodal regime for most farm crop production (Nieuwolt, 1978). The ratio between average annual rainfall and annual potential evapotranspiration (r/Eo) is 25-40%.

Two distinct wet seasons namely; the Short rains (October - December) and Long rains (March - May) are apparent with a comparatively dry period between them. There is a fairly high probability (60 - 80%) of a substantial risk of crop failure in any year. Bushland consisting of scattered short trees is the main type of vegetation within the sub-catchment. The rainfall received in this zone is inadequate to support dense vegetation cover.

The rainfall erosivity is high, estimated at 200 -250 (Atkins, 1984). The erosive rains are concentrated in the early part of the rainy season when moisture deficit is severe and vegetation cover is minimal as land preparation is incomplete in readiness of the onset of the seasonal rainfall.

The mean annual temperatures are 20 -22^0 with a mean maximum and mean minimum temperatures of 26 -28^{0}C and 14 - 16^{0}C, respectively. These high temperatures increase the rate of evaporation resulting in low moisture availability for establishment of crop cover. Hence, soil and water conservation are necessary for crop growth.

3.2 Land use

3.2.1 Crop production

Virtually all cropping is rainfed with an exception of a few coffee and pineapple estates and small scale subsistence farms in the low catchment areas where supplemtary irrigation is practised. Cropping zones correspond to agro-ecological zones and altitude which has a strong influence on rainfall and temperature. Excluding the high altitude areas of Mt Kenya and Aberdares, three cropping zones are recognisable (Sombroek, *et al*, 1982; and Jaetzold and Schimdt, 1983). These include:

(I) Tea zone: This zone comprises entirely of the humid climatic zone 1, which is characterised by high altitude (>1,500m), high rainfall (1100 - 2700mm), and low temperatures (4 - 6^{0} c). The ratio between average annual rainfall and annual potential evapotranspiration is more than 80% (Table 3.1) (Sombroek *et al*, 1982). The implication here is that the potential for plant growth is very high and hence crops like tea, maize and beans are grown.

(II) Coffee zone: This zone is characterised by moderate rainfall (800 - 1600mm) and high altitude (1200 - 1500m) comprising of the sub-humid and semi-humid climatic zones II and III. The ratio between average annual rainfall and annual potential evaporation ranges between 50% and 80%. Thus, this area where Kaihungu sub catchment lies has a good potential for crop production particularly coffee.

(III) Cotton zone: The major climatic characteristics of this zone are low rainfall (<900mm) and low altitude (900m - 1200m). It includes the semi-arid climatic zone IV and V. The ratio between annual rainfall and annual potential evapotranspiration is between 25% -50%. Thus the potential for plant growth varies from low to medium hence maize, pigeon pea and cotton are the major crops. Unlike in the first two zones, moisture deficit in this zone where Mathauta Sub Catchment is located is a limiting factor to crop production making the need for water retention through water harvesting technology on the crop land very apparent. On the other hand, it is important to ensure the removal of surplus water from the crop land in the higher rainfall areas through the use of relevant conservation measures such as cut-off drains, terraces, and waterways in order to avoid waterlogging in agricultural land.

The two cropping seasons in the Masinga Dam Catchment follow the bimodal nature of the rainfall regime of the Long Rains (March - May) and Short Rains (October - December). Subsistence crops are planted at the onset of each of the two rainy seasons.

3.2.2 Livestock production

The main type of livestock reared are cattle, goats and sheep. Exotic breeds of cattle which are a product of initial crosses between the local zebu and imported breeds such as jersey, ayrshire, guernsey and friesian for milk production are the most common in the cool areas of the catchment where zero grazing is also practised (Kenya, 1989). This practice reflects land shortage per household which is also evidenced by the few number of livestock kept per family particularly in the Kaihungu Sub Catchment. Infact, majority of the farmers grow nappier grass on terraces in their farms because they lack grazing areas.

In the low lying areas of the catchment such as Mathauta sub catchment, cattle, goats, donkeys and sheep thrive under poor grazing conditions especially during the dry seasons in January - February and August - October. Zero grazing is rarely practised but instead large numbers of livestock are kept mainly for milk production and draught power and are sold occasionally when financial needs particularly school fees arise. The grazing areas are rarely paddocked and due to lack of adequate watering points, livestock are driven for long distances to the seasonal rivers. At these watering points and along the cattle tracks, the land is heavily grazed and degraded.

3.2.3 Forestry

Forests are confined principally in the humid and sub-humid zones of the catchment. The Mt.Kenya and Aberdares forests are the major forests and are gazetted Government land, reserved for forestry and water catchment conservation purposes. These forests play an important role in soil and water conservation by providing dense ground cover and canopy which minimise the effects of rain drops and reduces the amount of run-off hence soil erosion.

However, deforestation is taking place in some parts of the forests as a result of population growth followed by increased demand for agricultural land. Coffee and tea are the major crops grown in this area although these together with wattle trees which are widely grown in the area provide a reasonable amount of ground cover. The wattle trees are planted mainly for fuel and polewood purposes and are an important source of income. The exorbitant fuel wood price is encouraging every farmer to plant trees as there are very few substitutes for fuelwood. Planting of trees is a move in the right direction in as far as soil conservation is concerned.

The lower margins of these forests are also under constant pressure, being cleared for agricultural, timber, fuelwood and polewood purposes. This is in response to the growing population and the critical wood deficit in the area. The demand for wood is projected to rise to 2.3 to 3.1m^3 by the year 2,000 from 1.0 to 1.5m^3 per person in 1983 (Atkins, 1984). Such increased demand will place greater pressure on existing trees with serious implications for soil erosion particularly on the Aberdares and Mt. Kenya forest.

3.3 The human environment

3.3.1 Population distribution

Population distribution in the Masinga Dam Catchment is, to a large extent, influenced by the physical environment. The high potential areas of the catchment which include humid and semi-humid agro-ecological zones where Kaihungu Sub-catchment lies have high population densities of more than 500 persons per km^2 (Fig.3.6). They are also characterised by high annual population growth rate (3.2%). Indeed, 63% of the administrative areas located in these high potential zones within the catchment, recorded

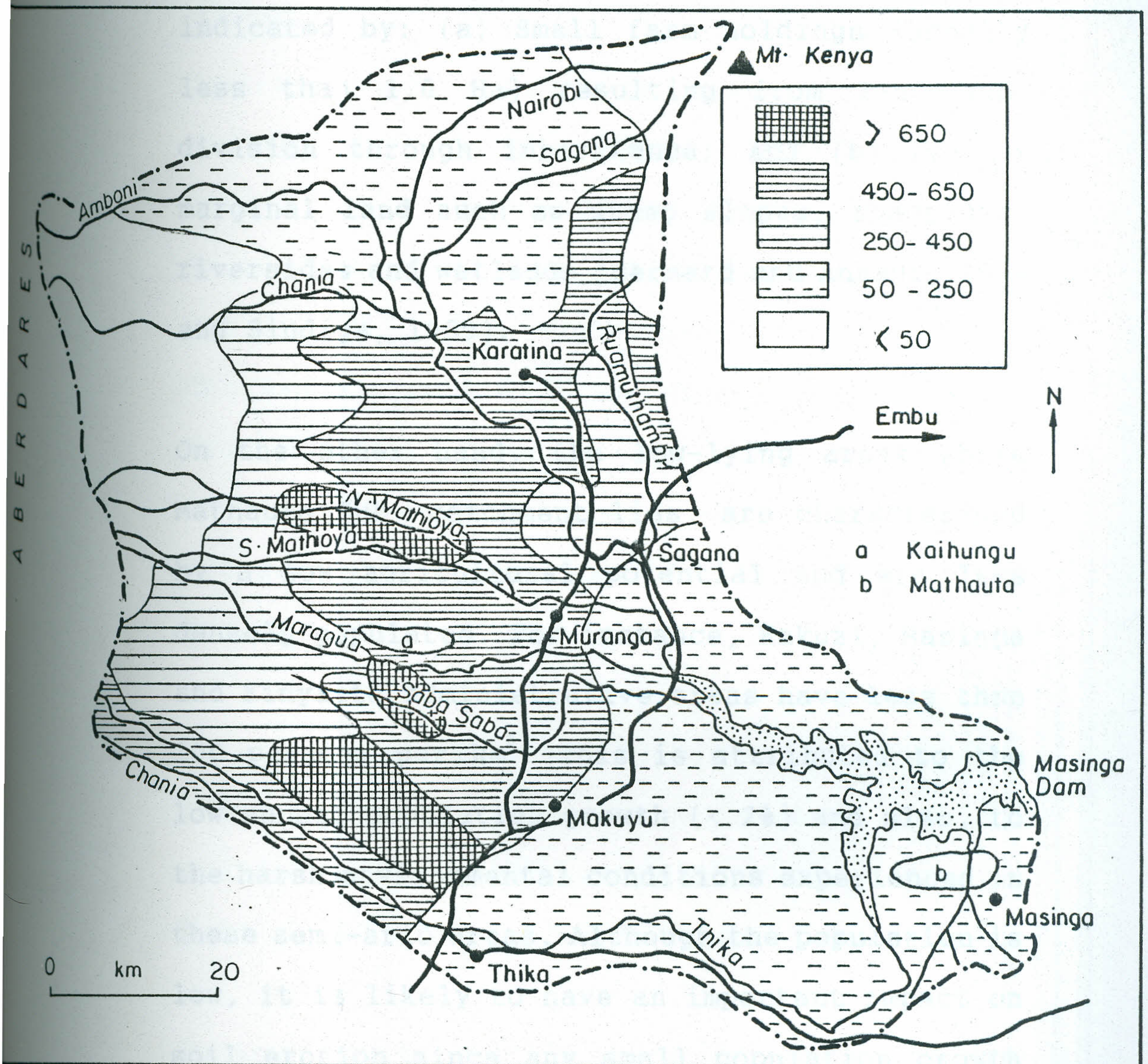


Fig 3.6: Population density in the Masinga Dam Catchment

densities of more than 250 persons per m^2 in the 1989 population census (Kenya, 1993).

The increasing population has exerted pressure on the limited available agricultural land as is indicated by: (a) Small farm holdings (usually less than 1.0 Ha) resulting from land sub-division through inheritance; and (b) Use of marginal land such as steep slopes, roadsides, riversides and wetlands (Bernard and Anzagi, 1979 and Sindiga, 1989).

On the other hand, the low-lying areas where Mathauta Sub- catchment lies, are characterised by a low agricultural potential and are less densely populated. For instance, Kakuzi, Masinga and Kinyatta administrative areas have less than 100 persons per km^2. This is attributed to the low annual population growth (< 2%) and also, to the harsh environmental conditions experienced in these semi-arid areas. Although the population is low, it is likely to have an important impact on soil erosion since any small population growth implies increased human activity in this fragile agro-ecological zone.

In the Kaihungu Sub-catchment, population increased from 10,923 in 1979 to 13,129 in 1989.

The annual growth rate at 2% is low compared to that of Murang'a district and Kenya (as a nation) which is 3.2% and 3.6% respectively. However, this seemingly low growth rate may have a serious implication on the land degradation issue as it is likely to lead to the expansion of cropping on to the marginal areas which are highly susceptible to soil erosion.

Population density increased from 458 persons per km^2 in 1979 to 550 persons per km^2 in 1989 while the average number of households also increased from 1,237 in 1979 to 1,629 in 1989 (Kenya, 1993). This, to an extent, suggests population pressure and resultant smaller farm holdings per family.

Female population is higher than the male population. The average population of the male and female was 3,060 and 3,3396.8 in 1979 and 3,830.3 and 4,248 in 1989, respectively.

In many farm households the adult male leave home to seek off-farm employment in such towns as Nairobi and Thika. They usually return home on a weekly or monthly basis. In such cases women are then involved in making day to day on-farm decisions like planting, weeding and employing labourers. On the other hand, however, decisions involving major farm investments are initiated by men who are normally away in towns.

On the other hand, the Mathauta Sub-catchment is sparsely populated compared to the Kaihungu Sub-catchment. Its population increased at an annual growth rate of 1.6% from 107,419 in 1979 to 124, 078 in 1989. The population density also, increased slightly from 79.5 persons per km ^{2} in 1979 to 96.5 persons per km ^{2} in 1989 (Kenya Bureau of Statistics, 1979; 1993). Due to the low population and low density, land size per household is higher, about 10 Ha acres compared to that in Kaihungu Sub- catchment where the average holding is less than 1.0 Ha.

The slow population growth in the catchment is largely associated with low population growth, late settlement and marginality of the physical environment. Most of the people occupying this area can be described as "immigrants" who have moved into the area from other densely populated parts of the country especially the neighbouring overcrowded Machakos Hills to the south. Increased land productivity will come through change in agricultural technology involving use of the necessary agricultural inputs and supplemntary irrigation.

3.3.2 The Economic Background

Agricultural production forms an important economic base of the Masinga Dam Catchment. The main agricultural products include; cash crops such as coffee and tea which are produced in the high altitude parts of the catchment; food crops, mainly cereals and pulses; meat and milk. These are of great significance both at the household and national level as a source of food, cash and foreign exchange.

Cattle contribute more to the rural economy in the lowlands. The agricultural produce is marketed either locally within the catchment in the trading centers including; Karatina, Murang'a, Nyeri, Matuu, Masinga, and Embu (Fig.1.1) or externally in towns outside the catchment especially Nairobi town where the demand for fresh food stuffs is quite high.

A large proportion of the population in the catchment area depends on the agricultural sector for employment due to the limited employment opportunities outside this sector. However, due to the increasing population, cases of unemployment and under-employment especially during off peak seasons are numerous. Other minor primary sector production include; forest and wood products, fishing, pottery and tourism.

CHAPTER FOUR

RESEARCH METHODOLOGY

4.1 Sampling Framework

This research was conducted in the Masinga Dam Catchment, Kenya (Fig. 1.1) during the period between September 1991 and December 1992. The entire catchment was not studied because of its' large size (7,950 km^2), financial and time constraints. Only two Sub-catchments were selected following various sampling stages, for indepth analysis of the agronomic and socio-economic factors influencing soil erosion in the catchment.

First, the whole catchment was divided into two main zones namely; upper and lower zones. This division was based on altitude. The former lies between 1,400 and 1750 M while the latter has altitude ranging from 1000 and 1400 M.

Second, using random sampling, only two sub-catchments; Kaihungu and Mathauta (Fig 4.1 and 4.2) were selected from two lists showing all Sub-catchments in the two zones. These Sub-

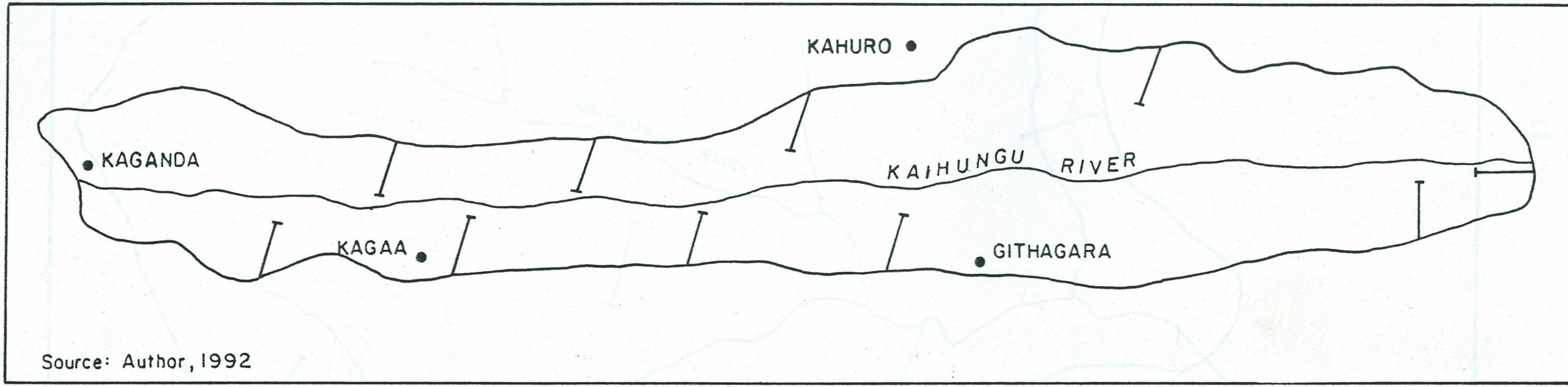


Figure 4·1: Kaihungu Sub-catchment Transects

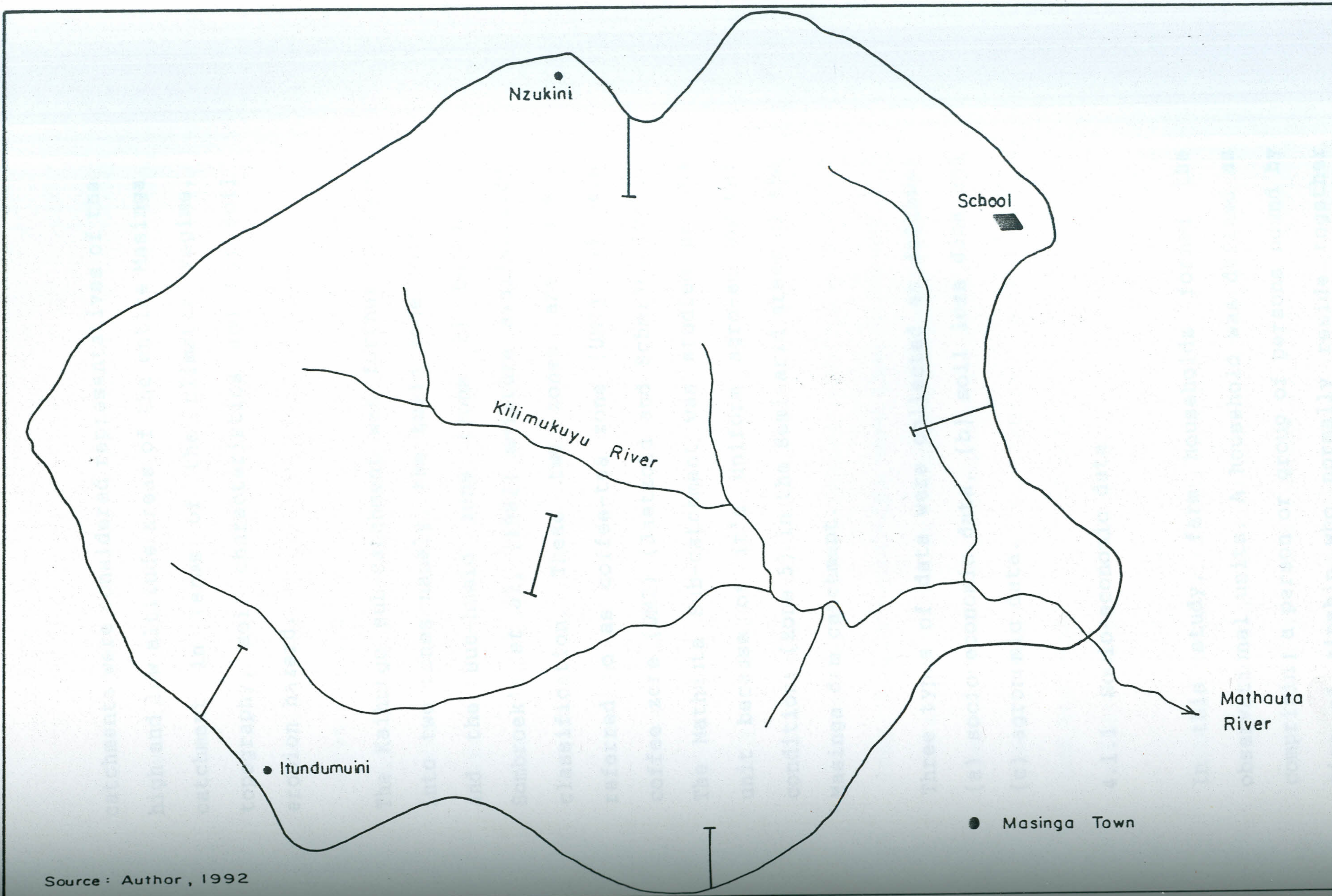


Figure 4.2 : Mathauta Sub-catchment Transects

catchments were considered representatives of the high and low altitude areas of the entire Masinga catchment in terms of the climatic regime, topography, soil characteristics and the soil erosion hazard.

The Kaihungu sub-catchment was further divided into two zones namely, the humid zone (zone 1) and the sub-humid zone (zone 2) based on Sombroek's *et al*, (1982) moisture availability classification. These two zones are, also, referred to as coffee-tea zone (UM1) and main coffee zone (UM2) (Jaetzold and Schmidt, 1983). The Mathauta Sub-catchment was studied as one unit because of it's uniform agro-ecological conditions (zone 5) in the Semi-arid areas of the Masinga dam catchment.

Three types of data were collected as follows: (a) socio-economic data, (b) soil loss data and (c) agronomic data.

4.1.1 Socio-economic data

In this study, farm households formed the observational units. A household was defined as comprising a person or group of persons bound by ties of kinship who normally reside together under a single roof or under several roofs within the same compound such persons who share community of life in that they are answerable to the same head and have a common source of food (Kenya, 1981). Under this definition, polygamous wives living within a single compound are included in the same household regardless of the cooking arrangements. Those in separate homesteads, are considered as two households. These were selected using the transect method. Transects were developed along the footpaths traversing across and into the interior of the Sub-catchments.

In the densely settled Kaihungu sub-catchment, ten (10) transects were developed. Each transect measured approximately one (1) kilometre (km) long. Sample households were then selected along the transects on an interval of 100 Metres. On the other hand, in the sparsely settled Mathauta sub-catchment five (5) transects were developed and households for inclusion in this study were selected after every 0.5Km.

This procedure yielded 20 households along each transect and a total of 200 and 100 households in the Kahingu and Mathauta sub-catchments, respectively. The heads of these households provided the socio-economic information used in this study to explain the soil erosion problem in the Masinga Dam Catchment.

4.1.2 Soil loss data

Soil loss was monitored only in the Kaihungu Sub-catchment during the following rainy seasons: Short Rains, 1991 (November to December); Long Rains, 1992 (March to June) and the Short Rains, 1992 (October to December). Initially, soil loss was to be monitored in the two sub catchments. However, there were problems encountered when installing soil traps in the Mathauta Sub-catchment due to low slope gradients as is indicated by low amounts of soil loss obtained from this part of the catchment during the Short Rain season (1991). Further, the Mathauta sub-catchment was excluded because; First, the former area (Kaihungu) forms an important part of the Maragua catchment which contributes a high proportion of sediments into the Masinga reservoir through Tana River (Atkins, 1984). Therefore, land use in Kaihungu sub-catchment is bound to affect the rate of sedimentation in the Masinga reservoir. Second; according to Wooldrige (1984), sediments in the reservoir contain almost entirely silt and clay particles originating mainly from the humid areas of the Masinga dam catchment. On the other hand, Mathauta consists of sandy coarse textured soils (derived from metamorphic rocks) which are not easily transportable over a long distance. Most of the sediments are deposited in the river bed. Further, sandy soils allow much water to percolate through, thus minimising the amount of run off.

In order to collect soil loss data, 26 soil traps were installed in 14 farms belonging to some of the 200 selected households in Kaihungu catchment. Selecting farms on which to place the soil traps was rather difficult because majority of the farmers expressed fear and distrust of the researcher (see section 4.5). Therefore, a list of the farmers who were willing to have the soil traps installed in their farms was prepared. From this list, 14 farmers were selected randomly and the soil traps were then placed in their farms.

4.1.3 Agronomic Data

Two sets of agronomic data namely; general and specific data were collected during the study period. The former which included; types of crops, cropping patterns and soil conservation measures was collected from the 300 farms. On the other hand, the specific agronomic data was collected from the farms where soil traps had been installed. This yielded data based on soil fertility, crop cover, and crop density in the Long Rain Season (March to June) and Short Rain Season (October to December) 1992.

4.2 Methods of Data Collection

Two research techniques including primary and secondary methods of data collection were employed. The methodology used to collect each type of data is described in the following sections.

4.2.1 Collection of socio-economic data

Data used in analysing the contribution of socio-economic factors to soil erosion were collected from a sample of 300 farmers in the study area. A questionnaire (Appendix A-1) was used to elicit information from the farmers. The questionnaire covered three major areas, namely (a) the farmers socio-economic background including; gender, age of the head of the household, family size, farm size, land tenure, income and employment; (b) Agricultural practises including; crop types, cropping patterns, purpose for farming, crop performance, types of livestock, watering and grazing places; (c) Soil erosion including; farmers awareness of the soil erosion problem, causes of soil erosion and soil conservation measures practised on the farms.

At the end of each questionnaire, the researcher made her own independent assessment of the extent of the soil erosion problem in each visited household. As was the case in Bernard and Anzagi, 1979), this was done by making observations in six areas of each sample farms, namely; food crop plots, coffee farm plots, pasture areas, farm boundary and homestead compound. The presence or absence of the following types of erosion; splash erosion, sheet wash, rills, gullies and mass movement and the quality of the conservation structures guided the researcher in assessing the severity of soil erosion in the study area. This method of assessement is similar to the one used by Bernard and Anzagi (1979).

Each observation was given a numeric weight; either "1" or "2". The areas suffering less severe erosion were assigned a numeric weight "1" while those severely affected scored "2" (Table, 4.1). This yielded an erosion value varying between 6 and 12 which assisted the researcher in reaching a final independent decision regarding soil erosion in the entire catchment. A farm was classified as experiencing less or severe erosion if it scored less than or equal 6 or more than or equal 7 points respectively.

Table 4.1 Method of assessing the severity of soil erosion

Areas of observation	Qualitative assessment	Numeric weighting
food crop plots	less severe erosion	1
coffee plots		
pasture areas		
footpaths	severe erosion	2
farm boundary		
homestead compounds		

Source: Modified from (Bernard and Anzagi, 1979)

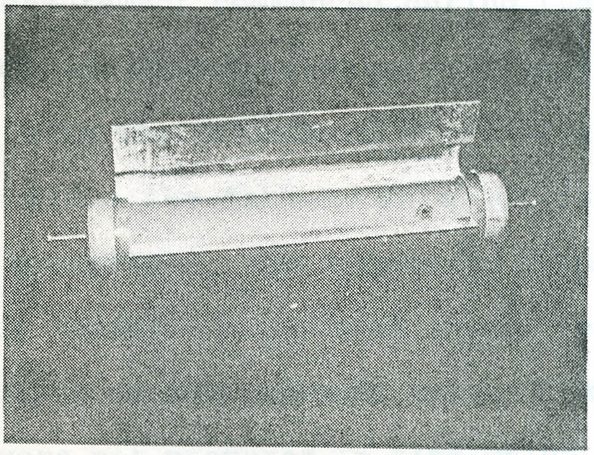
The questionnaire consisted of structured and unstructured questions. Although the questions were written in English, the interviews were conducted in Kiswahili and Kikuyu (in the upper catchment). Kikamba language was used in the lower catchment. The questionnaires administered in Kikuyu language took the longest time as the researcher is not very fluent in the language.

One interview took about 40 minutes. The interviews were conducted mainly during the rainy seasons, a time when most of the farmers were likely to be found working in their farms.

4.2.2 Collection of soil loss data

Soil traps (Fig.4.3) were used to collect eroded soil from the 14 farms under different crops, cropping patterns, and farm management practises. The soil traps used in this study are similar to the ones used by Lewis (1985) which are modified Gerlarch (1967) troughs. The major modification was that plastic pipes were used instead of sheet metal in the construction of the lower portion of the trap because of ease of construction and comparative low costs. Plastic material was also used to close the two openings at both ends instead of sheet metal.

Each trap measured 50cm wide and 110cm in diameter. The traps were installed prior to the beginning of the rains at the lower limit of the selected farms. The length of each field was determined by direct measurement using a tape measure. Slope angles were measured along the slope segment immediately above the trap using an Abney level. Soil samples collected from the



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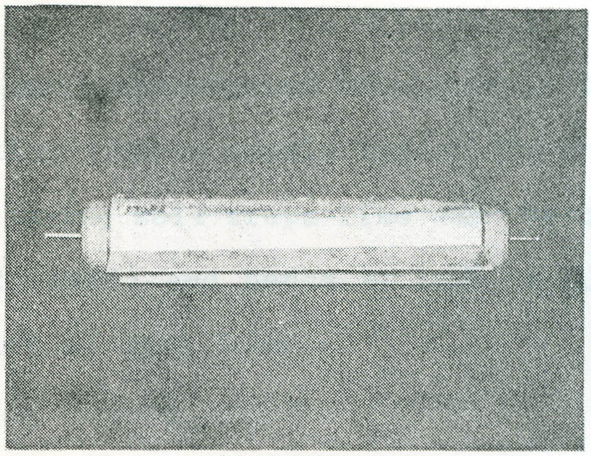

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Fig. 4.1: A sample of a Soil Trap

upper decimeter in the trap sites were analyzed for texture and fertility.

Soil loss measurement commenced during the short rains of 1991 to demonstrate and to familiarize the farmers with the procedures for emptying the soil traps. Since the farmers were not familiar with these procedures, the number of days with missing data tended to increase thus, reducing the reliability of the seasons data. Also, the soil traps were not prepared in time which led to late installation hence, affecting the quality of the data.

The trapped soil was emptied into plastic bags on a daily rather than a weekly basis. This was to avoid overflowing soil traps like was the case in Lewis (1982; 1988) and hence an underestimation of the amount of soil loss.

One member of the family was assigned the responsibility of emptying the soil traps. The bags into which the eroded soil was to be emptied were clearly labelled indicating the name of the head of the household, the crop(s) grown in the particular farm and the date on which the soil trap was emptied.

The trap soil was collected from the farmers on a weekly basis and transported to the Department of Zoology, University of Nairobi for drying and weighing. These soils were dried in the oven at $105\text{-}110^0$ to constant mass after which they were weighed and recorded in order to determine the amount of soil lost from the sample farms during the Long Rains, 1992.

During the Long Rains of 1992, most of the farmers were enthusiastic to empty the soil traps. However, in the following season, some of them appeared reluctant to continue with the exercise complaining that it was not only tedious but also time consuming. Therefore, the soil loss results of Short Rain season of 1992 are not included in the present analysis as the data collected produced some doubtful results.

4.2.3 Collection of agronomic Data

The general agronomic data including crop types, cropping patterns and soil conservation activities were assesed through the use of observation and the questionnaire methods. The farmers were asked questions regarding the type of crops and cropping patterns usually practised. The reasons for the choice of these patterns and their perception of the soil erosion problem and conservation measures were also recorded. The specific agronomic data was collected either by actual measurement or observation as is explained below.

4.2.3.1 Crop Cover

Crop cover on the food crop sections of the farms was assessed after every two weeks. The first measurement during the Long and Short Rain Seasons (1992) were taken at the end of the second week after the on-set of the rains and the crops had started to germinate. Prior to this, crop cover was assumed to be zero as they had not germinated.

Crop cover assessment was done using visual observation method by making an estimate of the bare ground in a 10M x 10M area as was the case in Schnneidder (1994). This method was used through out the study period because it was convenient, less taxing and did not interfer with the crops.

4.2.3.2 Soil Fertility

Composite top soil samples were collected around the trap sites. These were packed in plastic bags, sealed, labelled and transported to the National Agricultural Research Laboratories (NARL) for texture and available nutrients analysis (Hinga, Muchena and Njihia, 1980). Texture was determined using the pipette method as outlined by USDA (1951). Nitrogen and Organic Carbon were determined by Kjeldahl method and Walkley-Black procedures respectively (Hinga, *et al,* ibid). Potassium, Phosphate, and Calcium were extracted with Mehlich method and their concentrations determined with AAS (Hinga, *et al,* ibid). The results were used in the determination of soil fertility levels and in land quality assessment which was aimed at assessing the extent of soil erosion in the study area.

4.2.3.3 Crop Density

Crop spacing was first measured in order to calculate crop density. For this to be achieved, two types of crop spacing namely; row to row and plant to plant spacings were measured using a tape and the spacings were used to calculate crop density as shown below (Agricultural Information Centre n.d).

crop density = { (100/r-r) X (100/pl-pl)} X 10,000 }

where r-r = row to row spacing
pl-pl = plant to plant spacing

This method is similar to the one used by Scheneidder (1994).

4.3 Secondary Data

Information from documentary sources (published books, government documents and files) was collected to supplement the data in the field. These documents were from the following organisations: Kenyatta University Library, University of Nairobi Library, Central Bureau of Statistics, Tana and Athi River Authority Library and Ministry of Agiculture, Livestock Development and Marketing.

4.4 Data Analysis

The methods employed in analysing the data comprised of manual calculation and tabulation and computer processing. The latter involved the use of the Statistical Package for Social Sciences (SPSS). These methods are outlined in the following section.

4.4.1 Statistical Summaries

Simple descriptive statistics were generated from the data set using the SPSS procedure (Nie, Hull, Jekins and Steinbrenner, 1975). These included frequencies, percentages and the mean.

4.4.2 The Chi Square Test

The chi Square test was used to analyze the socio-economic data. Besides it being a nonparametric test, it was found most suitable for the present data because it (the data) is nominal. The Chi Square statistic (Ebdon 1985) is calculated as follows:

$$X^2 = \sum \frac{d^2}{e}$$

where: $\chi 2$ = symbol for Chi square

d = the difference between the observed and the expected frequency for each category

e = the expected frequency for each category.

In all cases, the degrees of freedom were calculated as follows:

$$df = (r-1)(k-1)$$

where: r = number of rows in tables

k = number of columns in tables.

The degrees of freedom are important because the probability of obtaining a specific Chi Square depends on the number of cells in the table. The significance level used was at 0.01 (Ebdon, ibid). The null hypothesis is usually rejected when the computed value of the Chi Square is greater than the critical value (Appendix A-2).

4.4.3 The Mann-Whitney U Test.

The Mann-Whitney U test (Ebdon,1985), a non parametric test was used to test for statistical differences between amount of soil loss from farms under different agronomic practices. It was found most useful in this study because it does not make any assumptions about the characteristics of the distribution of the population concerned. Also, it can be used with a small set of data (Shaw and Wheeler, 1985). It is calculated as follows;

$$U_x = n_x n_y + (n_x(n_x+1)) \div 2 - \sum r_x + U_y = n_x n_y + (n_y(n_y+1)) \div 2 - \sum$$

Where: n_x = are the number of individuals in sample X

n_Y = are the number of individuals in sample Y

Using this technique the null hypothesis is normally rejected when the calculated U value is less than the critical value (Appendix A-3).

4.4.4 Limitations in statistical analysis

There are some important limitations to the use of Chi-Square Ebdon, (1985). First; the data must be nominal; i.e in frequency form, second; the set of categories must be mutually exclusive meaning that a category cannot be counted in more than one category, third; the expected frequencies should not be small (i.e (1) if the number of categories is greater than 2, no more than 1/5 of the expected frequencies should be less than 5, and none should be less than one (1). (2) if the number of categories is 2 both the expected frequencies should be 5 or larger).

4.5 Research Limitations

A number of logistics and technical problems were encountered while conducting this research. The first one concerned the installation and emptying of the soil traps. Initially, a number of farmers especially the well off ones refused to have the soil traps installed in their farms. Some of them did not give any specific reasons for their refusal while others expressed fear and distrust about the researcher. They feared that the researcher's intention was to collect soil from their farms for commercial purposes and demanded big sums of money as a form of compensation. Another significant section of the farmers explained that they did not want their crops trampled on during the process of emptying the soil traps. Therefore, only those farmers who were willing to have the soil traps installed in their farms were included in the sample.

Due to lack of research funds the researcher was not able to employ research assistants, therefore, the farmers were entrusted with the responsibility of emptying the soil traps. This was done quite successfully in the Long Rains, 1992. However, in the following season, some of the farmers appeared reluctant to continue with the exercise. For instance, some farmers forgot to empty the soil traps. This resulted to cases of overflow of soil from such soil traps and consequently to a loss of the trapped soil.

Language barrier was another problem that made data collection slow and a difficult process in the Kaihungu sub-catchment. This is because farmers spoke in Kikuyu language which the reseacher is not very familiar with. In some cases, the assistance of an interpreter was sought.

CHAPTER FIVE

RESULTS AND DISCUSSION OF AGRONOMIC FACTORS INFLUENCING SOIL EROSION IN THE STUDY AREA

5.0 INTRODUCTION

As already discussed in Chapter 3, a large portion of the study area is densely populated. For instance, Kaihungu Sub-catchment is highly populated with a density of 550 people per km^2 and a growth rate of 2 %. This together with the land tenure system have resulted in small farms per household and the use of marginal land. In order to ensure that the available agricultural land continues to sustain the livelihood of the rapidly growing population, the causes of soil erosion in the catchment have to be understood. This is necessary, because accelerated soil erosion is highly associated with low farm yields. These can be attributed to a reduction in soil productivity (Lal, (1985).

In this chapter, the results of the agronomic factors influencing soil erosion in the study area are therefore presented and discussed. Also, soil loss results and land quality ratings are presented.

5.1 Agronomic factors influencing soil erosion

The theme of this section is to test the null Hypothesis ($H_0$1) which states that "There is no significant difference in the amount of soil loss between farms under different agronomic practices".

5.1.1 Description of the soil trap sites

Soil loss was monitored using 26 soil traps in the Kaihungu Sub- catchment. This was undertaken during the Long and Short Rainy seasons (1992). The soil traps were placed on farms with varying physical and agronomic characteristics. The hilly nature of the topography was reflected in the range and magnitude of the sample farm slopes whose angles ranged from 3° to 27° (Table. 5.1). About 69.2% of the farms in the study area were more than 7.5° steep (Table 5.2). Also, farms with long steep slopes were evident for instance, ST3, ST5, ST19 and ST20 (Table 5.1).

In 85% of the sampled farms, one or more soil conservation measures were practised. Although terracing was very common in the study area, the maintenance was poor and there was need for immediate re-working. About 11.5% of the sample

Table 5.1 Soil loss and physical characteristics of the sample farms

farm	soil loss $t.ha^{-1}$ (1992)		slope		CA (M)	crop(s)	crop cover (%)		
	LR	SR	angle (deg)	length (M)			March	April	May
ST1	7.9	35.4	3.00	1.70	0.85	C&B	30	35	40
ST2	41.1	54.6	13.00	1.75	0.86	C	15	10	20
ST3	14.3	3.3	23.00	9.00	4.50	M	0	10	15
ST3A	4.1	3.0	10.00	2.80	1.40	C&B	60	70	80
ST3B	4.5	4.3	17.00	3.00	1.50	C&B	60	70	80
ST4	30.1	80.4	24.00	8.00	4.00	C	10	10	10
ST5	17.4	16.4	26.00	7.60	3.80	M&B	0	10	20
ST5A	28.1	17.2	24.00	5.80	2.90	M&B	0	5	15
ST6	13.6	3.3	15.00	5.60	2.80	M&B	0	10	30
ST7	35.2	9.8	20.00	3.00	1.50	M&B	0	10	30
ST8	31.3	9.3	14.00	3.50	1.75	BARE	0	5	5
ST9	6.8	54.6	6.00	4.60	2.30	M	0	10	15
ST10	11.9	25.9	7.00	2.50	1.25	M&B	0	20	35
ST11	22.7	-	18.00	2.10	1.05	M&B	0	20	30
ST12	13.5	-	9.00	1.60	0.80	M&B	0	10	25
ST16	32.7	81.0	12.00	2.60	1.30	M	0	10	25
ST17	6.1	19.4	9.00	2.00	1.00	C&B	20	35	60
ST18	5.4	31.1	12.50	5.30	2.65	M	0	15	30
ST19	1.6	6.6	6.00	9.70	4.80	M&B	0	15	35
ST20	1.7	8.8	5.50	8.80	4.40	M	0	15	35
ST21	6.1	3.5	14.00	6.90	3.45	M&B	0	10	20
ST22	19.0	23.9	18.00	4.30	2.15	C&B	40	65	75
ST23	20.5	76.8	7.00	1.80	0.90	C&B	20	30	40
ST24	69.5	59.9	27.00	3.90	1.95	M	0	20	35
ST25	9.6	19.6	7.00	6.50	3.25	M&B	0	15	40
ST26	2.4	5.3	6.00	4.50	2.25	C&B	50	55	65

CA=contributing area; LR=Long Rains; SR=Short Rains; C=coffee, M=maize, B=beans
Source: Author

farms lacked any conservation measures which taken together with the slope angle and length can lead to serious soil erosion.

Only one farmer had fallow land. This was attributed to a land shortage problem experienced in the study area.

Table 5.2: Levels of slope angle of sample farms

Slope Categories	No. of farms	Percentage
1 - 3.5°	1	3.9
3.5 - 7.5°	7	26.9
7.5 -15.5°	9	34.6
15.5 - 30°	9	34.6
Total	26	100.0

Source: Author

As a result, farmers were forced to cultivate all the available land during every cropping season. Lack of fallow has resulted in over-cultivation, reduced soil fertility and hence soil erosion followed by low soil productivity.

The type of crops which were grown in the sample farms during the study period included coffee, maize, english and sweet potatoes. These were mainly intercropped, particulary maize and bean.

5.1.2 Soil loss in arable land

Soil loss measured during the Long and Short Rain season (1992) ranged between 1.6 $t.ha^{-1}$ to 69.5 $t.ha^{-1}$ and 3 $t.ha^{-1}$ to 81 $t.ha^{-1}$ respectively (Table 5.1). The total soil loss for the Long and Short Rain season was 457.1 $t.ha^{-1}$ and 653.4 $t.ha^{-1}$ respectively. On average each farm yielded 17.5 $t.ha^{-1}$ and 25 $t.ha^{-1}$ of soil loss in the Long and Short Rain seasons respectively. The seasonal rainfall was 823.2 mm and 699.2 mm in the Long and Short Rain Seasons, respectively (Schnneider, 1994).

These data, particularly that of the two Short Rainy Seasons, appear high when compared to soil losses under similar climatic conditions and topographic settings. For instance, Lewis (1985) obtained 351.9 $t.ha^{-1}$ and 60.3 $t.ha^{-1}$ during the long and Short Rainy seasons (1982) in Murang'a district. The difference in results could be attributed to the way in which the soil traps were emptied. In the case of Lewis, the traps were emptied on a weekly basis rather than daily like was the practice in the present study. Emptying the soil traps once a week could have resulted in loss of soil from the traps through over flow and hence yield relatively low amount of soil loss thus, making the current data more reliable. This is perhaps why soil loss obtained in the study of Lewis appears lower than that of the present study.

Unlike the researchers expectation, the highest amount of soil loss occurred during the Short Rain season (1992), when the highest single rainfall event totalled 48 mm. This was less than that received during the Long Rain season (1992), of 104.2 mm. During the the Short and Long Rain season (1992), 75.5% and 68% of the rainy days were recorded respectively, less than 20 mm of rainfall (Table 5.3). These low amounts of rainfall received during most of the rainy days cannot be considered to have been that erosive as to yield such high levels of soil loss.

Thus, the high amount of soil loss obtained during the Short Rain season (1992) in the present study can only be attributed to problems associated with the emptying of the soil traps particulaly, lack of cooperation from the farmers. Therefore, these results are not further discussed as they appeared to give an exaggerated impression of soil loss in the catchment, during the Short Rainy season.

Table 5.3: Rainfall received in the catchment during the Long and Short Rainy Seasons (1992)

Rainfall (mm)	Rainy Days	
	Long Rain Season	Short Rain Season
1 - 20	(68%)	(76%)
21 - 40	(12%)	(15%)
41 - 60	(6%)	(9%)
61 - 80	(9%)	0
81 - 100	(3%)	0
101 - 120	(3%)	0
Total rainy days	34	53

Source: Modified from Schneidder, 1992.

5.1.3 Cropping Patterns and Soil Erosion

In Table 5.4 it is shown that during the Long Rainy season (1992), maize and beans intercropping was practised in about 39% of the sample farms. In addition, 27% of the farmers intercropped coffee and beans. The reasons why intercropping was preferred to monocropping include: small farm sizes, crop security, low coffee prices, better use of farm inputs, and availability of ground cover.

Table 5.4: Crops and Cropping Patterns Practised in the Soil Trap Sites (Long Rains, 1992).

Crops	No.of farms	Farms(%)
Maize & Beans	10	38.5
Coffee & Beans	7	26.9
Maize	6	23.1
Young Coffee	2	7.7
Fallow land	1	3.8

Source: Author

The results of the measured soil loss from different cropping systems including intecropping and monocropping patterns are presented in Table 5.5. Total soil loss from the intercropped coffee and beans farms; and intercropped maize and beans was 51.6 $t.ha^{-1}$ and 214.0 $t.ha^{-1}$ with mean values of 7.4 $t.ha^{-1}$ and 21.4 $t.ha^{-1}$ respectively. On the other hand, total soil loss from the monocropped maize and young coffee farms was 89.0 $t.ha^{-1}$ and 71.2 $t.ha^{-1}$ with mean values of 14.8$t.ha^{-1}$ and 35.6 $t.ha^{-1}$, respectively.

Table 5.5: Soil loss ($t.ha^{-1}$) from farms under different cropping patterns

	COFFEE & BEANS (N=7)	MAIZE & BEANS (N=10)	MAIZE (N=6)	YOUNG COFFEE (n=2)	BARE (n=1)
Total soil loss	51.6	214.0	89.0	71.2	31.3
Average	7.4	21.4	14.8	35.6	31.3

Source: Author

These results revealed that intercropped coffee and beans had the lowest average amount of soil loss during the Long Rain season (1992). This is because as results from crop cover (Table 5.6) indicate, mature coffee, unlike the food crops provided good canopy cover throughout the season especially at the onset of the rainy season when cover was more than 40%. During this time, all the food crop farms were bare. This implied that the coffee farms were better protected from the impact of the first rains, which are usually the most erosive, than the food crop farms. Infact soil loss from coffee farms could have been much if mulch was used (Lewis, 1985).

Monocropped maize farms yielded the next lowest average soil loss (Table 5.6). This was contrary to the researchers expectation and to the findings in other studies (Hudson, 1971; Lal, 1985; Omwega, 1989) which associate monocropped maize with high levels of soil losses.

Intercropped beans and maize ranked third in average soil loss. These farms yielded about 21.4 $t.ha^{-1}$ on average which was higher than 14.8 $t.ha^{-1}$ produced by the monocropped maize farms. This does not concur with other studies elsewhere which have previously shown that intercropped maize and beans produce better crop cover than, for instance, monocropped maize and are, therefore, effective in controlling and reducing soil erosion in farmed land (Morgan, 1986; Omwega, 1989 and Obando, 1990). These studies show that the relationship between sediment yield and percentage of ground cover is linear and therefore soil loss declines as vegetation cover increases. This is because soil erosion is commonly associated with lack of vegetation cover. Their data were however, obtained on experimental plots with more than 20% cover while majority of the sample farms were characterised by low vegetation cover (< 20 %) through out the cropping season (Table 5.1 and 5.6).

Table 5.6: Percentage of Sample Farms Representing Varying Amounts of Crop Cover

Vegetation cover (%)	Beans (under coffee)	Maize and Beans	Monocropped Maize
0-20	57.1	50	83.3
21-40	28.6	10	16.7
41-60	14.2	30	_
61+	-	10	-

Source: Author

According to the information provided in Table 5.6 the development of the food crop cover was generally slow and poor. This was largely maize and beans produce better crop cover than, for instance, monocropped maize and are, therefore, effective in controlling and reducing soil erosion in farmed land (Morgan, 1986; Omwega, 1989 and Obando, 1990). These studies show that the relationship between sediment yield and percentage of ground cover is linear and therefore soil loss declines as vegetation cover increases. This is because soil erosion is commonly associated with lack of vegetation cover. Their data were however, obtained on experimental plots with more than 20% cover while majority of the sample farms were characterised by low vegetation cover (< 20 %) through out the cropping season (Table 5.1 and 5.6).

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Source: Author

According to the information provided in Table 5.6 the development of the food crop cover was generally slow and poor. This was largely attributed to poor agronomic practises such as low application of manures and fertilizers, lack of fallow farming, crop rotation, adequate and well maintained soil conservation measures and failure to replough crop residues in the farms. These agronomic mal-practices led to low soil fertility which when coupled with the problem of low plant densities resulted in poor cover establishment. Indeed, most of the food crops attained upto or less than 20% during the Long Rainy season, (1992) (Table 5.6).

Young coffee farms and the bare farm had the highest average soil loss (Table 5.5). This was because crop cover was below 20% and concurs with the findings of Othieno, (1978) and Hudson (1971) who argue that young tea and coffee and bare grounds can lead to serious erosion. Use of appropriate agronomic practices especially mulching is necessary to protect soils from the effects of rain drops.

However, using a Mann-Whitney U test it was revealed that soil loss from the following intrcropping patterns were not significantly different (Table 5.7): (i) intercropped coffee and beans farm and intercropped maize and beans farms;

(ii) intercropped maize and beans and monocropped maize farms; (iii) intercropped coffee and beans and monocropped maize. This implied that there was no significant difference in the amount of soil loss between farms under differrent cropping practises. The reason for this finding was that none of the sample farmers practised simultaneously all the appropriate agronomic measures. Nearly all the farmers adopted one or a few of the appropriate measures but not all at once, thus, increasing the vulnerability of their farms to agents of soil erosion.

Table 5.7: Mann-Whitney results for soil loss in farms under different cropping patterns

cropping pattern	computed value	critical value
C&B AND M&B	70	17
M&B AND M	60	14
C&B AND M	42	8
LOW AND HIGH DENSITY	39	6
LOW AND MEDIUM ORGANIC CARBON	76	17

C= coffee; B=beans; M=maize

Source: Author

5.1.4 Crop Density and Soil Erosion

In the present study, plant densities varied from low (12,000 -25,000 plants per hectare) to medium (26,000 - 50,000 plants per hectare) therefore, none of the sample farms had high plant densities (Table 5.8). For instance, all the maize farms did not meet the recommended KARI maize density of 53,333 ha^{-1} which is obtained with a 75cm x 25 cm and 75cm x 50cm spacing if there are 1 or 2 plants per hole respectively. However, all intercropped maize and beans farms were assumed to have a medium crop density. This was because the beans were an additional crop besides the maize whose crop density was easy to establish. The beans density could not be calculated because all the beans were randomly planted.

Soil loss from the low crop density farms was 248.8 $t.ha^{-1}$ with an average yield of 18.1 $t.ha^{-1}$. On the other hand, a total of 54.2 $t.ha^{-1}$ and a mean of 19.1 $t.ha^{-1}$ of soil loss was obtained from the farms with medium crop density. Although soil loss from the farms with low density appeared quite high, on average it was not very different. This implied that some of the farms with medium densities yielded high amount of soil loss. Indeed, a Mann-whitney U test shows that soil

Table 5.8 Crop Density

Trap No.	Crops LR 1992	Maize Crop Spacing(cm)	Crop Density
ST1	C&B	-	-
ST2	C	-	-
ST3	M	50x80	25,000 (L)
ST3A	C&B	-	-
ST3B	C&B	-	-
ST4	C	-	-
ST5	M&B	90x90	12,222 (L)
ST5A	M&B	90x90	12,222 (L)
ST6	M&B	45x100	24,000 (L)
ST7	M&B	40x100	24,000 (L)
ST8	FALLOW	-	-
ST9	M	90x70	15,714 (L)
ST10	M&B	35x60	48,00 (MD)
ST11	C&B	90x90	12,222 (L)
ST12	M&B	90x90	12,222 (L)
ST16	M&B	50x70	28,571 (MD)
ST17	C&B	-	-
ST18	M&B	30x90	13,750 (L)
ST19	M&B	30x90	13,750 (L)
ST20	M	30x90	13,750 (L)
ST21	M&B	65x90	16,667 (L)
ST22	C&B	-	-
ST23	C&B	-	-
ST24	M	80x90	13,750 (L)
ST25	M&B	40x90	27,500 (MD)
ST26	C&B	-	-

L= Low density; MD= Medium density
M= Maize; C= Coffee; B= Beans; LR=Long Rain Season
Source: Author

loss from farms with medium and low density, which have previously been found significanly different (Gumbs, *et al*, 1985) were not (Table 5.7). This was because vegetation cover remained low in majority of the farms under study regardless of their crop density. It appeared that the established cover did not adequatetly protect soils from the impact of rain drops. The bare space between the crops was larger than what it would be in the case of high plant densities. Further, good agronomic practises lacked in nearly all the sample farms and as a result soils were generally of low fertility and hence, easily erodible.

Soil loss obtained from farms under different crop densities in the present study are much higher than those obtained in Zimbabwe. In Zimbabwe, soil loss amounting to 12.5 $t.ha^{-1}$ and 0.7 $t.ha^{-1}$ were obtained in farms with low plant density (25,000 plants per hectare) and medium plant density, (37,000 plants per hectare) respectively (Hudson, 1957b in Hudson, 1971). In Rhodesia, N = 20 kg /ha and P_2O_5 =50 kg/ ha and N =100 kg / ha and P_2O_5 =80 kg / ha were added in the farms with low and medium plant densities, respectively. In the latter, all the crop residues were ploughed in, thus increasing soil fertility and consequently crop yield through reduced soil loss. This, to some extent, concurs with the findings of Rogers and Schumn (1991) that vegetation cover below 15 % does not play a major role in reducing soil erosion. In their study, Rogers and Schumn show that on a 10 % slope, soil loss increases rapidly when vegetation cover decreases from 43 % to 15 %.

5.1.5 Soil fertility status in the study area

The results of soil fertility analysis given in Tables 5.9 and illustrated in Figures 5.1 to 5.6, indicate that the catchment has low to medium soil fertility. This is indicated by low quantities of available Phosphorous (P), exchangeable cations such as Calcium (Ca), Potassium (K) and Magnesium (Mg) and a low soil organic matter (C) since the nutrient levels in the soil are either at threshold or lower than those recommeded by NARL for crop production. For instance, of the three primary plant nutrients, phosphorous and nitrogen were the most deficient. At least about 65% and 79% of the sample farms, were defiecient in phosphorous and nitrogen, respectively (Table.5.9). These findings conform with Young's (1976) assertion that the two nutrients are the most frequently deficient and are largely the cause of low crop yields in the Tropics.

Table 5.9: Average soil nutrient levels in the sample farms

Type of Nutrient	Recommended level by (NARL)	Average Amount Present in the Sample Soils	% of farms with recommended levels	% of farms not meeting the recommended levels
Potassium (K) me%	0.2 - 1.5	0.55	84	16
Phosphorous (P) (ppm)%	20 - 80	15.5	35	65
Magnesium (Mg) m.e.%	1 - 3	1.58	80	20
Organic Carbon (C)%	2 - 4	1.19	16	84
Organic Matter (O)%	3.45 - 6.89	2.05	16	84
Calcium Ca me%	2 - 15	2.35	42	58
Nitrogen (N)%	not less than 0.2	0.15	21	79
p^H	not less than 5.5	5.15	28	72

Source: Author

The problem of inadequate supplies of nitrogen and phosphorous can be solved by maintaining high levels of soil organic matter. First, it provides a continuing source of nitrogen and phosphorous through mineralization; secondly, organic phosphates appear to be less readily fixed than inorganic forms; and thirdly, organic acids

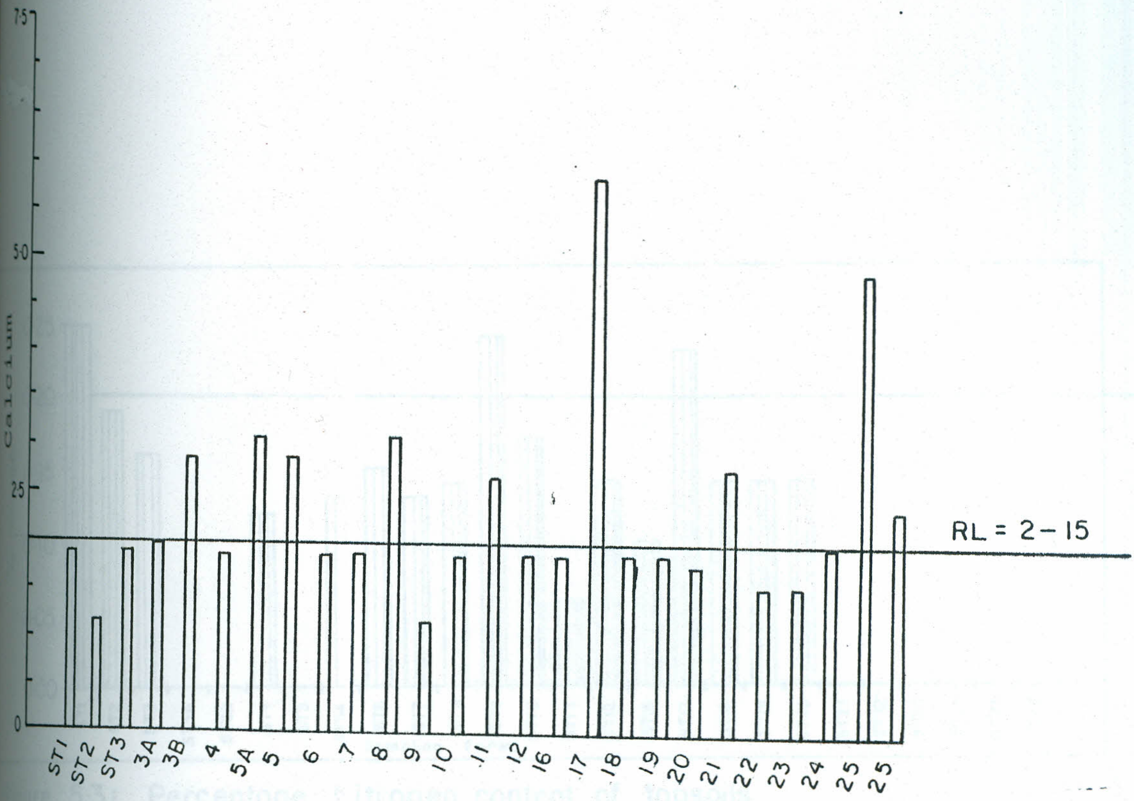


Figure 5·1: Calcium content of topsoils

RL = Recommended Level

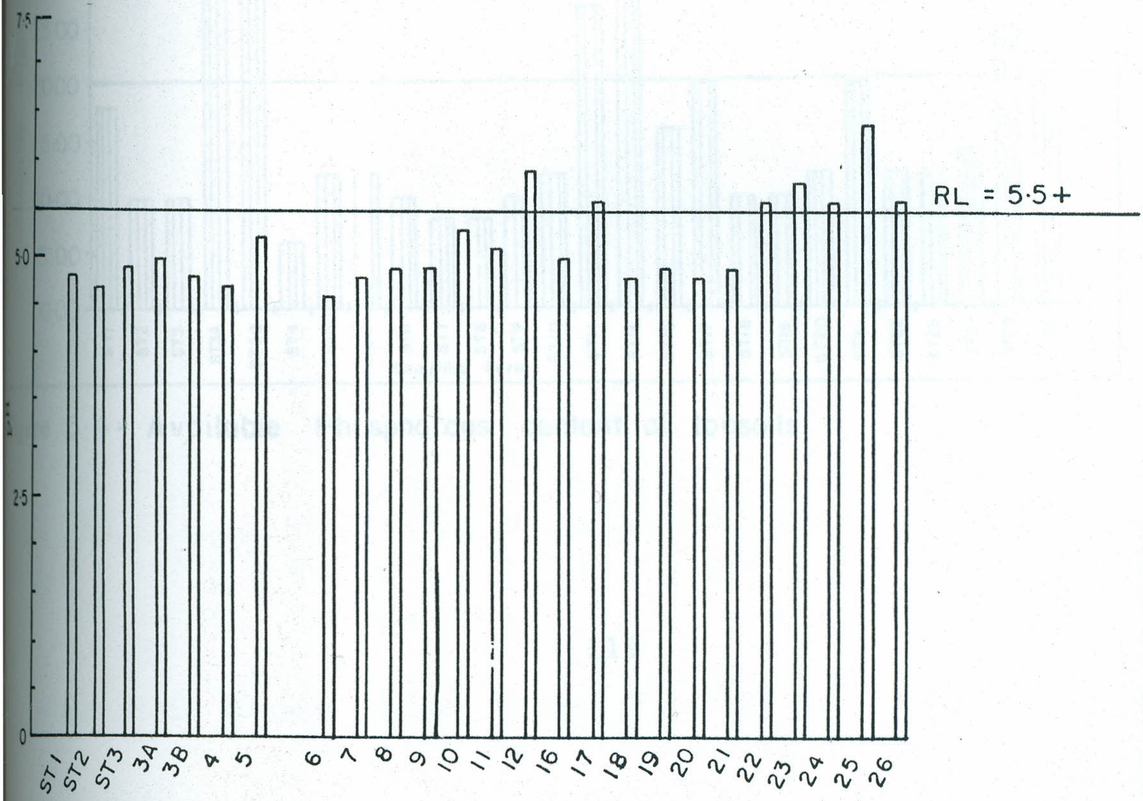


Figure 5·2: pH of topsoils

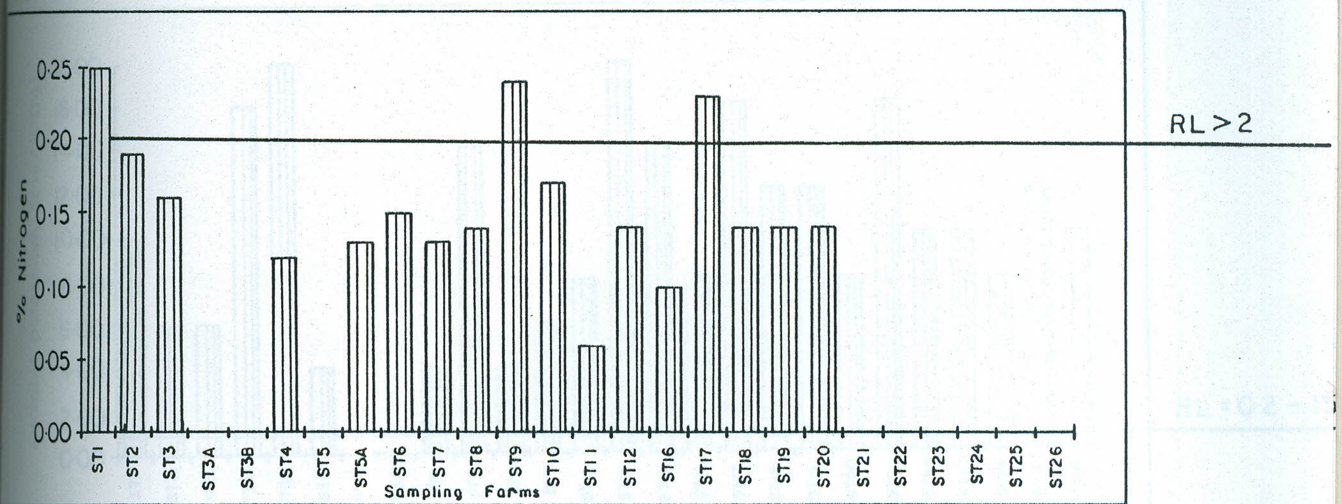
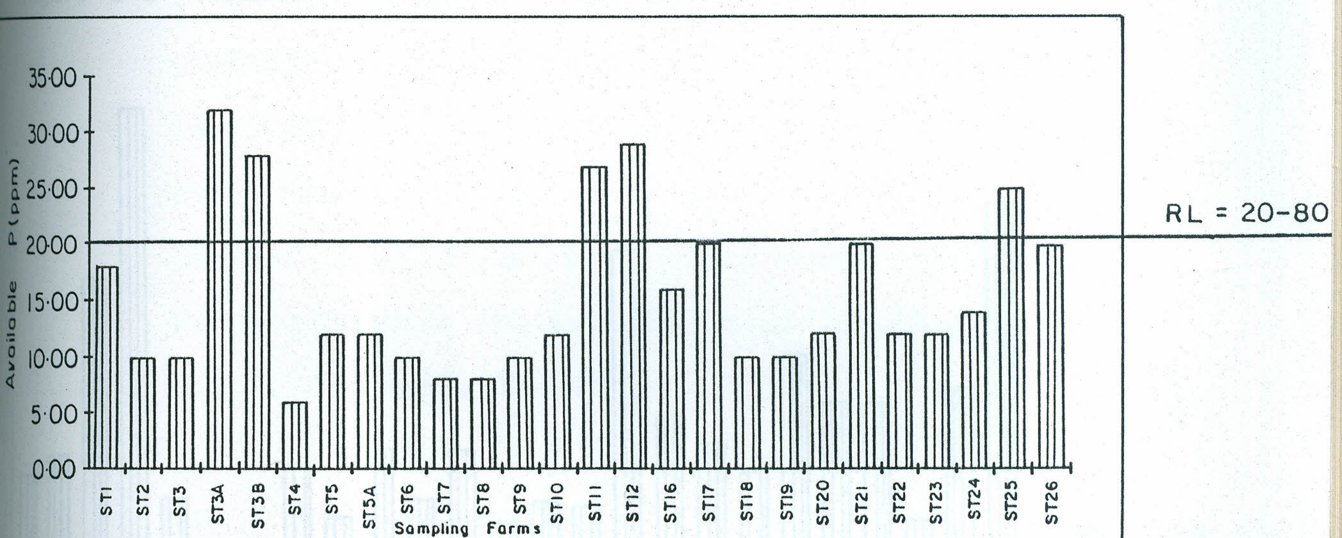


Figure 5·3: Percentage Nitrogen content of topsoils



igure 5·4: Available Phosphorous content of topsoils

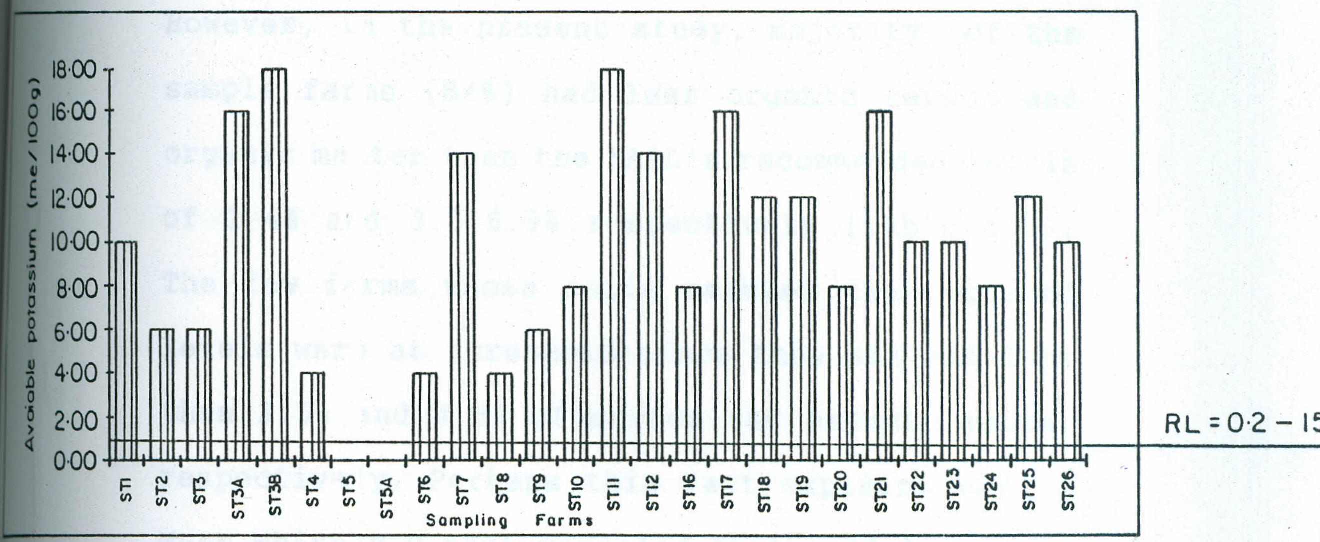


Figure 5·5: Available Potassium content of topsoils

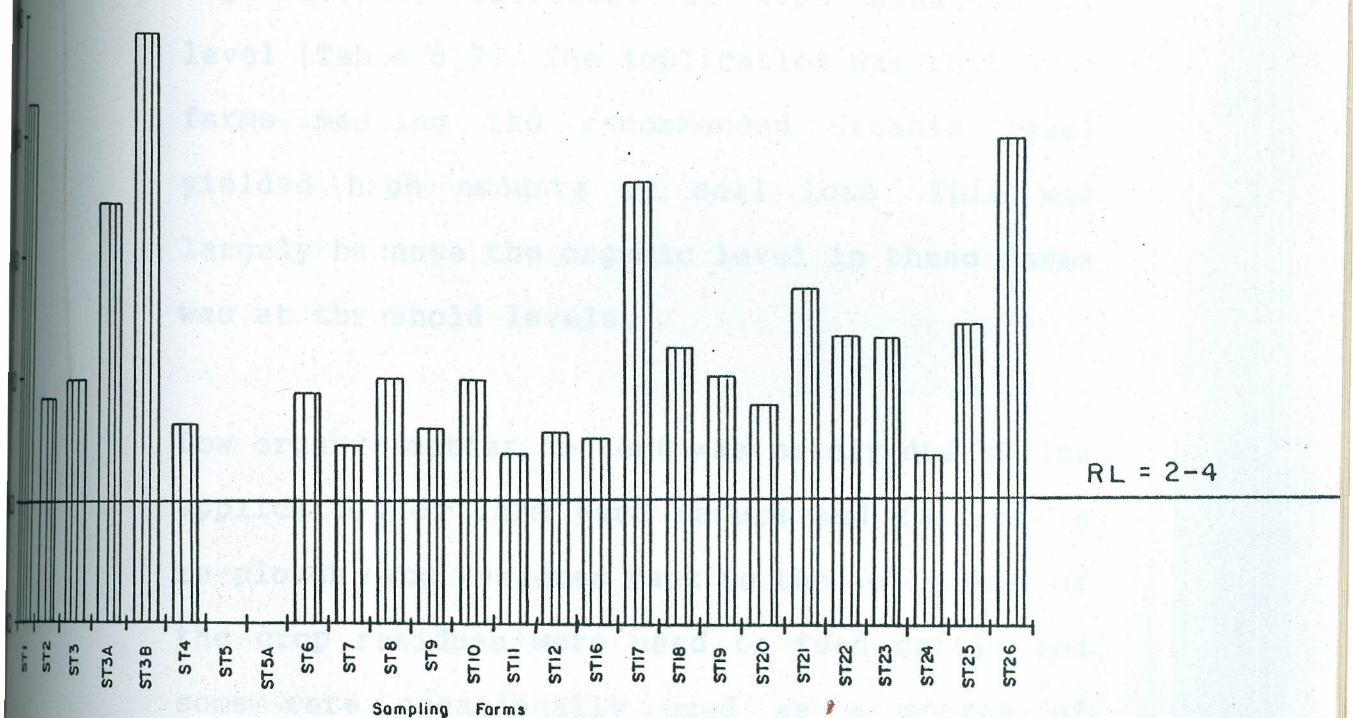


Figure 5·6: Organic carbon content of topsoil at trap sites dissolve some fixed phosphates thus rendering it available.

However, in the present study, majority of the sample farms (84%) had less organic carbon and organic matter than the NARL's recommended levels of 2-4% and 3.5-6.9% respectively (Table 5.9). The few farms whose soils reached the required levels were at threshold since they all had less than 2.5% and 4.3% of carbon and organic matter respectively. Perhaps this fact explains why a Mann Whitney U test revealed that soil loss from farms with high and low organic carbon was not significantly different at 0.05 significance level (Table 5.7). The implication was that some farms meeting the recommended organic level yielded high amounts of soil loss. This was largely because the organic level in these farms was at threshold levels.

Low organic matter content was mainly due to low application of farm yard manure and failure to re-plough crop residues back to the soil. Most of the crop residues were used to feed cattle and some were occasionally used as a source of domestic energy. The effect of low organic matter is a poor soil structure which in turn leads to reduced root penetration, soil moisture retention and increased vulnerability to soil erosion. Further, the cation exchange capacity (CEC) and the nutrient levels especially those of nitrogen and phosphorous are reduced. Only about 16 % of the sample farms had organic carbon and organic matter levels exceeding 2 % and 3.5% respectively (Table 5.9). All these farms were under coffee (Fig. 5.3, 5.4 and 5.6). This, to an extent, proves that famers in the catchment use a bigger share of their farm inputs on the coffee farms usually at the expense of the food crop farms. It also explains why soil loss from mature coffee farms with intercropped beans was low (Table.5.5).

Most of the soils in the study area have a low pH. That is about 72% of the sample farms had a pH less than 5.5 meaning that they are acidic. According to Young (1976), all primary and most other nutrients have their maximum availability in the p^H range of 6.0 to 7.5. Low pH levels particularly those below 5.5 make primary and secondary nutrients less available for crop growth. Also, soils with a low p^H and consequently low nutrients are characterised by low moisture retention, low crop yields, slow plant root development and high erodibility. However, although lime could be added in such acidic soils the financial costs involved is high. Young (1976) and Yost (1985) caution that it is not necessary to use lime on tropical soils because their pH is often below 6.0 at which high amounts of Phosphate are precipitated out.

Use of manure and fertilizer improves the soil fertility status, however, it must be realised that the use of fertilizer implies a high cost outlay. Also, the effectiveness of the fertilizer application is reduced by the high leaching rates of the tropical soils. Further, mineral fertilizers on their own do not have long term effect on the state of humus in the soil as organic support is required to improve the soil structure. Morgan (1986) states that too much use of fertilizer may lead to structural deterioration of the soil and increased erodibility.

On the other hand, farm yard manure increases organic matter content of the soil, improves the soil structure and reduces soil erosion. This aspect is confirmed by Young, (1976; 1989) who explain that a fall in soil organic matter alone causes a rise in the erodibility of the affected soil by about 0.04 units. According to Evans (1980), soils with less than 2 % of Organic

Carbon (equivalent to 3.5 % of organic matter content) can be considered highly erodible.

5.1.6 Land Qualitities (LQs) for rating soil loss

In order to integrate the effects of different agronomic factors on soil loss, land evaluation system (FAO, 1984) was followed whereby three land qualities namely (i) susceptibility to soil erosion (or hazard); (ii) soil resistance to water erosion and (iii) vegetation regeneration possibilities were used in the assessment of the extent of soil erosion in the cultivated land in the Kaihungu Sub-catchment. Appendix A-4 shows how these were derived.

The susceptibility of soil to water erosion was rated using the slope factors (angle and length), percent vegetation cover and agroclimatic zones Table 5.10A; Wamicha *et al*, 1993). Both the vegetation cover (measured directly in the field) and agroclimatic zones (as defined by Sombroek, *et al*, 1982) were taken to reflect the amount of run-off that can be generated in a given area; while the slope factor was asssumed to indicate the speed of the run-off.

The results indicated that nearly all the sample farms (92%) had a high soil erosion hazard. This implied that they depicted a high susceptibility to water erosion. They had a rating of "4" and "5" and yielded high amounts of soil loss (Table 5.10A). Only one farm had a medium susceptibility and it yielded a relatively low amount of soil loss.

Table: 5.10A Soil erosion hazard assessment

farm	r1	r2	r3	r1+r2+r3	rating	soil loss ($t.ha^{-1}$
1	5	4	3	12	5	24.5
2	5	2	3	10	4	7.6
3	7	7	3	17	5	30.1
4	7	7	3	17	5	22.8
5	5	4	3	12	5	26.7
6	3	4	2	10	4	9.4
7	5	2	2	9	4	18.1
8	5	4	2	11	4	19.4
9	5	4	2	11	4	2.9
10	5	4	2	11	4	12.6
11	5	4	2	11	4	45.0
12	3	2	2	7	3	6.0

r1=slope factor; r2=vegetation cover;

r3=agroclimatic zone

Final rating: r1+r2+r3	<5	5-7	7-9	9-11	>11
	1	2	3	4	5

———→ erosion hazard increases with the rating

Source: Author

Soil resistance to water erosion was rated using two parameters namely, percentage organic carbon and silt to clay ratio. The underlying assumption here was that soils rich in organic carbon and having a high silt to clay ratio are more resistant to soil erosion. The results revealed that soils in 67% of the sample farms had a low resistance to water erosion (Table 5.10B) as their final rating was as low as 2.

Table: 5.10B Soil resistance to water erosion asssessment.

farm	r1	r2	r1+r2	rating	soil loss (ton.ha^{-1}
1	2	2	4	2	24.5
2	2	2	4	2	7.6
3	3	1	4	2	30.1
4	3	2	5	3	22.8
5	3	1	4	2	26.7
6	3	2	5	3	9.4
7	3	1	4	2	18.1
8	2	1	3	2	19.4
9	3	2	5	3	2.9
10	2	2	4	2	12.6
11	3	2	5	3	45.0
12	2	2	4	2	6.

r1=%c; r2= silt to clay ratio

Final rating r1+r2:	<2	3-4	4-6	>7
	1	2	3	4

⟶ soil resistance decreases with the rating

Source: Author

Vegetation regeneration possibilities was rated using pH, percent organic carbon, agroclimatic zones and available nutrients (Potassium, Calcium, Magnesium, and Phosphorous). The pH value was included because it influences the availability of plant nutrients and hence quick vegetation growth. Nutrient availability is usually highest in the soils whose pH ranges between 6.0 and 7.5 and is reduced at both high and low values (Young, 1976; and FAO, 1984). The available nutrients were assumed to indicate the rate of plant growth while agroclimatic zones were taken to imply the amount of moisture availability for vegetation regeneration (plant growth). Majority of the farms (83%) had a final rating value of 4 which implied that vegetation regeneration possibility was generally low (Table 5.10C).

Table 5.10D represents the average amount of soil loss occurring in farms with varying levels of soil erosion hazard, resistance to erosion and vegetation regeneration possibilities. These results indicate that soil loss was highest in farms with the:

(i) highest erosion hazard. For instance, farms with the erosion hazard rating of 3 and 4 yielded 6 $t.ha^{-1}$ and 16.4 $t.ha^{-1}$, respectively;

(ii) lowest vegetation regeneration possibilities as is the case in farms with a rating of 3 and 4 which

Table: 5.10C Vegetation regeneration possibilities

farm	r1	r2	r3	r4	r5	r6	r7	total	rating	soil loss (tons/ha
1	2	2	3	3	3	3	3	19	4	24.5
2	2	2	3	2	3	3	3	18	4	7.6
3	2	3	3	3	3	3	3	20	4	30.1
4	2	3	3	3	3	3	3	20	4	22.8
5	2	3	3	3	3	3	3	20	4	26.7
6	2	3	3	2	3	3	3	19	4	9.4
7	2	3	2	3	3	3	3	19	4	18.1
8	2	2	2	3	3	3	3	18	4	19.4
9	2	3	2	3	3	3	3	19	4	2.9
10	1	2	2	3	3	3	3	17	3	12.6
11	1	3	2	3	3	3	3	18	4	45.0
12	1	2	2	2	3	3	3	16	3	6.0

r1=pH; r2=%C; r3=ACZ; r4=Pppm; r5=Ca; r6=Mg; r7=K

Final rating: <7 7-12 12-17 >17
1 2 3 4

——→ vegetation regeneration possibilities decreases with the rating

Source: Author

yielded on average 9.3 $t.ha^{-1}$ and 20.7 $t.ha^{-1}$, respectively;

(iii) lowest resistance examplified by farms with a rating of 2 and 3 which yielded a mean total of 18.1 $t.ha^{-1}$ and 20.1 $t.ha^{-1}$, respectively;

According to these results, it is concluded that the soils of Kaihungu Sub- catchment have a high erosion hazard and a low resistance to water erosion, which are further aggravated by the low vegetation regeneration possibilities. The poor status of the soils in this sub-catchment was attributed to the dominance of poor agronomic practices. These land quality rating results further emphasise the high soil losses, poor soil fertility (available nutrients), low organic matter and inadequate agronomic practices.

Table: 10D Ratings and Mean soil loss ($t.ha^{-1}$)

rating	erosion hazard	soil resistance	vegetation regeneration
1	-	-	-
2	-	18.1	-
3	6.0	20.0	9.3
4	16.4	-	20.7
5	26.0	-	-

Source: Author

5.2 Conclusion

Soil erosion is a serious land management problem in the study area. According to the results of the data presented and analysed in the foregoing sections of this chapter, it is evident that during the Long Rain Season 1992, high amount of soil loss 457.1 $t.ha^{-1}$ occured in the arable land in the Kaihungu Sub-catchment. Similarly high amount of soil loss, 356 $t.ha^{-1}$ were obtained in Muranga district in the Long Rain Season, 1982 (Lewis, 1982). These levels of soil loss obtained in two different periods but in a similar area are much higher than the acceptable level which is given as 12.5 $t.ha^{-1}\ yr^{-1}$ (Hudson, 1971). The latter is the acceptable or tolerable level of soil loss in Central Africa and in other areas characterised by deep loamy soils derived from volcanic rocks. High amount of soil loss in arable land is associated with land degradation which is ultimately results in low farm yields.

Further, soil loss did not appear significantly different in farms:
(i) under different crops and cropping patterns;
(ii) with low and medium plant densities ;
(iii) with low and medium soil fertility.
In all the above three cases, using a U-Mann Whitney test, the computed values were higher than the critical values. Therefore, the general null hypothesis (Ho^1) stating that "there is no significant difference in the amount of soil loss in farms under different agronomic practises" was accepted. These results indicate that nearly all sampled farms share a similar problem despite the type of crop and cropping pattern adopted, level

of plant density and amount of vegetation cover available in the farms. The farmers lack integrated agronomic practices and good farm management. They all practised one or more of the important agronomic measures such as use of fertilizer and manure, reploughing crop residues, leaving part of the agricultural land on fallow, crop rotation, practising high crop density and the maintenance of soil conservation measures; but not all of them simultaneously. This resulted in poor soil fertility and consequently low vegetation cover in almost all the sampled farms.

It is, therefore, imperative for the farmers to practise appropriate agronomic measures during all cropping seasons. The use of these measures will result in reduced soil erosion, increased soil fertility and finally to higher farm productivity.

Failure to use one or more of the appropriate agronomic practices may lead to serious land management problems. In support of the practice of good agronomic measures, Hudson (1971) argues that monocropped maize which is normally associated with high soil loss could lead to less erosion and increased soil fertility if good crop and farm management are practised.

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Lastly, these results portray a real on-farm situation and go along way to justify the problems of conducting applied research. As Stocking (1988) argues "it is one matter to demonstrate that a cropping or management system is technically viable on a research station, it is quite another different matter to do this under the real management constraints of a small farm".

CHAPTER SIX

RESULTS AND DISCUSSIONS OF SOCIO-ECONOMIC FACTORS INFLUENCING SOIL EROSION IN THE STUDY AREA

6.0 Introduction

In this chapter, simple descriptive statistics and the Chi-square results based on farmers socio-economic characteristics are presented and discussed. The simple descriptive statistics enabled a comparison of the study area on the following aspects: farmers characteristics, extent of soil erosion and soil conservation.

On the other hand, the Chi-square results were used to test for the differences in the farmers socio-economic factors between farms suffering or not suffering severe soil erosion in the study area. The null hypothesis "there is not a significant difference in socio-economic characteristics between farmers whose farms are experiencing less severe and severe soil erosion in the Masinga dam catchment" was tested. The socio-economic variables included in this Chi-square analysis were; gender, family size, age of the head of the household, education level, employment, level of income, and extension education. Each one of these variables was tested against the "presence of less severe or severe soil erosion". In each case, the null hypothesis was rejected when the computed chi square value was greater than the critical value at the 0.01 significance level (The critical values are shown in Appendix, A-2).

6.1. Characteristics of the farmers

Majority of the farmers (67.7%) in the study area were female especially in the young households. This female population in the farming enterprises was distributed as follows: 71%, 66%, and 66% in the humid zone, the sub- humid zone and the semi-arid zone, respectively. This contrasts with only 29%, 34%, and 34% of the farmers in the humid, sub-humid and semi-arid zones, respectively who were male. This was explained by the fact that men usually migrate from rural areas to urban areas in search of better paid off-farm employment to supplement the on-farm income. The largest recipient of these men is the city of Nairobi while others move to Mombasa, Thika, Machakos and Murang'a towns. They return home on weekly, or monthly, or yearly basis depending on their financial capability. Women, who are left to run the homes, then become the heads of the families and make important, day to day, farm decisions like planting, weeding and employing casual farm labourers among others.

The incidence of "joint decision making" was also noted in the cases where women have to wait for their husbands to come home to make decisions involving major farm investments such as the marketing of livestock, employment of permanent labourers, and other major on-farm investment projects. This is similar to the findings of Dolger (1990), that more than 50% of the respondents in Murang'a District were women who performed the duties of the head of the household.

More than half of the farmers (59%) can be described as middle aged, lying in the age group 31-50 years. About 65%, 54%, and 59.3% of the interviewed farmers belong to this age group in the humid, sub-humid and the semi-arid zone, respectively. The mean age of the farmers was 45.2 years. This does not reflect Kenya's demographic structure in which about 50% of the population is under 15 years (Kenya, 1993). The reason is because only the age of the head of the households was considered during the time of this study.

About 76%, 64% and 62% of the households in the humid, sub-humid and semi-arid zone had 6-10 members, respectively (Table 6.1). Large families consisting of more than 10 members were few in the study area. This was indicated by 3% of the households in the humid zone, 8% in the sub-humid zone and 3% in the semi-arid zone with more than 11 members. In the entire catchment, only 1% of the families had more than 16 members.

Table 6.1: Family size distribution in the different agro-ecological zones

Family size	Humid zone	Sub-humid zone	Semi-arid zone	Study area
1 - 5	21 %	28 %	25 %	24.7 %
6 - 10	76 %	64 %	62 %	67.3 %
11 - 15	3 %	8 %	10 %	7 %
16 +	-	-	3 %	1 %

Source: Author

The mean family size was 7.3 members in the study area which was not very significantly different from the mean family size of 6.3 obtained during the Murang'a farm survey conducted by Dolger (1990). Family members included all unmarried daughters and sons (and their children if any), relatives and labourers living together with the head of the household, sharing the same compound and cooking pot.

Farmers who had attained secondary and post-secondary education were generally few with an exception of the humid zone where a relatively higher number of farmers, 44% and 9% had gone upto secondary and / or post-secondary levels respectively. Only 21% and 11%; and 19% and 12% of the farmers in the sub-humid and semi-arid zones had attained secondary or post secondary education, respectively (Table 6.2). This was explained by the fact that farmers in this part of the catchment earned more income from coffee than those in the sub-humid zone (Atkins, 1984) and were thus, able to to meet the cost of educating their children better than their counterparts in other parts of the catchment.

Table 6.2: Farmers education levels

Education level	Humid zone	Sub-humid zone	Semi-arid zone	Study area
Primary level	47 %	68 %	69 %	61.3 %
Secondary level	44 %	21 %	19 %	28 %
Post secondary level	9 %	11 %	12 %	10.7 %

Source: Author

Majority of the farmers, (61.3%) in the entire study area had achieved primary level education. Regionally, 47%, 68% and 69% in the humid, sub-humid and semi-arid zones, respectively (Table 6.2) had attained only primary school education or had not attended school at all. To a large extent, this pointed to the financial constraints facing most of the farmers. It is almost impossible for most of the farmers to afford secondary school education.

Majority of the farmers, 64%, 75% and 65% in the humid, sub-humid and semi-arid zones, respectively are self employed in their small farms (Table 6.3) which formed the major source of food and income. It was informally learnt that a large number of the farmers spend most of their time upto 8 hours per day, in the farm, ploughing, planting, weeding, and harvesting. About 60% of some of the farmers informally interviewed said that farm work begins at approximately 8 a.m ending at around 5 p.m. with or without a brief lunch break. According to the farmers, soil conservation was not awarded an important proportion of their time as the farmers were busy with other urgent farm work. Their busiest time is during the rainy season.

Table 6.3: Farmers types of employment

Place of employment	Humid zone	Sub-humid zone	Semi-arid zone	Study area
on farm	64 %	75 %	65 %	68 %
both on-farm and off-farm	36 %	25 %	35 %	32 %

Source: Author

It had been expected that a high number of the heads of the sampled households would receive income from off-farm activities. However, only 34%, 25% and 35% of the farmers in the humid, sub-humid and semi-arid zones, respectively (Table 6.3), relied on both on-farm and off-farm employment. This, to an extent, is a result of the low education levels among the farmers which disqualified them from competing effectively for higher paid off-farm employment.

Most of the farmers throughout the catchment had low incomes. About 66%, 69%, and 70% of the farmers in the humid, sub-humid and semi-arid zones respectively earned less than Kshs 600 (£6) per month (Table 6.4). Indeed only 16 %, 5 % and 10.7 % of the farmers in the humid, sub-humid and semi-arid zones, respectively, said that they earned more than Kshs 5,000 (£50) per month. This

Table 6.4: Farmers levels of farm incomes

Level of income (Kshs)	Humid zone	Sub-humid zone	Semi-arid zone	Study area
¾ 600	66 %	69 %	70.4 %	69 %
601 - 1,800	5 %	13 %	7.7 %	10 %
1,801 - 5,000	13 %	16 %	9.3 %	12 %
= 5,000	16 %	5 %	10.7%	9 %

Source: Author

was as a result of low farm productivity hardly leaving any surplus for marketing. Further, high salaried off-farm employment is usually beyong the reach of the low educated rural population. Farmers in the Kaihungu Sub-catchment attributed the prevailing low farm incomes to the current low world and local market coffee prices. Also, the problem of low farm incomes was compounded by the failure of about 86% of the farmers to take credit from their cooperative societies, banks or any other credit institutions. These farmers gave the following reasons to explain why they never considered taking a loan to solve their financial problem: (i) lack of any substantial items of fixed capital or undisputable title to land which could serve as colateral and (ii) fear of losing their property in case they were unable to pay for the loan. What this meant was that the relatively low level of incomes restricted the operations of the family to small enterprises forcing them to remain poverty stricken producers and further reducing their credit worthiness. Evidence of low incomes in the study area include; poor housing structures, inadequate food, poor clothing and over-used farm tools among others.

6.2 Farm characteristics

6.2.1 Land tenure

About 89%, 81% and 14% of the farmers in the humid, sub-humid and semi-arid zones possessed less than 3 acres of land, respectively. On the other hand, only 3%, 11% and 50% of the farmers in the humid, sub-humid and semi-arid zones owned more than 5.1 acres, respectively. These results clearly showed that majority of the farmers in the Kaihungu Sub-catchment had relatively smaller farms than those of the farmers in the Mathauta Sub-catchment. The main explanation was that the former area, Kaihungu Sub-catchment, has favourable ecological conditions and has thus, been settled over a long time (since the 18th Century). The area has attracted a high population because of the associated high carrying capacity. Therefore, land subdivision, mainly through inheritance among family members and sale, has been going on over a long period culminating into small farm plots. This leads one to the conclusion that the predominance of small farms is due to high population densities and the existing land tenure system which allows every male member of a family the right to inherit part of the family land.

One indicator of the land shortage problem in the Kaihungu Sub-catchment was use of marginal land including roadsides, river channels, and steep slopes. About 53% and 71% of the farmers in the humid and sub-humid areas, respectively practised agricultural activities on some of these fragile areas, exposing them to the agents of soil erosion. Cases of maize crop grown on steep road embankments without any conservation measures and cattle grazing along roadsides and river sides were apparent in the Kaihungu Sub-catchment. Use of marginal land especially roadside agriculture due to the shortage of arable land in other parts of Central Province, Kenya is well documented in the work of Mbwesa (1989).

On the other hand, the lower Masinga Dam Catchment has only been settled since the 1920's and due to the low land productivity associated with the semi-arid areas, the area has remained sparsely populated, thus allowing farmers to own large tracts of land. Further, since the 1980s the Government has been allocating 10 acre pieces of land to families migrating from densely populated areas into this area. This was reflected in the difference in the farm sizes in the two different areas.

The dominant type of land acquisition in the study area was through inheritance. About 61% of the farmers in the study area said that they had inherited land from their parents. However, this type of land acquisition was more dominant in the Kaihungu Sub-catchment as was indicated by 78% and 81% of the farmers who had acquired land through inheritance in the humid and sub-humid areas respectively. Only 25% of the farmers in the Mathauta Sub-catchment have acquired land that way. In the latter, two unique types of land acquisition were recognised. These included; one, clearing of formerly unsettled land by about 35% of the farmers who migrated from other population pressure stricken areas particularly Machakos district, Kenya. According to informal interviews, these immigrants started moving into this area in the early 1920s. This is a common practice in Machakos district where farmers migrate from over-crowded hilly areas such as Mbooni, Mbitini, and Kangundo to the lowlands in search of unsettled land for agricultural purposes (Owako, 1971). Two, farmers allocated land by the Government; these constituted about 12% of the respondents.

6.2.2. Major crops produced in the study area

The farms are mainly under agricultural use. The subsistence crops grown include; maize, beans, pigeon peas, sorghum, cow peas and potatoes, among others. Maize and beans formed the most important food crops, grown virtually by all the farmers in the catchment because they provide the basic food requirements. Coffee was the main cash crop grown in the Kaihungu Sub-catchment. Following is a brief description of crops grown in the Kaihungu and Mathauta Sub-catchments.

(a) Coffee (*Coffea arabica*): Coffee is a major cash crop and about 90% of the farmers grew it. When it was introduced on small farms in Kenya (in the mid 1940s), the colonial government insisted on the use of soil conservation measures particularly terracing in all cash crop farms (Thomas, 1988). Hence, it was observed that cash crop sections of the farms were better conserved than those occupied by the food crops.

In most cases different types of grass were planted on the terrace banks to stabilize them. These included grasses such as *Brachiavia decumbens* or *Panicum trichocladum*. Certain grasses such as *Bana* grass and *Guatamala* grass were less popular among the farmers as they compete with the crops grown in the field (Thomas, 1988). However, there were a few isolated cases of unterraced coffee farms. These farms were severely eroded as was evidenced by the presence of numerous rills, gullies and exposed plant roots.

Previously, the farmers in this part of the catchment like their counterparts in other cash crop growing areas, devoted large proportions of their small farms and inputs to coffee farming. Coffee was thus being grown almost to the exclusion of food crops. This trend has attracted the Kenya's Government attention as far as food security was concerned since it was evident that the trend was likely to cause food deficit (Kenya, 1986). However, following the fall in coffee prices in the world market during the 1980s, farmers attention has, to a large extent, crop sections of the farms were better conserved than those occupied by the food crops.

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It was observed that a good canopy was establishsed in farms where coffee was well managed and the ground was well protected against erosion. However, use of mulch was not common due to lack of suitable mulching material as is reported in the works of Thomas, (1988) and Ngugi and Kabutha (1989). Most of the crop residues were used as fodder instead of being used as mulch.

(b) Maize (*Zea mays*) was grown in both sub-catchments during the two cropping seasons mainly for subsistence purposes . Surplus in maize production was rare as the yields were generally low about 675 kg.ha^{-1}. The low yield was attributed to inadequate use of manure and fertilizers, late planting and other poor agronomic practices.

Land preparation was usually done using mainly the hoe and the ox-drawn plough in Kaihungu and Mathauta Sub-catchments, respectively. Tractors were occasionally used in the Mathauta Sub-catchment.

Soil conservation was less practiced in the maize farms and in other farms where annual crops are grown. The few terraces in the annual crop sections of the farms were widely spaced and rarely stabilized with grasses. This was due to the fact that soil erosion was less conspicuous in the latter farms because the rills were regularly removed through cultivation. It was, therefore, very common to find monocropped maize on the steep, unconserved slopes particularly in Kaihungu Sub-catchment.

Farmers depending entirely on farm-incomes sold their maize produce immediately after harvesting. This was said to have had serious repercussions on food availability and security at the household level particularly when the following season's crop failed.

(c) Beans (*Phaseolus vulgaris*): This is an important food and cash crop grown nearly by all the farmers. Very often, beans were intercropped with maize. The farmers stated that bean harvests are generally low which they attributed to the inadequate use of chemical fertilizers.

(d) Potatoes (*Solanum tuberosum*): These are mainly grown in Kaihungu Sub-catchment and are a major source of food and income to a lesser extent. At least 56% of the farmers grew potatoes in this sub-catchment. They, however, complained that the crop suffers from a disease commonly known as potatoe blight which reduces the yields. According to Ackland (1971) the reasons for the spread of this disease are the absence of either winter or a prolonged drought to check the disease. Further, the ecological conditions necessasry for fungus to thrive and the crop are conducive in East African Highlands.

Potatoe farms were all mulched and where manure was used vegetation cover was quickly established (plate A-1). Nearly all the farmers (95%) said that they always planted the potatoes before the rains.

(e) Bananas (*Musa spp*): These were an important food, fruit and cash crop grown by majority of the farmers in the Kaihungu Sub-catchment. They were grown in close association with coffee and fruit trees which together provided a good canopy cover and minimal risk of soil erosion. In other cases, they were grown on terraces for soil conservation purposes.

Plate A-1: A well established potato cover

(f) Pigeon pea (*Cajanus cajan*): The local pigeon pea was widely grown and was considered an important food and cash crop mainly in the Mathauta Sub-catchment. It was usually intercropped with maize and was sown in the Short rains (November - December) taking upto 10 months to mature. Pigeon pea is a deep rooted drought resistant crop well suited to areas of low and uncertain rainfall.

(g) Sorghum (*Sorghum vulgare*): It is a more drought resistant crop than maize so together with pigeon peas it was grown mainly in the Mathauta Sub-catcment. Field survey revealed that only a small number of farmers grew it because of:- labour shortage associated with bird scaring; poor marketing avenues and change of eating habits.

(h) Cow peas (*Vigna unguiculata*): This is a dual leguminous crop grown for its leaves and its seed. It is a drought resistant crop likely to reach higher yields than beans. However, farmers asserted that cow peas yields were normally low due frequent attacks from diseases such as *Zonate* leaf spots and Pseudo rust, and pests such as pod borers.

Other minor crops included french beans, sweet potatoes, arrow roots and vegetables which were produced primarily for home consumpiton.

The primary objective for engaging in agriculture was to produce food to feed the family and hence majority of the respondents are small scale subsistence farmers. This was confirmed by the fact that about 76% and 82%; 78% and 81%; and 46% and 65% of the respondents in the humid, sub-humid and semi-arid zones said that they do not market any of their maize and beans produce, respectively (Table 6.5). This is similar to the findings of Dolger (1990) in which about 70% of the farmers gave "food security" as the most important reason for engaging in crop production in Murang'a district. A higher number of farmers in the semi-arid zone (54% and 35%) market their maize and beans, respectively unlike in the Kaihungu Sub-catchment where only 24% and 22% ; and 18% and 19% market their maize and bean crop in the humid and sub-humid area, respectively (Table 6.5). The reason why more farmers sold their crop harvest in the Mathauta than Kaihungu Sub-catchment was that the food crops formed a major source of income. This can be contrasted with the Kaihungu Sub-catchment where coffee supplemented on-farm incomes.

A large number of the farmers 86%, 86% and 82% in the humid, sub-humid, and semi-arid zones, respectively observed that crop yields had been declining over the last ten years (Table 6.6). Only a few farmers (9.3% and 6%) reported that yields were either increasing or fluctuating in response to the varying amount of farm inputs used and rainfall received per season.

Table 6.5: Disposal of major food crops

	Humid zone (%)		Sub-humid zone (%)		Semi-arid zone (%)	
CROPS	NONE	SOME	NONE	SOME	NONE	SOME
MAIZE	76	24	78	22	46	54
BEANS	82	18	81	19	65	35
PIGEON PEAS	100	0	98	2	62	38
POTATOES	90	10	92	8	99	1
COW PEAS	100	0	100	0	88	12

None= all the food is for subsistence
Some= food is for subsistence & marketing purposes

Source: Author

Table 6.6: Status of crop yields

Farm yields	Humid zone	Sub-humid zone	Semi-arid zone	Study area
Declining	86%	86%	82%	84.6%
Increasing	9%	7%	12%	9.3%
Fluctuating	5%	7%	6%	6%

Source: Author

Farmers who said that farm yields were declining over time attributed this to soil erosion, over cultivation, unaffordable farm inputs, climate and diseases (Table 6.7). This table shows that about 64%, 61% and 51% of the farmers in the humid, sub-humid and semi-arid zones, respectively, observed that overcultivation was an important factor leading to low soil and crop yields in the study area. They clarified that over cultivation was a result of continous cultivation of one piece of land for a long of period of time without the use of adequate farm inputs.

Another 42% of the farmers in the humid zone, 42% in the sub-humid zone and 38% in the semi-arid zone argued that soil erosion was responsible for the low soil and crop productivity (Table 6.7). It was claimed that soil erosion was due to lack of approriate soil conservation structures, heavy rainfall storms, steep slopes and inadequate ground cover.

Only 9.3 % of the farmers reported increasing yields in their farms which they attributed to soil conservation and constant use of farm inputs. These were the well-to-do farmers with surplus capital and relatively larger farms.

Another proportion of the farmers, 6%, stated that yields fluctuated with weather.

Table 6.7 Reasons for declining crop yields

Reasons	Humid zone	Sub-humid zone	Semi-arid zone	Study area
soil erosion	42%	42%	38%	41%
over cultivation	64%	61%	51%	66%
climate	24%	24%	56%	35%
diseases	14%	14%	21%	16%

Source: Author

Multiple cropping system was the most preferred and widely practised pattern compared to monocropping. About 73%, 76%, and 73% of the farmers practised multiple cropping in the humid, sub-humid and semi-arid zones, respectively. These observation was associated with: low coffee prices, food security, better use of farm inputs, land shortage and provision of good crop cover (Table 6.8). Similar observations have been reported from other parts of the tropics (Sanchez, 1976; Richards, 1985 and Francis, 1990).

Low coffee prices was also given as an excuse for intercropping coffee with other crops in the

Table 6.8: Farmers' reasons for choice of cropping patterns

Reasons	Humid zone	Sub-humid zone	Semi-arid zone	Study area
MONOCROPPING				
high yields	11%	12%	21%	14.7%
easy to weed	7%	6%	7%	6.7%
MULTIPLE CROPPING				
low coffee prices	36%	32%	-	22.7%
crop security	67%	71%	73%	70.3%
better use of farm inputs	12%	6%	13%	10.3%
small farm sizes	75%	87%	75%	79%
ground cover	5%	1%	2%	0.3%

Source: Author

Kaihungu Sub-catchment. About 36% and 32% of the farmers in the humid and sub-humid zone, respectively (Table 6.8) explained that the current low coffee prices had significantly reduced their of on-farm income, thus making it uneconomical to invest heavily on the crop. Thus, coffee farms were perceived as an additional area where such food crops as beans and potatoes could be grown. This, to an extent, was important to the farmers who had planted coffee to the exclusion of food crops. Such farmers could not use low income from their coffee to purchase food for their families.

About 67%, 71% and 73% of the farmers in the humid, sub-humid and semi-arid areas, respectively said that crop security was the main reason for multiple cropping (Table 6.8). According to these farmers, it was possible to obtain higher yields by growing a mixture of crops than from pure stands. They, further, reported that multiple cropping assured them of some harvest in case of the failure of one crop due to unfavourable weather conditions and /or incidence of disease and pest attacks. Thus, the near universality of multiple cropping throughout the catchment must be a strong presumptive evidence of some direct benefit associated with the practice. Similar findings are expressed in the work of Richards (1985).

Some other farmers, 12%, 6% and 13% in the humid, sub-humid and semi-arid zones, respectively (Table 6.8) reported that multiple cropping resulted in better use of farm inputs. These farmers argued that the available farm inputs were used to the benefit of several crops under multipple cropping systems than one crop under the monocropping system. For instance, farm labour, which was identified as a major problem particularly during the peak season, was best utilised under the multiple cropping systems since all crops were weeded in one operation. The farmers, also, explained that crops in multiple cropping system were easier to protect against birds, animals and thieves than those under monocropping systems. It is a system also encouraged by the proponents of organic farming since it increases biodiversity in a farm (Njoroge, 1994).

Another reason raised by the farmers to explain the dominance of multiple cropping was related to land shortage in the study area. Majority of the farmers, 75%, 87% and 75% in the humid, sub-humid and semi-arid zones respectively said that they onwed small farms and that these were best utilised under multiple cropping system. They considered monocropping a waste of the scarce land resource. This is the same reason which led Harwood and Price (1976) to the conclusion that "the extent and importance of multiple cropping system increases as farm size decreases". Similarly, Francis, (1990) states that small farmers employ multiple cropping systems in part because of their limited access to resources, mainly land and farm inputs, to sustain monoculture.

The last reason given to explain the dominance of multiple cropping system was that it provided good ground cover, thus, protecting the ground from the agents of soil erosion. This explanation was given by farmers who had attained secondary school education which could imply that the education curriculum is also sensitising young people about the soil erosion problem.

6.3 Types of livestock

Livestock is an important component of the smallholder farming system in the study area. Cattle are the major type of livestock and, therefore, most of the questions about livestock were based on cattle. Other forms of livestock include; goats, sheep, and donkeys.

The number of cattle per family ranged between 1-5 in the upper catchment while in the lower catchment, it was much higher, 6 cattle per household. About 52% and 32% of the farmers in the semi-arid zone owned between 1-5 and 6-10 cattle respectively (Table 6.9). This is in line with the fact that over 50% of Kenya's livestock is kept in the arid and semi arid areas.

The explanation for the difference in the average number of cattle in the two sub-catchments was that land shortage was acute in the Kaihungu Sub-catchment which the farmers responded to by, not only reducing the number of livestock but, also, by changing from the traditional to the exotic breeds. The latter are favoured by the cool climate existing in this sub-catchment.

Table 6.9: Number of cattle per household

No. of cattle	Humid zone	Sub-humid zone	Semi-arid zone	Study area
1-5	90%	95%	52%	79%
6-10	0	0	32%	10.7%
11-15	0	0	6%	2%
16+	0	0	4%	1.3%

Source: Author

On the other hand, farmers in the lower catchment onwed bigger tracts of land and therefore kept a larger number of cattle. They, however, explained that the importance of cattle for social functions such as dowry had declined. They further reported that the increased value attached to education; improved housing and the continually declining grazing areas (in size and quality), had stimulated the sale of livestock resulting in less livestock per household. However, even with reduced number of livestock, overgrazing particularly in the Mathatuta sub-catchment was still apparent.

A relatively small number of farmers in the Kaihungu Sub-catchment, 49% and 38%, in the humid and sub-humid zones, respectively water their livestock on the farm. That is, they do not drive the animals to the river to drink water but instead, the farmers fetch the water from the rivers for the animals to drink at the farm. On the other hand, all the farmers in the Mathauta Sub-catchment water their livestock in the rivers, wells and Masinga dam.

Approximately, 48%, 42% and 2% of the farmers in the humid, sub-humid and semi-arid zones, respectively practised zero grazing. Their livestock was completely stall fed, mainly with Napier grass (which is mostly grown on farm terraces), crop residue and animal feed bought from the market. Another 42% and 54% of the farmers in the humid and sub-humid zones respectively, practised both stall feeding and occasional grazing. Due to lack of adequate land for grazing purposes the farmers used road reserves and river valleys as additional grazing land in order to supplement their diet as was the case in Kiambu district and Masailand (Mbwesa, 1989 and Sindiga, 1989).

This cattle movement to and from the grazing areas and watering places is likely to lead to soil erosion along the cattle tracks, and river banks as is indicated in Atkins (1984) and Valentine (1985). For instance, animal hooves compact the ground surface thus allowing free movement of run off. Once cattle tracks become compacted, they turn into gullies as a result of concentrated run off in them. The problem is likely to be worse in the Kaihungu Sub-catchment because of the presence of steep and long slopes along which the animals are driven .

6.3 The Extent of Soil erosion in the Study Area

Contrary to the researchers expectation, farmers in the study area appeared to have a high perception of the soil erosion problem in both arable and grazing land. About 85%, 90% and 91% of the farmers in the humid, sub-humid and semi-arid areas, respectively said that they had noticed some signs of severe soil erosion in their farm land. Only a small number of the farmers, 15%, 10% and 9% in the humid, sub-humid and semi-arid areas, respectively, said that their farms were experiencing less severe soil erosion. The latter group of farmers explained that they had invested heavily on soil conservation in an effort to control soil erosion.

The farmers responses were confirmed through an erosion observation exercise conducted by the researcher whose results are presented in Table 6.10. These results revealed that about 85%, 90%, and 91% of the sample farms in the humid, sub-humid, and semi-arid areas of the catchment, respectively suffered severe erosion. Further, these results showed that agricultural land was not the only source of sediments. Other areas in the farms including unprotected homesteads, farm boundaries and footpaths also contributed to the sediments discharged into the river channels. Indeed, 88%, 92%, and 91%; 85%, 90%, and 87%; and 83%, 87%, and 94% of the sample farms in the humid, sub-humid and semi-arid had severely eroded footpaths, boundaries and homestead compounds respectively.

Nearly all the farmers in the study area perceived soil erosion as having grave implications on their agricultural land. They associated it with reduced farm productivity.

Table 6.10: Soil erosion in different farm holding areas

	Humid Zone		Sub-humid Zone		Semi-arid Zone		Study Area	
Observation Unit	LSV	SV	LSV	SV	LSV	SV	LSV	SV
food crop farms	8	92	4	96	13	87	8.3	91.2
coffee farms	23	77	15	85	-	-	19.0	81.0
pasture land	-	-	-	-	4	96	4.0	96.0
footpaths	12	88	8	92	9	91	9.7	90.3
farm boundaries	15	85	10	90	13	87	12.7	87.3
homestead	17	83	13	87	6	94	12.0	88.0

LSV = less severe erosion; SV = severe erosion

Source: Author

According to these farmers, soil erosion was the result of: (i) lack of soil conservation measures (ii) unmaintained soil conservation measures (iii) inadequate soil conservatio measures (iv) poor farming methods best exemplified by tilling down hill (v) steep slopes (vi) high rainfall (vii) inadequate vegetation cover (viii) run off from neighbouring farms, roads, and footpaths (ix) trampling by livestock (Table 6.11).

Only a small number of the farmers in the catchment (4.7%) did not practise any form of physical soil conservation. This confirms the fact that farmers in the study area had a high perception of the soil erosion problem.

Table 6.11: Farmers views concerning causes of soil erosion in the study.

Cause of erosion	Humid zone	Sub-humid zone	Semi-arid zone	Study area
unconserved farms	3%	3%	8%	4.7%
unmaintained conservation structures	80%	86%	83%	83%
tilling down hill	5%	10%	6%	7%
inadequate conservation measures	69%	67%	75%	70.3%
steep slopes	49%	36%	27%	37.3%
high rainfall	48%	30%	26%	34.7%
inadequate vegetation cover	4%	3%	81%	29.3%
run off from road and footpaths	29%	20%	11%	20.3%
livestock	11%	15%	33%	19.7%

Source: Author

About 80%, 86% and 83% of the farmers in the humid, sub-humid and semi-arid areas, respectively reported that soil conservation structures in their farms needed immediate repair work. Cases of unmaintained and broken terraces were for instance, evident in both coffee and food crop farms in the study area (Plate A-2).

The effectiveness of such structures was obviously reduced due to lack of constant

Plate A-2: A poorly maintained terrace in a maize farm maintenance and repair. One noted agent of destruction of these soil conservation structures were the farmers who walk over them .

Another 69%, 67%,and 75% of the farmers in the humid, sub-humid and semi-arid areas, respectively reported that inadequate soil conservation measures evidenced by widely spaced terraces on steep slopes greater than 20^0 , unstabilised terraces, undeveloped grass strips and trash lines among others caused and accelerated soil erosion in their farms (Table 6.11). This problem appeared more serious in the Kaihungu catchment, particularly in the food crop farms planted with maize. Rills developed immediately after the seasonal rains even before the crops had germinated.

The farmers blamed persisting socio-economic problems such as the scarce financial resources, for their inability to implement sustainable soil conservation measures. Indeed, as is indicated in Biamah, (1989) and Thomas (1991), farmers with limited resources attach priority to more demanding household obligations such as the construction of a family house than engaging in soil conservation.

In order to counteract the effect of some of the mentioned socio-economic problems, farmers in the semi-arid zone have established communal self-help groups locally known as " Ikundi sya Mwethya". The number of members varies between 10 and 70 with an average of 35 individuals. "Mwethya" can be defined as shared work which is of a voluntary nature and organized according to group rules so that each member plays his part (Mbithi, 1974). One of their duties is to maintain soil conservation particularly through the construction of terraces which is usually undertakenduring the dry months of August and September. The groups work for 2-3 days in a week, working for a different member each day.

High rainfall was another factor causing soil erosion in the study area. A significant proprtion of the farmers, 48%, 30% and 26% of the farmers in the humid, sub-humid and semi-arid areas, respectively cited rainfall as a contributory factor to soil erosion (Table 6.11). These farmers explained that immediately after a heavy down pour, a concentrated thick sediment laden red run off flows from the unconserved and the inadequately conserved farms, along the footpaths and cattle trucks into the rivers and dams. For instance, the water in the Kaihungu river was clear before the rains commenced but turned deep red immediately after the onset of rains in April, 1992.

Another 49% 36% and 27% of the farmers in the humid, sub-humid and semi-arid areas, respectively related soil loss to the degree and length of the slope (Table 6.11). They were aware that steep slopes were eroded faster than the gentle slopes and flat land and noted the importance of proper soil conservation techniques in reducing the amount of soil loss from the slopy agricultural land. These observations made by the farmers confirmed what scientists such as Omwega, (1989); Obando, (1990); Hurni, (1985); and Lal, (1977) have reported with regard to the relationship between steep slopes and soil erosion.

Inadequate vegetation cover was also blamed for the existence of soil erosion especially by farmers in the Mathauta Sub- catchment. About 4%, 3% and 81% of the farmers in the humid, sub-humid and semi-arid areas, respectively associated soil erosion with inadequate vegetation cover. They argued that most of the ground which was bare ground or covered by a few scattered trees was not protected from the effect of rain drops

(Table 6.11). The farmers further reported that this problem was most notable in the grazing fields and was a result of over- grazing as is indicated in the work of Nnyiti, (1981); Stocking, (1985); Biamah, (1989); Dregne, (1990); Maro, (1990) and Groot, *et al*, (1992). The above view is supported by Biamah, 19891 and Groot, et al, (1992) who blame low vegetation cover resulting from overgrazing for the persist soil erosion in Baringo Disrtict, Kenya. On the other hand, however, overgrazing was almost absent in the densely populated Kaihungu Sub-catchment where zero grazing was being practised. Therefore, overgrazing was not an important cause of soil erosion in this Sub-catchment.

Soil erosion, particularly, in the semi-arid areas was evidenced by the presence of gullies, exposed vegetation roots and lateritic and quartz stonny surfaces which are a result of geological change in the area such as those observed in badlands of Spain (Thornes and Gilman, 1983). It is the opinion of the researcher that the rate of erosion in these semi-arid areas could be declining because the exposed stony (lateritic) surfaces are more resistant to erosion than the upper soil horizon. This is similar to the findings of Christiansson (1984) who explains that soil loss on bare uncultivated grounds decreased during the third year of his experiment while it increased in the bare cultivated ground in the semi-arid areas of Central Tanzania. He explains that splash erosion and sheetwash detach and remove the fine particles leaving a coarse gravelly layer which protects the ground from further erosion. According to Thomas and Barber (1983), the stony surface slows soil erosion by (i) intercepting and reducing rain drop energy; (ii) retarding run off hence allowing more time for infiltration and (iii) facilitating the establishment of grasses not easily grazed down to the roots or trampled out of existence.

Approximately 29%, 20% and 11% of the farmers in the humid, sub-humid and semi-arid areas, respectively reported that run-off from neighbouring farms, footpaths, cattle trucks and roads contributed to the soil erosion problem in their farms (Table 6.11). This led to the development of gullies within the catchment especially in areas where excess water from roads, footpaths and cattle trucks was channelled. Cases of numerous badly eroded footpaths running up and down the steep slopes, leading to the rivers, markets and farms were noted. These are always bare and clean thus forming the channels from which gully erosion develops. Soil erosion associated with run off from roads and footpaths has also been noted in the work of (Atkins, 1984; amd Kamau, 1981). For instance, Adams and Andros (1990) explain that roads are a major source of erosion and sedimentation in steep terrain in the humid areas most of which are characterised by high rainfall intensities.

On tillage, about 5%, 10% and 6% of the farmers in the humid, sub-humid and semi-arid areas, respectively were found tilling their land down-hill instead of farming along the contours (Table 6.11). Rills had developed in these farms along the wrongly designed crop rows.

From the foregoing, it is clear that the soil erosion problem was similar throughout the catchment. The only exception was in Mathauta Sub-catchment where farmers associated the causes of soil erosion with the incidence of over grazing and aridity.

6.4 Soil conservation measures practised in the study area

Majority of the farmers in the study area practised at least one or more types of soil conservation (Table 6.12). Only 3%,3% and 8% of the farmers in the humid, sub-humid and semi-arid areas, respectively did not engage in any form of physical soil conservation. These latter group of farmers said that they occasionally used some forms of biological practices. Their farms were among those which were severely eroded.

The farmers who did not practise any form of soil conservation and those whose farms were inadequately conserved gave the following reasons for inadequate soil conservation measures; (i) low incomes (ii) shortage of farm labour (iii) old age (iv) lack of technical advice (v) inadequate farm tools (6) presence of small farms (Table 6.13) which are further discussed in section 6.4.

Table 6.12: Types of conservation measures practised in the study area

Conservation measures	Humid zone	Sub-humid zone	Semi-arid zone	Study area
PHYSICAL				
contour farming	75%	78%	65%	73%
micro- ridging	100%	100%	92%	97.3%
terracing	98%	99%	84%	93.7%
cut off drains	43%	38%	6%	29%
check dams	3%	3%	6%	4%
sandbags	0%	4%	6%	4%
BIOLOGICAL				
rotation	39%	36%	38%	37.3%
fallowing	5%	1%	10%	5.3%
mulching	40%	33%	0%	24.3%
manuring	71%	85%	82%	82%
fertilising	87%	94%	4%	60.7%
trash lines	16%	24%	35%	25%
sisal/euphobia	0%	0	34%	11.3%
napier grass	51%	40%	4%	31.7%
agro-forestry	86%	82%	23%	63.7%

Source: Author

Table 6.13: Farmers reasons for lack of or inadequate soil conservation measures in the study area.

reasons advanced by the farmers	humid zone	sub-humid zone	semi-arid zone	study area
low income	72%	78%	86%	78.7%
shortage of labour	38%	59%	46%	47.7%
old age	11%	21%	19%	17%
lack of technical advice	6%	3%	10%	6.3%
inadequate farm tools	25%	33%	31%	29.7%
small farms	35%	41%	31%	35.7%

Source: Author

6.4.1 Physical methods of soil conservation

Contour farming:- it involves cultivating along contours but not down hill. About 75%, 78% and 65% of the respondents in the humid, sub-humid and semi-arid areas, respectively practised this type of farming (Table 6.12). As Wenner (1988) observed, these farmers explained that contour farming was rarely used as a single method of soil conservation because it was not effective in reducing soil erosion especially on steep slopes, and in areas that receive heavy storms of high intensity. Most of these tend to be concentrated in the early part of the rainy seasons when vegetation is minimal. Other soil conservation measures were, therefore, used together with contour farming.

Micro-ridging:- Nearly all the farmers in the study area practised it (Table 6.12). This consisted of ridges and furrows prepared using a hoe in the Kaihungu Sub-catchment or a oxen plough in the Mathauta Sub-catchment. Except in a few farms, most of the micro-ridges observed in the field were narrow and shallow and were covered after the first heavy down-pour. Those in the maize and beans farms were also removed during the first weeding while those in the monocropped maize farms were retained through-out the cropping season especially in places where the plough was used. These micro-ridges are of greater importance as a method of rain water harvesting in the Mathauta Sub-catchment areas which have a high (60-80%) moisture deficit in both the Long and Short rainy seasons. This creates a substantial risk of crop failure in any year (Sombroek, *et al*, 1982). However, as observed by Morgan (1986), most of the farmers seemed aware of the fact that micro-ridges alone were not effective in controlling soil erosion. They, therefore, used other conservation measures together with the micro-ridges. These results compare with those of Mati (1989) who carried her work in Kiambu district, Kenya and observed that micro-ridges were used together with other conservation measures.

Terracing: These are earth embankments constructed across the slope to intercept run off and convey it to a stable outlet. They also shorten slope length and reduce the run off velocity and soil erosion. The main types of terraces practised in the study area included bench terraces and "fanya juu" terraces.

Studies undertaken by Mati (1989) and Ngugi and Kabutha (1989) confirm that terracing was a major soil conservation technique practised by nearly all the farmers. The current study revealed that 98%, 99% and 84% of the farmers in the humid, sub-humid and semi-arid areas, respectively (Table 6.12) practised it. These farmers were appreciated the advantages of terracing in reducing run off and soil loss through the reduction of the slope angle and slope length, water retention and increased agricultural land productivity. However, majority of the farmers viewed terracing as: (a) a costly exercise in terms of labour, tools and time required in designing, construction and maintenance; (b) a consumer of space which could otherwise be utilised for crop production and (c) leading to the exposure of the infertile sub-soil especially in places that have thin soils. Problems associated with terracing are being experienced in other parts within the tropics such as Rwanda, Tanzania, Indonesia and Malawi (Lewis, 1988; Temple, 1972; Suwardjo and Abujamin, 1985 and Millington, *et al*, 1986).

Terracing was predominant in the coffee farms in the Kaihungu Sub-catchment. Here it was possible to find a neatly terraced coffee plot adjacent to a poorly conserved plot both lying at the same slope angle and belonging to the same farmer. This was possible due to the monetary returns associated with coffee. Soil conservation on the coffee farms was better than in the food crops. To an extent, this reflected the effect of marketing policies which tended to favour cash rather than food crops. Farmers respond to price incentives by concentrating nearly all their effort on the cash crop farms. This practice has led to food shortages both at the local and national levels. Also, the dominance of conservation measures in the coffee farms could be explained by the fact that it was a must to conserve coffee farms during the colonial days (Thomas, 1981). Secondly, rills were usually removed by cultivation making soil erosion less conspicuous in the food crop farms than in the cash /tree crop farms where exposed tree roots make the need for conservation apparent.

However, following the fall in coffee prices some farmers had a negative attitude towards soil conservation in the cash crop farms. This attitude was represented by the numerous cases of broken terraces which required immediate repair. Many farmers associated the decline of soil conservation measures with the fall in coffee incomes.

Terracing of land under food crops in the Kaihungu Sub-catchment just like in other humid areas of Kenya appeared less popular. According to Thomas (1988), the explanation could be that the benefits are less conspicuous in the humid areas than in the marginal areas where water is a critical factor limiting crop production.

In the Mathauta Sub-catchment, terracing and virtually all other conservation techniques were concentrated on the arable land. Terracing was not witnessed anywhere in the grazing/pasture land during the time of this research. The farmers were aware of the soil erosion problem in the grazing areas but explained that they could not yet engage in soil conservation in those areas mainly due to financial constraints. Other farmers explained that terracing could not be an appropriate form of conservation in the grazing areas as the terraces would be a hinderance to the animals.

The risers of the embankments of the terraces appeared vulnerable to soil erosion in farms where they were not protected by vegetation cover. In the cases where this was not done then serious erosion was evident.

Cut-off drains : These are diversion ditches dug across the slope meant for trapping run-off originating from outside the farm such as roads and footpaths. They were not a common form of soil conservation particularly in Mathauta sub-catchment. Only 43%, 38% and 6% of the respondents in the humid, sub-humid and semi-arid areas, respectively had cut-off drains during the course of this research (Table 6.12). According to the respondents, cut-off drains were effective in controlling soil erosion as they were able to trap a lot of run off where they were properly designed. However, these structures were costly and time consuming to construct. Elsewhere, these structures have been found effective in erosion control, for instance, in Rwanda (Clays and Lewis, 1990) and in Kiambu district where Mati (1989) found out that about 49% of the farmers interviewed had cut-off drains.

Through out the catchment, cut-off drains were found to be placed along the upper boundary of the farm. The soil from such drains is thrown down hill and facilitates the to collection of run off originating from hill sides, roads and footpaths. Such run off infiltrates slowly to the sub-surface. The trapped run off was considered useful for crop production particularly in the Mathauta Sub-catchment where it is perceived as an important method of water harvesting to supplement the deficient seasonal rains. In some cases bananas were planted inside the ditches to benefit from trapped run off.

Other physical conservation structures used include; check dams and sand bags. Only a few farmers practised these latter methods since they were mostly concentrated on footpaths and gullies.

Physical conservation methods appeared to be awarded a lot of attention by the farmers. However, while these are potentially very useful in controlling soil erosion they pose a number of disadvantages. Most of them are very expensive to construct and to maintain (Chorley, 1984; Lal, 1983; and Hudson, 1971). Further, it is sometimes argued that these mechanical practices of soil conservation are less effective than improved soil management practices (Lal, 1983).

6.4.2 Soil fertility management and Biological methods of soil conservation

Crop rotation : Crop rotation invovles the growing of different crops in a given farm in different seasons. According to the present data, only 39%, 35% and 38% of the farmers in the humid, sub-humid and semi-arid areas, respectively practised crop rotation at one time or another (Table 6.12). The aim was usually to increase soil fertility, to break the build up of pests and diseases and to change the rooting depth in order to vary the uptake of moisture or nutrients. Although farmers in the study area were aware of the benefits associated with crop rotation, majority of them were unable to adapt it due to prevailing land shortage problem. They prefered to intercrop the same crops in the same farm, year after year with the intention of making the maximum use of their small farms.

Fallow farming: Despite the many advantages associated with fallow farming which invoves leaving part of the farm uncultivated for a given period (Nye and Greenland, 1961) only farmers (about 5.3%) in the study area practised. These comprised of the very "wealthy farmers" with sufficient resources including; high incomes and surplus land. Otherwise majority of the farmers were characterised by a scarcity of resources particularly, land, and were, therefore, forced to cultivate their small farms all year round; season after season, low farm productivity as a result of over cultivation and use of inadequate farm inputs especially manure and fertilizer. This land shortage problem, is a manifestation of high population growth and land tenure system which encourages land subdivision through inheritance. The overall result is lack of fallow farming, over cultivation and soil erosion in Rwanda and Kiambu district (Lewis, 1988 and Mati, 1989) respectively.

Mulch : Mulch is defined as any material used at the surface of a soil primarily to prevent loss of water by evaporation, to keep down weeds, to dampen temperature fluctuation or to promote soil productivity. The mulch was only practised by 40% and 33% of the farmers in the humid and sub-humid areas, respectively (Table 6.12). The farmers explained that the use of mulch had declined due to lack of suitable and adequate material. This was because material used for mulch such as crop residue, in particular maize stalk, and grass were used as fodder for the stall fed livestock and in some cases as a source of fuel for domestic needs. The available little mulch was used only in the potato sections of the farms and none was being used in the coffee farms as has been the practice (Lewis, 1982). None of the farmers in the Mathauta Sub-catchment areas used mulch in their farms during the time of this research. Besides mulch being difficult to find, it is also eaten by termites. Cases of inadequate mulch application have been noted in (Thomas, 1988 and Ngugi and Kabutha, 1989).

Farm yard manure (FMY) : The most important source of organic matter in the study area is farm yard manure. About 71%, 85% and 82% of the farmers in the humid, sub-humid and semi-arid areas respectively used it in their farms (Table 6.12). A large proportion of the farmers said that manure had a relatively longer lasting effect on the humus content of the soil than inorganic fertilizer. They further explained that, unlike fertilizer which must be applied in the farms in every season, the effects of farm manure lasts upto 3 years. However, majority of the farmers were aware that the amount of manure they used was insufficient. They explained that their cattle did not produce enough manure as they did not have enough food due to the persisting fodder shortage in the study area.

Transportation of manure poised a problem in the study area. A few farmers (12%) owned ox-carts which provided a reliable means of transportation while the rest of the farmers said that they carried it on their shoulders or backs in the case of men and women, respectively.

The manure was usually spread over the whole field, particularly, in the Mathauta Sub-catchment where the supplies are not as limited as in the Kaihungu Sub-catchment due the larger number of livestock kept (Table 6.9). In the latter catchment the manure was applied in rows or in the specific holes where the seeds had been planted. Other farmers said that they spread the manure on selected places which they identified as having a lower fertility level compared to the rest of the farm.

Fertilizer: Fertilizers like Diammonium phosphate (DAP) and Calcium ammonium nitrates (CAN) among others were used by many farmers in the study area. It was observed that about 87%, 94%, and 4% of the farmers in the humid, sub-humid and semi-arid areas, respectively use fertilizer to supplement farm yard manure (Table 6.12). The reasons why majority of the farmers in the Mathauta Sub-catchment did not use fertilizer include: (i) the high cost involved in purchasing it (ii) a relatively larger supply of manure than the farmers in the Kaihungu Sub-catchment and (iii) unavailability of fertilizers; farmers in the Mathauta Sub-catchment travelled for long distances, approximately 50 KM, to purchase fertilizer unlike in the Kaihungu Sub-catchment where fertilizers were easily available in the numerous coffee factories.

Farmers in the study area observed that fertilizers alone did not have a long term effect on the state of humus on the soil and, therefore, they also, needed to add organic matter to bring about an improvement in the aggregate structure. This is because nutrients from fertilizers are easily leached away. Over 50% of the farmers using fertilizers said that the amounts they used were inadequate as fertilizers were too costly for them to afford in substantial quantities.

Trash lines : About 16% 24% and 35% of the farmers in the humid, sub-humid and semi-arid areas, respectively used some type of trash lines

(Table 6.12). These consisted of crop residue and tree branches cut into small pieces piled along the contours which trapped eroded soils from the slopes above them. Trash lines could effectively check soil erosion following the subsequent deposition of the eroded material. Farmers reported that trash lines were a cheap soil conservation measure if the necessary material required for their construction was readily available and if they were not easily consumed by termites.

Agroforestry:- refers to land use systems in which trees or shrubs are grown in association with agricultural crops, pasture or livestock and in which there are both ecological and economic interactions between the trees and other components. The advantages agro-forestry in soil conservation include: (i) to increase soil cover by litter and prunnings; (ii) to provide partly permeable hegderow barriers; (iii) to lead to the progressive development of terraces through soil accumulation upslope of the hegde-rows; (iv) to increase soil fertility and resistance to erosion by maintenance of organic matter; (v) to stabilize earth structures by root systems; and (vi) to make productive use of the land occupied by conservation work (Eckholm, 1979).

Agroforestry was widely practised in the study area particularly in the Kaihungu Sub-catchment where the area under woody mass is almost equal to the area under coffee. As was the case in Murang'a (Ngugi and Kabutha, 1989) a large proprotion of the visited farmers; 86%, 82% and 23% of in the humid, sub-humid and semi-arid areas, respectively had planted different types of tree species in their farms (Table 6.12). The main purpose for planting trees was the provision of fuelwood which was said to be extremely expensive. According to Eckholm (1979), the need for fuel wood in tropical countries will exceed the available supplies by the year 2000 by about 25% and therefore, agro-forestry should help meet this increased demand. The trees also provided fodder, building material, shade, and were used to mark farm boundaries. Trees planted on the terrace banks stabilized the back slope and decreased the risk of their breakage and eventual failure. Thus, the trees played an important role in the farming economy and in the controlling of soil erosion on the steep land.

According to the interviewed farmers, trees were normally planted during the Long Rains (April-May) in the Kaihungu Sub-catchment and during the Short Rains in the Mathauta Sub-catchment. *Black* *wattle (Acacia mearnsii)* and *Grevillea robusta* were the two common tree species in the Kaihungu and Mathauta Sub- catchments, respectively. These were mainly planted along the farm boundaries and were usually lopped regularly for firewood. Fruit trees including; avocado, mango, orange, lemon, guava also formed an important part of Agroforestry.

6.5 Chi-square results of the socio-economic aspects of soil erosion

6.5.1 The problem of soil erosion in the study area

In this section the three zones; humid, sub-humid and semi-arid, will be discussed together and shall commonly be referred to as the study area. This is because a low computed chi square value (2.1) and a high critical value (9.21) show that there was not a statistically significant difference between the number of farms experiencing less severe and severe soil erosion within the three cropping zones. In table 6.14, it is shown that the number of farmers whose farms suffered severe soil erosion was uniformly high and those whose farms suffered less severe erosion was low throughout the catchment. About

85%, 90%, and 91% of the farmers in the humid, sub-humid, and semi-arid zone had farms that suffered from severe soil erosion, respectively. On the other hand, only 15%, 10%,and 9% of the farmers in the humid, sub-humid, and semi-arid

Table 6.14: Signs of erosion by cropping zone

signs of erosion	Humid zone	Sub-humid zone	Semi-arid zone	row total
less severe	15 44.1 15	10 29.4 10	9 26.5 9	34 (11.3%)
severe	85 32.0 85	90 33.8 90	91 34.2 91	266 (88.7%)
column total	100 33.3%	100 33.8%	100 33.3%	300 100%

chi-square = 2.1; df = 2; significance level = 0.01

Source: Author

zones had farms that did not suffer from severe soil erosion. These results indicated that soil erosion was a common problem, experienced by majority of the sample farmers (88.7%) in the study area.

6.5.2 Gender, age and family size

Table 6.15 shows the Chi-square results of the investigated variables with the presence or absence of soil erosion in the study area. Three

Table 6.15: Chi-square results of the investigated socio- economic variables against the presence or absence of accelerated soil erosion in the study area.

variables	Computed value	Critical value
gender	0.63	6.64
family size	0.59	9.21
age of the head of the household	1.05	9.21
farm size	17.99	11.34*
level of education	56.2	9.21*
extension service	30.1	6.64*
level of income	22.8	9.21*
employment	55.8	6.64*

* shows the significant values at 0.01 significance level.

Source: Author

of the investigated variables including; gender, family size and age of the head of the household did not appear to be significantly different between farmers whose farms suffered or did not suffer from severe soil erosion. According to the chi square results gender did not have any significant influence on the soil erosion problem hence there was no significant difference in the severity of soil erosion between farms which were headed by male or female (Table 6.16). This was indicated by a small computed Chi-square value

(0.63) compared with a larger critical value (6.64) therefore not significant at 0.01 significance level (Table 6.16). The implication was that both men and women were equally aware of the soil erosion problem but were facing a common bottle-neck which hindered them from actively engaging in soil conservation procedures and would have perhaps tackled it similarly if some of the socio-economic problems facing them were solved.

Table 6.16 Signs of soil erosion by gender

signs of erosion	male	female	row total
less severe	13 38.2 13.4	21 61.8 10.3	34 11.3
severe	84 31.6 86.6	182 68.4 89.7	266 88.7
column total	97 32.3	203 67.7	300 100

Chi-square = 0.63 df = 1

Source: Author

Family size did not appear to have any significant influence on soil erosion in the study area as was indicated by a small computed chi square value (0.59) and a large critical value (9.21) (Table 6.17). That is, there was not a significant difference in the severity of soil erosion between farm whose onwers had small or large families (Table 6.17). The explanation

Table 6.17: Signs of soil erosion by family size

signs of erosion	1 - 5	6 - 10	≥11	row total
less severe	8 23.5 10.8	23 67.6 11.4	3 8.8 14.3	34 11.3
severe	66 24.8 89.2	179 67.3 88.3	21 7.9 87.5	266 88.7
column total	74 24.7	202 67.3	24 8	300 100

Chi-square = 0.59 df = 2

Source: Author

was that most of the families, whether large or small, consisted of children who attended and spent most of their time in school thus reducing labour availability at the household level. This is a deviation from the traditional trend where children were considered as an important source of family labour as they did not attend school, and, therefore, the more children a family had, the better it was well off in terms of labour provision. The problem is made worse by the fact that majority of the young persons migrate into towns, particularly Nairobi, in search of high salaried employment after completing school thus creating labour shortages within the rural areas. The latter problem was blamed on the former Kenya education system which prepared students for white collar jobs hence alienating them from " the supposedly dirty" farm work. Also, besides the fact that farming may not give a relatively high income, it is a highly risky business due to climatic fluctuations.

Age of the head of the household was also found not to have a significant influence on the presence or absence of severe soil erosion in the study area as is indicated by a small computed chi square (11.38) and a large critical value (13.38) at 0.01 significance level (Table 6.15). That is, there was not a significant difference in the presence or absence of severe soil erosion between farms headed by young, middle aged or old aged farmers (Table 6.18). The implication here is that there were other important socio-economic factors influencing the occurrence of soil erosion in the study area, than the age of the farmer.

6.5.3 The influence of farm size on soil erosion

According to the results of the present study, there was a significant difference in farm sizes between farmers whose farms suffered severe or less severe soil erosion. This was indicated by the large computed Chi-square value of 17.92 and a small critical value of 11.34 at 0.01 significance level (Table 6.15). The results revealed that farmers with large farms had a less serious soil erosion problem than the ones with smaller farms.

Table 6.18 Age of the head of the household by signs of erosion

signs of erosion	≤30	31 - 40	≥41	row total
less severe	3 8.8 7	9 26.5 11.1	22 64.7 12.5	34 11.3
severe	40 15 93	72 27.1 88.9	154 57.9 87.5	266 88.7
column total	43 14.3	81 27	176 58.7	300 100

Chi-square = 1.05 df = 2
Source: Author

In Table 6.19, it is shown that about 64% of the 266 farmers whose farms suffered from accelerated soil erosion and 41% of the farmers whose farms did not suffer from accelerated soil erosion had small farms less than 3 acres. On the other hand it is shown that 27% of the 34 farmers whose farms did not suffer from accelerated soil erosion and 17% of the 266 farmers whose farms suffered from accelerated soil erosion had large farms exceeding 6 acres.

Table 6.19: Signs of soil erosion by size of farms (in acres)

signs of erosion	0.01-3	3.1 - 6	6.1 - 9	9.1 +	row total
less severe	14 41.2 7.6	11 32.4 17.7	5 14.7 45.5	4 11.8 9.3	34 11.3
severe	170 63.9 92.4	51 19.2 82.2	6 2.3 54.5	39 14.7 90.7	2 66 88.7
column total	184 61.3	62 20.7	11 3.7	43 14.3	300 100

Chi-square = 17.99; df = 3 P = 11.34

Source: Author

It was observed that some conservation techniques particularly terracing and bund building were associated with loss of valuable land which is considered by farmers to be wasted. Some farmers complained of the waste of land occupied by the ditch from which soil was excavated during the time of constructing the embankments.

Although only 35.7% of the farmers openly gave "small size of farms " as a reason for not engaging in effective soil erosion control (Table 6.13), the problem appeared to have an important influence on the adoption and practise of soil conservation. It explained the presence of widely spaced terraces particularly in the food crop farms in both Sub-catchments. The same problem has been noted by Millington *et.al* (1989) and Thomas & Biamah (1991) (Table 6.20).

In addition, the reason why farmers with large farms had less erosion in their farms was that most of them had comparatively larger incomes than to those with small farms. This was indicated by a large computed chi square value (31.4) and a small critical value (13.28) (Table 6.15) which shows that there was a significant difference in the level of income between farmers who owned large farms and those who owned small ones. Thus, the results revealed that farmers who had high incomes and large farms did not face soil conservation problems. These could afford to lose some portion of their farms to soil conservation bunds, and also to purchase tools and to hire farm labour.

Table 6.20: Land loss associated with commonlly adopted soil conservation techniques

Conservation technique	Land loss per hectare	
	area (m)^2	proportion (%)
bench terracing	75 - 525	7.5 - 52.5
grass strips	167	16.7
contour bunding	91	9.1
stick / stone bunding	22	2.2
broad based bunding	0	0
contour cultivation	0	0
conservation tillage	0	0

Source: Millington, *et al,* (1989)

On the other hand, majority of the farmers who owned small farms were also characterised by low incomes which was a notable handicap towards soil conservation. Also, a large computed Chi-square of 22.9 and a small critical value of 20.9 showed that there was a significant difference in education levels among the farmers with large or small farms. Indeed, majority of the farmers with large farms were among the most educated. This was because the educated farmers were able to obtain off farm employment which formed an extra source of income enabling them to purchase additional land rather than to rely on the inherited family land only.

6.5.4 The influence of level of education on soil erosion

Similarly, it was found that the farmers level of education also influenced the presence or absence of severe soil erosion in the study area. A large computed Chi-square value of 56.2 and a small critical value of 9.21, shown on Table 6.15, indicated that there was a significant difference in the education level between farmers whose farms were or were not affected by the soil erosion problem.

About 85.3% and 14.7% of the farmers with secondary and, or post secondary education and primary school education had well conserved farms respectively. On the other hand, 32.6% and 67.3% of the farmers in possession of secondary and, or post secondary and primary education had farms depicting signs of soil erosion respectively (Table 6.21). This implied that farmers with higher education engaged in soil conservation more than the less educated. This emanated from the fact that most of the highly educated farmers were able to acquire off farm employment which enabled them to earn additional income on top of the on-farm income. This category of farmers were consequently able to spare some of their income for soil conservation.

Table 6.21: Signs of soil erosion by education level

signs of erosion	primary	secondary	post secondary	row total
less severe	5 14.7 2.7	14 41.2 16.7	15 44.1 46.9	34 11.3
severe	179 67.3 97.3	70 26.3 83.3	17 6.4 53.1	266 88.7
column total	184 61.3	84 28	32 10.7	300 100

Chi-square = 56.2; df = 5; P = 9.21

Source: Author

6.5.5 The influence of Extension Advice on Soil Erosion

The influence of extension education on the presence or absence of severe soil erosion was also investigated. According to the results of this study, a large computed chi square value of (33.4) and a small critical value (6.64) were obtained (Table 6.15). These showed that there was a significant difference in the severity of soil erosion between farms which were or were not visited by extension officers. The indication was that farmers receiving extension advice had better conserved farms compared to those who had not received any advice. These extension officers offered general technical advise on soil conservation and also practically measured and designed some of the mechanical structures in line with contours, thus reducing the incidence of having wrongly laid terraces.

About 55.8% of the farmers whose farms sufferred less severe erosion had received one or more visits from the extension officials during the previous two rainy seasons while 85% of the farmers with eroded farms were never visited at all (Table 6.22). This implied that extension education was important in disseminating agricultural information regarding soil conservation, and use of farm inputs (fertilizers, insecticides and pesticides) among others.

This study like the one conducted by Atkins (1984) revealed that agricultural extension officers concentrated their advice on only a few farmers, mainly the wealthy farmers who were able to induce them with money for favours. Indeed, majority of the farmers in the study area 80.7% said that they had never received any extension visits in their farms (Table 6.23). The latter problem was due to the low ratio of extension officials to the rural population.

Table 6.22: Signs of soil erosion by extension visits

signs of erosion	never visited	visited > 1	row total
less severe	15 44.1 6.2	19 55.8 32.8	34 11.3
severe	227 85.3 93.8	39 14.8 67.2	266 88.7
column total	242 80.7	58 19.3	300 100

Chi-square = 30.4 df = 1; P = 6.64

Source: Author

Table 6.23: Percentage of farmers visited by extension education officers in the previous two rainy seasons

Number of visits	Percentage of farmers
Never	80.7
1 - 2	14.3
3 - 4	12
5 +	3

Source: Author

According to field observation some of the farmers who most needed advice had never been visited by extension officers. Although these farmers complained that the extension officers only visited the progressive wealthy farmers, a small computed Chi-square value of 5.22 and a large critical value of 11.34 indicated that there was not a significant difference in farm sizes between farmers whose farms had or had not been visited by extension officers (Table 6.24). This was perhaps explained by the fact that farmers, regardless of their socio-economic background were free to invite the extension officers to their farms when need arose.

Table 6.24 Farm size by agricultural extension visits

farm size (acres)	never visited	visited >1	row total
0.01 - 3	154 83.5 63.6	31 16.8 53.4	185 61.7
3.1 - 6	36 75 14.9	12 25 20.7	48 16
6.1 - 9	10 62.5 4.1	6 37.5 10.3	16 5.3
>9.1	42 82.4 17.4	9 17.6 15.5	51 17
column total	242 80.7	58 19.3	300 100

Chi-square = 5.22; df = 3;

Source: Author

However, although majority of the farmers had never been visited by the extension officers, most of them were aware of the soil erosion problem and its related implications and were practising some form of soil conservation measures. Further, about 44% of the farmers whose farms did not suffer from severe soil erosion were indeed never visited by any agricultural extension officers (Table 6.24). This indicated the presence of other sources of soil erosion and conservation information sources besides the agricultural extension officers. These included; local administrative chiefs, church meetings, friends / neighbours, mass media and the agricultural shows (Table 6.25). None of the respondents mentioned Mwethya groups as a source of soil conservation information although some of them were members of the groups. It occurred to the researcher that farmers were already aware of the need for soil conservation before they joined the Mwethya groups.

The local administrative chiefs appeared to be an important source of soil erosion information in the study area. This was because these meetings, usually held on Saturdays, were mandatory for everybody to attend. In these meetings the administrators help in sensitising and increasing the farmers awareness of the soil erosion problem. But it was the authors contention that the role of the extension officers was still important in that they gave the farmer an on-farm practical advise. For instance, they measured the terraces hence minimising the incidence of wrongly laid terraces.

Table 6.25: Other sources of soil conservation information in the study area

Sources of information	percentage of the farmers
chiefs meeting	67.7
church meetings	8.7
friends/neighbours	9
mass media	13
agricultural shows	1.7

Source: Author

6.5.6 The influence of type of employment and level of income on soil erosion

Two other interrelated important factors explaining the extent of soil erosion in the study area were; the type and nature of employment and the farmers level of income. Majority of the farmers, 68%, and a minority, 24.8% relied on farm and both off-farm and farm employment. And about 75.2% and 24.8% of the farmers with farms affected by severe soil erosion depended solely on their farms, or both off farm and farm employment respectively; while only 11.8% and 87.1% of the farmers whose farms suffered less severe erosion relied solely on farm employment and both off farm and farm employment respectively (Table 6.26).

Table 6.26: Percentage of farmers depending on either farm or both off farm and farm employment

type of employment	farms with erosion	farms without erosion
farm employment	75.2	11.8
off farm & farm employment	24.1	87.1

Source: Author

A large computed Chi-square value of 55.8 and a small critical value of 6.64 indicated that there was a significant difference in the severity of soil erosion between farms whose owners depended solely on farm employment and those who depended on both farm and off farm employment. Only 11.8% and 88.2% of the 34 farmers whose farms did not suffer severe soil erosion had farm and both off farm and farm employment, respectively (Table 6.27). On the other hand 75.2% and 24.8% of the 266 of the farmers whose farms suffered severe soil erosion had both farm and off farm employment, respectively. The implication was that the employment of the head of the household both in the farm and off the farm earned him an additional source of income, which improved his financial status. While the former group of farmers depended on two sources of income, both off farm and farm, the latter category relied entirely on on-farm incomes which were more often than not low due to low crop yields and poor marketing policies.

Table 6.27: Signs of soil erosion and type of employment

signs of erosion	farm employment	both farm and off farm employment	row total
less severe	4 11.8 2	30 88.2 31.3	34 11.3
severe	200 75.2 98	66 24.8 68.8	266 88.7
column total	204 68	96 32	300 100

Chi-square = 55.8; df = 1

Source: Author

The above argument was further justified by comparing the farmers level of incomes to the severity of soil erosion. A large computed Chi-square value of 22.8 and a small critical value of 9.21 (Table 6.15) indicated that a significant difference in the level of incomes existed between the farmers whose farms suffered or did not suffer severe soil erosion. The results indicated that 52.5% and 5.1% of the 59 farmers whose farms suffered from severe soil erosion had low incomes (≤ Kshs 1800) and high incomes (≥ Kshs 5,000), respectively (Table 6.28).

Table 6.28: Signs of soil erosion by income (Kshs)

signs of erosion	≤1,800	1,801 - 5,000	≥5,000	row total
less severe	3 10 8.8	16 53.3 39	11 36.7 78.6	30 33.7
severe	31 52.5 91.2	25 42.4 60.9	3 5.1 21.4	59 66.3
column total	34 38.2	41 46.1	14 15.7	89 100

Chi-square = 22.8; df = 2; P = 9.21 missing cases = 211

Source: Author

Most of the respondents could be described as subsistence farmers who make the bulk of the rural population in the study area. They frequently failed to supply their resident members of families with adequate food let alone produce a surplus even when a favourable weather prevailed. These farmers explained that food yields were usually low due to poor soil fertility resulting from over cultivation and soil erosion.

The implication of low farm incomes was the inability of the farmers to invest in their farms. This appeared as a serious bottleneck to the development of the rural agricultural sector. For instance, (i) some of the farmers explained that they were unable to purchase essential farm tools such as the hoe, shovel, and the fork. Lack of these farm implements hindered 40.2 % of the farmers from participating effectively in soil conservation measures. About 47.7% of the farmers explained that they could not afford to hire farm labour to supplement family labour. They considered hiring farm labour quite costly. The hired labour costs between Kshs 700 to 1,500 per month (£ 7 to 15) or Kshs 25 to 40 per day (£ 0.2 to £ 0.4). This meant that low incomes were to a large extent contributed to the existence of the soil erosion problem in the catchment.

The above argument then, lends support to Dudals' (1981) and Thomas' (1991) contention that the first requirement for effective soil conservation is that the farmers income should be large to maintain soil and water conservation measures. Besides, the progrssive farmers have access to varied sources of information which also enhances their knowledge on soil conservation.

6.6 Conclusion

The results of this study revealed that soil erosion is a widespread problem in the study area. This was indicated by the fact that majority(88.7%) of the farmers in this study had farms that experienced a severe soil erosion problem. The Chi-square test results accurately reflect differences in the socio-economic aspects of the farmers and their varying responses to soil erosion problem.

The minority group of the farmers (11.3%) with well conserved farms are characterised by (i) relatively high incomes (ii) off farm employment (iii) relatively large farms (iv) high education and (v) access to extension officers. These farmers can be described as the "wealthy" or educated ones facing less constraints. Due to inadequacy of resources, the former group of farmers place an ever increasing demand on the few available resources that they control. Indeed, it is through their effort to subsist within the limited resources that these farmers introduced unstable changes in the agricultural land through environmentally unsound activities such as over-cultivation, deforestation, over grazing and use of marginal land.

On many occasions, the rural poor are blamed for land degradation and soil erosion problems (Clayton, 1964; Kelly, 1983; Blaikie, 1989 and Hauck, 1985). For instance, Hauck, (1985) states that " In general, the main cause of land degradation and soil erosion stem from indiscriminate human interference in the natural ecological balance, from abuse and mismanagement of the soil and water resources, and from trying to farm land beyond its capability." Further, Kelly, (1983) states that," It is not high wind or rain that is the cause of accelerated erosion..... it is the people who destroy the soil by demanding more from the land than it can provide. " As Blaikie, (1989) rightly puts it, researchers do not seek to understand and address the socio-economic problems that these people face. For example, due to increasing population pressure and inadequate land tenure system the "alternative" situation of the farmers will deteriorate further following continued land sub-division and unemployment. As a result, the long term viability of production systems are likely to be sacrificed to meet the immediate needs. Therefore, in order to sustain an environmentally sustainable rural development, the small scale subsistence producers must have the appropriate incentives to undertake those practices that serve to improve rather than to damage their resource base. To alleviate rural poverty, the Government should introduce policies that ensure sustainable livelihoods of the rural resource poor.

Therefore, according to the Chi-square results, the null hypothesis stated in chapter 2 that "there is no significant difference in socio-economic characteristics between farmers whose farms are experiencing less severe and severe soil erosion in the study area " is rejected. The majority of the investigated variables including farm size, level of education, extension service, level of incomes, and nature of employment were found significant at 0.01 probability level (Table 6.15). The implication is that there is a significant difference between farm size, level of education, availability of extension advice, level of income and nature of employment among farmers whose farms suffered or did not suffer severe soil erosion. The Chi-square results further show that there is not a significant difference between the (a) gender (b) age of the head of the household and (c) family size of the farmers whose farms suffered or did not suffer a severe soil erosion problem. Thus, the alternative hypothesis can be accepted in this form: that "there is a significant differrence in some socio-economic characteristics between farmers whose farms are experiencing less severe and severe soil erosion problem in the study area".

CHAPTER SEVEN

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

7.0 Introduction

This chapter contains a summary of the findings of the present study. The purpose of the summary is to give an insight into the nature and human-related causes of soil erosion in the study area. Measures geared towards improved land use for sustainable soil and water management of the Masinga Dam Catchment and other areas with similar environments for crop production are discussed.

7.1 Summary of the Findings and Conclusions

(a) Soil Losses

According to the results of the field data analysis, Accelerated soil erosion is a major environmental problem experienced in the study area. This was indicated by:

(i) the fact that majority of the sample population, 88.7% had farms that depicted severe signs of soil erosion. Only a minority of the farmers had farms that did not experience a severe soil erosion problem; and

(ii) the high amount of measured soil loss, 457.1 $t.ha^{-1}$ that occurred from the cultivated land in the Kaihungu sub-catchment during the Long Rain Season of 1992 is high considering that it was obtained during one rainy season. This is much higher than 12.5 $t.ha^{-1}yr^{-1}$ which is the acceptable level of soil loss in Central Africa and in other areas characterized by loamy soils derived from volcanic ash deposits. Such high levels of soil loss are likely to have serious land degradation effects, resulting to low farm yields. Thus, improved land management is imperative for the achievement of sustainable agriculture and food self-sufficiency.

(iii) the high soil erosion hazard, low soil resistance to water erosion and a low vegetation regeneration possibilities revealed by the land quality assessment results.

(b) Agronomic Practises

The Mann-Whitney U test results indicated that there was not a significant difference in the amount of soil loss between farms:

(i) under different crops and cropping patterns;

(ii) characterized by low and medium crop densities;

(iii) with well and poorly conserved physical measures; and

(iv) with high and low vegetation cover.

Thus, the general null hypothesis stated in section 1.4 that "there is not a significant difference in the amount of soil loss between farms under different agronomic practices" is accepted which was contrary to the researchers expectation. This state of affairs was, however, explained by the fact that none of the sample farmers practised a combination of all the required appropriate agronomic measures. For instance, some farms characterized by one or a few of the appropriate agronomic measures such as the use of manure and fertilizers, mulch, high crop densities, crop rotation, leaving land on fallow and adequate soil conservation measures yielded high amount of soil loss. This was attributed to the farmers inability to practice all the good agronomic measures. Therefore, it is important for farmers in the catchment to practise appropriate agronomic measures during all planting seasons. These should be used simultaneously because adopting one or a few good agronomic practices is not enough to arrest the soil erosion problem.

Indeed, poor agronomic practices prevailed in a large part of the catchment. These manifested by (i) inadequate use or lack of use of mulch, farm yard manure and fertilizers; (ii) reduced resistance to the agents of soil erosion; (iii) the dominance of low crop densities which were much lower than the standard densities recommended by Kenya Agricultural Research Institution (KARI) for such areas. (iv) A combination of low crop densities and low soil fertility resulted in poor establishment of crop cover. The latter was more serious in the food crop farms than in the coffee farms. Most of the food crops, 63.5% attained less than 30% of cover by the end of the Long Rain Season 1992. Therefore, the soils were not adequately protected from the impact of erosive rain drops; and (v) poorly maintained physical conservation measures. For instance, terracing and cut-off drains were the most common physical conservation measures practised in the study area. While many of the terraces were broken, a number of the cut-off drains were almost filled-up with silt. As a result, these conservation measures were unable to check the run-off particularly in the steeply sloping farms. Therefore, such structures need immediate repair so that they can effectively protect the agricultural land from further degradation.

In conclusion, these results show that poor agronomic practices adopted by majority of the farmers are, to a certain extent, to blame for the existence of the soil erosion problem in the study area. Further, it can be inferred from these results that good agronomic practices will slow down the process of soil erosion, lead to increased soil fertility and consequently result to high land productivity.

(c) Socio-economics

Third, the Chi-square results of this study showed that a large number of the farmers whose farms experienced severe soil erosion were characterized by numerous intricate socio-economic problems. This was revealed by the significant difference in (a) farm size; (b) level of education; (c) availability of extension advice;(d) level of farm income and (e) nature of employment between farms suffering from a severe or less soil erosion problem. The central argument here is that farmers who faced a resource constraint reflected by small farms, low levels of education, low farm incomes, lack of off-farm employment and lack of extension advice had farms that depicted serious soil erosion problems. This was largely because the available financial resources were utilized by the farmer to meet other more pressing household obligations such as shelter, clothing and education. Indeed, very little or none of the farmers financial resources were re-ploughed back for soil conservation measures and farm inputs.

The limited resources cause the farmers to introduce such unsustainable changes to the agricultural land as over-cultivation, deforestation, over-grazing and use of marginal land. Therefore, in order to ensure an environmentally sustainable rural development, these farmers must be given incentives to undertake those practices that serve to improve rather than to damage their resource base.

On the other hand, the results show that the few farmers whose farms did not suffer severe soil erosion were characterized by: (1) relatively high incomes; (2) off farm employment; (3) relatively large farms; (4) high education and (5) extension advice. These farmers can be described as "Wealthy", with less socio-economic constraints, unlike the resource poor ones.

Therefore, according to the chi-square results the general null hypothesis stated in section 1.3 that " there is no significant difference in socio-economic characteristics of farmers experiencing less severe and severe soil erosion in the study area" was partly rejected as majority of the investigated variables including; farm size, level of education, extension advice, level of incomes and nature of employment were found significant at 0.01 probability level.

The results further showed that there was not a significant difference in; gender, age of the head of the household and family size between farmers whose farms suffered or did not suffer from severe soil erosion. The implication was that the level of farm resources plays a key role in improved farm management for sustainable agriculture than the farmers age, gender and family size.

The Chi-square results also, showed that there was no significant difference in the number of farms experiencing or not experiencing severe soil erosion between the three agro-ecological zones namely; sub-humid, semi-humid and semi-arid zones. The number of farms affected by the soil erosion problem was uniformly high in the three different zones. This implied that soil erosion was a serious land management problem in the whole of the Masinga dam catchment.

7.2 Policy Implications And Guidelines For Sustainable Soil and Water Conservation.

The results of this study indicated the need to consider some important management issues in order to give the soil erosion problem a workable approach. This is essential if any sustainable land management is to be achieved. Thus, recommendations that could be used for improved land use hence less soil erosion and increased agricultural productivity are outlined in this section.

(a) Soil conservation benefits

The government should increase short and long term benefits to the rural small scale subsistence farmers in order to attract many of them to practise soil conservation. This can be done in the form of increased or more assured farm incomes. These can be realized by targeting at production oriented conservation activities geared towards increased yields per hectare. By so doing, the farmers will be able to satisfy their domestic food requirement, market the surplus and consequently boost their on-farm incomes. Some of these incomes could be re-invested to ensure soil conservation. This can be achieved by:

(i) subsidizing the prices of farm inputs to a level that the rural poor farmers can afford;

(ii) supplying the farmer with free fertilizers on completion of certain amount of conservation work or on the basis of the quality of the maintenance of existing conservation structures;

(iii) increasing agricultural commodity prices. This would encourage farmers to use their small farms more intensively through the application of farm inputs and adoption of appropriate technology. This may be particularly important to the subsistence farmers since as the threat to survival is reduced and the constraints on resources eased, a switch to more sustainable agricultural practices may be possible.

(iv) removal of food marketing restrictions as well as opening up of new market outlets so that farmers are assured of selling their farm produce.

(b) Involvement of the Land Users in all Soil Conservation Projects

It is essential to involve the farmers who are the land users in all the soil conservation programs. This is important because land users make decisions independently about land use and management, responding particularly to the immediate social and economic pressures. Indeed, the severity of soil erosion in an area is closely related to the physical characteristics of the area, the decisions made by the land users and the nature of the socio-economic pressures under which the decisions are made. Thus, conservationists are likely to achieve greater success in promoting non degrading land use systems by working in conjunction with the farmers. This will enable the planners to appreciate what the farmer wants to do or can be persuaded to do with his land. This can be done by explaining to him the objectives of the programs and seeking ideas from him which can be incorporated in the program.

(c) Increase the Mobility of The Agricultural Extension Officers

It was observed that most of the agricultural extension officers lacked transport to visit farmers in their farms. The government, through the Ministry of Agriculture and Livestock Marketing should ensure that the field extension officers are equipped with suitable and well maintained vehicles to enable them to reach as many farmers as possible.

(d) Reduce Population Growth By Increasing Family Planning Awareness

Rapid population growth exacerbates social and economic problems resulting in a population-resource imbalance. This leads to congestion and additional pressure on the available agricultural land and manifests itself in: excessive farm fragmentation, landlessness, use of the fragile marginal areas, over-grazing and deforestation. The result of these population-land related problems is serious land degradation and disturbance of the hydrological cycle, especially in the water catchment areas. Further, with a rapidly growing population, a large share of the individual household and national resources will be increasingly devoted to the needs of the unemployed population. This will not only take away gains in standards of living at both family and national levels but will also make it difficult for a large section of the population to meet their basic needs. A society faced with numerous socio-economic problems emanating from population explosion is less likely to invest on agricultural development. In such a situation, soil conservation might not be accorded any meaningful attention.

In order to eliminate or minimise population related problems, family planning programs should be introduced in all areas within study area.

7.3 Areas For Further Research

Research is urgently required into the following areas;

(a) The magnitude and extent of soil erosion emanating from bare grounds: Footpaths and other open grounds could be an important source of the sediments discharged into the dams and reservoirs in this catchment through rivers Kaihungu and Maragua among others. Therefore, there is need to monitor and assess the amount of soil loss originating from them. This would enable scientists to identify the major source of sediments discharged into the reservoir and dams in the study area.

(b) Soil erosion in the Semi-arid areas of the Catchment

There is need to investigate the cause and rate of soil erosion currently occurring in the semi-arid areas within the Masinga Dam Catchment. This is important because the extensive stony lateritic surface appearing in large portions of these areas is indicative of declining agricultural productivity. The upper horizon has already been removed through the soil erosion processes leaving behind a hard lateritic surface. The latter is not only resistant to the impact of the erosive rain drops but is also highly unproductive. The results could be used in designing methods of rehabilitating these "badlands".

(c) Soil erosion in the entire Catchment

There is need to monitor annual soil loss in the entire catchment for a period of 5-10 years. First, such a study would show the trend of soil erosion in the catchment. Second, the geographical areas contributing most significantly to sediment discharge into Masinga Dam Catchment would be highlighted. Consequently, ways of minimizing the rate of soil erosion in the identified high risk areas would be devised.

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APPENDIX A-1

SOIL EROSION IN THE MASINGA DAM CATCHMENT
A SOCIO-ECONOMIC SURVEY

Good morning/ Afternoon. I am a researcher from Kenyatta University conducting a soil erosion study in Masinga dam catchment. To carry out this work I need information on a sample of farms and families. This information will be used in the preparation of better soil and water conservation programs. Such programs will be used to advise farmers on how to improve farms productivity. The information provided by you will be treated strictly confidentially.

Date:.......................... Time:

Start....................

End ....

1. Cropping zone...... (i) humid zone

   (ii) sub-humid zone

   (iii) semi-arid zone

2. Is the head of the household?

(i) male ......(ii) female........

3. What is the age of the head of the household?..........

4. What is the size of this family?...........

5. How many years did you spent in school?

   (i) 0-8 years

   (ii) 9-14 years

   (iii) 15 and above

6. What is the size of this farm?

(i) 0.01 - 3.00 acres

(ii) 3.1 - 6.00 acres

(iii 6.1 - 9.00 acres

(iv) 9 and above

7. How did you acquire this land?

(i) inheritance

(ii) purchase

(iii) other means (specify)

8. Do you have other pieces of land elsewhere? IF NO, GO TO Q10

if yes, how many are they?

(i) 1 - 2

(ii) 3 - 4

(iii) 5 - 6

(iv) 7 and above

9. What is the total size of those other farms?

(i) 0.01 - 3.00 acres

(ii) 3.1 - 6.00 acres

(iii) 6.1 - 9.00 acres

(iv) 9 and above

10. What crops do you normally grow?

maize	cotton
bean	coffee
millet/sorghum	bananas
pigeon peas	english potatoes

sweet potatoes fruits (Specify)

others (specify)

11. Do you sell any of the food? Yes .. no..

12. (i) In your own assessment, are crop yields:

(i) increasing

(ii) decreasing

(iii) not changing

(ii) Give reasons for 12 (i)

....

....

....

....

13. Under which of the following cropping patterns do you plant your crops:

(i) monocropping

(ii) intercropping

14. (i) Which one of the above cropping patterns is most preferred? ....

(ii) give reasons for 14(i)

....

....

....

15. What is the source of your income?

(i) on-farm

(ii) off-farm and on-farm

16. If on farm income is earned, how much is it per

season?

(i) less than or equal Kshs 1,800.00

(ii) Kshs 1,801.00 - Kshs 5,000.00

(iii) Kshs 5,001 and above

17. If off-farm income is earned, how much is it per month (including income earned by other members of this family)?

(i) less than or equal to Kshs 1,800.00

(ii) Ksh 1,801.00 - Kshs 5,000.00

(iii) Kshs 5,001.00 and above

18. Have you ever applied for credit from any credit institution? Yes... No.... If No, Why?

....

19. How is the family income spent?

purchase of foodstuff

animal feed

school fees

clothing

farm inputs: (fertilizer... seeds... ploughing...labor...)

others (specify)

20. Have you noticed any signs of soil erosion in your farm?

IF NO, GO TO Q 22. IF YES, in which of the following farm areas is it most severe?

(i) food crop farms

(ii) coffee farms

(iii) grazing areas

(iv) footpaths

(v) farm boundaries

21. What do you think is the cause of soil erosion in your farm?

....

....

....

....

....

....

....

22. Do you practice any soil conservation measures?

Yes .... No......Partially.........

IF No or Partially please give reasons

....

....

....

....

If Yes and Partially, which of the following soil conservation measures do you practice?

contour farming...

terracing.........

crop rotation.....

mulching..........

manure...........

fallowing........

fertilizing.......

strip cropping....

cut-off drains....

others (specify)..

23. How many times has someone from the government visited this farm to give advise on soil conservation measures during the last two rain seasons?

(i) never

(ii) 1 - 2

(iii) 3 - 4

(iv) 5 and above

24. Do you have other sources of soil conservation information? IF YES, name them

....

....

....

....

25. Do you own livestock? (IF NO, there are no more questions for you. **THANK YOU. IF YES**, (i) what type, (ii) how many are they?

type of livestock	number of livestock
cattle	
goats	
sheep	
donkeys	

26. Where are the livestock watered?

(i) on the farm

(ii) at the river

(iii) both

27. Where do the livestock feed?

(i) completely stall fed

(ii) bush

(iii) stall fed plus occasional grazing

28. If stall fed plus occasional grazing where do they graze when they are taken outside their stalls?

river-side

roadside

on crop residue

others (specify)

INTERVIEWER'S OBSERVATION

29. Identify ground slope

(i) flat

(ii) Gentle (4^{o} - 15^{o})

(iii) steep (16^{o} - 40^{o})

(iv) very steep (more than 40^{o})

(v) changing from steep to gentle

30. (i) Is there any observable sign of soil

erosion?

(ii) **IF YES**, estimate whether the farm is less severely or severely eroded

Method of assessing the severity of soil erosion

Area of observation	Qualitative assessement	Numeric weighting
food crop plots	less severe erosion	1
coffee plots		
pasture areas		
farm boundary	severe erosion	2
homestead compounds		
footpaths		

31. Are marginal lands cultivated? Yes ... no ....

APPENDIX A-2 CRTITICAL VALUES OF CHI-SQUARE TEST

df	0.10	0.05	0.01	0.001
1	2.71	3.84	6.64	10.83
2	4.60	5.99	9.21	13.82
3	6.25	7.82	11.34	16.27
4	7.78	9.49	13.28	18.46
5	9.24	11.07	15.09	20.52
6	10.64	12.59	16.81	22.46
7	12.02	14.07	18.48	24.32
8	13.36	15.51	20.09	26.12
9	14.68	16.92	21.67	27.88
10	15.99	18.31	23.21	29.59
11	17.28	19.68	24.72	32.26
12	18.55	21.03	26.22	32.91
13	19.81	22.36	27.69	34.53
14	21.06	23.68	29.14	36.12
15	22.31	25.00	30.58	37.70
16	23.54	26.30	32.00	39.29
17	24.77	27.59	33.41	40.75
18	25.99	28.87	34.80	42.31
19	27.20	30.14	36.19	43.82
20	28.41	31.41	37.57	45.32
21	29.62	31.41	38.93	46.80
22	30.81	33.67	40.29	48.27
23	32.01	35.17	42.64	49.73
24	33.20	36.42	42.98	51.18
25	34.38	37.65	44.31	52.62
26	35.56	38.88	45.64	54.05
27	36.74	40.11	46.96	55.48
28	37.92	41.34	48.28	56.89
29	39.09	42.34	49.59	58.30
30	40.26	43.77	50.89	59.70

Source: Ebdon, 1985.

Critical Values of U for a One-Tailed Test at the 0.05 Significance Level or a Two-Tailed Test at the 0.1 Level

n_x \ n_y	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1																			0	0
2					0	0	0	1	1	1	1	2	2	2	3	3	3	4	4	4
3					1	2	2	3	3	4	5	5	6	7	7	8	9	9	10	11
4				1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18
5		0	1	2	4	5	6	8	9	11	12	13	15	16	18	19	20	22	23	25
6		0	2	3	5	7	8	10	12	14	16	17	19	21	23	25	26	28	30	32
7		0	2	4	6	8	11	13	15	17	19	21	24	26	28	30	33	35	37	39
8		1	3	5	8	10	13	15	18	20	23	26	28	31	33	36	39	41	44	47
9		1	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54
10		1	4	7	11	14	17	20	24	27	31	34	37	41	44	48	51	55	58	62
11		1	5	8	12	16	19	23	27	31	34	38	42	46	50	54	57	61	65	69
12		2	5	9	13	17	21	26	30	34	38	42	47	51	55	60	64	68	72	77
13		2	6	10	15	19	24	28	33	37	42	47	51	56	61	65	70	75	80	84
14		2	7	11	16	21	26	31	36	41	46	51	56	61	66	71	77	82	87	92
15		3	7	12	18	23	28	33	39	44	50	55	61	66	72	77	83	88	94	100
16		3	8	14	19	25	30	36	42	48	54	60	65	71	77	83	89	95	101	107
17		3	9	15	20	26	33	39	45	51	57	64	70	77	83	89	96	102	109	115
18		4	9	16	22	28	35	41	48	55	61	68	75	82	88	95	102	109	116	123
19	0	4	10	17	23	30	37	44	51	58	65	72	80	87	94	101	109	116	123	130
20	0	4	11	18	25	32	39	47	54	62	69	77	84	92	100	107	115	123	130	138

ect H_0 if calculated value of U is **less than or equal to** critical value at chosen significance level.

APPENDIX 4

Land quality rating procedure

Soil erosion hazard assessment

Slope factor

Slope Length (M)	(r1) slope angle (%) 0-2	2-5	5-8	8-16	(r2)		(r3)
					1	>70	I-II
<50	1	1	3	3	2	50-70	III-IV
50-100	1	3	3	5	4	20-49	V
100-200	1	3	5	5	7	<20	VI-VII
>200	3	5	5	7			

r1-Slope factor r2- vegetation cover r3 Agro-climatic zones(AEZ)

Soil resistance

	r1	r2
1	>3	<0.2
2	1-2	0.2-0.4
3	<1	>0.4

r1 -%C r2-silt to clay ratio

Vegetation regeneration possibilities

	r1	r2	r3	r4	r5	r6	r7
1	6.6-7.3	>3	I-II	>60	>75	>40	>25
2	6.1-6.5	1-2	III-IV	20-60	25-75	10-40	5-25
3	5.6-6.0	<1	V	<20	0-25	0-10	0-5
4	5.1-5.5		VI-VII				
5	4.5-5.0						
6	<4.5						

r1-pH r2- %C r3- AEZ r4- Available Pppm r5-Ca meq(%) r6- Mg meq(%) r6- K meq(%)