LAND DEGRADATION IN REFUGEES SETTLEMENT AREAS; A CASE OF ULYANKULU, URAMBO DISTRICT, TABORA REGION, TANZANIA.

BY

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DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCIENCE IN LAND USE PLANNING AND MANAGEMENT OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2009

ABSTRACT

The study was carried out in Ulyankulu refugee's settlement, Urambo district, Tabora region. The district is among the districts with the oldest refugees settlements in Tanzania. It is also among leading districts producing tobacco crop in the country. A review of available literature provides some evidence of land degradation in refugee accommodating areas. The country has become more sensitive to the potential economic loss due to environmental damage once refugees are repatriated. This study assessed the extent and trend of land degradation particularly vegetation and soil degradation, and it identified the socio-economic factors influencing land degradation. Aerial photographs, satellite imagery, topographic maps, soils map and questionnaire were used during the study. Soil sample analysis was done to determine the trend of soil fertility. Questionnaire survey was conducted to collect information on socio-economic activities responsible for land degradation and the data were analysed using SPSS software. The results revealed that about 85% of the woodland area degraded during the period from 1978 to 2006 period at a rate of 3.0% per year. Forest was degraded to about 100%. The area with soil erosion above tolerance level was increased from 3.4% in 1978 to 5.9% in 2006. The status of nutrient level particularly nitrogen, organic carbon, phosphorous and level of pH varies between the study periods. Farming practices, agricultural land expansion and firewood collection for domestic use and curing of tobacco were among major factors influencing the land degradation observed in the study area. Human population dynamics, education level, farming systems practices were also found to contribute on soil degradation. It is recommended that government and other agencies sensitize and involve refugee's community in all stages of natural resources

utilization planning and management and they assess the land capability of the refugee's settlement areas.

DECLARATION

I, KIMAMBA HERMAN LYOBA, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has not been nor concurrently being submitted for a higher degree award in any other University.

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DEDICATION

I dedicate this Master's dissertation to my lovely father Mr Michael Lyoba. May God rest his soul in peace. Also to my wife Theresia Lyoba and my children for their tolerance for my long absence from home for the entire study period.

ACKNOWLEDGEMENT

In pursuit of this work a number of people have directly or indirectly assisted towards the successful completion of this dissertation. It is not possible to mention each one by name, but I wish to express my sincere gratitude to them all. For special thanks I wish to express my sincere thanks to my supervisors Dr B. P. Mbilinyi and Dr M. K. Mulengera first for accepting me as their student and for their tireless supervision, guidance and encouragement which paved a way to the fulfilment of my research work.

I wish to extend grateful acknowledgement to the Permanent Secretary, of the Ministry of Agriculture, Food security and Co-operative whose sponsorship made it possible for me to be at SUA for the Postgraduate studies. I would also like to gratefully acknowledge the staff of Agricultural Land use Planning Department of the Ministry of Agriculture, Food Security and Co-operative for their empathy, encouragement and sincere interest in my study. I wish also to thank the Director of Refugee Services at the Ministry of Home Affairs for granting me a resident permit and permission to conduct research in the Ulyankulu refugees settlement area.

I am very grateful to Professor N.I. Kihupi Head of Department, for administrative support, and Professor A.K.P.R. Tarimo, the Postgraduate Co-ordinator and the entire academic and none academic staff of the Department of Agricultural Engineering and Land Planning, and my fellow postgraduate students, whose advice, consultation and cordial hospitality made my academic potential useful. A special

mention goes out to Mr Vedast Makota and Mr Rudovic Kashaga who assisted me in remote sensing analysis and other GIS manipulation operations.

I would like to extend my gratitude to my field assistants in Ulyankulu refugee settlement area who served as guides, enumerators and translators, the help they rendered is sincerely acknowledged. A special mention goes to the Settlement Commandant, who allowed and assisted me in all matters of research work in the settlement, local and refugees' communities, local leaders, government agents and non government organizations that devoted their time to respond to continuous interviews and their cooperation shall always be remembered

Finally I want to make a special note to my wife, Theresia, for being ready to endure the loneliness during my absence at home for studies. Her earnest prayers, encouragement and wise handling of family matters on my behalf were a working force behind my success. My thanks may also go to my children; Gedrudes, Felister, Michael, Veronica and Rosemary for tolerance of my long absence from home and their lovely prayers, encouraging words and observance of silence at home which made me study peacefully.

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LIST OF ABBREVIATIONS AND SYMBOLS

DEM	Digital Elevation Module
DRC	Democratic Republic of Congo
ETM	Enhasment Thematic Mapper
FAO	Food and Agriculture Organization
GIS	Geographical Information Systems
HADO	Hifadhi Ardhi Dodoma
K	Soil Erodibility
KE	Kinetic Energy
LS	slope length
LULC	Land Use/ Land Cover
NW-SE	North West-South East
PRA	Participatory Rural Appraisal
R	Rainfall Erosivity
RGB	Red, Green, Blue
RUSLE	Revised Universal Soil Loss Equation
SI	International System
SIDA	Swedish International Development Agency
SOM	Soil Organic Matter
SPSS	Statistical Package for Social Science
SSA	Sub-Saharan Africa
SUA	Sokoine University of Agriculture
TIFF	Tag Image File Format
TM	Thematic Mapper
UN	United Nations

UNEP	United Nations Environment Programme
UNHCR	United Nations High Commission for Refugees
URT	United Republic of Tanzania
USLE	Universal Soil Loss Equation
UTM	Universal Transformation Marcator
WRI	World Resources Institute

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

The most important natural resource, upon which all human activity is based since time immemorial, is land. Land, as employed in land evaluation, land use planning, etc., has a wider meaning than just soil. It refers to all natural resources which contribute to agricultural production and forests. Land thus covers climate and water resources, landform, soils and vegetation, including both grassland resources and forests (FAO, 1976). Land degradation has been defined in different ways but a more comprehensive definition describes it , as the aggregate diminution of the productive potential of the land, including its major uses (rainfed, arable, irrigated, range land, forest), its farming system (e.g. small holder subsistence) and its values as economic resource (Stocking and Murnaghan, 2001).

The land can be viewed as a component of ecosystem interacting with many other components to create a dynamic balance within certain limits. Man can influence the balance when in need of production. Within certain limits, ecosystems can sustain pressure caused by this influence and not degrade. Should the pressure be continuous, however, the ecosystem supporting power will be overloaded and there will be on-site and offsite forms of degradation.

Land degradation is one of the world's major socio-economic and environmental problems, affecting one billion people in 110 countries worldwide and is prevalent across about 40 per cent of the Earth's surface (UNEP, 1997). It involves the processes and end results of both vegetation and soil degradation due to

anthropological factors such as population increase, change of land use activities, overgrazing and can also occur as a result of natural factors such as tectonic processes and climate change (Darkon, 2003). The importance of land degradation in global issues is enhanced because of its impact on world food security and quality of the environment (Eswaran and Reich, 2001).

Rapid population growth is among the social-economic causes of land degradation, which has been singled out to be the principal cause of this critical environmental catastrophe (SIDA, 1993). It has been established that excessive growth of human population on an ecological area, directly exerts pressure and stress on limited land resources (Jodi, 1993). Following this population increase, demands for sufficient food production and other basic needs, including firewood, water and settlements have correspondingly been increasing.

The environmental changes generated by mass population displacements have critical implication not only for well-being of the refugees themselves, but also for their relationship with the host country, and for the development potential of the areas where they settle (Low, 1994). A review of available literature provides some evidence of land degradation in refugee-affected areas, although the reliability of this evidence varies considerably (Black, 1993). Cote d'Ivoire and the Democratic Republic of the Congo experience higher levels of habitat loss each year through uncontrolled logging and clearance of land for agriculture by refugees. It is noted that about 2900 and 1800, square kilometres of forest were respectively cleared per annum in the countries (UNHCR, 2004). In Somalia, Young (1985) noted destruction

of woodland surrounding refugee settlements. Wilson (1985) identified loss of woodland around Mozambican refugee settlements in Malawi. In Tanzania, it was revealed that about 570 square kilometres of forest was affected, of which 167 square kilometres was severely deforested (Black, 1993) during the influx of refugees from Rwanda in 1994.

Many refugee camps are now surrounded by vast stretches of barren-land, and host countries have become more sensitive to the potential economic loss they may suffer, due to environmental damage caused by large concentrations of refugees, as well as the lack of a consistent policy covering the rehabilitation of the damaged areas once refugees are repatriated.

Soil erosion by water and vegetation degradation is the most devastating types of land degradation found in refugee's settlement areas; others are water deterioration and fertility decline. The study of temporal and spatial distribution of soil erosion and vegetation degradation are important in establishing areas of different degree of land degradation, to which different management practices can be applied. In many developing countries, including Tanzania, very few studies have been so far conducted using soil erosion model and remote sensing in the GIS environment in estimating the extent and rate of land degradation. Most of the current methods in environment-related monitoring are centralized, labour intensive and expensive (UNEP, 2005). It is an attempt of this study to apply soil erosion model and remote sensing in the GIS environment as tools to provide information towards halting further land degradation processes.

1.2 Problem statement and Justification

In Tanzania, land degradation affects the majority of the people, and is a major problem in the dryland areas as well as refugees impacted areas (URT, 2001). Parts of country affected severely by land degradation are the semi-arid areas including, Dodoma, Shinyanga, Singida, Tabora, Manyara and some parts of Arusha, Mbeya, Iringa and Morogoro regions. Various accounts have been given to the reasons of this degradation; human activities including, overstocking of livestock, encroachment of marginal areas, extensive bush clearing for cultivation and inappropriate land use practices are reported to have contributed to land degradation (Payton *et al.*, 1992). For many researchers land degradation is basically a function of rapid population increase especially in the poorest countries of the world, Tanzania inclusive. These people usually depend on the available natural resources for their survival.

Tanzania has been hosting refugees for almost 45 years since its independence. At the end of 2002, the country has hosted one of Africa's largest refugee populations, approximately 520 000, including more than 370 000 from Burundi, some 140 000 from DRC, about 3000 from Somalia and fewer than 3000 from Rwanda. Also it hosted 300 000 to 470 000 Burundians who resided in western Tanzania in refugee-like circumstances without official refugee status (UNHCR, 2004). Refugees were welcomed on humanitarian grounds assuming that they would return to their countries of origin as soon as peace and security were restored in their respective nations. The support refugees are getting does not sustain their livelihood and are mostly relying on their surrounding natural resources. Initially, the refugee problem seemed to be temporary and therefore received little attention as a result no serious

analysis was made on how refugees could harm the environment. Limited studies have been made to determine the magnitude on land degradation particularly vegetation and soil degradation in refugee settlement areas (UNEP, 2005). In order to select appropriate conservation measures and land management strategies, the identification and analysis of erosion sources is necessary (Dicknson and Collins, 1998).

Ulyankulu refugee's settlement in Urambo district, Tabora region is among the earliest refugees settlement in the country. Others are Katumba and Mishamo in Mpanda district. The settlement was established in early 1970s during the major influx of Burundian Hutu refugees following massacres in Burundi (Stein, 1990). It was located within Ulyankulu local authority forest reserve and Igombe forest reserve. Their main economic activities are agriculture, livestock keeping, logging, beekeeping and petty trades. The refugee settlement is an important agricultural area of Urambo district since the government of Tanzania allowed the refugees to be involved in agricultural production. The district is one of the leading flue-cured tobacco production in Tanzania; others are Sikonge and Uyui in Tabora region together producing about 68% of flue cured tobacco in Tanzania (Waluye, 1994). Currently the settlement supports about 60 000 refugees. The area faced problems of vegetation degradation particularly forest and woodland, shortage of water during dry season, encroachment of forest reserve surrounding the settlement, fuel-wood for domestic consumption and tobacco curing. According to Hof *et al.* (1980) by 1980 there were an indication of rill and gully erosion on the roads, within footpaths and farmer's fields especially on lower part of isolated steep hill slopes, foot slopes and upland plain.

The purpose of this study is therefore to provide essential information on extent and trend of land degradation, particularly vegetation and soil degradation in the refugee's settlement areas. The results from the study will enable the government, implementing agencies and other stakeholders to acquire detailed, reliable and up to date information for sound land use planning and environmental management of refugee settlements areas. This will also help the extension agents and policy makers to recognize the relative severity of degradation in a given locality to prioritise and suggest appropriate soil management strategies in accordance with the level of hazard.

1.3 Research objectives

1.3.1 General objective

The general objective of the study is to determine the extent and trend of land degradation in refugee's settlement areas, Urambo district, Tabora region, Tanzania.

1.3.2 Specific objectives

The specific objectives of the study are to:

- Determine the current land use/cover distribution patterns in the Ulyankulu refugee settlement and surrounding areas.
- Determine the spatial and temporal change of land degradation in the refugee settlement
- To identify socio-economic factors influencing land degradation in a study area

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Land degradation

Land degradation is a massive, global environmental problem (FAO/UNEP, 1995; Scherr, 1995). It refers to deterioration in the physical, chemical, and biological characteristics of soil, and the long-term loss of natural vegetation (UNEP, 1992). Its main manifestation include decrease in land productivity, decline in land output potential, loss of land resources, and emergence of surface conditions unfavourable for production (Zhu, 1994).

FAO/UNEP (1995) reported that degraded lands worldwide include 5.8 million km^2 degraded by deforestation - mainly for agricultural production, 6.8 million km^2 degraded by overgrazing, 1.37 million km^2 degraded for firewood, 5.5 million km^2 degraded by agricultural mismanagement (as a result of wind and water erosion; salinization and water logging; and soil nutrient loss), and 0.195 million km^2 degraded by industry and urbanization. Thus, overall, about 18.1 million km^2 of land (92% of total degraded land) has been degraded as a result of agriculture, with 32% of it due to deforestation, 30% to mismanagement and 38% due to overgrazing.

Land degradation has diverse effects on individual farmers, local communities, society, economic activity, and the environment (Brown and Wolf, 1984). Classification, evaluation, and mapping of degraded land are a major issue throughout the world. Some methods to evaluate degraded land have been proposed (Scoging, 1993). Remote sensing and GIS techniques have been widely applied to

identify and characterizes degraded land and monitor the trends of degraded land. However, due to the lack of awareness and information about the environmental state, different physical and social backgrounds, no satisfactory evaluation system for degraded land has been adapted to the specific characteristics of each ecosystem (Rubio, 1998). There are a number of interrelated land degradation components, all of which may contribute to a decline in agricultural production. The most important are soil degradation, vegetation degradation, water degradation, climate deterioration and losses to urban/industrial development (Douglas, 1994). For the purpose of this study, the following are the most important in the area, namely soil degradation and degradation of vegetation cover, which is crucial to any real effort to ensure productivity, food security and environmental sustainability.

2.1.1 Vegetation degradation

Vegetation degradation is defined as the deterioration of the healthy conditions of the vegetation, expressed through changes in its composition, structure and function (Michael and Vicksburg, 2006). Vegetation degradation, unlike deforestation, is not a very obvious phenomenon. The changes occur gradually, sometimes not in terms of decrease of area, but represented by qualitative losses, for example, through the reduction of species diversity, increase of invasive species, decrease of the shrub layer, reduction of woody species and biomass decline. Most of the vegetation degradation research has been directed at arid landscapes associated with land degradation, desertification and soil erosion processes (Michael and Vicksburg, 2006) or at degradation of temperate and tropical forests.

The process of deforestation is a very important form of land degradation. It is a major contributing factor to soil degradation particularly with regard to soil erosion and loss of organic matter (Douglas, 1994). Vegetation is the buffer between soil surface and the processes that can cause degradation by soil displacement. Once vegetations of various types have been removed, several factors come into play in destroying the soil mantle, which is the precursor to desertification. The extent of degradation of vegetation followed by degradation of natural resources in general is of great concern and has a direct implication to the development and livelihood of mankind.

The effects of vegetation removal are more complex. The direct effect is a reduction in inputs of litter and root biomass. Indirectly, however, forests generally get rid of more heat through evapotranspiration from the warming effect of the sun than do bare soil or grassland. Removal of large areas of forest could sufficiently alter the albedo to reflect regional, and possibly global heat flux, i.e. altered reflection of solar radiation from the area could be enough to change air mass movements (Rinos *et al.*, 2001). However, if clearance is of at least medium size, say more than 100 km^2 there may well be a downwind effect, for example, Mann (1987) note signs of climatic change in the Gambia after extensive clearance of forest.

Socio-economic and political forces that determine the mode of development in many developing countries have played an important role in the processes of vegetation degradation (Mather, 1992). Population pressure has been frequently suggested as one of the major causes of environmental degradation in developing

countries (Babu and Hassan, 1995). Various forms of population growth either by migration/ refugees/ natural population increase have significant effect on the sustainable use of these resources. Man influences the vegetation by land clearing in shifting cultivation through requirements of food and other agricultural products. Also cutting trees for house-building, fencing and fuel, use of fire for hunting and stimulating new grass for domestic stock, all these influence vegetation degradation. Another feature of population dynamics plays an important role, namely urbanization. A first effect arises from population concentration, which makes the impacts on resources felt acutely over peripheral zone which typically suffers disproportionately from deforestation. A second effect arises from changes in habits: Urban dwellers frequently prefer charcoal to wood; this increases the impact on wood resources per consumption unit. Overall, population pressure is a determinant factor in vegetation loss especially in areas with limited land reserves and energy resource abuse (Babu and Hassan, 1995).

Most of the vegetation degradation research has been directed at arid landscapes associated with land degradation, desertification and soil erosion processes (Bridges and Bakker, 2001; Kebrom and Hedlund, 2000). Eswaran and Reich (2001) mentioned the need for establishment of distinct criteria for evaluating vegetation degradation. The author argued that the overlap between vegetation and land degradation is associated with conceptual similarities, since both processes may imply reduction of biomass, decrease in species diversity, or decline in nutritional value for livestock and wildlife. The situation has generated studies that combine vegetation degradation with other processes, such as, soil erosion.

There are various methods of vegetation degradation assessment carried out by various researchers, but most of these methodologies are used according to the vegetation assessment objectives. It has been proposed in different researches, that the vegetation cover is the core indicator of desertification and degradation processes. Vegetation dynamics can be assessed through field surveys, remote sensing and even informed opinions. (Gibson, 2000). The differentiation of vegetation variability due to natural and anthropological factors is then attained by determining the trend of vegetation changes through change detection processes. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Essentially, it involves the ability to quantify temporal effects using multitemporal data sets (Singh, 1989). Many change detection methods have been developed and used for various applications. However, these are broadly divided into; post classification, and spectral change detection approaches (Lunetta *et al.*, 2002; Singh, 1989).

Post classification is among the most widely applied techniques for change detection purpose. Numerous studies have been carried out using post-classification approach. In this approach, two images from different dates are classified and labelled. The area of change is then extracted through the direct comparison of the classification results (Lumetta and Elvidge, 1999). Two types of vegetation trends can be determined, namely areas that show continuous reduction in vegetation cover over the specified periods, and those areas that show vegetation loss followed by recovery over the monitoring periods. The principal advantages of the post-classification include; detailed 'from-to' information (Chen, 2000). It bypasses the difficulties

associated with the analysis of images acquired at different time of year or sensor (Chen, 2000). The main disadvantage of the post-classification approach is the dependency of the land cover change results on the individual classification accuracies. Therefore it is imperative that the individual classification be as accurate as possible (Chen, 2000). For the purpose of this study the post-classification approach was used to determine the land use/cover changes. These changes were categorised as degradation based on overall loss or decrease in vegetation cover over the study period (FAO, 1993; Kiunsi and Meadows, 2006).

2.1.2 Soil degradation

Soil degradation is defined as the decline in the productive capacity of the soil as the result of soil erosion and changes in the biological, chemical and physical properties of the soil (Douglas, 1994; Young, 1998). The physical degradation is caused by processes like soil erosion, compaction, and laterization. Chemical soil degradation is related to processes which reduce the fertility of the soil or accumulation of toxic chemicals. Other important processes are acidification and salinization. Biological soil degradation may be due to decline in soil organic matter or changes in the macro and micro fauna (Johnson, 1986). This study will deal with two categories of soil degradation processes, namely, soil erosion by water and fertility decline.

2.1.2.1 Soil erosion

Soil erosion is one of the most important and challenging problems facing farmers and natural resources managers worldwide (Lal, 1995). It is defined as the removal of top soil (both soluble and insoluble materials) by various agents, including water flowing over and through the soil profile, wind and gravitational pull (Nill *et al.*,

1996). The erosion process involves the detachment and transport of sediments in particular, silt, sand, clay and organic matter and solutes, from one place to another (Morgan, 1988). These processes are generally determined by locational factors including climate, soil, relief, vegetation and man made soil conservation measures. Soil erosion has adverse effects on agricultural land, range land as well as public infrastructure such as roads, bridges, houses, canals and reservoirs and can be a disaster to the ecology of water resources.

Water erosion is one of the most serious forms of soil erosion in the world (Sohan and Lal, 2001). The processes of water erosion comprise: splash erosion, sheet erosion, rill and gully erosion. Splash erosion occurs when raindrops fall onto the bare soil surface, detach and transport soil particles as a result of the impact of falling raindrops. Sheet or interrill erosion, occurs when soil particles are removed from the whole soil surface on a fairly uniform basis in thin layers and are caused by the combined effects of splash erosion and surface runoff. Rill and gully erosion may result when the runoff becomes concentrated into channels. Rills are small rivulets, in such that they can be worked over with farm machinery. Gully erosion occurs when the flow concentration becomes large and the rills incision becomes deeper and wider (Douglas, 1994).

Water erosion is categorized as the most serious environmental problem because it threatens agriculture and the natural environment (Pimentel *et al.*, 1995). Erosion degrades soil by removing topsoil, decreasing plant nutrients, rooting depth and water reserve. It generates strong environmental impacts and high economic costs by

its on-site effects on agricultural production and off-site effects on infrastructure and water quality (Ananda and Herath, 2003). Other erosion agents include ice, wind and stream, and are referred to as glacial erosion, eolian erosion and fluvial erosion respectively (Morgan, 2001).

On a global scale, water erosion is by far the widest spread cause of soil degradation. It is estimated that erosion is causes the loss of the world's topsoil at a rate of 7% each decade (Brown and Wolf, 1984). Loss of topsoil is one of the major soil degradation problems confronting agriculture throughout the world (Dardis *et al.*, 1988). This layer contains most of the organic matter and nutrients for most soils (Papendick, 1992). Experiment show that yields of crops where the top soil has been removed or severely eroded are 20-65% less than where the top soils are only slightly eroded (Massee, 1990).

In SSA area the average loss in crop yields due to erosion is estimated at 6 percent and the average productivity loss for irrigated land is 6.8 percent, for rainfed cropland 14%, and for rangeland, 45% (Dregne and Chou, 1992). Soil degradation caused by soil erosion is wide spread in SSA; about 320 million ha of land have been degraded moderately or severely by overgrazing, deforestation, and poor farming practices, while about 5 million ha are degraded beyond rehabilitation (Oldeman, *et al.*, 1991). In Ethiopia for example, severe erosion has been associated with continuous deforestation activities, uncontrolled grazing and unsuitable farming practices. The latter resulted in severe drought and famines, both attributed to soil degradation (Sohan and Lal, 2001). Soil water erosion is very dynamic and is a

spatial phenomenon which depends on relief geometry and surface properties influencing overland flow (Jaroslav *et al.*, 1996). Soil erosion in particular, has been widely perceived to be the major factor constraining land productivity in Tanzania, (Johnson, 1986). And in most cropping systems more plant nutrients are depleted than are being added (Smithson, *et al.*, 1993).

2.1.2.2 Soil fertility decline

Soil fertility decline is a major form of soil degradation, it occurs when the use of soil nutrients exceeds their replenishment. One major cause of soil fertility depletion is related to removal of more nutrients from the soil than are replenished by natural processes or fertilizers. Leaching can result in soluble nutrients being removed from the plant root zone, whereas acidification may result in soluble nutrients fixed and unavailable to plants. When soils are used for agricultural purposes, significant quantities of nutrients are removed in the harvested products. According to FAO (1993), with present level of world yields the annual amount of harvested plant nutrients in three major cereals (rice, wheat and maize) is estimated at 40 millions tons of N, 15 million tons of P_2O_5 and 28 million tons of K_2O. If nutrients removed are not replaced in the form of chemical fertilizers, organic manure, by fixation from the air or by weathering of rock minerals, then there will be a net decline in soil nutrient levels.

Most soils in SSA have a low nutrient content (particularly in nitrogen and phosphorus) and a low level of soil organic matter (because the higher temperatures favour the more rapid decomposition of organic residues) and have low water-

holding capacity due to a coarse texture and low clay content (Douglas, 1993). About 71% of a major part of cultivable land in SSA suffers from low fertility, loss of soil nutrients, and poor soil drainage (FAO, 1993). Stoorvogel and Smaling (1998) noted that net nutrient removal exceeds replenishment in many Sub-Saharan countries. This is considered one of the major reasons for a decline in food production in these countries (Sanchez, 2002).

In Tanzania, Smithson, *et al.*, (1993) found that in all cropping systems more nutrients were depleted through the system than were being added. Example, the decline in sisal yields in Tanzania has been caused by the depletion of plant nutrients (Hartemink, 2006). In addition to reduction in yield, some data show that the quality of the crop produced is also affected by accelerated soil erosion. Smithson *et al.*, (1993) observed that food crops and vegetables grown in eroded soils tend to be deficient in some essential elements. A quantitative knowledge on the depletion of plant nutrients from soils helps to understand the state of soil degradation and may be helpful in devising nutrient management strategies.

2.1.2.3 Assessment of soil degradation

(i) Assessment of soil erosion

The assessment of soil erosion hazard describes chances of an environment that allow soil erosion to occur (Stocking, 1987). It defines areas where they have similar degree and kind of erosion hazard which is valuable for land use and soil conservation planning. In addition, the assessment is also important for future planning and management of the available natural resources so as to insure its

sustainability for the future generation. Erosion hazard assessment involve all the factors affecting erosion namely rainfall erosivity, soil erodibility, topograph, plant cover and soil management practices. And it can basically be done in three different ways.

The first is to measure soil erosion rates at different locations using some measuring device or erosion plots (Hudson, 1993). These field measurements are mostly used for assessing the role of a specific erosion factor, model development, or validation purposes, but not for spatial evaluation of erosion. However, accurate measurements are generally expensive and time-consuming, standard equipment is hardly available (Stroosnijder, 2005), and measurement results may be highly variable under similar circumstances (Nearing, *et al.*, 1994). The second approach is the execution of erosion field surveys in which features formed due to erosion processes are identified, such as pedestals or rills. Although quantitative information may be obtained through repeated measurement of feature dimensions, surveys are often performed in a qualitative sense thus classifying the amount of erosion based on the features encountered. Survey timing is important, because features may not be visible throughout the year due to e.g. management practices like ploughing. Surveys may allow spatial erosion mapping for small catchments of about 2 km^2, but for larger regions this becomes difficult. However, systematic visual identification of certain features from aerial photographs would be another form of erosion survey that could be performed for larger areas up to 50 km^2 (Bergsma, 1974).

The third and most common method for soil erosion assessment is through integrating spatial data on erosion factors. Widely-used is the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) and the adapted version RUSLE (Renard, *et al.*, 1997), although many other erosion models exist that allow spatial mapping of erosion (Merritt, *et al.*, 2003). Most of these erosion models require a large amount of detailed data on a wide variety of rainfall, soil, vegetation, and slope parameters. In data-poor environments especially in developing countries and Tanzania in particular, these data are often not readily available, or only at very coarse scales.

In this study the Revised Universal Soil Loss Equation was used for the assessment of erosion hazard using GIS environment. RUSLE was selected due to the model being one of the most technically advanced and showing potential for use in other parts of the word, including developing countries (Lane *et al.*, 1992). Furthermore, the flexibility of the RUSLE model proved to be advantageous for application on a cathment scale (Smith *et al.*, 2000). The RUSLE has been extensively used to estimate soil erosion loss, to assess soil erosion risk, and to guide development and conservation plans in order to control erosion under different land cover conditions, such as croplands, rangelands, and disturbed forest lands (Mat and Veihe, 2001; Angima *et al.*, 2003). The interaction factors influencing erosion includes the following (Wischmeier and Smith, 1978).

a) Rainfall factor

Soil loss is closely related to rain fall through the combined effect of detachment by raindrops striking the soil surface and by runoff (Mitasova and Mitas, 1999). Rainfall erosivity is the ability of rainfall and runoff to cause soil detachment and transport. The ability of rainfall to cause erosion (erosivity) depends on characteristics such as rainfall amount, energy load, rainfall intensity particularly half-hour rainfall, rainfall distribution, it's seasonality and variability (Lal and Elliot, 1994). These characteristics determine the ability of raindrops to detach soil particles and the possible occurrence of surface runoff, a primary means for transportation and deposition of detached soil particles (Nanna, 1996).

The amount of rainfall governs the overall water balance and the relative proportion that becomes runoff (Pimentel *et al.*, 1995). Erosion is related to two types of rainfall events, the short-lived intense storm where the infiltration capacity of the soil is exceeded, and the prolonged storm of low intensity, which saturates the soil before runoff begins. In addition to the rainfall amount, drop size distribution, Kinetic energy and depth of overland flow are important characteristics affecting splash detachment. Detachment is due to the size of the raindrop and its velocity. Big rain drops have high erosive power to detach the soil particles. The ability of rain or the rainfall energy to cause detachment and transport is partly the result of raindrop impact, and partly due to the runoff that rainfall generates. The rate and drop size distribution are both good indications of the energy load of a rainstorm. Many rainfall erosivity indices which are based on the kinetic energy and rainfall intensity have been proposed by different researchers for different local environmental

conditions (Carter, 1974). Some of them use rainfall volume or compound parameters of rainfall intensities and rainfall volumes (Lal, 1990). However, the EI_{30} index remains the widely use estimator of rainfall erosivity (Mkonga, 1998).

The EI_{30} index was developed by Wischmeier and Smith (1978), from soil splash, overland flow and rill erosion experiments. It was estimated from long-term continuous storm data as a product of an individual storm's kinetic energy (E) and the maximum 30 minutes storm intensity. The 30 minutes maximum storm intensity is calculated from recording rain gauge charts. Different researchers have come up with different equations relating to kinetic energy of the rainfall intensity (Wischmeier and Smith, 1978; Kinnel, 1981).

Due to non-availability of long term (at least 20 years of continuous rainfall intensity records) or inefficiency rainfall data information to compute rainfall erosivity based on rainfall intensity in various place in the world, especially developing country and Tanzania in particular, various researchers have related the kinetic energy with widely available rainfall data by developing equations which can be used to predict erosivity values. Elwell (1979) used mean annual rainfall to determine kinetic energy in Zimbabwe, Moore (1979) used mean annual rainfall volumes to determine rainfall erosivity in East Africa in the following equation.

$y = 11.36x - 701$ 2.1

Where; y = KE_{15}>25 (is the kinetic energy in Jm^{-2}) and x is the mean annual rainfall in (mm). To obtain the rainfall erosivity, the regression equation proposed by Moore (1979) as shown below was used.

R = 0.029 KE – 26.0.....2.2

Where; R is the erosivity parameter in ft. tons in/acre per year and KE the kinetic energy. To obtain rainfall erosivity in SI units 'R' value is multiplied by 17.02 (Foster *et al.*, 1981) .

b) Soil factor

Soils differ in their resistance to erosion, which is a function of a range of soil properties such as texture, structure, soil moisture, roughness, and organic matter content. The susceptibility of soil to erosion agents is generally referred to as soil erodibility (Lal, 2001). The soil erodibility factor (*K*) is the soil loss rate per erosion index unit (in ton/MJ/mm) for a specified soil as measured on a unit plot (Wischmeier and Smith, 1978). It accounts for the influence of soil properties on soil loss during storm events (Renard *et al.*, 1997). The effect of soil on erosion is reflected through the resistance of soil to both detachment and transport (Morgan, 2001). Soils with high erodibility index are more sensitive to erosion than soils with low erodibility index.

- Soil erodibility (K-factor), varies with soil characteristics, e.g., texture, bulk density, shear strength, organic matter content, aggregate stability, infiltration capacity,

chemical properties and transportability of detached soil particles. Transportability determines how easily these loosened soil particles can be washed away. Particle size is an important element in soil erodibility. Lager particles are more resistant to transport, due to greater force entailed to move them. However, in soils with particles less than 0.6 mm, the erodibility is limited by the cohesiveness of the soil particles. The particles that are less resistant to erosion are therefore silt and fine sand (Petter, 1992). Soil texture also influences the infiltration capacity. This is defined as the maximum sustained rate at which soil can absorb water, and depends on pore size, pore stability and the form of the soil profile. Clay soils have a low infiltration capacity and produce more overland flow than soils consisting of coarse material, with higher infiltration capacity (Petter, 1992).

Several attempts have been made to devise a simple index of erodibility based on the properties of the soil determined either in the laboratory or in the field. Wischmeier and Smith (1978) use soil structure, profile permeability, organic matter content, silt and clay in the model they developed. Okoba and De Graaff (1987) estimate soil erodibility of some Kenyan soils, by using clay, organic carbon and bulk density.

Finding a suitable erodibility index for soils in the tropical areas specifically, poses a number of problems because the majority of the existing indices were developed for soils from temperate regions. Romkens *et al.* (1988) proposed equation based on soil texture to be use in areas where the nomograph is not useful, Mulengera (1996) derived equations for estimating soil erodibility in tropics condition based on soil texture-related parameters. Researchers revealed that nomograph could not be used

in tropics soil conditions due to the different soils condition to those in the temperature countries where it was developed (Ngatunga *et al.*, 1984). Mulengera (1996) derived the following equation for estimating soil erodibility value of soils in tropic condition based on soil texture-related parameters.

$K = 1.333 \times 10^{-4} + 2.459 \times 10^{-5}$ Mn (Mulengera, 1996).....2.3

Where:

K = is soil erodibility in t.ha.h/(ha.MJ.mm);

M = is a (a + sa);

a = is si +vfs;

si = is silt (2 μm to 50 μm) (%);

vfs = is very fine sand (50-100 μm) (%);

sa = is coarse sand (0.1 – 2 mm) (%)

c) Topographic Factor

Slope length and slope steepness represent the topographic effect in the RUSLE model i.e. slope gradient and slope length. Researches have shown that increased slope length and steepness produces higher overland flow velocities and correspondingly higher erosion (Haan *et al.*, 1994). Therefore both of them are useful in evaluation of erosion. Slope length is defined as the horizontal distance from the origin of overland flow to the point where either the slope gradient decreased enough that deposition begins or runoff becomes concentrated in a defined channel (Wischmeir and Smith, 1978). Various approaches and algorithms for quantifying

slope length have been developed, including raster grid accumulation (Hickey, 2000) and unit stream power theory) techniques (Moore and Wilson, 1992. Wischmeier and Smith (1978) proposed a following equation to be used in determine slope length in USLE model which is also used in RUSLE.

$$L = \left(\frac{\lambda}{22.13}\right)^{m} \quad \text{.....2.4}$$

Where; L = is slope length factor, dimensionless.

λ = is slope length in meters

22.13 = is the standard plot length in meters.

m = is a slope length exponent (Wischmeier and Smith, 1978).

In the Revised Universal Soil Loss Equation (RUSLE), the exponent, m is defined as a continuous function of slope gradient and the expected ration of rill to interrill erosion (Liu *et al.*, 1997). The slope length exponent m is estimated with the following relation:

$$m = \frac{\beta}{1+\beta} \quad \text{.....2.5.}$$

The slope-length exponent m is related to the ratio β of rill erosion (caused by flow) to interrill erosion (principally caused by raindrop impact). Rill erosion is mostly affected by flow and interrill erosion by raindrop impact. McCool *et al.* (1993), recommend the slope length exponent, m, of 0.5. McCool *et al.*(1989) computed the value of β for soil moderately susceptible to both rill and interrill erosion as:

$$\beta = \frac{\sin\theta}{0.0896 * \left[3.0 * (\sin\theta)^{0.8} + 0.56\right]} \quad \text{.....2.6}$$

Where; β = is the ratio of rill erosion to interrill erosion, and θ = is the slope angle. Soils in the RUSLE are classed as having low, moderate, or high susceptibility to rill erosion. Equation (2.6) is for soils that are moderately susceptible to erosion. Conversion for soils that have low or high susceptibility to erosion are based on the assumption that , soils highly susceptible to rilling have a β that is twice that given by equation (2.6), and soils with low susceptibility to rilling have a β that is half of value given by equation (2.6).

Slope steepness factor is the ratio of an effect of a given slope steepness on erosion to the effect of 9% slope steepness (McCool *et al.*, 1987). Slope gradient has an exponential relationship with erosion. There are a number of methods for estimating slope steepness (Dunn and Hickey, 1998), including neighbourhood, quadratic surface, maximum slope, and maximum downhill slope techniques (Engel, 1999). In RUSLE, the slope steepness factor (S) is significantly modified from the original USLE. McCool *et al.* (1987), propose the following equation for determine the slope steepness:

For slopes less than or equal to 9%: $S = 10.8 \sin\theta + 0.03$ 2.7

and For slopes greater than 9%: $S = 16.8 \sin\theta - 0.50$.....2.8

McCool *et al.* (1993), proposed the following equation to determine slope steepness factor regardless of the inclination of angle.

$$S = (\text{Sin } \theta/0.0896)^{1.3} \quad \text{.....2.9}$$

Where; θ is the angle in degree,

1.3 is slope steepness exponent factor

This relation was used in combination with the L factor to approximate the LS factor. However, the interaction of angle and length of slope has an effect on the magnitude of erosion. As a result of this interaction, the effect of slope length and degree of slope should always be considered together (Edward, 1987). Combined slope length and slope steepness factors were calculated using the factors from equations (2.4) to (2.9). In this study the topographical factor (LS), was estimated using GIS environment by utilizing the theoretical and technical procedures described by Moore and Wilson, (1992). The equation that was used to compute the LS-factor using GIS is as proposed by Moore and Wilson (1992) and Engel (1999).

$$LS = [A_s/22.13]^m * [\sin\theta/0.0896]^n \quad \text{.....2.10}$$

Where A_s is equivalent to the derived slope length (λ) from the DEM, θ is the slope steepness (S) derived from the DEM, n is slope length exponent, and m is slope steepness exponent. Application of the previous equation to calculate LS-factor produced the corresponding LS-factors for different cells of the DEM.

d) Vegetation factor

Vegetation cover is a very crucial factor in reducing soil loss (Petter, 1992). In general, as the protective canopy of land cover increases, the erosion hazard decreases (Mitasova and Mitas, 1999). Vegetation cover protects the soil against the falling raindrops, increases the degree of infiltration of water into the soil, maintains the roughness of the soil surface, reduces the speed of surface runoff, binds the soil mechanically, and improves the physical, chemical and biological properties of the soil (Petter, 1992). The effects of vegetation cover on erosional processes especially on surface erosion are varied depending on the type of vegetation cover, density, undergrowth cover and litter. The vegetation cover (C) factor is the crop/vegetation and management factor used to determine the relative effectiveness of soil and crop management systems in terms of preventing soil loss (Smith, *et al.*, 2000). It is defined as the ratio of soil loss from land with specific vegetation to the corresponding soil loss from continuous fallow (Wischmeier and Smith, 1978). It's value depends on vegetation cover and management practices. The vegetation cover, and especially ground (surface) cover, is perhaps the most important modelling factor as it represents conditions that can be managed to reduce erosion (Smith *et al.*, 2000). As long as vegetation cover is undisturbed, erosion and runoff are small despite erosivity of the rainfall, slope steepness and soil instability. The effects of vegetation cover on erosional processes are varied depending on the type of vegetation cover, density and litter. These determine the interception loss, absorption of kinetic energy and increasing water infiltration. The above ground cover absorbs energy of falling raindrops, running water and wind, so that less is directed at the

soil. The below ground components comprising the root system contribute to the mechanical strength of the soil (Pimentel *et al.*, 1995).

In order to determine the *C* factor values to be used in the equation, a number of sources were examined. Wischmeier and Smith (1978) present extensive tables for evaluating crop and management effects based on the experiments conducted in the USA. Efforts have been made in an attempt to generate *C* factor values for Africa. Roose (1977) produced *C* factor values for West Africa. Smith (1999) established good correlations between percentage canopy cover and leaf area index with respect to maize and soya beans in South Africa; He uses rainfall simulator results to provide local input data with respect to soil erodibility and mulch and canopy cover effects in South Africa.

The C values for a particular area are calculated from soil loss ratios representing six crop stage periods (rough fallow, seedbed, establishment, development, maturing crop and residue/stubble) and three levels of canopy cover at the mature stage (Stocking, 1994). In RUSLE, The C- factor for untested conditions can be estimated using a sub-factor method as a function of five sub-factors i.e., land use factor, crop canopy factor, surface or ground cover factor (including erosion pavement), soil moisture factor and surface roughness factor(Smith, 1999). The estimation of sub factor values for a particular condition requires long term experiments and considerable resource base. However, no extensive efforts have been made to determine *C* factors values for a wider range of crops and conditions (Smith, 1999) and particularly existing small scale farming systems. This lack of information

proved problematic in the determination of exact *C* factor values for this study. This lead to the use of values of crop management factors from experimental findings in other parts of the country and outside Tanzania. The C-factor values obtained here, are within the ranges quoted by various sources throughout the world (Wischmeier and Smith, 1978; Aina *et al.*, 1979; Ngatunga, 1981; Lewis, 1992; Mulengera, 1996; Mati *et al.*, 2000). More detailed analysis of C-factors using soil loss ratios needs to be conducted when more crop growth and climatic data becomes available.

e) Management (Support Practice factor)

In circumstances where farmers cultivate in marginal and in very steep slope areas, soil erosion can be accelerated if there is no proper conservation techniques applied. Proper management practices such as terracing on steep slopes, mulching, and crop rotation can significantly reduce soil erosion. The support practice factor 'P' in RUSLE is the ratio of soil loss with a specific support practice to the corresponding loss with up and down slope tillage. The support practices principally affect erosion by modifying the flow pattern, grade, or direction of surface runoff. For cultivated land the support practice generally includes, contouring, strip cropping, terracing, and surface drainage. The prediction of P factor normally relates to cultivated fields where specified soil conservation measures are operational and is related to slope. Experimentally derived P factor values in East and West Africa are few, partly due to difficulties associated with setting up erosion plots that contain soil conservation measures. According to Foster *et al.* (1982), most of the P factors for support practices such as contouring, strip cropping and terracing are transferable, and in Kenya P factors obtained using Wischmeier's tables provide realistic value (Mati *et*

al., 2000). For the purpose of this study the P value used were obtained from Mati *et al.* (2000) and Wischmeier and Smith (1978).

f) Generating soil erosion hazard map

In the RUSLE model, soil erosion hazard map is generated by interaction of the factors influencing erosion as expressed in the following equation as proposed by Wischmeir and Smith (1978).

$A = R*K*LS*C*P$ 2.11

Where:

A = average annual soil loss caused by sheet and rill erosion [t ha^{-1} y^{-1}]

R = rainfall erosivity factor [MJ mm h^{-1} ha^{-1} y^{-1}]

K= soil erodibility factor [t ha h ha^{-1} MJ^{-1} mm^{-1}]

LS = topographical factor (dimensionless)

C = land cover and management factor (dimensionless)

P = support practice factor (dimensionless).

(ii) Assessment of soil fertility decline

Few studies have been conducted on soil fertility decline at lower aggregation scales i.e. the farm or field because of the variability of the farming systems. Another possible explanation for the relatively few studies on soil fertility decline at farm or field level is that many soil scientists are more at ease at the regional or country level (Hartemink, 2006). Monitoring of soil fertility trends on smallholder's farms is

difficult and repeated measurements and long-term observations are required as measurements are subject to a large amount of variation both in time and space (Zinck and Farshad, 1995).

Information at the farm or field level could, however, become available if the archives of soil survey organizations were used. Such archives usually contain soil analytical data of various soil types under different land use systems and from different periods. Young (1991) suggested that for the assessment of soil fertility decline, samples from different periods from one particular site can be compared. Results can also be obtained when the same soil type but with different land use history is sampled at one time, for example natural vegetation and cultivated land. According to Young (1991) the analysis of fertility decline using soil survey data could yield important information on where, and to what extent, soil fertility decline is taking place and a position could be reached from which to take action to arrest or reverse it.

Assessing soil fertility decline is difficult because most soil chemical properties either change very slowly or have large seasonal fluctuations (Hartemink, 2006). There are several other confounding factors that make assessment of soil fertility decline complicated (e.g. spatial and temporal variation, soil analytical methods), and, for those reasons, other techniques have been used to estimate the rates and changes in soil fertility decline. Most soils in Tabora region and particularly in the study area are highly weathered and low in plant available nutrients (Acres, 1983). There is poor biomass production (because of low soil fertility and often inadequate

rainfall), and therefore little availability of organic materials for composting or for direct incorporation into the soils. The rate of accumulation of soil organic matter is also reduced by the very rapid mineralization that occurs in the prevailing hot climates. Termites also consume much of the organic matter, especially in semi-arid areas. SOM plays an important role in the sustainability of agricultural systems (Swift and Woomer, 1993). Similarly, Larson *et al.* (1983) have emphasised that SOM is the single most important indicator of soil quality and that soil in upper few centimetres of profile is the most important determinant of soil quality. The major limiting nutrients in Western zone, Urambo district inclusive are nitrogen (N) and phosphorus (P) (Kaliba *et al.*, 1998). Other necessary soil factors such as soil pH must be favourable to promote proper nutrient uptake and therefore adequate growth, production and yield. For the purpose of this study monitoring of soil chemical properties over time was used using soil survey report data (Young, 1991). Four parameters were chosen, namely soil organic carbon, soil pH, available phosphorous and total nitrogen.

2.2 Socio-economic factor influencing land degradation

Land degradation is a complex phenomenon driven by strong interaction among socio-economic and biophysical factors. The different causes of land degradation can broadly be categorised as natural or human induced factors. Natural causes include climatic and landscape factors, or processes that have been in operation over long periods in the geological time scale (Payton *et al.*, 1992). The major human-induced factor in the tropics is over-exploitation of natural resources through agricultural practices, overgrazing, deforestation, and fire (Adesina, 1994).

Many researchers often see land degradation as the consequence of the social and economic factors of the final beneficiaries (i.e. the farmers). Socio-economy refers to the environmental, economic, social and institutional relationships and patterns, which compose the concept of development (Sheng , 1989). Social and economic factors form a situation where people interact with certain problems through roles, regulations, and social relationships represented by gender, age, ethnicity, traditions, culture, inheritance and other social factors. Small-scale, primarily subsistence, farmers face a range of socio-economic constraints, such as population pressure, insecure land tenure, lack of alternative sources of family welfare, limited access to credit and limited knowledge of alternative practices. Unless such constraints are overcome, farmers have little option but to pursue short term production goals that they are well aware cannot be sustained.

2.2.1 Household characteristics

Various household characteristics influence the farmer's decision to adopt certain farming system such as use of various types of fertilizers, types of farming practices and land management practices. Age determines the wealth of the household to accumulate various traditional knowledge on farming and land management practices on which modern ones have to learn from. Education on the other hand enable farmers to see and understand proper farming practices and perceive relevance to his/her situation. The size of household reflects to a certain extent of the utilization of natural resources.

2.2.2 Population change

Population dynamic is one of the most frequently cited causes of land degradation by various researchers. This is due to the fact that population increases results in higher exploitation of resources of the environment (Maenda, 1999). Rapid population growth hastens deforestation by adding to the demands for agricultural land and firewood (WRI, 1996). Severe degradation, scarcity of land, and shortage of pasture, are considered to be the push factors for population out-migration. Migration of agro-pastoralists from Mwanza, Shinyanga, Tabora, Arusha and Manyara to neighbouring regions in search of grazing and virgin land for cultivation imposes new cycles of land degradation in locations where the migrant population happen to settle (Ngazi, 1993). Misana *et al.* (1996) noted that about 4 000 ha of forest have been cleared in Kigoma, Kagera, Rukwa and Tabora regions due to the influx of refugees from Rwanda, DRC and Burundi, in the mid 1990s.

2.2.3 Farming practices

It is articulated that poor land use and farming practices have contributed to today's situation. In many parts of Tanzania, clearing of natural vegetation by man during tsetse control campaigns, overgrazing and extensive cultivation resulted in land degradation (Christiansson, 1988). The destruction of forests is caused for the most part by land clearance for agricultural purpose. Shifting cultivation that entails cutting trees, shrubs and tall grasses, burning the litter is estimated to have contributed about 60 percent of the farmland expansion between 1973 and 1988 (Harrison, 1992). Traditionally, fields under the various shifting cultivation systems were left fallow for at least 10-20 years. In that period, 90% of the wood biomass

would regenerate. Over time, the resource/man ratio changed due primarily to relatively rapid increase in population changing the nature of resource utilisation. People cleared the natural forests to form agricultural lands and human settlements and as a consequence, the length of fallow was, in many instances, shortened so that the farming system moved from woodland fallow to bush fallow, and in many cases to grass fallow. This process of intensification has contributed to deforestation and degradation of sub-humid forests of SSA. In fact, the traditional shifting cultivation is the leading cause of deforestation in the sub-humid areas of SSA accounting for 70% of the woodland converted (FAO, 1979). In addition, fires often set by shifting cultivators and other forest dwellers are a major cause of forest degradation and impede regeneration of woody plants (Rowe *et al.*, 1994). This traditional agriculture also results in mining soils of plant nutrients by removing crop residues, leaching, and soil erosion (Smaling *et al.*, 1997).

In Tanzania expansion of agriculture especially for cash crop to boost export earning and raising farmer's income, is one of the leading causes of deforestation in the country. Tobacco growing is a widespread and a highly economic activity within the small scale farming system in most countries of the sub-humid zone. Tobacco growing however requires substantial quantities of wood for curing and has consequently led to massive clearance, destruction and degradation of sub-humid forests (Geist, 1997; Brigham *et al.*, 1996). Woodland losses are amplified by the need for fresh land each year in order to avoid the risk of root-knot nematodes (Misana *et al.*, 1996). Overgrazing is caused when the number of livestock exceeds the carrying capacity of a particular rangeland. In Tanzania due to infections from

tsetse flies in some of potential grazing areas, livestock population were concentrated in none tsetse fly areas. This led to severe land degradation and siltation of water reservoirs, such as depth reduction of Nyumba ya Mungu dam (Misana *et al.*, 1996).

2.2.4 Utilization of firewood

Firewood and charcoal are the cheapest available fuels in most rural areas, and are used extensively to provide energy for cooking, heating and lighting. Ferguson, (1988) noted that much of the deforestation of Haiti was due to the firewood collection. Survey in western Tanzania found that refugees used an average of 2.8 kg of wood per person per day, whereas local hosts used just 1.7 kg per person per day because they rarely put out fires between meals and dried food rations take longer to cook than fresh crops (Whitaker, 1999). In Tanzania about 97% of all annual wood production is consumed in form of woodfuel, accounting for 91% of Tanzania's total energy consumption (FAO, 1993). Wooodfuel in Tanzania is used for cooking and in rural and urban agricultural industries. However, quantitative information on consumption of woodfuel for various activities is inconsistent and sometimes is lacking. For example, Mangora (2006) revealed that 15 m^3 is used to cure 500 kg (equivalent of 1m^3 per 33 kg of tobacco), while Abdallah and Sauer (2007) estimates that about 1 m^3 of firewood was used to cure 57 kg of tobacco. However, the actual amount of firewood used varies with the design of the barn.

2.3 The role of remote sensing and GIS in assessing land degradation

The use of remote sensing and GIS technologies has proved successful in many fields of natural resources management. Its synoptism and large area extent as well

as the ability of GIS to collect store and manipulate various types of data in a unique spatial database, helps performing various kinds of analysis and thus, extracting information about spatially distributed phenomena. Space technology, in particular satellite remote sensing, currently offers an important contribution to the synoptic and timely evaluation of natural resources over large areas. The term remote sensing means that information about objects or phenomena is acquired from a distance, without having physical contact with the object or phenomenon under study (Collins and Woodcock, 1983). In practice, the term is mostly used for the acquisition, processing, and interpretation of data which are recorded by a sensing device mounted on an aircraft or satellite. The sensors record electromagnetic radiation (EMR) that is reflected or emitted from these objects or features.

Traditionally, remote sensing has been used for soil erosion research through aerial photo interpretation both for detecting erosion features (Bergsma, 1983) and obtaining model input data (Stephens *et al.*, 1985). Starting in 1972 with the launch of Landsat-1, satellite imagery has become increasingly available to the scientific community. Satellite data can be applied to directly detect erosion or to detect erosion consequences. The development of computer hardware and software has meant possible to apply models in a computer-based environment. According to Shrestha (1997) remote sensing complemented with field ground truthing and GIS; provide the best methodological toolset to investigate soil erosion. Visual and digital image interpretation can be used to derive input parameters, such as land use and land cover and to a less extent the conservation and erodibility factors (Jaroslav *et al.*, 1996). GIS also allows scaling data and results to either local or regional levels.

Several studies (Shrestha, 1997; Wessel *et al.*, 2001) have shown that GIS is an excellent tool in erosion modelling. Most of the data used in models i.e. vegetation, soil, relief, climate, etc can be processed in a GIS and used as first stage input to identify and map degraded lands. (Jaroslav *et al.*, 1996; Shigeo *et al.*, 1998).

Erosion assessment by remote sensing is highly useful for the planning of more detailed erosion assessments and soil degradation studies (Boggs *et al.*, 2001). It has been proved that land cover changes relevant to soil erosion can be detected using satellite data collected at different times. Remote sensing together with the use of a geographic information system is helpful for integrating information on spatial distributed erosion causative factors and for identifying the classes of soil erosion severity.

Mbilinyi (2000) used panchromatic aerial photographs of 1963 and 1978, Landsat TM satellite imagery of 1995 and GIS to assess land degradation and its consequences in Isimani division, Iringa Region, Tanzania. The change detection analysis showed that a large part of miombo woodland was cleared during the period 1963 – 78 due to the settlement program of the 1970s. The analysis also showed that increase in the coverage of miombo woodland was realized in the period 1978 – 95 due to results of woodland conservation efforts by community in the area. Maps showing the existing land use have many planning applications, both in developing and developed countries, and air photographs and satellite images with a measure of ground control are eminently suited to this task.

Land use/cover can be readily seen on air photographs and satellite images, including such aspects as the proportions of arable and maintained pasture, forest plantations, orchards, the pattern of the fields and the extent of urban or village use of land (Dent and Young, 1981). Ngalande (2002) used remote sensing techniques to carry out a comparative study of changes in agricultural land use in Siavonga district Zambia, where changes in land use were observed.

In Morogoro region, Tanzania, Norris (1990) quantified trends of deforestation by using remote sensing techniques. The results showed that annually 0.5% of the area outside the rain forest was converted from woody vegetation to cultivated land and wooded grassland. Monela(1995) conducted a study on land use/land cover changes and deforestation rates for the rain forests of the Uluguru mountains, using remote sensing techniques, maps and field survey. The results showed that forest encroachment for subsistence agriculture as well as establishments of settlements by indigenous people is the main cause of rain forest degradation and degradation pressure. Kaoneka and Solberg (1994) carried out an analysis based on sequential aerial photography at Shume-Magamba area in the Usambara Mountains in Tanzania. It was found that the natural forest reserve decline at a fairly high rate of 3.8% per year. The area under farmlands and village settlements were increased dramatically by 83% per year. It was concluded that the main cause of deforestation was expansion of farmlands and settlement due to growing population.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Descriptions of the study area.

3.1.1 Location of area

The study was conducted in Ulyankulu refugee settlement areas, Ulyankulu division, Urambo district, Tabora region, Tanzania. The settlement is located on both sides of the Igombe river, and lies between 31^0 50' and 32^0 20' E and 4^0 30' and 4^0 50' S (Fig. 1). It is within 990 m and 1230 m above sea level (Berry, 1971). The area is 50 km and 90 km from Urambo town and Tabora municipality respectively. In the settlement itself there are well developed network of roads linking homestead sites with the administrative quarters, dispensary, school and other facilities.

3.1.2 Climate

The Urambo district is receiving a unimodal type of rainfall, with mean annual rainfall equal to 981 mm and it falls between November and mid May (Fig. 2). The temperature is uniform throughout the year, and ranges from 21^0C in June and July to 25.5^0C in October which is the hottest month in the year (URT, 1998).

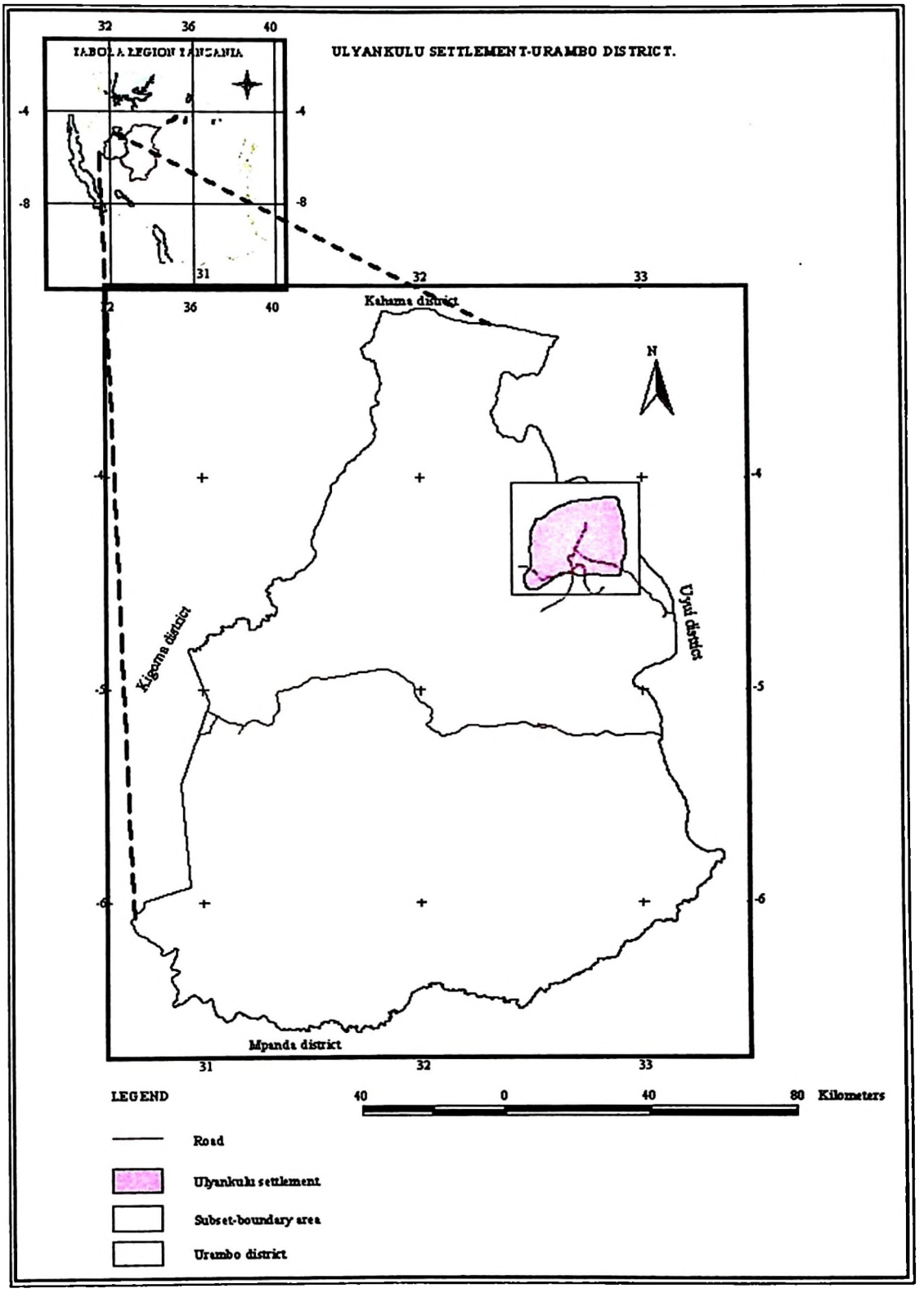
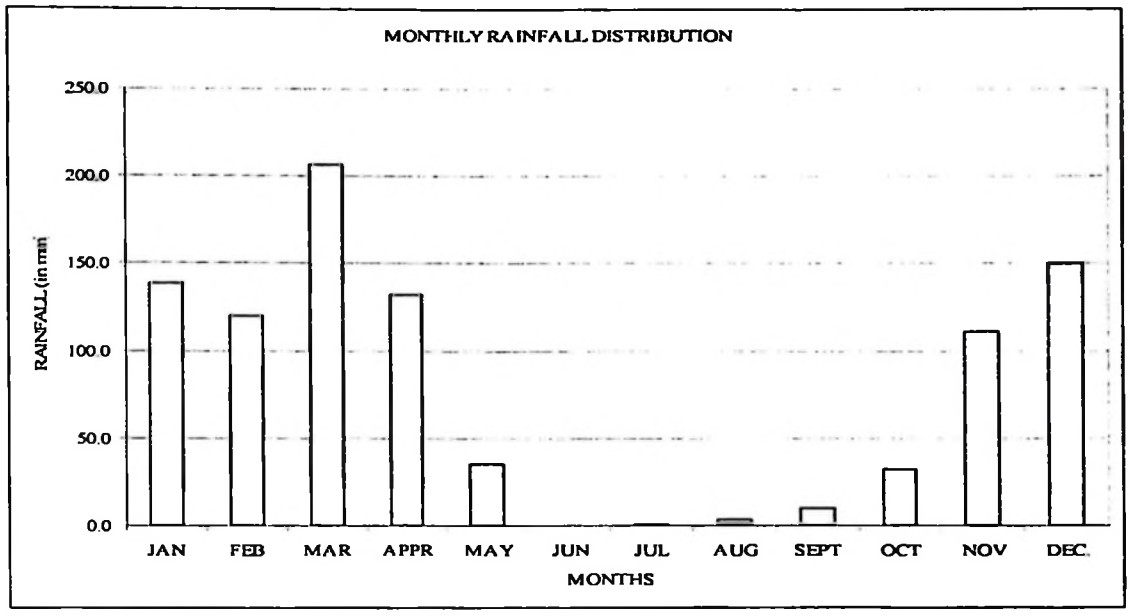


Figure 1: Geographical location of the study area



Source: Water Development office-Tabora

Figure 2: Monthly rainfall distributions in the study area during 1977-06

3.1.3 Geology and physiography

Ulyankulu refugee settlement lies in the central Granite of the East African Basement system. The area is gently sloping with rock outcrop hills bisected by broadly defined drainage line (known as mbuga) which drains into Igombe river passing in the refugee's settlement. The rocks which trend NW-SE, are mainly coarse grained granite and gneisses. They form the substratum of the area. A thick regolith of weathered rocks and soil, cover the foot slopes and upland plain. The bottomlands are overlain by both alluvial and colluvial, sandy and clayey sediments (Hof *et al.*, 1980).

The settlement occupies a gently sloping upland plain between two ranges of steep, isolated hills with granitic rock outcrops and extensive footslopes. The upland plain has been dissected by the Igombe river forming a wide main valley and a network of

smaller tributary valleys. The tributary valleys run parallel or at right angles to the main valley. Four major physiographic units were recognized, these include; isolated steep hills, footslopes, upland plain and bottomlands.

3.1.4 Soils

The soils of the area are described on the basis of the physiographic units. The isolated steep hills are characterized by a complex pattern of generally shallow, rather coarse-textured soils and numerous granitic rock outcrops. Dominant slopes range from 16 to 40 percent, exceeding 100 percent in some places (Hof *et al.*, 1980). Main limitations for agricultural development are rockiness, steep slopes and severe drought and erosion hazards.

The foot-slopes include gently sloping areas, 0-6 percent slope, at the foot of the isolated hills. The major soils on the upper parts are well drained, deep, friable sandy clay loams and sandy clays, sometimes with abundant ironstone gravels at less than 100 cm from the surface. The surface horizon is usually dark red or dark reddish brown in colour, the subsoil is either red/dark red or yellowish red. Soil reaction is slightly to moderately acid. Low natural fertility and moderate to severe erosion hazards are the main limiting factors for a sustained crop production.

The upland plain is covered by the same kinds of soils as footslopes. Dominant slopes are 0-2 percent. The bottomlands include a wide range of soils occurring in intricate patterns. Texture varies from sand to sandy clay, and colour from greyish brown to dark grey, sometimes dark brown, usually with prominent strong brown

mottles. Some of the soils have a hardpan at about 50 cm of the surface. Drainage is generally poor. A good part of the soils remain water logged during the growing season, which precludes most agricultural crops except paddy rice. Many areas receive water mainly as runoff and groundwater seepage from adjoining higher-lying land. In some years areas near Igombe river are flooded (Hof *et al.*, 1980).

3.1.5 Vegetation and Land Use

Most of the vegetation cover types found in Ulyankulu settlement are open miombo woodland and bushlands. The cover is interspersed with grasses, herbs and hedges (Hof *et al.*, 1980). The well drained soils are used for rainfed crops, mainly maize, cassava, beans and sweet potatoes. Tobacco and groundnuts though grown on a rather small scale are main cash crops together with sweet potatoes. Intercropping is a common practice e.g. maize and beans, cassava and sweet potatoes. Rice is the main crop in bottom valleys, especially in the Igombe River flood plain.

3.2 Data collection

The data required for this study generally consisted of climate, soils, land use and land cover. The collection activities consisted of two phases, namely the pre field and fieldwork phase. Details of activities conducted during these stages are explained in the proceeding sections.

3.2.1 Pre-field work

The main activities during this stage were reviewing relevant literature on main issues of the study, which include literature on land degradation problems particularly vegetation degradation, soil erosion and soil fertility decline in Tanzania

and refugees settlement areas in general. Other activities of this phase were to collect research materials, prepare questionnaire and field base maps.

3.2.1.1 Acquisition of research materials

The material used included; Twenty eight black and white aerial photographs of 14 June, 1970 (scale of 1:50 000), topographical sheets (Map sheets number 97/1, 97/2, 78/3 and 78/4) with scale 1:50 000, of 1978 produced from aerial photograph of May-June 1974. These materials were obtained from the Department of Survey and Mapping of the Ministry of Lands, Housing and Settlement Development, Dar es Salaam. In addition to the aerial photos and topographic maps, satellite images in electronic form, from Landsat-TM of path number 171 and row number 063 of 13 June, 1984 was obtained from archive of Sokoine University of Agriculture GIS Laboratory. Landsat-TM of path number 171 and row number 063 of 13 September, 1994 was obtained from archive of the Institute of Resource Assessment GIS Laboratory, of University of Dar es salaam and Land sat ETM, path number 171,row 063 images of 7 August, 2001 were obtained from National Bureau of Statistics office, Dar es Salaam. Arc-view 3.2 software was used on data manipulation and map preparation. Global Positioning System (GPS) was used on ground verification of land use and land cover mapping units of the base map. Other materials were the literature documents and maps.

3.2.1.2 Image interpretation and analysis

A familiarization of the area was carried out by visual inspection of topographical maps, air photos and Land sat TM images. During this phase, the images were Geo-

referenced, enhanced using spatial and image analyst extension of Arc view software. Landsat ETM satellite of 2001 which is already geo-referenced to the coordinate system of the study area (UTM zone 37S) was used as a master image for geo-referencing the 1984 and 1994 images. The topographical maps were scanned and geo-referenced to Universal Transversal Mercator (UTM) coordinates, zone 37 south using control points selected and referenced from unscanned topographical maps.

Image processing was done using colour composite of bands 4, 3, and 2 in RGB transformation. On screen visual interpretations of the image and topographical maps was done to generate the land use/cover maps of a study area. The different land use/cover categories were distinguished based on the image elements e.g. colour, texture, shape and pattern. The forest was delineated as dark red, Woodland as red, Bushland as light red, grassland as light red, and cultivated land with fallow land as deep green. The texture was rough in the forest, woodland and bushland while the grassland was smooth. Cultivated land with fallow land and grassland have similar characteristics in terms of colour and texture, but their difference is that cultivated land with fallow has tiles like shape patterns. Other features such as landform, drainage pattern and road networks were considered in the interpretation. Land use/cover map of 2001 was interpreted following procedures outlined by Lillesand and Kiefer (2000). A map was produced at a scale of 1:100 000 and used as base map for field surveys.

3.2.1.3 Preparation of questionnaire for socio economic survey.

Open and closed ended questionnaires were prepared for socio-economic data collection. The questionnaire (Appendix1) included important attribute on; household characteristics, level of literacy, farming practices, farmer's awareness on land degradation, and all issues of land resources utilization and management.

3.2.2 Fieldwork stage

This involved collection of primary data using various data collection methods. The fieldwork was carried out during 2006/07 to collect data for soils and validating land use/cover analyzed from satellite image of 2001, and for characterization of each land use/cover class. Accesses to the areas off-road were poor, but a number of observations were carried out from the roads, footpath and tracks. The field work phase begun with a reconnaissance survey of the area to understand the soil-landscape relationship and to test questionnaires. This was followed by soil sampling, collection of data required for the study. During also this stage, formal and informal interviews were also conducted with farmers, officers and other selected key informants at the study area and district headquarters. The techniques used to collect socio-economic information, soils and vegetation data used in the study are described below.

3.2.2.1 Soil sampling

Soil samples were taken during the rainfall period, and were sampled from four sites namely P1, P4, P10 and P32 in the study area as located in a previous detailed soil map of 1978 with a scale of 1: 50 000 prepared by the National Soil Service centre

Mlingano. Sample sites were selected on the basis of the availability of soil physical and chemical properties data from 1978 soil analysis records in soil survey report. The land use/cover and soil types of the sample sites are shown in appendix 35. Mini-pits were dug with the hoes and soil samples were taken with a spade at the depth of 0-20 cm and kept into the polythene bag. The soil sample were taken at this depth since, this is where most changes caused by erosion are expected to occur and the upper few centimetres of profile is the most important determinant of soil quality (Larson and Pierce,1994). The samples were taken in the same coordinate position as the previous ones using GPS for site location according to the coordinates obtained from the soil map and taken up to the lab for analysis.

3.2.2.2 Land use/cover characterization

During this phase, Land use/cover types identified from the land sat imagery of 2001 were counterchecked in the study area. The assessment was based on the physiognomic types according to visible (or physical) attributes, notably the height and canopy cover (or density) of the dominant life forms of those plant associations which actually occur. Morgan (1988) suggested that the continuity of canopy, the density of the ground cover and root density were the most important factors controlling soil erosion. At each of the sample sites, the recognizable features on both the ground and the colour composite print outs were marked on the colour composite print out. The identification of features was done through first locating easily-observable features such as roads, footpaths, farm boundaries, there after they were related to other features such as vegetation types. The local refugee's community members provided the onsite local knowledge including locations and

historical land use and cover. Geographical Positioning System (GPS) was used to locate into ground the land use/cover according to the land cover mapping unit identified in the base map produced. Land cover map of year 2001 was updated to incorporate current changes which give a full picture of land cover up to the year, 2006 of the study period..

3.2.2.3 Socio-economic survey

A purposive procedure was employed to select the household. Although the procedure of purposeful sampling did not provide an entirely random sample it was considered to be the most efficient procedure for obtaining a sample which was representative of the population in terms of the variables considered important for the study. Participatory Rural Appraisal (PRA) was carried out using the prepared open and closed ended questionnaire to collect socio-economic data. As most of the refugee's respondents could not express themselves sufficiently in Kiswahili, most of the interviews with this group were conducted through Hutu speaking interpreters. A total of 105 respondents were interviewed.

Key informant interviews were carried out to government officials from various disciplines working in the study area. These included: Settlement Commandant Officer, Natural Resources Officer, Livestock Field Officer, Crop Officer and refugee's community leaders and elders. Key informants are people who are accessible, willing to talk and having great knowledge regarding the issues under discussion. At the district, officials interviewed included: District Agricultural and Livestock Development Officer, District Forest Officer, District Land Officer and

District Fisheries Officer. This was done to fill in gaps of missing information and help to clarify issues which arose from formal interviews. It is under this point where information included historical trends over time regarding land cover dynamics, socio-economic activities; population dynamics and community awareness about land degradation were attained. The interviews were guided by a checklist (Appendix 1).

3.3 Data analysis

This involved post field work, including soil samples analysis in laboratory, assessment of spatial and temporal distribution of land use/cover, determining the extent and trend of land degradation and assessment of socio economic factors influencing land degradation.

3.3.1 Assessment of spatial and temporal distribution of land use/cover

Land use/cover distribution in the study area was assessed through generating the land use/cover maps from landsat images, aerial photographs and topographical maps in GIS environment using Arc view computer software. The image analysis was done using image elements and characteristics such as tone, texture, shape, patterns, association of object and characteristics of object and features such as river, roads etc. (Dent and Young, 1981). Four classes of land use/cover were established, i.e. forest, woodland, bush land, grassland and cultivated land. The extent coverage areas of various land use/cover classes of 1978, 1984, 1994 and 2006 were established. The four generated land use/cover maps for 1978, 1984, 1994 and 2006 were further analysed in GIS using overlay method. The overlay method has been applied by a

number of researchers to perform change detection analysis. This analysis gives the extent of land use/cover change between 1978 and 1984, between 1984 and 1994 and between 1994 and 2006.

3.3.2 Determination of the extent and trend of land degradation

3.3.2.1 Determination of the extent and trend of vegetation degradation

The analysed data of the section 3.3.1 was used in determining vegetation degradation using post classification change detection approach. In this approach images from different dates were classified and labelled. The area of change was then extracted through the direct comparison of the classification results (Lunetta and Elvidge, 1999). The technique used for change detection was GIS overlay in arc view using geo-processing extension (intersect operation). This resulted into a matrix table out put from the overlay of maps of different dates. The table was then exported as DBF table and further processed in Excel (with pivot table function) to qualify and quantify the land cover changes. Land cover changes were investigated for the periods of 1978-84, 1984-94 and 1994-06. This land use/cover change data was used to determine the vegetation degradation based on the trends of land cover changes. Certain types of vegetation cover change were classified as degradation, i.e. loss or decrease in vegetation without recovery, either in between the 1978s and 1984, 1984 and 1994, and between 1994 and 2006. The vegetation degradation maps were compile and prepared to have spatial distribution of vegetation degradation between 1978 and 2006.

3.3.2.2 Assessment of the extent and trend of soil erosion

The extent and trend of soil erosion in the study area was determined by using RUSLE model in GIS environment using arcview software. The datasets used included soil map, topographical maps, vegetation cover maps generated from aerial photograph, Landsat TM and ETM images. The RUSLE factors thematic layers as described below were created and the map calculator in GIS environment was used to determine the extent of erosion hazards for the year of 1978, 1984, 1994 and 2006. The matrix table was generated in Excel (with pivot table function) to determine the trend of soil loss from 1978 to 2006.

(a) Generation of the erosivity factor layer

The generation of the rainfall erosivity layer was based on the monthly rainfall amount obtained from the regional water office. The data was from the Uyowa rainfall station adjacent to the study area. The equations 2.1 and 2.2 that estimate rainfall erosivity were applied. The rainfall data obtained was first aggregated into annual rainfall amounts, and then mean annual rainfall was calculated. The average mean annual rainfall was computed for the respective durations (i.e. 1978, 1984, 1994 and 2006). The averages obtained were used in the equation 2.1 and 2.2 to determine kinetic energy and rainfall erosivity (R factor) respectively for the respective years mentioned above. There is only one rainfall station around the study area, therefore the layer prepared has one polygon with one value of rainfall erosivity. This erosivity value was signed to the polygon attribute table and then rasterised and converted into rainfall erosivity value grid theme. Having one

polygon the layer produced was used in the equation by assigning erosivity value according to the study periods of soil loss determined.

(b) Generation of soil erodibility factor layer

This was done using the soil map and soil survey report of the study area obtained from the Agricultural Research Institute Mlingano at a scale of 1:50 000 (Hof *et al.*, 1980). The K values were determined using equation 2.4. The soil units and their associated K factor values (soil erodibility) were used to create the K factor grid value layer of a study area. This layer was then rasterised and converted into a K value grid theme (Macmillan *et al.*, 1985).

(c) Preparation of topographical factor layer

The topographical (LS) factor was determined using GIS package basing on the technique designed by Engel (1999). The technique uses DEM as the input layer and the hydrological and spatial analyst extensions in ArcView 3.2 for processing. The topographical factor is the most difficult one to derive in GIS, because the slope length aspect is not direct. The DEM was created using topographic maps number 78/3, 78/4, 97/1 and 97/2 of 1978. These topographic maps were scanned and transformed into TIFF format. The scanned topographic sheets were geo-referenced using the selected topographic maps co-ordinate references. The contour lines of a vertical interval of 20 m from the scanned geo-referenced topographic maps were onscreen digitized to produce contour theme. Using 3D and spatial analyst's extensions and the contour theme as an input, the digital elevation model (DEM) was generated by transforming contour theme and converting it to grid using spatial

extension, with a grid size of 10 m. Using DEM theme as an input, and 3D analyst extension in arc view software, the slope theme (in radian) was derived.

This slope length was calculated from the above generated DEM following logical steps with GIS processing capabilities in the hydrologic extension of Arc View 3.2. In order to estimate slope length in GIS environment, the flow accumulation theme was needed. The technique is based on the principle that flow algorithm distributes flow according to relative slope of downhill pixels. The flow accumulation used to estimate the topographic factor in the GIS is determined through the steps as described by Engel (1999).

Using hydrologic extension and DEM theme as an input, the flow direction theme was derived. The flow direction theme was in turn used as an input for computing a flow accumulation theme which show the area that contribute flows through each grid. Since RUSLE is suitable for estimating interill and rill erosion processes, there is a limit on slope length. According to the RUSLE User's Guide (Foster *et al.*, 2002), it was recommended to use the slope lengths of less than 122 m (400 ft) because overland flow becomes concentrated into the rills in less than 122 m (400 ft) under natural condition (Foster *et al.*, 2002). In this study the slope limit was 120m. Therefore, the flow accumulation theme was modified to accommodate this limit. To modify the flow accumulation theme, the map calculator was used to create two themes. One theme was created where value 12 was assigned to all pixels that had flow accumulation greater than 12 (i.e 10m grid size time 12 equals 120m slope length). Another theme was also derived where pixels that had flow accumulation

below 12 and slope length calculated as flow accumulation number time 10m grid size. The above two created flow accumulation themes were added together to obtain a new flow accumulation layer. The new flow accumulation layer and the slope steepness layer were then used as inputs for computing topographical factor using equation below as described by (Mitasova and Mitas, 1999).

$$LS = (\text{Flow Accum grid} * (\frac{Cell\ size}{22.13})^{0.5} * (\text{Sin (Slope grid} * 0.01745) / 0.0896)^{1.3} \quad \ldots\ldots\ldots\ldots\ldots 3.1$$

(d) Generating cover factor layer

The C-factor was determined according to different land cover/land uses obtained in the study area. The C cover factor values for different vegetation types were adopted from literature (Wischmeier and Smith, 1978; Aaina *et al.*, 1979; Ngatunga, 1981; Lewis, 1992; Mulengera, 1996; Mati, 1999) used and assigned to the correspondent type of land cover in the land cover attribute table. Then this layer was rasterised and converted to the grid theme.

(e) Generating management practices layer

The P-values were adopted from literature (Singh *et al.*, 1985). Then these values were assigned to the attribute table of the land use classes that were derived from a classification of remote sensing imagery. Through field observation it was found that ridging is one of the most used practices in cultivated land. The ridges are constructed across the slope. In uncultivated land there are no any management practices conducted. Therefore in this area the P factor value was set at 1.0. In cultivated land the P factor value was set to 0.68 (Singh *et al.*, 1985). Then P factor

layer was prepared by assigning the corresponding values as per land use and converted to grid to have P factor grid layer.

(f) Creating soil erosion hazard map.

The GIS input layers discussed above were combined, as described by the RUSLE equation 2.11, to estimate extent and trend of soil erosion hazard for respective years of 1978, 1984, 1994 and 2006 through the multiplication of individual factor grid layers using the map Calculator of the spatial analyst extension of the arc view. Rainfall amount, change of vegetation types and area, and change in area of the management practices were taken as the key dynamic variables on determining the extent and the trend of soil erosion loss over time in the study area. Other remain variables i.e erodibility and topographic were assumed constant over the study period.

3.3.2.3 Assessment of soil fertility decline

The soil samples collected in the field were analysed in the laboratory to determine soil organic carbon, soil pH, available phosphorus and total nitrogen. The soil samples were analysed in the central soils laboratory of the Agricultural Research Institute, Mlingano,Tanga region, following standard procedure (Page *et al.*, 1982) as described in National Soil Service (1990). The following methods were used: Walkley and Black's chromic acid oxidation ($K_2Cr_2O_7$ H_2SO_4 oxidation) was used to determine organic Carbon; soil pH was measured in 1:2.5 suspension of soil and water; available phosphorus was extracted with 0.03 M ammonium fluoride in 0.025 hydrochloric acid (Bray and Kurtz No.1 solution) for soils with pH<7 and estimated

calorimetrically; and total nitrogen was estimated by the semi-micro Kjeldahl method. The land use/ cover over the sampling points for the period of 1980 and 2006 were determine through the land use/cover maps (Appendix 35). The assessment of soil fertility decline was based on the comparison of the content of soil organic carbon, soil pH available phosphorus and total nitrogen of the 1978 soil properties (Hof *et al.*, 1980) and 2006 soil properties. This method was used for assessing soil fertility decline as proposed by Young (1991) due to the availability of the previous soil analysis data of the study area. According to Young (1991) the analysis of fertility decline using soil survey data yield an important information on where, and to what extent, soil fertility decline is taking place and a position from which action could be taken to arrest or reverse the problem.

3.3.3 Assessment of socio economic factors influencing land degradation

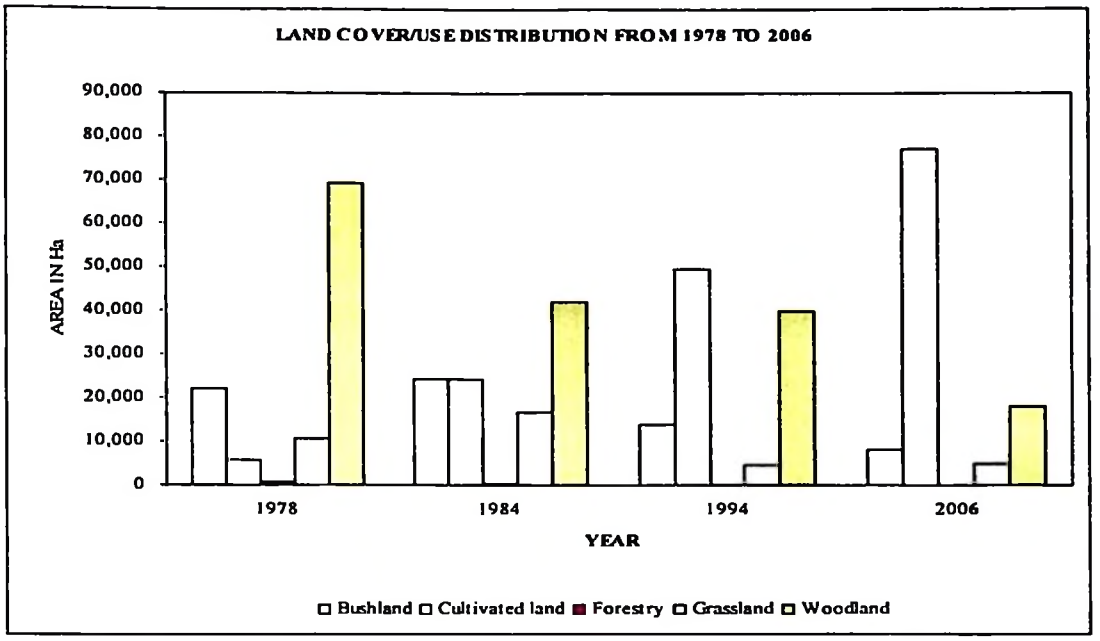
The socio-economic information obtained through questionnaire survey was coded, cleaned and the open ended questions were categorized and transformed into a form amenable for further analysis. A Statistical Package for Social Sciences (SPSS) was used in analyzing the quantitative data. Descriptive statistics data analysis was used to study the socio-economic activities that influenced land degradation (i.e. vegetation degradation and soil degradation) for the 1978-06 temporal periods.

CHAPTER FOUR

4.0 RESULTS AND DICUSSION

4.1 Spatial and temporal distribution of land use/cover of the study area.

Temporal and spatial distribution of different land use/cover types of the subset areas (study area and neighbouring areas) is given in Fig. 3 below and appendices 2 up to 6. The area includes a land outside the study area in order to minimize error when converted to the grid theme (Engel, 1999). The results show that in 1978 the large land cover area was covered by woodland, accounting to about 63.9%. Bush land and grassland amounted to 20.5% and 9.8% respectively. Other land cover types were cultivated land 5.2% and forest 0.6%. On the other hand, the land covers analysis from Land sat TM imagery of September 1984 revealed that woodland was the largest cover in the subset study area. It was accounting to about 38.6 %, followed by bush land 22.9%, cultivated land 22.5%, grassland 15.6% and forest 0.5%. In 1994, the cover analysis showed that cultivated land accounted to 45.6%, bushland 26.2, grassland 4.4% and woodland 23.8%. In 2006, cultivated land was the largest land cover occupying 71.0% of the subset area followed by bush land 15.0% woodland 9.3%, and grassland 4.7%.



Source: Topo sheet map of 1978, Landsat TM of 1984, 1994 and Landsat ETM of 2001

Figure 3: Land cover distribution for 1978, 1984, 1994 and 2006 years.

The results demonstrate spatial and temporal variations of coverage of different land use/cover types. During this period bush land, cultivated land and grassland increased in area while woodland and forest decreased in area. The variations were due to the high dynamics of the population hence increased demand of food and resources surrounding them for their survival. During the study period the refugee population increased from 26 000 in 1972 to 60 000 in 2006. . This was found also by Kaoneka and Solberg (1994) in Shume-Magamba area in Usambara Mountains, that the deforestation was mainly caused by expansion of farmlands due to increase of population. From the end of 1970s to early 1990s, the cover analysis showed that cultivated land increased up to 45.6% of the subset area and bush land increases to 26.2%, grassland and woodland decreased to 4.4% and 23.8% respectively and forest was totally destroyed. The increase in cultivated land in 1980s was due to the

reduction of humanitarian aid to refugee's community especially food. This allows the refugee's communities to engage into agriculture in order to attain their basic needs. Whereas the refuges grew in number they were not given additional land accordingly and were not allowed to move outside the settlement camp leading to over utilization of the natural resources within settlement and areas surrounding the settlement camp. Also due to movement difficulties outside the settlement camp to find an alternative life, the refugees were forced to engage in tobacco farming which was almost the only reliable cash crop in the camp. This crop need about 23 m^3 of staked wood for curing a 1.3 ha of tobacco (Mangora, 1984). These resulted in increased clearance of woodland and forest in the area.

4.2 Extent and trend of Land degradation

4.2.1 Vegetation degradation

Land cover change analysis by post-classification method reveals 54 types of change in the three periods (Fig. 4.2 and Appendices 7-13). However, not all of the changes were taken into consideration. Changes during the study which does not show the continuous change and unchanged cover were not taken into consideration since they are not important with respect to degradation concept. The net amount of increase is presented by positive number and the amount of decrease is indicated by a negative number. The amount of increase, decrease and the percentage change is based on initial values of individual land use and land cover types for the year of 1978, 1984 and 1994 (Appendix 7). The number in brackets shown in the matrices tables (Appendices 8 to 10) indicates the cover area which remained unchanged, while others not in brackets indicate class cover areas that changed to other class cover categories. During the study periods, woodland and forest decreased while cultivated

land continued to increase. Bushland and grassland had increases and decreases status. Woodland decreased by 39.6% between 1978 and 1984, and 38.4% for 1984-1994, and 61.0% between 1994 and 2006. The bushland increased by 11.4% and 14.4% for the period of 1978 to 1984, and 1984-94 respectively while in 1994-06 it decreased by 42.6%. Cultivated land increased in all three periods by 328%, 103% and 55.5% respectively. The forest decreased by 20.0% from 648.8 ha to 519.3 ha between 1978 and 1984; while in 1984-94 it decreased by 100.0% from 519.3 ha to 0 ha. Grassland increased by 59.7% for 1978-84, decreased by 71.5% between 1984 and 1994, and it increased again by 6.2% during the 1994 to 2006 period. In all the three periods cultivation lands were increasing on the expenses of woodland, forest, bushland and grassland.

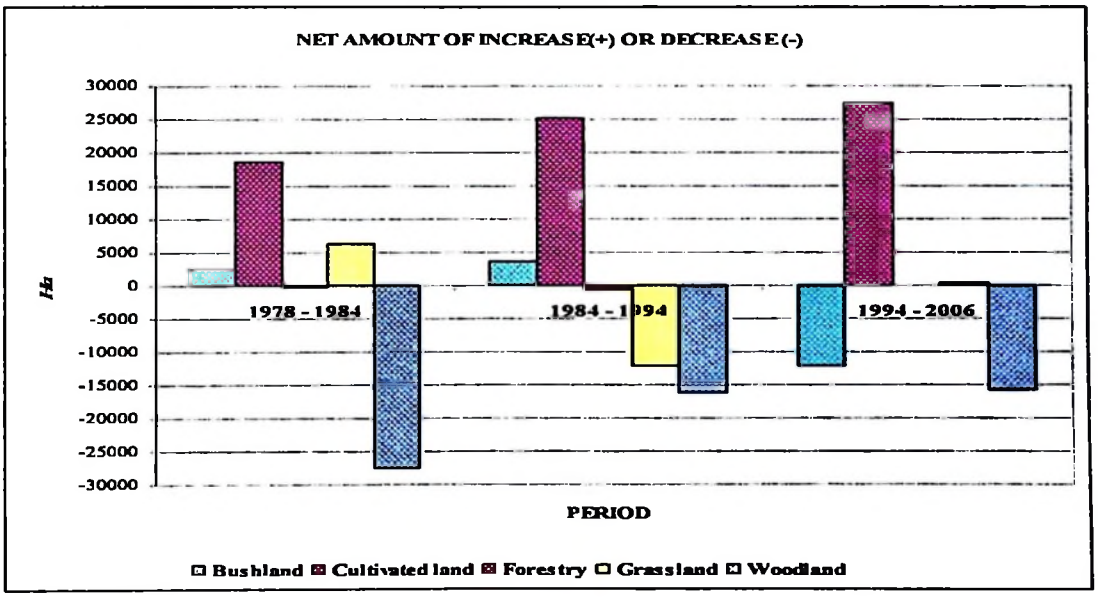


Figure 4: Net amount of increase (+) or decrease (-) in hectares of land cover classes between 1978-84, 1984-94 and 1994 and 2006.

Some of the recorded vegetation cover changes have been categorised as degradation based on overall loss or decrease in vegetation cover over the study periods (FAO, 1993). Appendix 14 represents the vegetation degradation (particularly forest and

woodland) in the study area. Forest and woodland have negative changes throughout the period therefore they have been categorised as degradation. The other remaining land cover (bush land, cultivation and grassland) categories have negative and positive changes which were not considered as vegetation degradation because there was an improvement in land cover.

In this study period (1978-06) about 85.5 per cent equivalent to 59 237.5 ha of woodland and 100% equivalent to 648.8 ha of forest have been subjected to degradation. This degradation of woodland and forest in the study area was also acknowledged by 85.7% of respondents (Table1). The main contributing factors for this environmental degradation is the expansion of agricultural land, trees cutting for construction materials, firewood for domestic and tobacco curing. The continuous increase of cultivated land have been due to the increase of refugee's population and the ceasing of International agencies and other related agencies in providing humanitarian aid to refugee's community especially food.

Table 1: Farmer's awareness on vegetation degradation in Ulyankulu refugee's settlement area.

Response	Frequency	Percent
Yes	90	85.7
No	14	13.3
No idea	1	1.0
Total	105	100.0

The clearing of land for firewood and agricultural production in refugee areas was also noted by Babu and Hassan (1995) in the study of the impact of Mozambican refugees on forest resources in Malawi. Iddi (2002) found that the degradation of

forest and woodland in west Usambara mountains was due to firewood collecting for domestic uses, tobacco curing and building materials. It was found that in the study area there is about 14.3% of the refugee's household growing flue cured tobacco. This crop requires curing before being sold and firewood is the only resource available in the area for tobacco curing. Forest or woodland area ranging from 0.5 to 1.0 ha of forest or woodland is required to cure one ha of tobacco per year (Boesen and Mohele, 1979). The wood requirements for tobacco curing are taken from open, accessible natural forests and woodlands. Also tobacco growing is rotational and is usually undertaken on newly cleared land. Its cultivation means that trees are cut each year to open new areas for cultivation. However, it has been noted that, the increasing production trend of cash and food crops at this refugee's settlement has a negative impact on the environment. Refugees are expanding their farms by clearing the forest searching for virgin land so as to increase their food and cash crop production. This unsustainable utilization of land resources done by the refugees community in order to sustain their livelihood have led to the degradation of particularly forest and woodland. In addition fetching firewood for domestic consumption and tobacco curing outside the refugee's settlement area provides further evidence of the magnitude of forest and woodland depletion. The data show that about 13.3% of the respondents are getting firewood for domestic consumption and 3.8% of respondent are getting firewood for tobacco curing outside the refugee's settlement area (Table 2).

Table 2: Farmer's firewood collection in Ulyankulu refugees settlement Area.

Responses	Firewood used for domestic		Firewood for tobacco curing	
	Frequency	Percent	Frequency	Percent
Within settlement	88	83.8	4	3.8
Outside settlement	14	13.3	4	3.8
Both	3	2.9	-	-
No idea	-	-	97	92.4
Total	105	100.0	105	100.0

4.2.2 Soil degradation

4.2.2.1 Soil erosion

The spatial and temporal distribution of estimated soil loss for the study area is given in Table 3 and appendices 25, 28, 31 and 34. These were obtained after the generating of soil erosion interaction factors layers (Appendices 15-36). Many researchers use the term of soil loss tolerance in soil erosion studies. Soil loss tolerance denoted the maximum allowable soil loss that will sustain an economic and high level of productivity (Wischmeir and Smith, 1978; Foster *et al.*, 2002). The estimated soil loss tolerance in Tanzania is 2 t to 4 t/ha (Mulengera, 1996). The assignment of a range depends on judgement of how much erosion will be harmful to the soil. Consequently, soils with shallow depth and fragile ecosystem are assigned the lower level of soil loss tolerance. For soils with large depth and good physical characteristics, the upper limit of soil loss tolerance is used (Foster *et al.*, 2002). In the study area, most of the soil types have depth that are moderate to deep (above 100cm), with low organic matter and moderate by strong aggregates (Hof *et al.*, 1980). For this reason, the upper limit of soil loss tolerance (i.e.4 t/ha) was used to assess the erosion risk areas. This threshold was adopted as the soil loss tolerance limit for the study area, and was used as the critical value for separation of low and high annual soil erosion categories. The estimated annual soil loss were classified

into 2 classes, the first category is with value of 0-4 t /ha/yr and second is with value of above 4 t/ha/yr.

Table 3: Spatial and temporal distribution of soil erosion in the Ulyankulu refugee settlement area

year	1978		1984		1994		2006	
Area	Ha	%	Ha	%	Ha	%	Ha	%
Below (4 t ha^{-1})	50,198.3	96.6	50,012.3	96.2	48,827.2	93.9	48,908.1	94.1
Above (4 t ha^{-1})	1,773.8	3.4	1,959.8	3.8	3,144.9	6.1	3,064.0	5.9
Total	51,972.1	100.0	51,972.1	100.0	51,972.1	100.0	51,972.1	100.0

The spatial distribution of the estimated soil loss of 1978 is shown in table 3 and appendix 25. This was obtained after GIS multiplication of the factors influencing erosion shown in layers of appendices 20, 21, 22, 23 and 24. In 1978 the study area had 96.6% of the area with soil loss below the soil loss tolerance level and 3.4% of the area with soil loss above 4 t/ha. However in 1984 the area of soil loss of 0-4 t/ha was 96.2% and 3.8% of the area had soil loss above 4 t/ha (Table 3 and Appendix 28). These results were obtained after GIS multiplication of the soil erosion factors of layers shown in appendices 16, 20, 21, 22, 26 and 27. In 1994 about 93.9% of the area has soil loss of low class and 6.1% of the area has soil loss of above soil loss tolerance level. These were obtained as explained above using appendices 16, 21, 22, 29 and 30. Year 2006 the soil loss area of 0-4 t/ha was 94.1% and above soil tolerance level was 5.9%. These were obtained using values in appendices 16, 21, 22, 32 and 33. There are spatial and temporal variations in area and quantity of soil loss both for soil loss below and above the used soil loss threshold values. The areas predicted by model to have soil erosion above acceptable tolerance level occurs within the steep and gently slope areas. If the soil loss tolerances in Tanzania

mentioned by Mulengera (1996) are acceptable, the results therefore indicate that the largest proportion of the study area is within the acceptable soil loss tolerance thresholds. This indicates that the problems of soil erosion are not an alarming condition compared to the vegetation degradation in the study area.

About half of the farmers in the study area said they experience soil erosion on their land. The result from the interviews show that about 52.4% of the respondents have agreed that there is a problem in the area. The remaining 47.6% did not consider it to be an important problem (Table 4).

Table 4: Farmers' awareness of the existence of soil erosion on their land in the Ulyankulu refugees Settlement area.

Awareness	Frequency	Percent
Aware of soil erosion	55	52.4
Not aware of soil erosion	50	47.6
Total	N = 105	100.0

In the study area developments of rills and gullies, and washed away ridges and plants during rainy season in sloppy lands were the common indicators acknowledged by a considerable number of farmers. (Table 5). Farmers also reported other soil erosion indicators such as poor performance of crops and deposition of sediments on the farm. These indicators were also observed in the field by the author. Gullies were very prominent in the hill slope areas especially on the roads and footpath which act as water ways for the runoff coming from the ridges furrows. Washed away ridges and plants were seen on the upper part of the field located in the slope areas of the hills. Sheet and rill erosion features were prominent features on

gentle slope areas. Dejene *et al.* (1997) found that most of the farmers in Kondoa district were aware of soil degradation taking place on their farm and surrounding area. This indicates that farmers are knowledgeable on their environmental degradation taking place in their areas.

Table 5: Ulyankulu refugees farmer's perceptions on features indicating problem of soil erosion

	Indicating features of erosion					Total
	Development of rills and gullies	Washed away of ridges and plants	Sediments deposition	Poor performance of crops	No idea	
Response	24	26	2	3	50	105
Percentage	22.9%	24.8%	1.9%	2.8%	47.6%	100.0%

Reasons given by farmers' for continued soil-erosion processes are as listed in Table 6 below. About 30% of farmers mentioned clearing of vegetation cover particularly forest and woodland and 20% mentioned high rainfall as the major causes of soil erosion while about 48% said they didn't know the reasons. Very few farmers 3.8% and about 1% mentioned slopes and types of soil to respectively be the reasons behind soil erosion problems.

Table 6: Refugees farmer's perception on the causes of soil erosion in Ulyankulu settlement area

	Causes of soil erosion					Total
	Slopes	Clearing of vegetation cover	Rainfall and slopes	Types of soil	No Idea	
Response	4	30	21	1	49	105
Percentage	3.8%	28.6%	20.0%	0.9%	46.7%	100.0%

The farmers' perceptions are in some way in agreement with Sierra Leone farmers who associated the erosion problem on their land with high rainfall, steep slopes and lack of vegetation cover (Millington, 1987 cited by Morgan, 2001). In Tanzania, due to deforestation, many parts of the country have been experiencing serious soil erosion problems particularly in the central region where miombo woodlands dominate (Misana *et al.*, 1996). Field observations showed that erosion indicators were more evident on steep and gentle slopes of the southern and north east hills, than on very gentle slopes and nearly flat areas. Most of these areas are cultivated land and cleared area with sparse grasses. A low presence of erosion indicators on very gentle slopes was in most cases the result of ridge cultivation practices. Although from those interviewed about 31% of the respondents indicated the presence of gully erosion.

The field observation results indicate the presence of gullies in the sloppy landscape areas, mostly along the roads which makes some of them not passable by motor-vehicles during the rainy season. These areas were also predicted by the model results as the area with soil loss above 4 t/ha. (Appendices 25, 28, 31 and 34). In the farm where ridging across the slope direction is practised there were no observed gullies. This was also found by Temple (1972) when he reviewed the experiment of assessing runoff and soil loss in Mpwapwa where he observed no runoff from the plot with contour ridging cultivation.

4.2.2.2 Soil fertility decline

Generally the lab analysis of the soil samples indicates that there is an alteration of most of the chemical properties when compared with the previous chemical properties from the soil survey report. Table 7 shows the results of soil lab analysis of OC, pH, available P and TN for the soil samples taken during field work and the one from the soil survey report of 1978. The level of soil condition according to the pH value of the field soil samples and soil survey report are varied. Site P1 the level of soil conditions changed from medium acid to slightly acid, site P4 level of soil condition remain strongly acid, site P10 the level changed from slightly acid to mildly alkaline, and P32 remain slightly acid. These variations are caused by the change of land use /cover and land management practices (Appendix 35). Increase in soil pH with land management practices was reported by Cihacek and Swan (1994). The level condition of total nitrogen for both periods is low due to the available organic carbon and the texture of the soil derived from granitic rock. This was also noted by Kaliba *et al.*, (1998) that nitrogen (N) is among the limiting nutrients in the western zone inclusive Urambo district. The level of content of TN% for 1978 and 2006 is increasing at low rate for almost the whole sample sites. This indication of increase in TN indicates that there was a possibility of an application of fertilizers although not at optimum level. During he interview about 42% of the farmers mentioned that they are using inorganic fertilizers in their farms. The application rate of fertilizer in the study area in general is 70kg/ha of nitrogen ((N) and 130 kg/ha of P_2O_5 (Kaliba *et al.*, 1998). But due to the cost of industrial fertilizers, most of the farmers cannot afford to buy this fertilizer so they apply below the recommended application rate. The OC% value of sample site P1, P10 and P32 shows decline

between 1978 and 2007. Sample site P4 show slight increase. The decline of OC% entails the intensification of cultivation and clearing of vegetation cover and burnt, where by organic materials are removed during field preparation.

Table 7: Levels of pH, total nitrogen (TN), organic carbon (OC) and phosphorus (P) within the 0-20 cm deep of the soils in Ulyankulu refugees settlement area for 1978 and 2007.

	pH (1:2.5 H_2O)		TN (%)		OC (%)		P	
Soil sample site	1978	2007	1978	2007	1978	2007	1978	2007
P1	6.03	5.80	0.06	0.07	1.31	0.68	8.00	3.94
P4	5.48	5.40	0.04	0.04	0.53	0.84	7.25	14.54
P10	6.15	7.80	0.05	0.11	1.47	1.15	5.00	24.47
P32	6.10	6.50	0.03	0.05	0.61	0.34	7.00	1.72

Source: For 1978 data, adopted from Hof *et al.* (1980) and Field sampling for 2007

This was confirmed by farmers during questionnaire survey where by about 82.9% of farmers practice slash and burn farm preparation practices before tilling the land. Any increase of OC% value is due to the application of farm yard manure. About 32% of interviewed farmers used farm yard manure on their farms (Table 8). The available P at sites P4, and P10 show an increase between 1978 and 2007 at significant level. This was due to application of farmyard manure at Sample site P10 which was few metres from the cattle boma resulting to the higher available P value of 2007.

Table 8: Application of farm yard manure and inorganic fertilizer in Ulyankulu refugees settlement area.

Responses	Application of manure		Application of inorganic fertilizer	
	Frequency	Percent	Frequency	Percent
Yes	34	32.4	45	42.9
No	71	67.6	60	57.1
Total	105	100.0	105	100.0

About 95.2 % of household interviewed said that there is a soil fertility decline problem in the study area (Table 4.9). The main indicator identified by the farmers was poor performance of the crop plants in the farm. Other indicators mentioned by farmers included decline of crop yield, increase of fertilizer application rate in there farms and emergence of weeds (Stringa siatic) especially in their maize farms. During field work symptoms of fertility deficiencies to the crops in the field where farmer did not apply fertilizers were observed. The most observed symptoms were yellow crop leaves and stunted crops

Other reason of fertility decline problem is continuous cultivation. About 75.2% of the 105 farmers interviewed, said that they are not practicing fallowing while 22.9% are practices (Table 19). The lack of fallowing results in over cultivation and soil fertility decline. This was also found by Ngalande (1985) in a study conducted in Siavonga district where most plots cultivated every year, experienced significant loss in soil fertility.

Table 9: Farmer's perception on the soil fertility problem in Ulyankulu refugees settlement area.

Response	Frequency	Percent
Yes	100	95.2
No	5	4.8
Total	105	100.0

4.3 Socio-economic aspects and land degradation

4.3.1 Human Population dynamics

Human population changes in the study area between 1972 and 2006 are presented in Table 10. The population increased by 24% from 1972 1975 and by 93% in 2006, with an average of annual growth rate of 2.3%. The observed population dynamics has increased pressure on limited land resources including land, forest and woodland. This led to expansion for cultivated land for both food and cash crops to meet the demand of food and other human basic needs. Also the population growth has increased demand on fuel wood for domestic uses and tobacco curing and wood for building materials. Most of the unsustainable utilization of land resources has resulted in to deterioration of natural resources. Many studies have shown that, increasing population resulted in opening up of more land, and usually for agricultural production (Sentis, 1989).

Table 10: Population dynamics in Ulyankulu refugee settlement area.

Year	Population	Population change		Annual growth rate
		Number	Percent	
1972	26 000	-	-	-
1975	32 207	6 207	24	8
2006	56 410	24 203	93	3

4.3.2 Household characteristics

Table 4.11 shows that 46.7% of the respondent belonged to the household with 5-8 members followed by 34.4% respondent with above eight members and 19.0% with below five members. The average household size in the study area is 7.4 persons. While nationwide household size was 4.9 persons in 2002 (URT, 2003). The average household size of 7.4 persons per household recorded in the study area is above national average as well as Tabora region's average household size of 5.9 persons recorded in 2002 (URT, 2002). The larger number of people per household in the study area may be either due to higher birth rates and the tendency of farmers to hire labourers for farming activities. About 29.5% of the respondent hired labour for the farming activities. Also most people prefer many children possibly due to the fact that in small holder farms, the family is the main source of labour for agricultural production (Njuki, 2001; Epaphra, 2001; Kingazi, 2002; Maenda, 1999). This was also noted in the study area that about 70.5% of 105 household interviewed have indicated using farmily labour force in the farming activities. This may lead to large populations hence increased demand for food and humanitarian basic needs

Household size can give an indication of the extent of pressure that could be exerted on natural resources. On the other hand it can also be an indication of the available labour. A household size is an important variable in determining sustainability of natural resources in an ecosystem (Mung'ong'o, 1995 cited by Nduwamungu, 2001). Large households tend to over-exploit their resources in order to meet their needs, while also undermining their very sources of livelihood. This means that as the

average household size increases a situation is likely to threaten ecological integration and sustainable management of natural resources in the study area.

Table 11: Average family size per household in the Ulyankulu refugees settlement area.

Family size	Frequency	Percent
Up to 5	20	19.0
5 to 8	49	46.7
Above 8	36	34.3
Total	105	100.0

Size of the household

4.3.3 Literacy level

Education plays a very important role in farmer's perception of technologies, how they are disseminated and their sustainability. It influences the level of understanding and assimilation of development issues. This affect the adoption or responsiveness of farmers to issues or technologies disseminated in the long run. In the study area the illiteracy levels among the farmers interviewed was 31.4%. About 58.1% of farmers had gone up to primary level. 5.7% gone up to secondary level and 4.8% went as far as the higher education level (Table 12). Education is perceived as among the factors that influence an individual's perception of a particular development intervention for decision making. Kajembe and Luoga (1996) argue that education tends to create awareness, positive attitude, values and motivation. Malaisse (1978) asserts that, given everything else, educated rural household are more productive in agriculture and likely to have more off-farm income earning opportunities than the non-educated. Thus, education promotes better management of household resources and reduces pressure on the easily accessible natural resources.

Table 12: Education levels of respondent household heads in the Ulyankulu refugee settlement area.

Response	Frequency	Percent
Primary Education	61	58.1
Secondary Education	6	5.7
Other	5	4.8
Informal Education	33	31.4
Total	105	100.0

4.3.4 Land acquisition and availability

Land distribution in this area was done by UN during establishment of the settlement (Stein, 1990). This was also noted during the research where about 80% of the farmers in the study area interviewed have been given land by the UN during settlement establishment, and 18.1% of the respondents inherited land from their parent and relatives and 1.9% bought/hired their land from others (Table 13). The given land size was about 5 ha per family for food production (UNHCR, 1997). Currently, about 65.7% of farmers have land for cultivation of less than 2 ha and 34.3% have cultivated land of more than 2 ha (Table 13). There is land fragmentation in the study area, and this could be due to the high population growth. Also the government of Tanzania's policy limits the movement of refugees outside the camp or designated area. The Refugee Act and the Land act clearly define the limit of the camps as the maximum limit of movement for the refugees. As a consequence, the land available for refugees has been fragmented. This method of land fragmentation leads to soil degradation as it encourages agricultural intensification without restoration of the soil fertility.

Table 13: Land acquisition in the Ulyankulu refugees settlement area.

Response	Frequency	Percent
Given by UN	84	80.0
Inherited from their parent/relatives	19	18.1
Other (bought, hired ets)	2	1.9
Total	105	100.0

4.3.5 Source of energy

The most important source of energy in the study area is fuel wood, others are charcoal and kerosene. About 92.4% of the farmers interviewed use firewood, 3.8% use firewood and charcoal, and 1.9% use charcoal and kerosene as well as firewood and charcoal (Table 14). This indicates that households in the study area solely depend on firewood as the major source of energy for home use. The households also grow tobacco and use firewood for curing the crop before being sold. On average tobacco farmers use about 1 m^3 firewood to cure 57 kg of tobacco (Abdallah and Sauer 2007). Geist (1997) reported that 20 m^3 of miombo woodlands is used to cure 1 ha of tobacco. Source of firewood in the study area is from natural vegetation. The increase in demand of firewood due to the population increase, ceasing of humanitarian aid to refugees and unavailability of an alternative source of energy for domestic and tobacco curing results into unsustainable utilizing of natural vegetation resources and lead to degradation. This was also noted by Ferguson (1988) that collection of firewood can result to forest and woodland degradation.

Table 14: Source of energy for refugees in Ulyankulu settlement area.

Types of energy source	Frequency	Percent
Firewood	97	92.4
Firewood and charcoal	2	1.9
Firewood and kerosene	4	3.8
Firewood, charcoal and kerosene	2	1.9
Total	105	100.0

4.3.6 Livelihood and resource endowment

The questionnaires survey indicate that all the households interviewed depend on agriculture as a major source of income. About 65.7% of the households interviewed depend on crop production, 30.5% depend on crop and livestock production and 3.8% on crop production and other non farm activities (Table 15). The major source of income was sale of crop produce and livestock. Apart from the above source of income, other sources of income is sale of forest by product such as timber, charcoal, honey and building poles (URT, 1998). These economic activities can led to deterioration of land resources if exploit into unsustainable basis..

Table 15: Source of income for the Ulyankulu refugees settlement area.

Source of income	Frequency	Percent
crop production	69	65.7
crop and livestock production	32	30.5
crop production and other	4	3.8
Total	105	100.0

4.3.7 Farming system practiced and major crops grown

The majority of land users in the study area are subsistence farmers with traditional farming. Traditional farming methods use simple equipment like axe and hoe and are

hampered by limited access to agricultural inputs such as fertilizer and improved seed. During the research it was observed that about 83.8% of those interviewed practice the slash and burn method on farm preparation and 16.2% practices other methods of farm preparation (Table 16). This farm preparation practices mostly results to soil degradation due to the fact that the nutrient utilized by plants are not returned back to the soils.

Table 16: Farm preparation by refugees in Ulyankulu settlement area

	Frequency	Percent
slash and burn	88	83.8
plough under	17	16.2
Total	105	100.0

The cultivation methods noted during survey include ridging and flat cultivation. About 81 households (77.1%) of the respondents are practising ridge cultivations and 24 household (22.9%) practising both ridging and flat cultivation (Table 17). This may be due to the type of soil and slope percentage. About 83% of the area has a slope of less than 2%, 15% has a slope of 2-6%, 2% has the slope greater than 6%. The dominant soils in the study area are 54% sandy clay loam, 44% sands and loamy sand and 2% gravel soils. This has an implication on the crop growth during rainfall season. Ridging reduce the water logging risks to crops, especially maize and tobacco which are highly susceptible to an excess of water during growing period. Ridging also reduce soil erosion by reducing the slope length and or conveying run off to the water way without eroding the soil at rill or gully level.

Table 17: Cultivation methods by refugees in Ulyankulu settlement area.

Cultivation methods	Frequency	Percent
Ridging	81	77.1
Ridging and flat cultivation	24	22.9
Total	105	100.0

The vast common feature of the cropping systems in the study area is the widespread practice of intercropping. The survey result revealed that 61.9% are practicing intercropping, 34.3% both mono-cropping and intercropping and 3.8% are practicing single cropping (Table 18). From the survey the major crops grown in order of importance are maize, beans, tobacco, cassava, groundnuts and rice. The actual main combination of crops intercropped in the farming system include; maize and beans, maize and cassava, maize and groundnuts. Other cropping system are mono-cropping which include; tobacco and paddy crops.

Table 18: Cropping system in Ulyankulu refugee settlement area

Cropping systems	Frequency	Percent
Single crop	4	3.8
Intercropping	65	61.9
Both	36	34.3
Total	105	100.0

Intercropping, particularly that which utilizes legumes is a deliberate measure to maintain soil fertility. It is also an effective means of spreading risk in areas where rainfall is unreliable. The common soil fertility restoration in the traditional farming system is land fallowing. This practices was observed in the study area. Out of the 105 household interviewed, 24 households (22.9%) are practising fallowing in their land and 79 households (75.2%) are not (Table 19).

Table 19: Refugee farmers perception on fallowing practices in Ulyankulu rettlement area.

Response	Frequency	Percent
Yes	24	22.9
No	79	75.2
No idea	2	1.9
Total	105	100.0

This result reveals that there is intensive continuous cultivation of a piece of land due to the lack of land for fallowing. Another restoration system is the utilization of crop residues. The way in which crop residues are utilized in a farming system has important implication for nutrient recycling and soil and water conservation. In the study area about 64.8% of respondent are ploughing under the crop residues, 20% of farmers are burning and 9.5% are grazing by livestock (Table 20). This could be the result of small differences showed in the result of soil fertility status of nitrogen, and pH between 1978 and 2006 (Table, 8).

Table 20: Management of the crop residues in Ulyankulu refugee settlement area.

	Frequency	Percent
Plough under	68	64.8
Grazing	10	9.5
Burning	21	20.0
No idea	6	5.7
Total	105	100.0

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

The study indicates that land degradation, particularly vegetation and soil degradation are present in the study area. The magnitude of the degradation varies from one component of degradation to another depending of the causal factors. The study demonstrates that the differentiation of vegetation degradation can be attained through permanent vegetation change using change detection analysis. The assessment of erosion by water can be attained using models through remote sensing analysis in the GIS environment. The soil fertility status can be assessed using the previous available information of soil properties comparing with the current analysed properties. The methods employed takes into account both anthropological and natural factors that cause land degradation.

The refugees population has doubled since 1972, from 26 000 to 50 410. The increase of population has many implications but most of all is food requirement. This demand can be met by expansion of agricultural land or by intensification of existing food production systems. It was revealed that the cultivated land were increased from 5 693.4 ha to 77 015.5 ha between 1978 and 2006, at the increase rate of about 37% per year. During this period the woodland also decrease from 69 295.3 ha to 10 058.4 ha. This was the result of agencies stopping to provide refugees humanitarian aids, especially food and basic needs. Also the settlement was handed over to the Tanzania government whereby no assistance was provided from international communities. Soil erosion by water above soil tolerance level occurs

mostly on slope gradients above 4%, and substantial fertility decline was observed between 1978 and 2006 particularly for the available phosphorous and nitrogen. There is severity of soil degradation particularly on agricultural land caused by inappropriate crop production practices where fertility restoration is not common. The areas of erosion above soil tolerance level were observed mostly on the slope gradient greater than 4% accounting for about 4% of the total area. This shows that soil erosion is not a problem on about 96% of the land areas. However, it is important to not that the figure are just indicative since the erosion hazard mapping used does not give actual soil erosion rates taking place. Soil and water conservation in the area particularly rehabilitation of degraded through fertility management ought to be given priority

5.2 Recommendation

- Farmers should be sensitised on the severity and influence of land use changes on land degradation and the relevance of soil and water conservation measures such as agroforestry techniques, appropriate cropping system and fertility management. This will require a multidisplinary and participatory approach where various stakeholders including end users (beneficiaries), extensionists, researchers and politicians are fully involved.

- Land suitability assessment is needed to analyse the potential of land in the refugee settlements.

- Farmers should be encouraged to plant fast growing trees on their farm boundaries, homesteads or on unproductive land (land not suitable for cropping),

- The refugee's community farmers should be sensitised on the severity and influence of land use changes on land degradation and the relevance of soil and water conservation measures such as agro-forestry techniques and appropriate cropping system..

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APPENDICES

Appendix 1: Household questionnaire

PART A: GENERAL QUESTION.

1.1 Refugee settlement .....

1.2 Barabara.....

1.3 Zone .....

1.5 Date .....

1.6 Age of respondent.....years.

1.7 sex (Tick) 1. Male 3. Female

1.8 Family age distribution

1. Less than 15 (.....) 2. 15 – 55 years (.....) 3. Greater than 55 (.....)

1.9 Family size (Tick) 1. Less than five 2. 5 -8 3. Above 8

1.10 Education of respondent (Tick)

1. Primary education 2. Secondary education 3. Other 4. Informal education

PART B: SOCIO - ECONOMIC ACTIVITIES.

2.1 What is your main source of income?

(1)Crop production (2) Livestock keeping (3) Both livestock and crop production

(4) Other (specify).....

2.2 Is the household labour sufficient for all your farm activities 1. Yes 2. No

2.3 If No where do you get extra labour? (Mention).....

2.4 For which operations do you need extra labour? (Mention).....

2.5 What kind of payment do you offer them 1. Cash 2. In kind

(Specify).....

2.6 Is your road network accessible for the whole year 1. Yes 2. No

2.7 If no why? (Mention reasons).....

2.8 Do you use fertilizer in your crop fields? 1. Yes 2. No

2.9 If yes what types of fertilizers do you use (Tick)

1. TSP 2. CAN 3. SA 4. Urea 5. N-P-K 6. Others (Specify).....

2.10 Have there been changes in the type of fertilizers used over time in terms of type, quantities, or crops on which they are applied? 1. Yes 2. No [Please explain].....

2.11 Do you apply manure (FYM/Compost) in your crop field? 1. Yes 2. No

2.12 If Yes to which crop do you apply the manure (Mention).....

2.13 Why are you applying fertiliser/manure? (Explain).....

2.13.1 Source of domestic energy (Mention).....

2.14 Do you have sufficient food for the whole year 1. Yes 2. No

2.15 If No for how long the food is sufficient (Mention months).....

2.16 What reason make food not sufficient (Mention reasons) .....

PART C: LAND USE

3.1 What crops are you growing (Mention).....

3.2 What Cropping systems do you practices

1. Single crops 2. Intercropping 3. Strip cropping 4.Other.

3.3 Are you cultivating all your land you owned? 1. Yes 2. No

3.4 How do you prepare new land for cultivation (specify).....

3.5 How many hectares do you cultivate (mention).....

3.6 What cultivation types are you practices?

1. Flat cultivation 2. Ridging 3. Both 4. Other

3.7 Would you think of expanding agricultural land 1.Yes 2. No.

3.8 How much land is available for expansion? (Estimate in ha).....ha.

3.9 How far are your crop field from the homestead? (Give average distance).....km.

3.10 What type of tenure do you own your land?

1. Right of Occupancy. 2. Customary Land Tenure. 3. Communal Land Tenure.

3.11 Do you keep livestock 1 Yes 2. No

3.12 If yes, what type, number and purpose of livestock you keep.....

3.13 If no why (Tick) 1 Shortage of grazing land 2. Lack of cash to buy animal 3 Environmental Considerations 4. Vulnerability to diseases 5. Other (specify)

3.14 Where do you graze your livestock (Tick)

1. During rain season (Within settlement, outside settlement, within and outside settlement)

2. During dry season. (Within settlement, outside settlement, within and outside settlement)

3.15 Where did you get fuel wood for domestic consumption

1. Within settlement, 2. Outside settlement, 3. Within and outside settlement

3.16 Where did you get fuel wood for tobacco curing

1. Within settlement 2. Outside settlement, 3. Within and outside settlement

3.17 Source of water (mention).....

3.18 Is water sufficient for the whole year? 1. Yes 2. No

3.19 If No why (give explanation).....

3.20 Have there been changes in land use over time? 1. Yes 2. No [Explain]

PART D: MAJOR ISSUE OF LAND DEGRADATION.

4.1 Duration of stay in the settlement .....Years.

4.2 Do you perceive the problem of vegetation degradation? 1. Yes 2. No

4.3 If yes, what indicators lead you to believe that such problem exists?

4.4 When does that indicator(s) started? (Estimate in terms of years).....years

4.5 What have you done from that problem?.....

4.6 Do you perceive the problem of soil erosion on your land? 1. Yes 2. No.

4.7 If yes what features lead you to believe that such problems exist.....

4.8 On your opinion what causes soil erosion (Explain).....

4.9 What have you done from that problem?.....

4.10 Do you perceive the problem of soil fertility decline on your cultivated land?

1. Yes 2. No

4.11 If yes has it been 1. Increasing 2. Deceasing 3. Unchanged

4.12 What features leads you to believe that such problem exists?.....

4.13 Do you observe change in the level of crop yield on your cultivated land?

1. Yes 2.No

4.14 If yes, has it been increasing or declining? (Tick)

4.15 If increasing or declining what are the major reasons?.....

4.16 What are the trends in crop/livestock yields in the past fifteen years?

1. Increasing 2. Decreasing 3. Fluctuate 4. Remained the same

4.17 For how long (years) have you experienced this problem(s).

4.18 From your experience, would you associate soil degradation with cropping pattern And/or livestock system? 1. Yes 2. No (Explain)

4.19 What do you usually do with crop residues? (Explain).....

4.20 Do you protect your land from soil degradation? 1. Yes .2. No.

4.21 If yes what measures do you use to protect your land (Mention).....

4.22 Do you practice fallowing? 1. Yes 2. No

4.23 If yes for how long (Mention duration)..... years.

4.24 If no why .....

4.25 Do you have an by laws on resource utilization and management1. Yes 2. No

4.26 If No why? (mention reasons) .....

4.27 If yes, mention by laws do you have .....

PART E: CHECKLIST QUESTIONS

5.1 Is the settlement boundaries surveyed?

5.2 What criteria used to make decision on the establishment of the settlement

5.3 What planning procedure used on the establishment

5.4 How land is located in the settlement

5.5 What is the status of the resource utilization within and outside the refugee settlement?

5.6 How do you rank the problems of land degradation in the refugee's Communities in general?

5.7 What strategy do you have concerning land degradation problems

5.8 What is the root causes of land degradation

5.9 What is the status of resources before and after the presence of refugees

5.10 What is your opinion regarding the presence of refugees.

5.11 What is the production trend of crop and livestock in the area for the past 20 years?

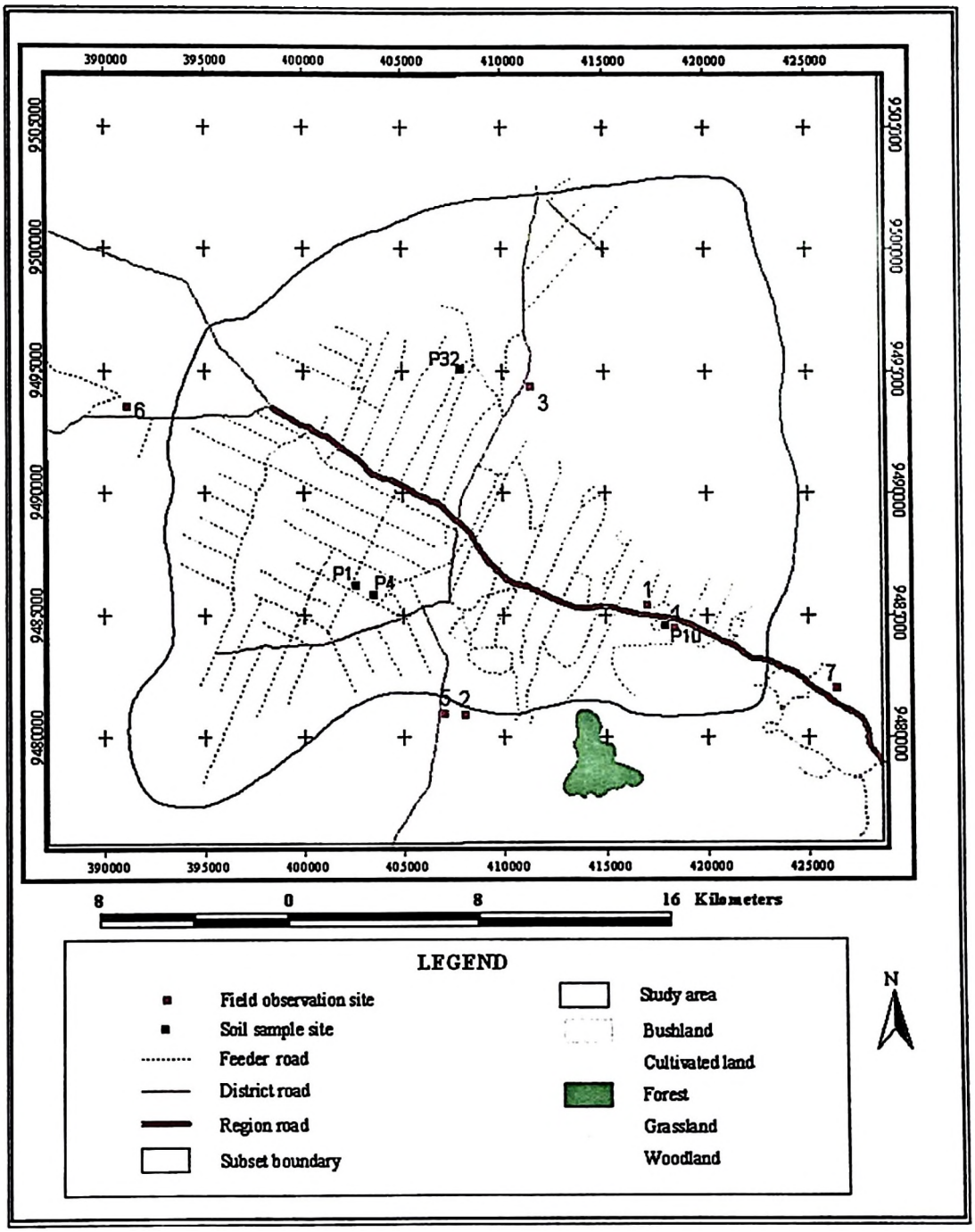
5.12 Is there an problems resulted from land degradation?

Appendix 2: Spatial and temporal distribution of land covers classes for the subset area

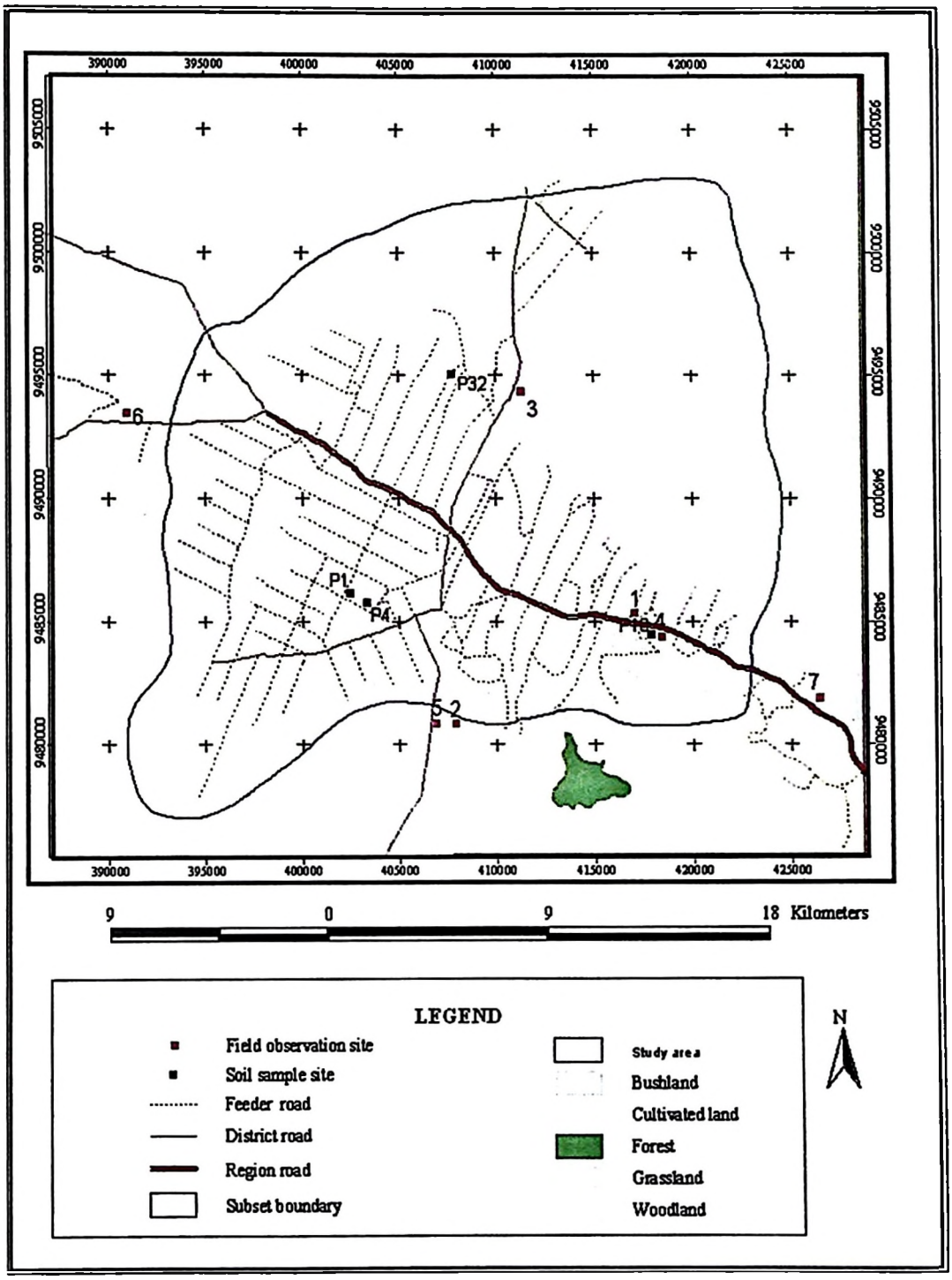
Land use/cover	1978		1984		1994		2006	
	Area (in ha)	%	Area (in ha)	%	Area (in ha)	%	Area (in ha)	%
Bush land	22,260.6	20.5	24,807.5	22.9	28,370.1	26.2	16,295.1	15.0
Cultivated land	5,693.4	5.2	24,365.0	22.5	49,514.4	45.6	77,015.5	71.0
Forest	648.8	0.6	519.3	0.5	0.0	0.0	0.0	0.0
Grassland	10,579.7	9.8	16,898.2	15.6	4,811.1	4.4	5,108.8	4.7
Woodland	69,295.3	63.9	41,887.8	38.6	25,782.2	23.8	10,058.4	9.3
Total	108,477.8	100.0	108,477.8	100.0	108,477.8	100.0	108,477.8	100.0

Source: Topo sheet map of 1978, Landsat TM of 1984, 1994 and Landsat ETM of 2001

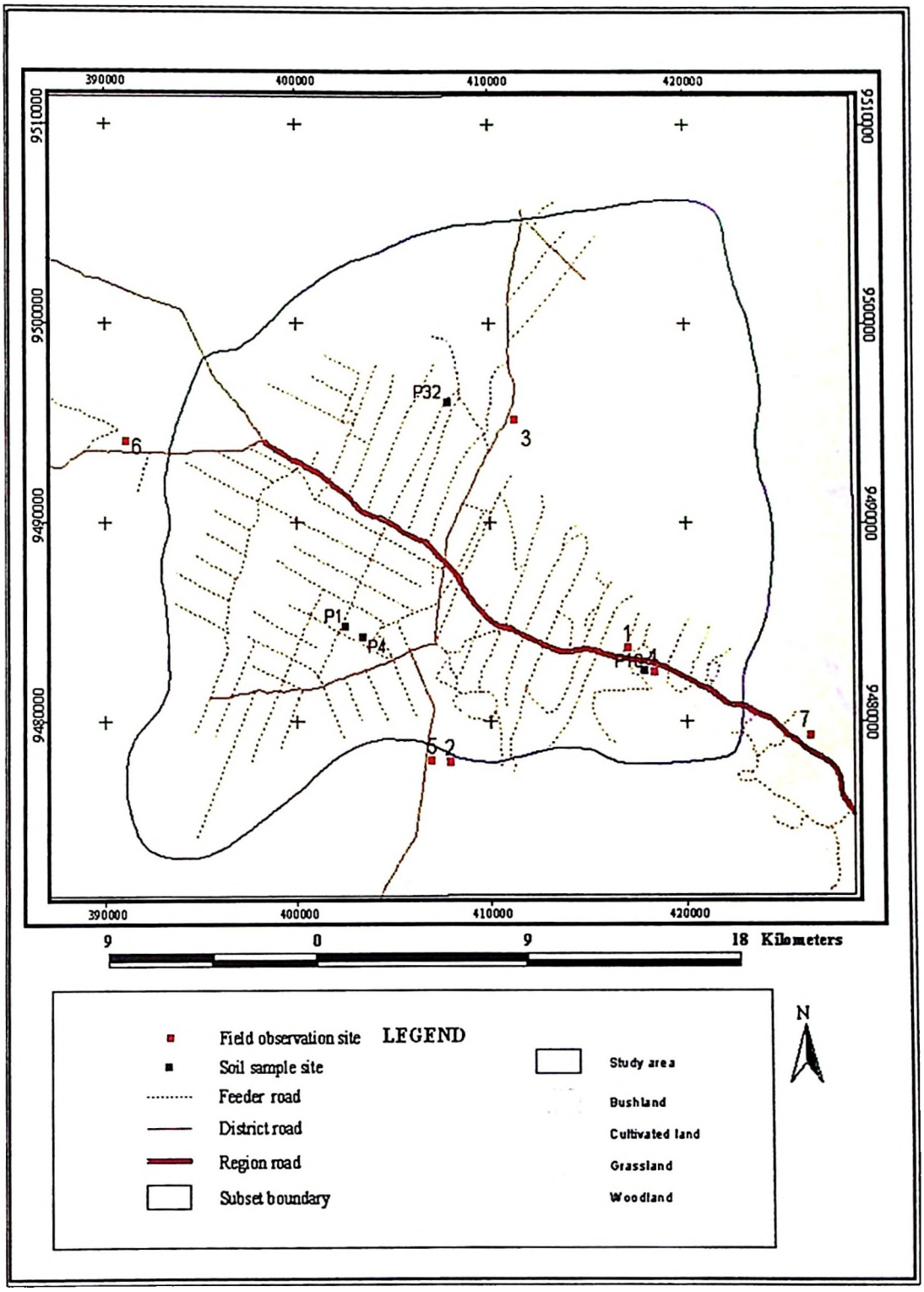
Appendix 3: Land use/cover map of 1978



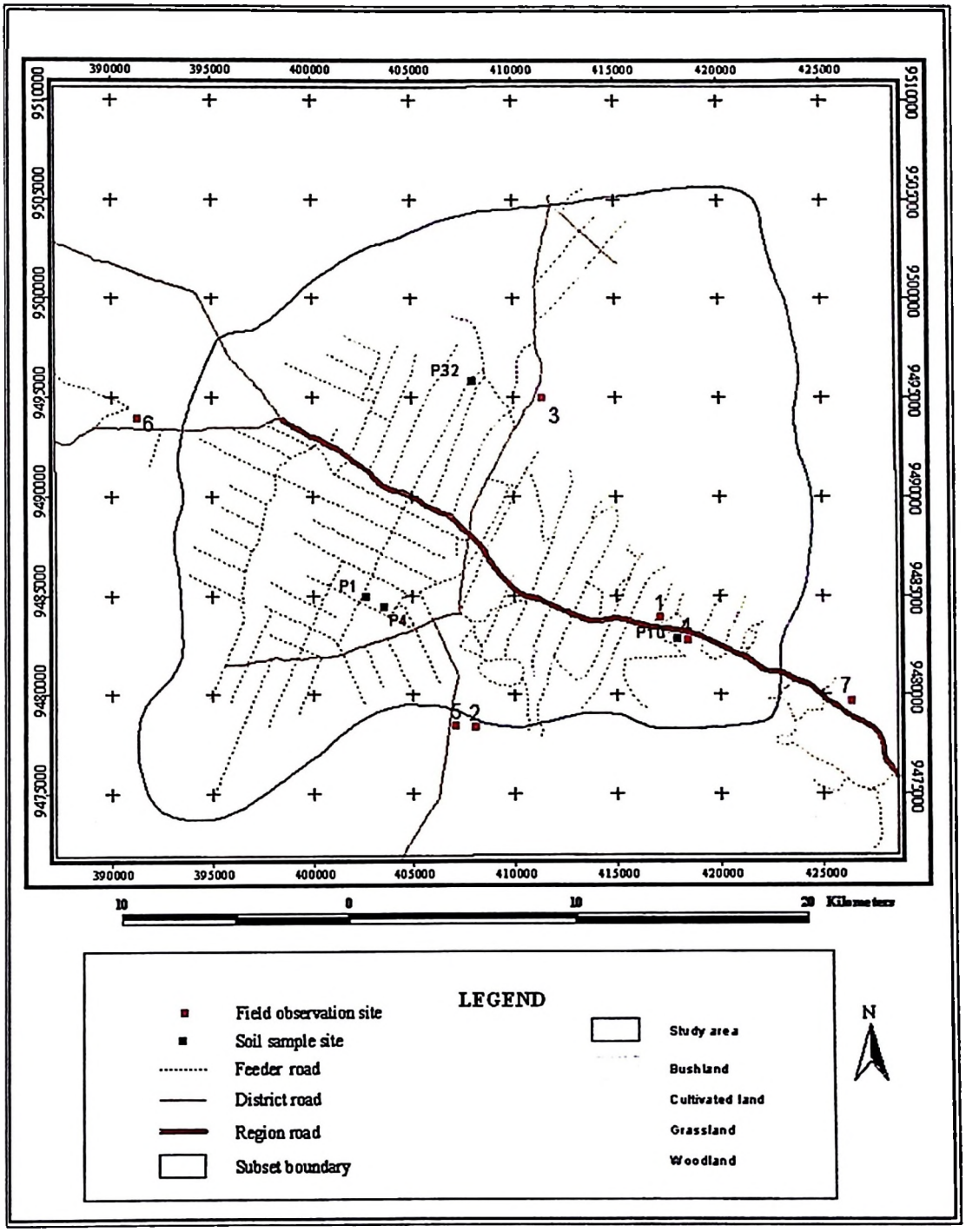
Appendix 4: Land use/cover map of 1984



Appendix 5: Land use/cover map of 1994



Appendix 6: Land use/cover map of 2006



Appendix 7: Net amount of increase (+) or decrease (-) in hectares of land cover classes between 1978-1984, 1984-1994 and 1994-2006/

Land cover class description.	PERIOD (Years)					
	1978 - 1984 (Area in)		1984 - 1994 (Area in)		1994-2006 (Area in)	
	(Ha)	%	(Ha)	%	(Ha)	%
Bushland	2,546.9	11.4	3,562.6	14.4	-12,075.0	-42.6
Cultivated land	18,671.6	328.0	25,149.4	103.2	27,501.1	55.5
Forest	-129.5	-20.0	-519.3	-100.0	0.0	0.0
Grassland	6,318.5	59.7	-12,087.1	-71.5	297.7	6.2
Woodland	-27,407.5	-39.6	-16,105.6	-38.4	-15,723.8	-61.0

(Percentage refers to the initial value of the individual class area in 1978, 1984 and 1994)

Appendix 8: Change detection matrix between 1978 and 1984 (Areas in Ha)

Land cover classes in 1978	Land over classes in 1984					
	Bushland	Cultivated land	Forest	Grassland	Woodland	Total
Bushland	(10,684.1)	5,383.9	0.0	6,192.6	0.0	22,260.6
Cultivated land	313.8	(4,972.4)	0.0	407.2	0.0	5,693.4
Forest	32.3	97.2	(519.3)	0.0	0.0	648.8
Grassland	819.5	2,190.4	0.0	(7,569.8)	0.0	10,579.7
Woodland	12,957.8	11,721.1	0.0	2,728.6	(41,887.8)	69,295.3
Total	**24,807.5**	**24,365.0**	**519.3**	**16,898.2**	**41,887.8**	**108,477.8**

(Figures in brackets represent land cover that remain unchanged)

Appendix 9: Change detection matrix between 1984 and 1994 (Areas in Ha)

Land cover classes in 1984	Land over classes in 1994				
	Bushland	Cultivated land	Grassland	Woodland	Total
Bushland	(15,806.8)	8,227.5	773.2	0.0	24,807.5
Cultivated land	1,935.4	(22,075.9)	353.7	0.0	24,365.0
Forest	468.3	51.0	0.0	0.0	519.3
Grassland	3,744.4	10,953.3	(2,200.5)	0.0	16,898.2
Woodland	6,415.2	8,206.7	1,483.7	(25,782.2)	41,887.8
Total	**28,370.1**	**49,514.4**	**4,811.1**	**25,782.2**	**108,477.8**

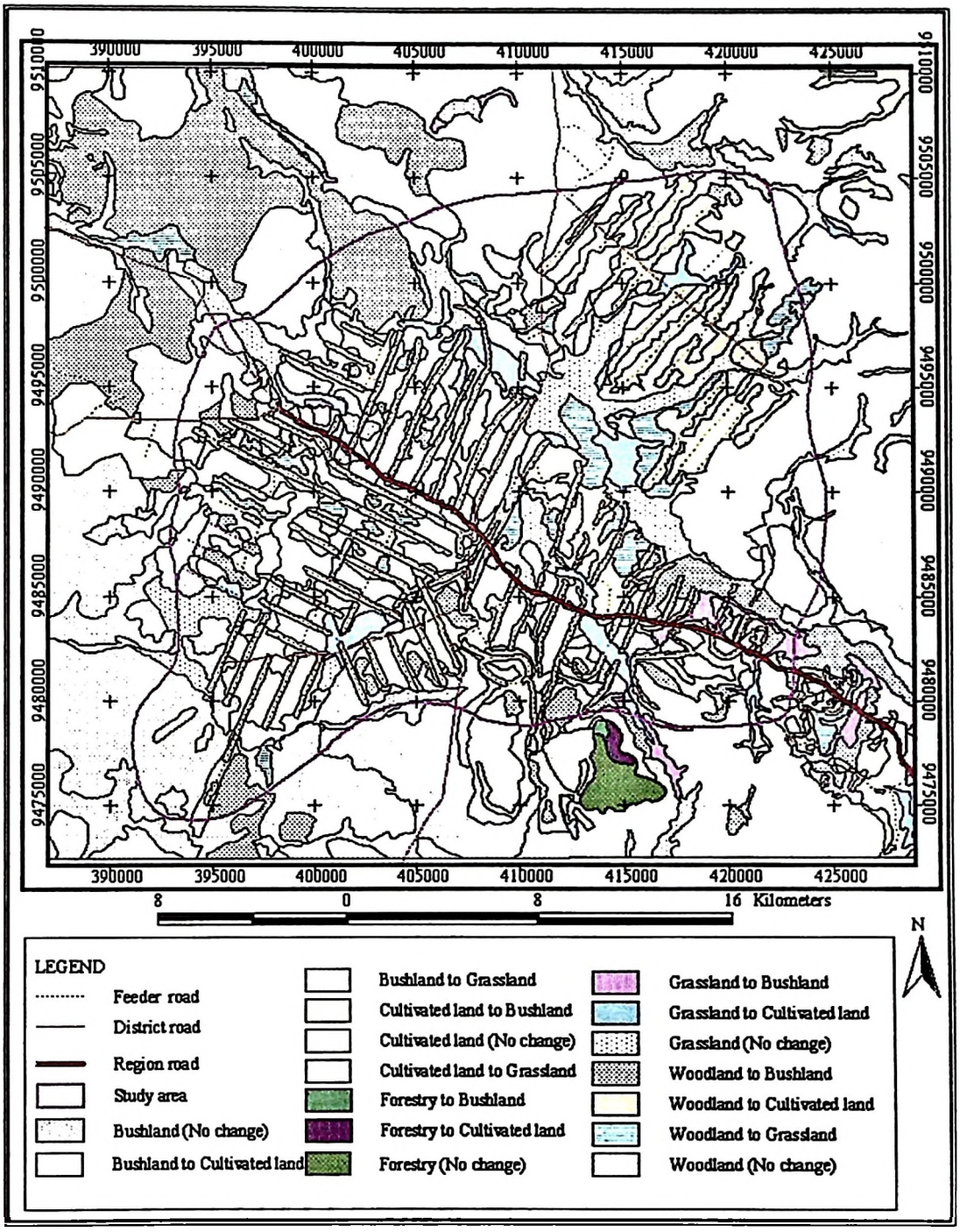
(Figures in brackets represent land cover that remain unchanged)

Appendix 10: Change detection matrix between 1994 and 2006 (Areas in Ha)

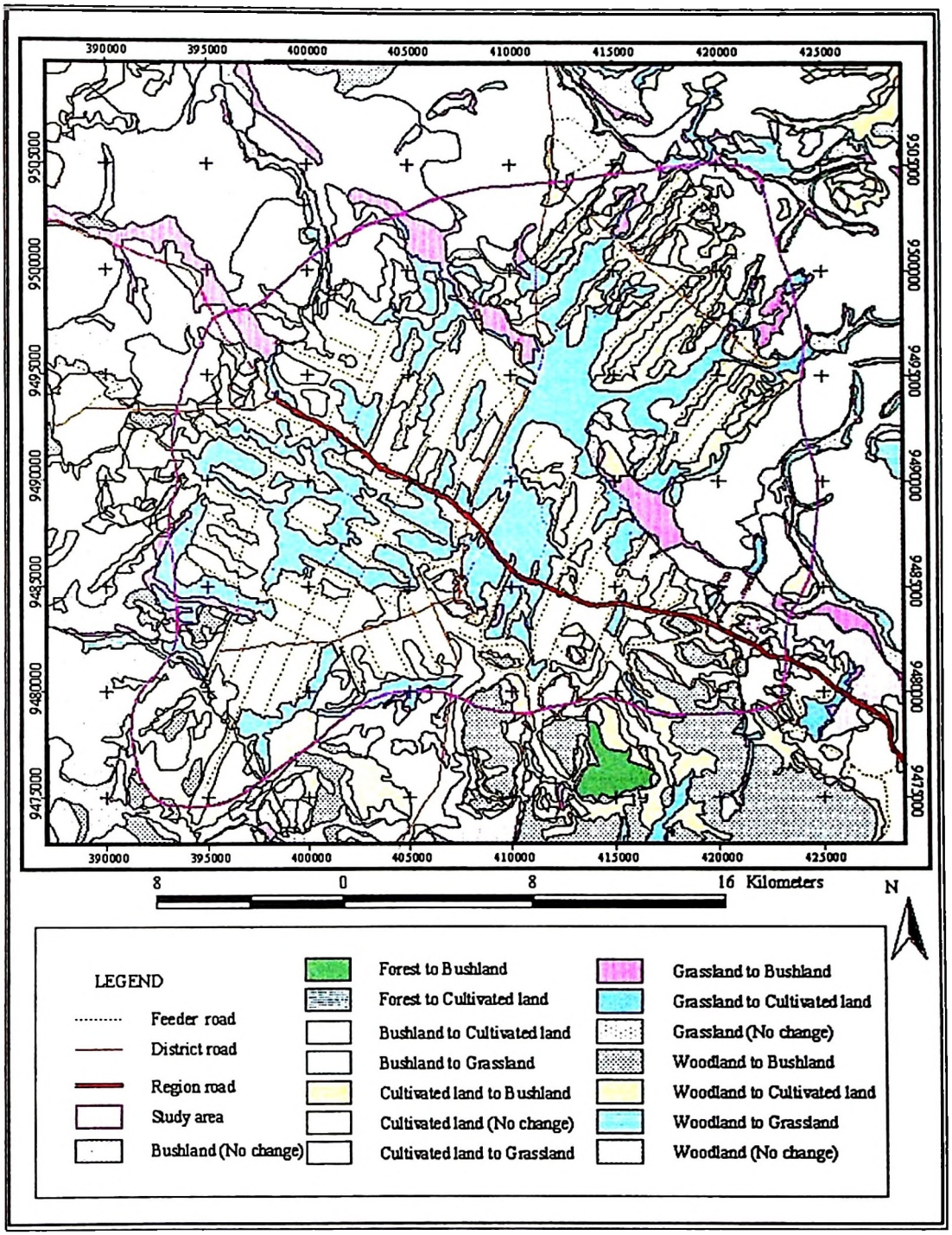
Land cover classes in 1994	Land over classes in 2006				
	Bushland	Cultivated land	Grassland	Woodland	Total
Bushland	(12,115.3)	13,883.6	2,371.2	0.0	28,370.1
Cultivated land	1,664.8	(47,165.4)	684.2	0.0	49,514.4
Grassland	1,023.3	2,945.8	(842.0)	0.0	4,811.1
Woodland	1,491.7	13,020.7	1,211.4	(10,058.4)	25,782.2
Total	**16,295.1**	**77,015.5**	**5,108.8**	**10,058.4**	**108,477.8**

(Figures in brackets represent land cover that remain unchanged)

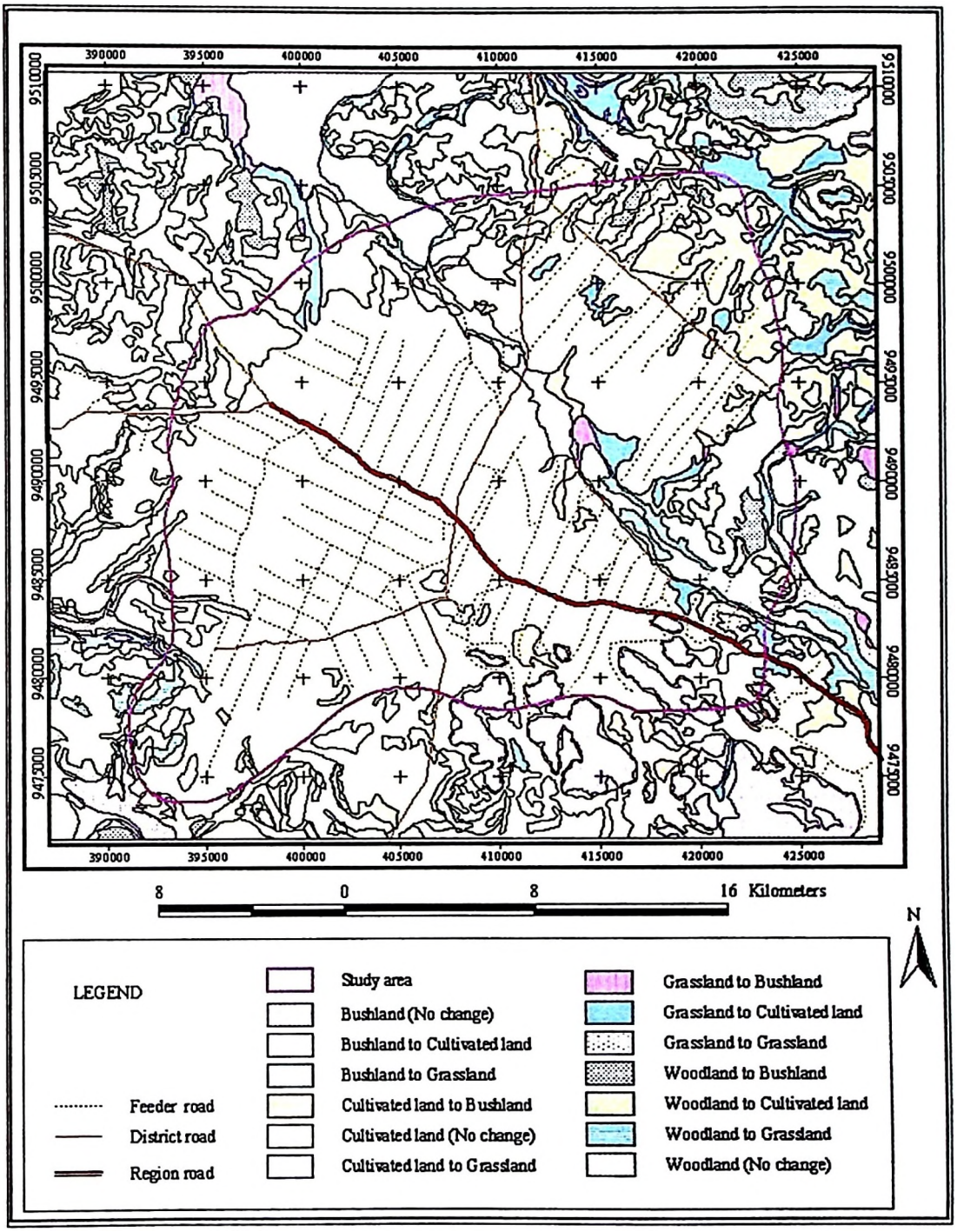
Appendix 11: Land use /cover change map between 1978-84



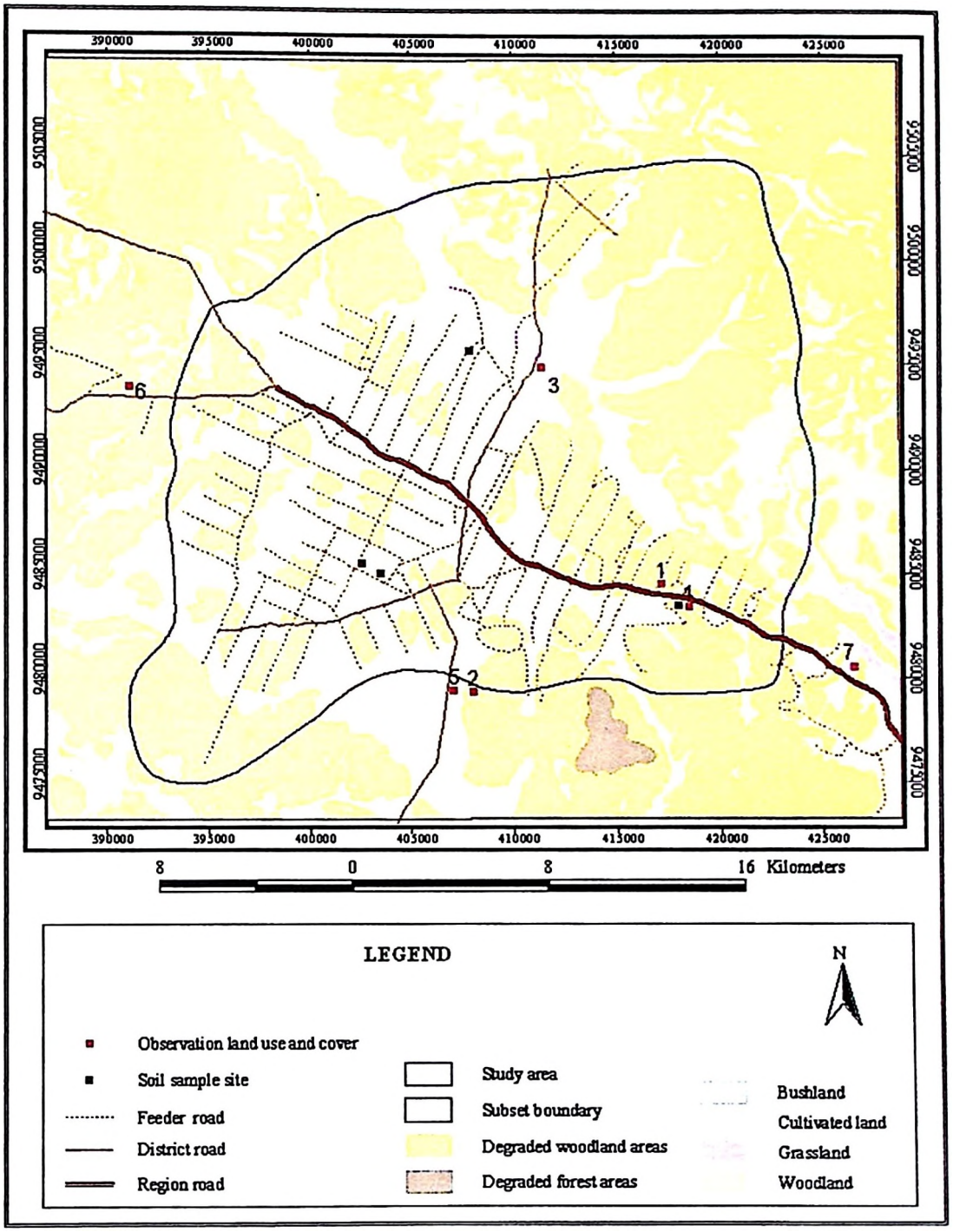
Appendix 12: Land use /cover change map between 1984-94



Appendix 13: Land use /cover change map between 1994-06



Appendix 14: Vegetation degradation between 1978-06



Appendix 15: Rainfall data used from Uyowa weather station

YEAR	JAN	FEB	MAR	APPR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC.
1976										49.5	117.0	173.2
1977	168.1	134.5	193.4	231.7	70.4	0.0	0.0	0.0	0.0	65.0	120.0	72.9
1978	86.4	120.8	202.3	32.3	1.0	0.0	0.0	0.0	4.3	9.0	228.0	113.9
1979	75.8	219.1	30.1	135.2	5.0	0.0	0.0	0.0	0.0	37.9	53.1	86.8
1980	161.8	117.6	0.0	144.1	0.0	0.0	0.0	0.0	16.2	48.3	83.1	124.2
1981	72.1	99.9	188.6	180.8	41.4	0.0	0.0	0.0	6.3	24.4	37.1	247.4
1982	73.1	93.4	132.4	49.4	37.1	0.0	0.0	0.0	0.0	68.6	176.0	67.9
1983	140.2	15.5	119.0	79.0	17.0	0.0	0.0	14.8	0.0	17.3	68.0	74.4
1984	360.0	83.0	82.3	67.9	5.0	0.0	0.0	0.0	0.0	0.0	0.0	84.2
1985	131.2	143.8	113.2	156.6	7.2	0.0	0.0	0.6	7.9	9.5	157.0	145.7
1986	235.2	184.1	177.1	226.8	84.8	0.0	0.0	0.0	3.6	51.1	160.0	252.2
1987	135.5	51.5	216.2	147.9	29.9	0.0	0.0	0.0	84.9	37.5	139.0	112.1
1988	146.3	53.6	179.2	130.0	7.7	0.0	0.0	14.4	0.0	43.5	113.0	229.7
1989	128.2	131.9	189.3	219.8	68.2	0.0	0.0	0.0	7.0	11.1	191.0	201.2
1990	128.3	217.6	160.2	113.5	55.3	0.0	0.0	0.0	18.0	19.1	100.0	232.4
1991	215.9	91.7	182.3	208.8	54.9	0.0	0.0	0.0	3.0	158.0	77.2	181.2
1992	76.6	226.5	175.3	215.8	61.2	0.0	0.0	0.0	0.0	41.2	55.0	263.6
1993	112.7	108.7	201.3	93.9	113.0	0.0	0.0	0.0	0.0	0.0	34.5	105.3
1994	173.0	93.6	193.4	125.0	19.0	0.0	0.0	0.0	0.0	36.6	123.0	283.4
1995	112.7	150.1	171.7	178.9	19.0	0.0	0.0	0.0	0.0	25.3	31.4	89.8
1996	144.3	233.1	166.5	135.5	4.1	0.0	0.0	0.0	8.5	54.2	97.0	33.8
1997	145.4	24.3	89.9	116.8	92.5	0.0	0.0	0.0	0.0	13.1	140.0	331.7
1998	213.7	128.5	83.3	159.3	25.4	0.0	0.0	0.0	48.3	9.0	43.0	175.6
1999	97.0	84.2	160.0	164.3	6.0	0.0	0.0	25.0	26.1	9.6	97.2	105.1
2000	89.4	154.2	150.8	104.4	2.6	0.0	0.0	0.0	9.1	16.4	153.0	95.0
2001	116.2	102.5	183.1	43.2	27.0	0.0	23.0	2.0	20.6	50.5	79.6	113.3
2002	146.3	118.8	197.1	121.3	89.6	0.0	0.0	0.0	1.8	8.7	255.0	130.4
2003	148.8	54.3	69.9	117.3	59.9	0.0	0.0	0.0	8.1	51.9	64.2	102.5
2004	61.3	142.4	162.8	55.4	0.0	0.0	0.0	0.0	20.4	51.1	96.8	193.3
2005	156.5	51.4	149.6	83.9	22.8	0.0	0.0	0.0	0.0	0.8	69.6	86.4
2006	101.6	173.9	239.0	132.0	42.5	0.0	0.0	44.8	0.6	1.7	295.0	165.9

Appendix 16: Estimated of Rainfall erosivity 'R' Factor

Year	Average rainfall erosivity Value (R)
1976/77 – 1977/78	4,366.1 MJ-mm/ha/hr
1978/79 – 1983/84	3,354.0 MJ-mm/ha/hr
1984/85- 1993/94	4,747.2 MJ-mm/ha/hr
1994/95 – 2005/06	3,925.4 MJ-mm/ha/hr

Appendix 17: K-Factor

MAPPING UNITS	SOIL UNITS	PROFILE	TEXTURE CLASS	DEPTH IN CM	% SAND 2-0.05 = sa	% MODEFIED 0.05-0.02	% SILT 0.02-0.002=si	%Clay	Mn	$K=1.333*10^{-4}+2.459*10^{-5}*Mn$	Average K	K PER MAPPING UNITS
1	H			0-1								
			SL	1-5	82	6	2		528	0.01312	0.01312	0.013
			SL	5-10	82	6	2		528	0.01312		
2, 4	U1	P1	LS	0-7	77	8	4	11	680	0.01685	0.01499	
			SL	7-21	82	6	2	10	528	0.01312		
2,4	U2	P2	SL	0-4	75	6	3	16	486	0.01208	0.01388	
			SL	4-10	71	8	4	17	632	0.01567		
2,4	U4	P22	SL	0-5	75	13	1	11	1,144	0.02826	0.02416	0.018
			LS	5-20	81	9	3	8	810	0.02005		
3, 5	U7	P4	S	0-8	92	0	0	8	92	0.00240	0.00240	
3, 5	U8	P32	LS	0-12	87	6	0	7	558	0.01385	0.01385	0.008
6	L2	P7	LS	0-5	82	6	4	8	528	0.01312	0.01076	0.011
			SL	5-17	80	4	2	15	336	0.00840		
EQUATION TO DETERMINE Factor $K=1.333*10^{-4}+2.459*10^{-5}*Mn$												

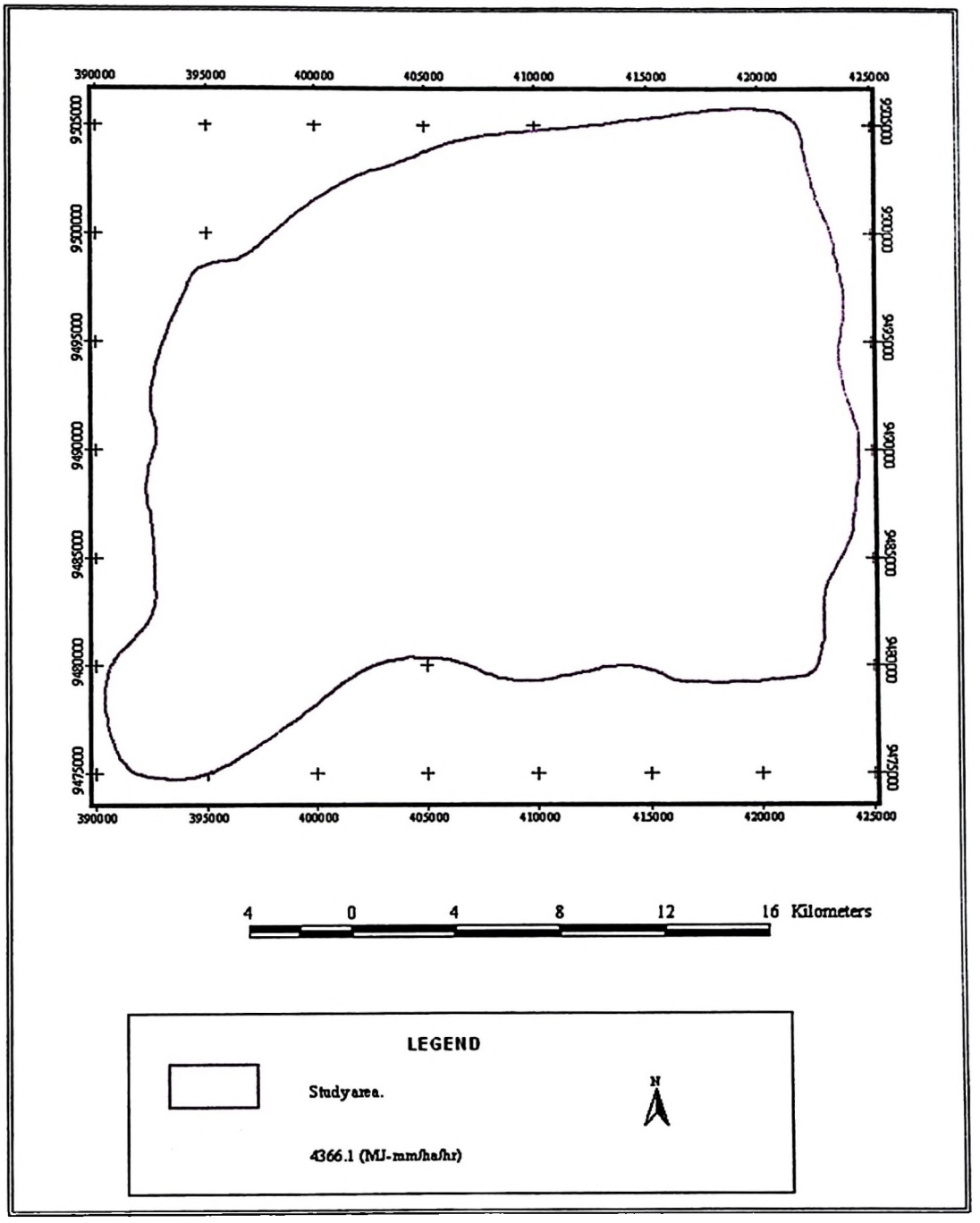
Appendix 18: C-factor per land use/cover

Land use/cover categories	C-factor	Source
Cultivated land	0.300	Adopted from Stocking *et al.*, (1988)
Bushland	0.013	Adopted from table 10, (Wischmeier, and Smith, 1978).
Woodland	0.053	Adopted from Stocking *et al.*, (1988)
Forest	0.002	Adopted from table 11, (Wischmeier, and Smith, 1978).
Grassland	0.170	Adopted from Stocking *et al.*, (1988)

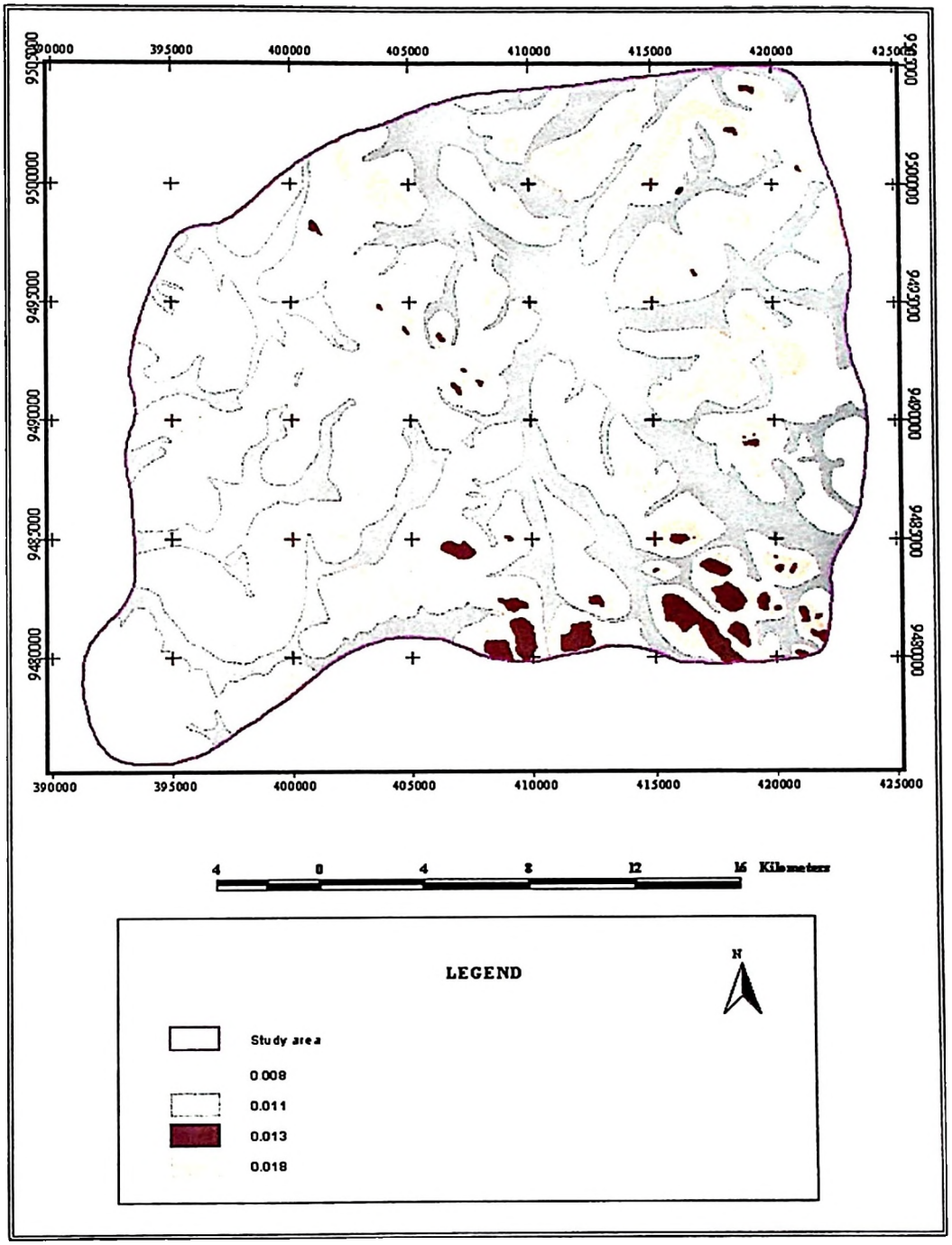
Appendix 19: Conservation practices 'P' Factor

Support practices	P factor	Reference
Contour farming	0.68	Adopted from Singh *et al.*, 1985
None (Natural vegetative land)	1.000	Adopted from Wischmeier, and Smith, (1978).

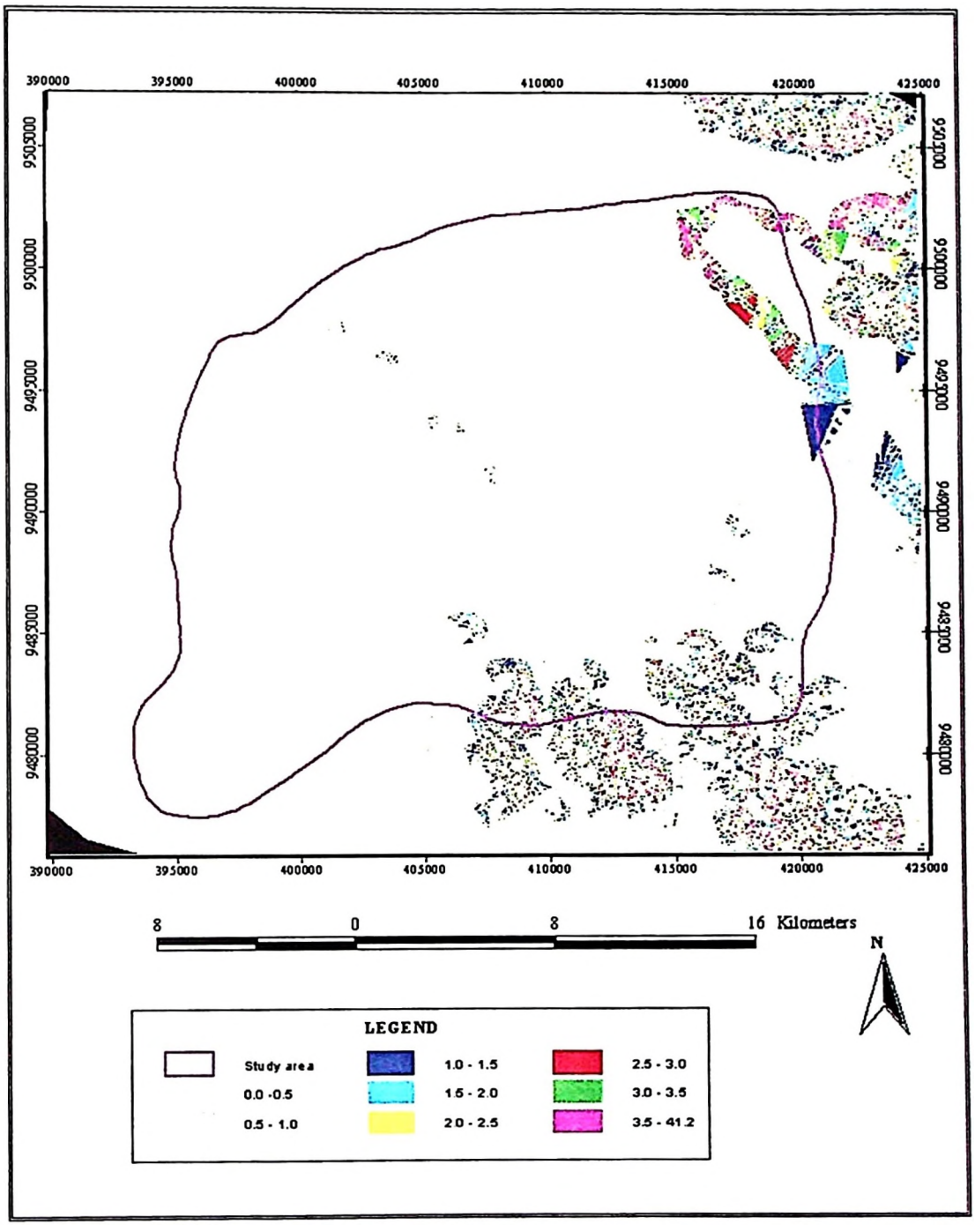
Appendix 20: Rainfall erosivity map



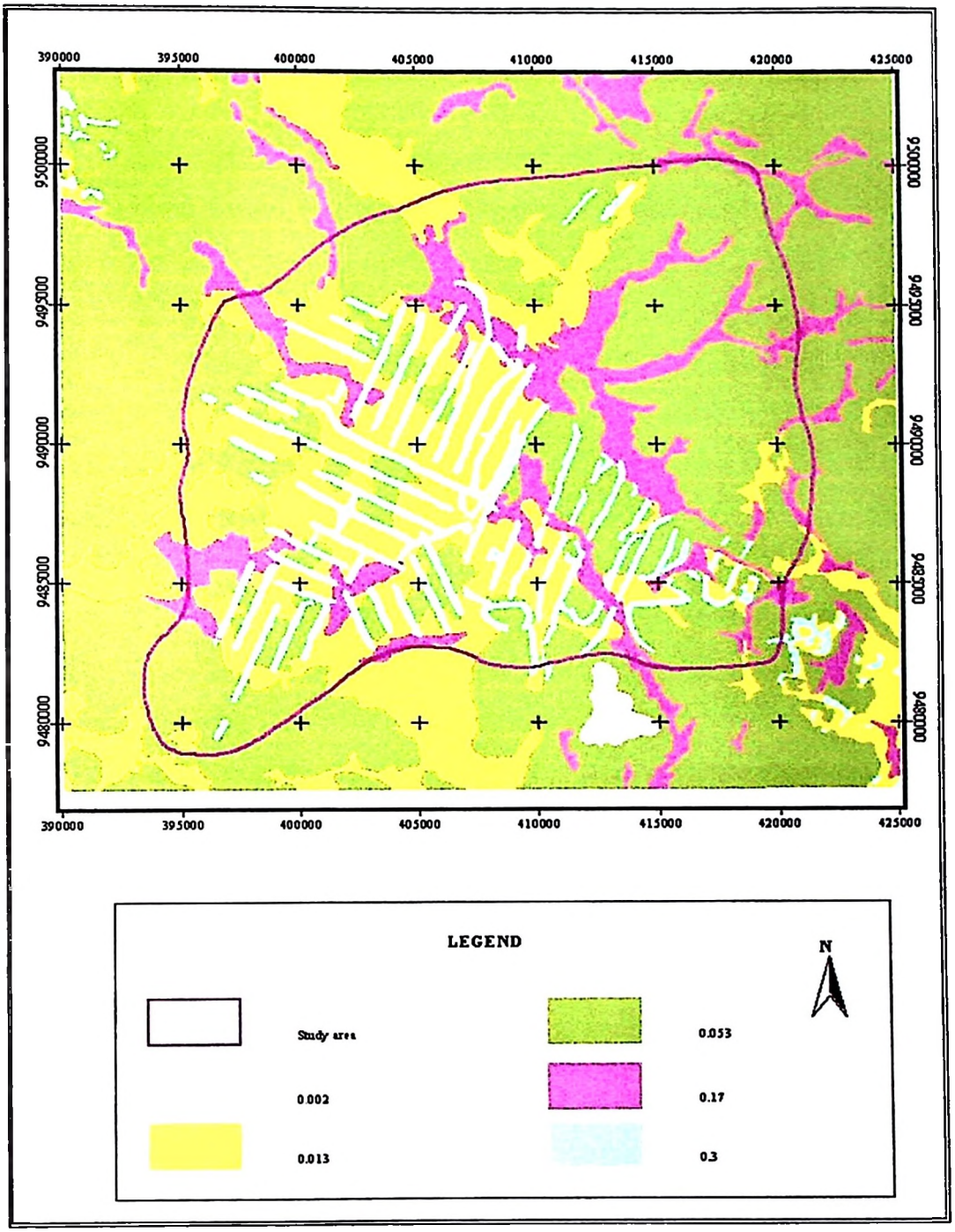
Appendix 21: K-Factor map



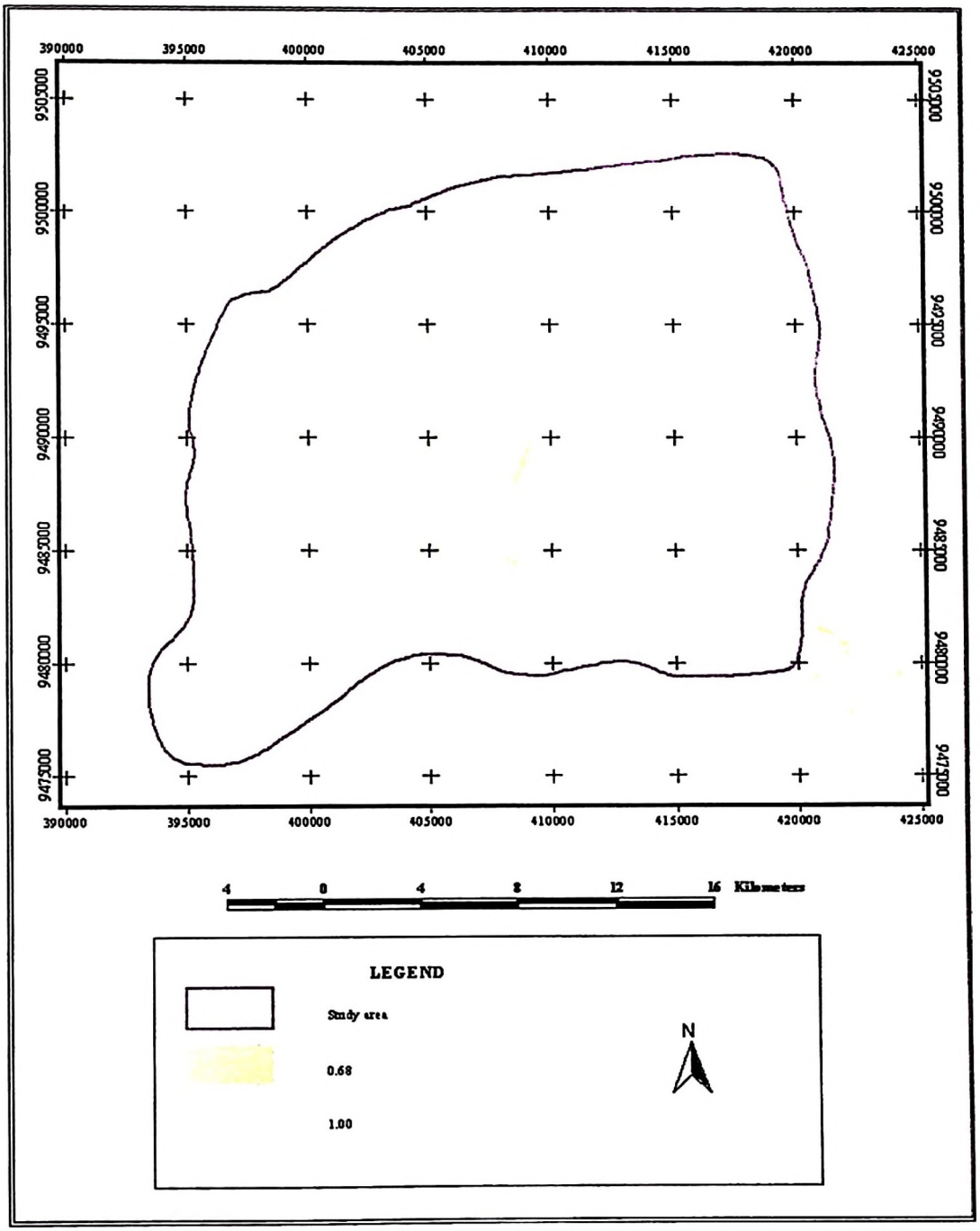
Appendix 22: LS factor map



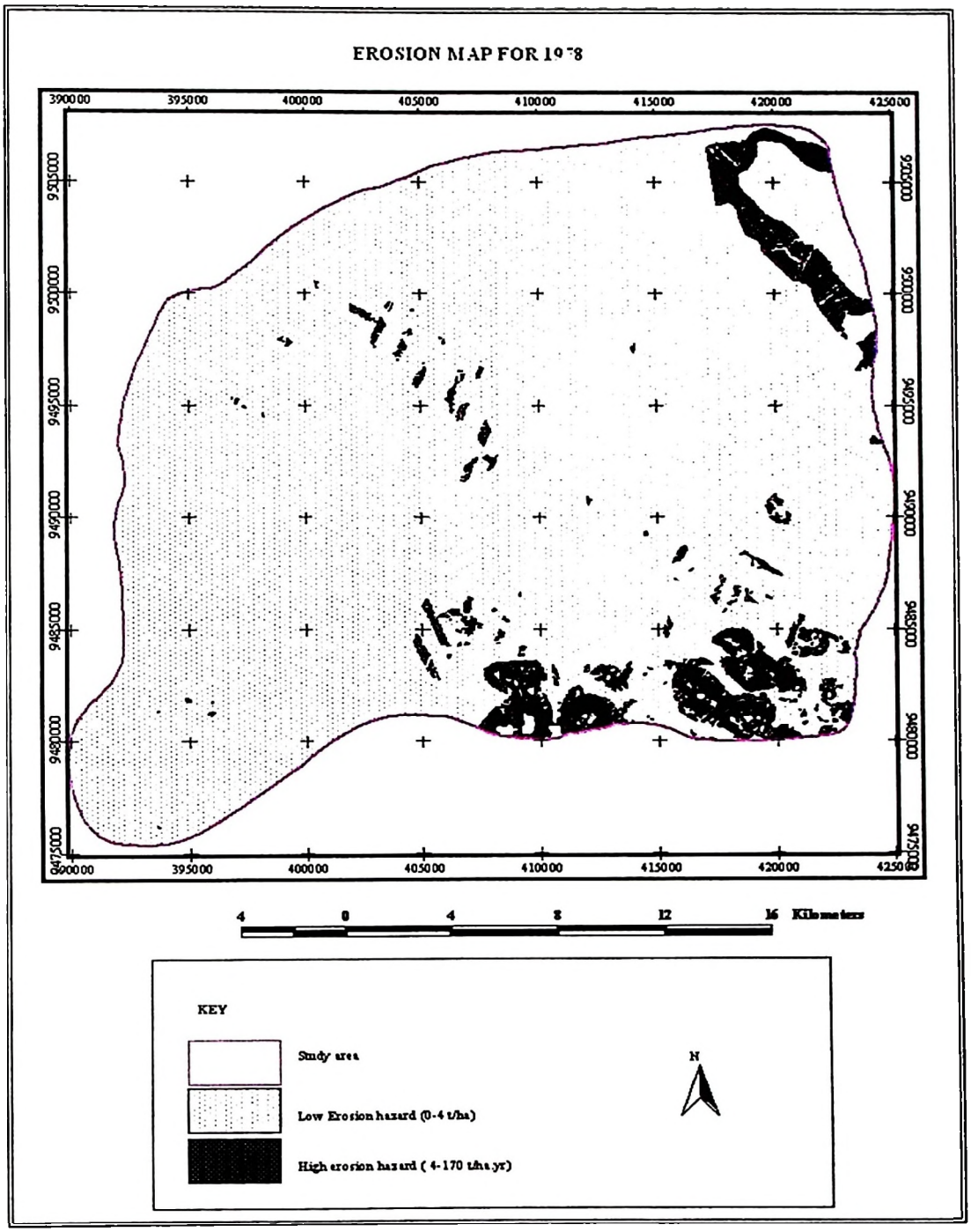
Appendix 23: C-Factor map of 1978



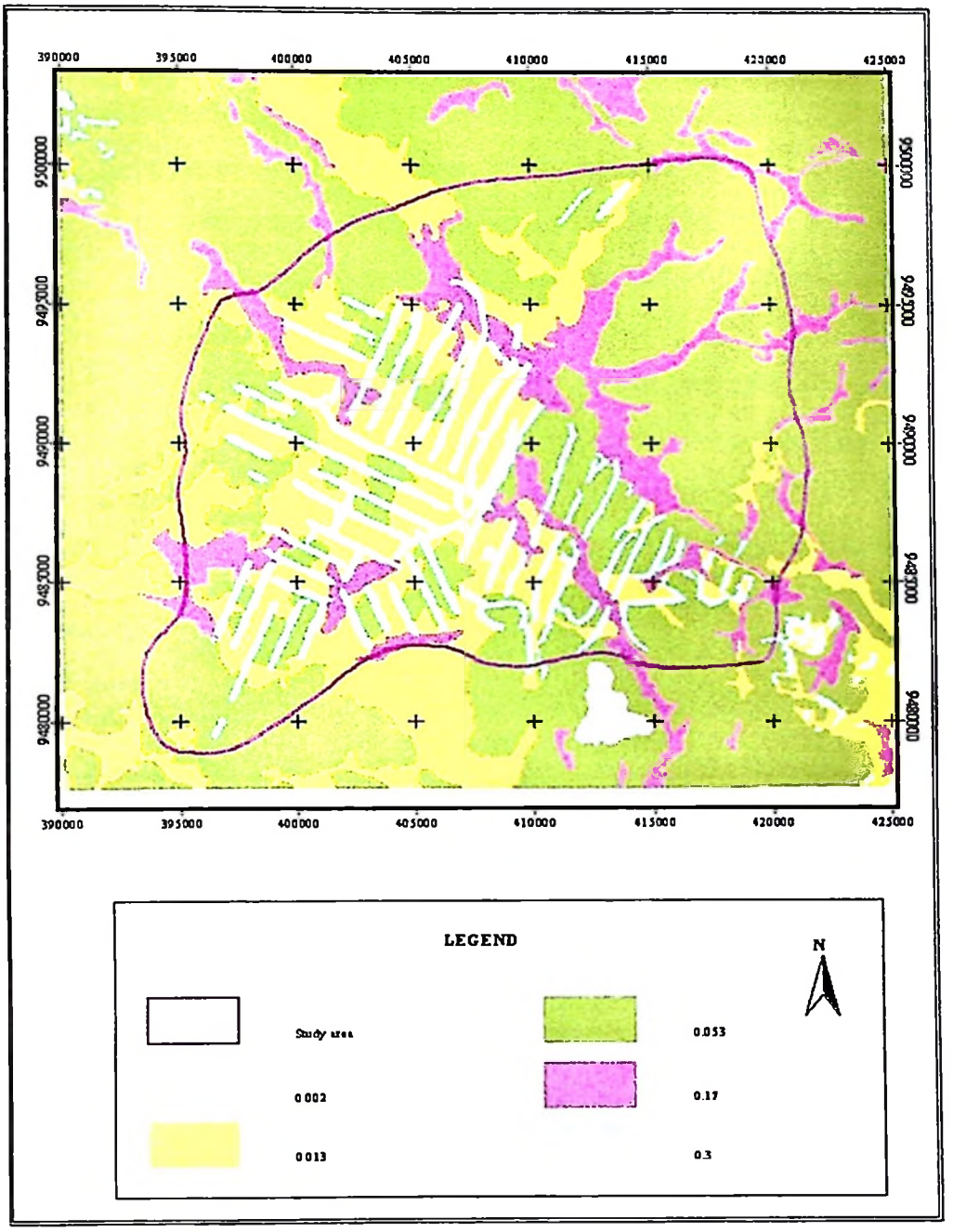
Appendix 24: P-Factor map of 1978



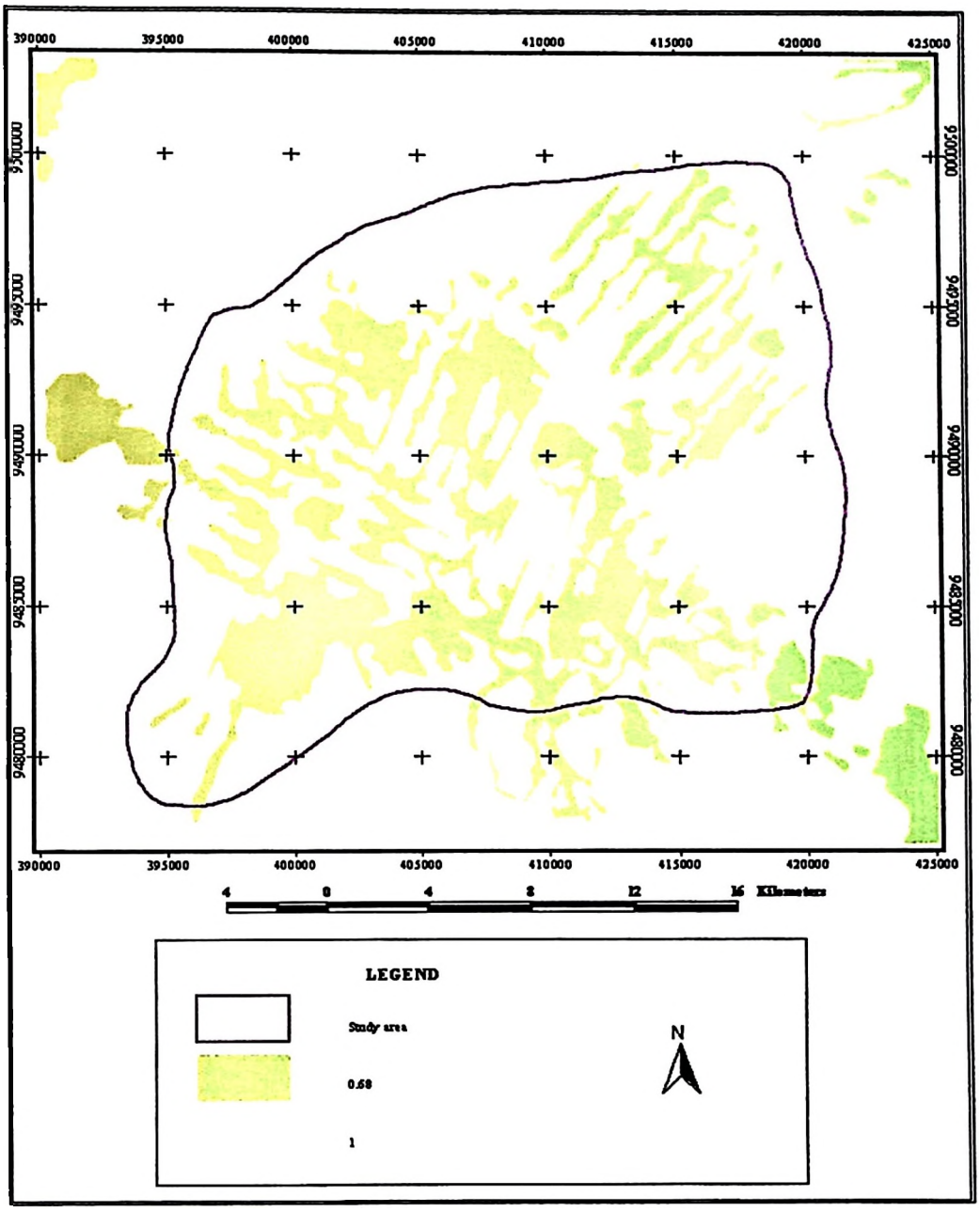
Appendix 25: Soil erosion loss risk map of 1978



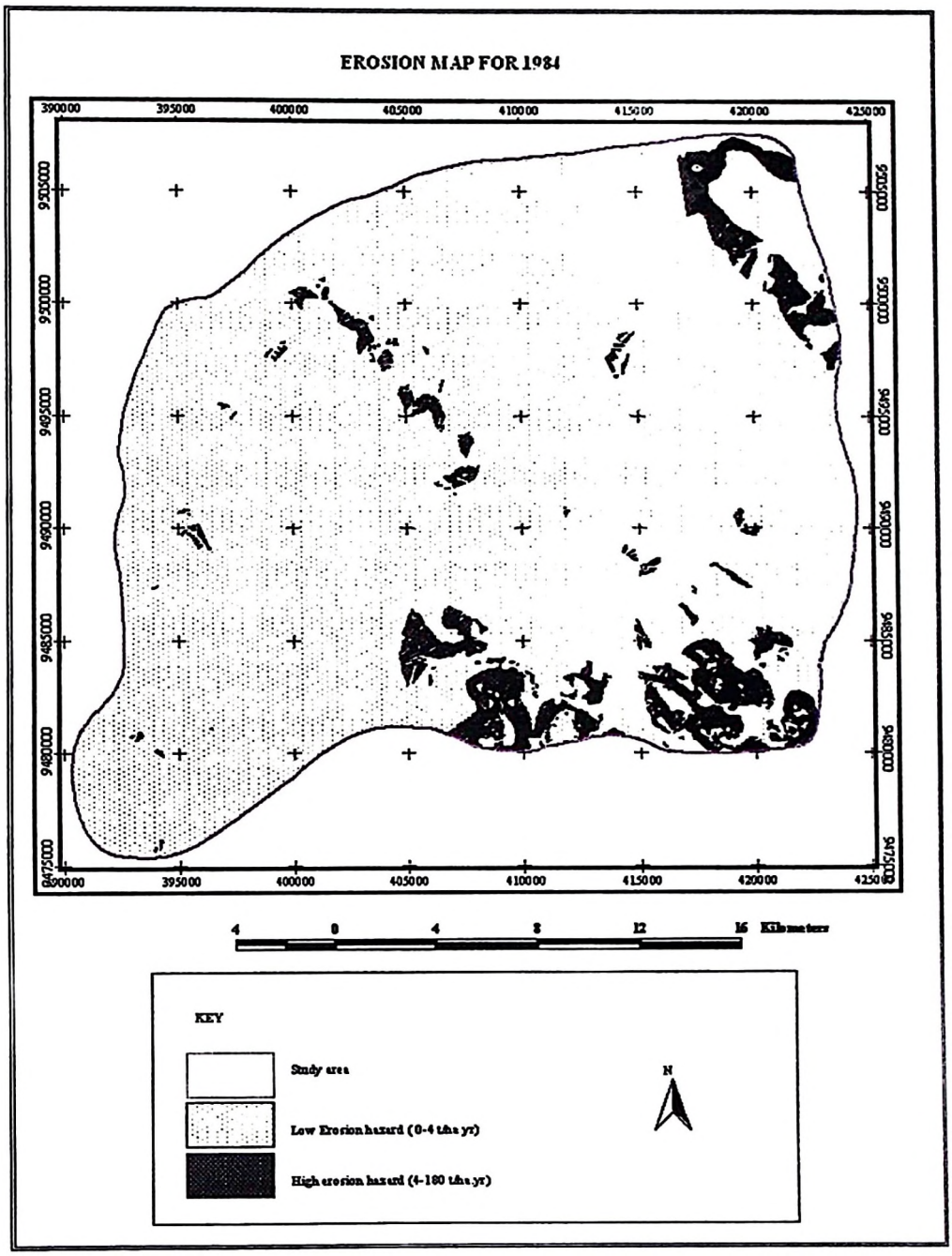
Appendix 26: C-Factor map of 1984



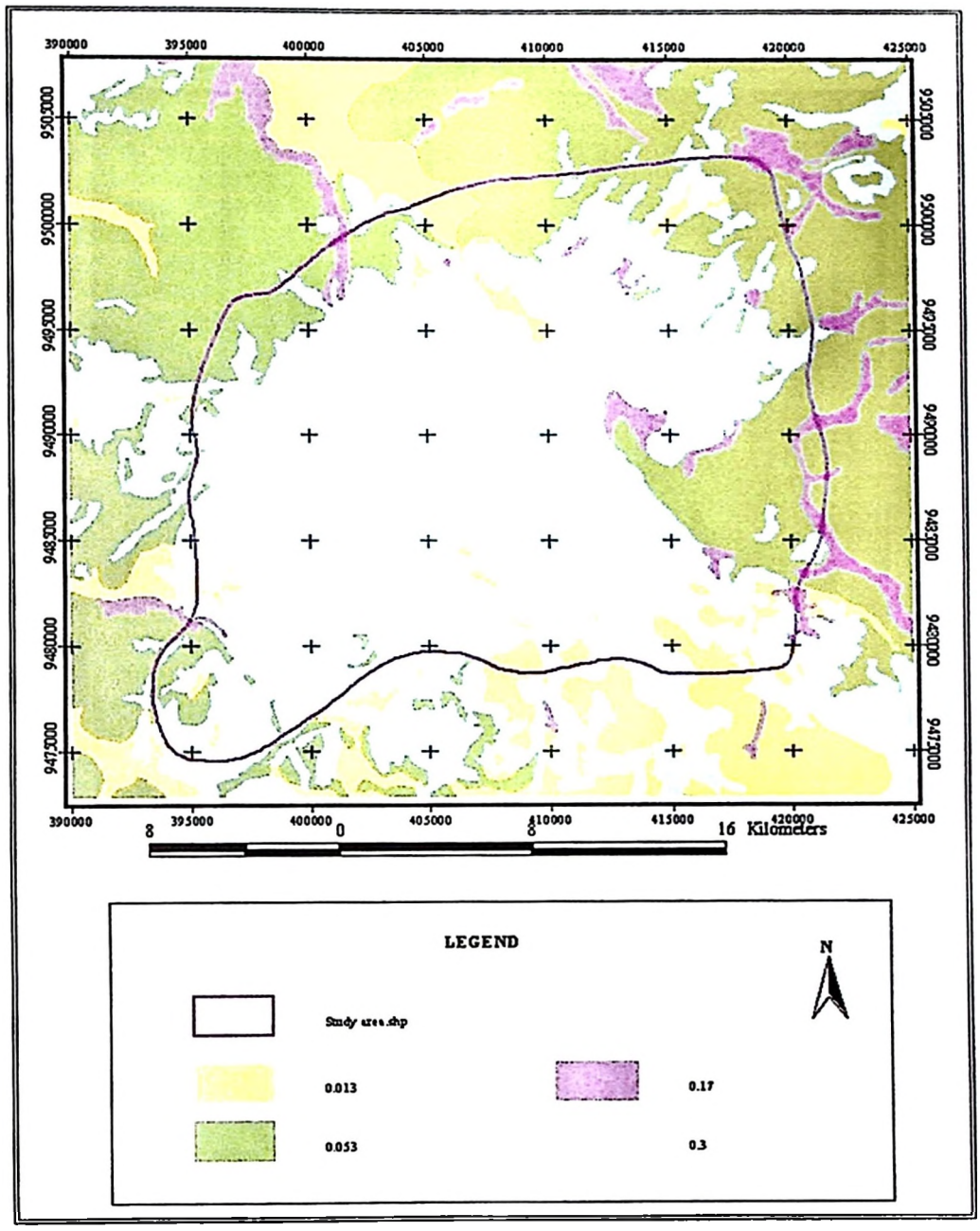
Appendix 27: P-Factor map of 1984



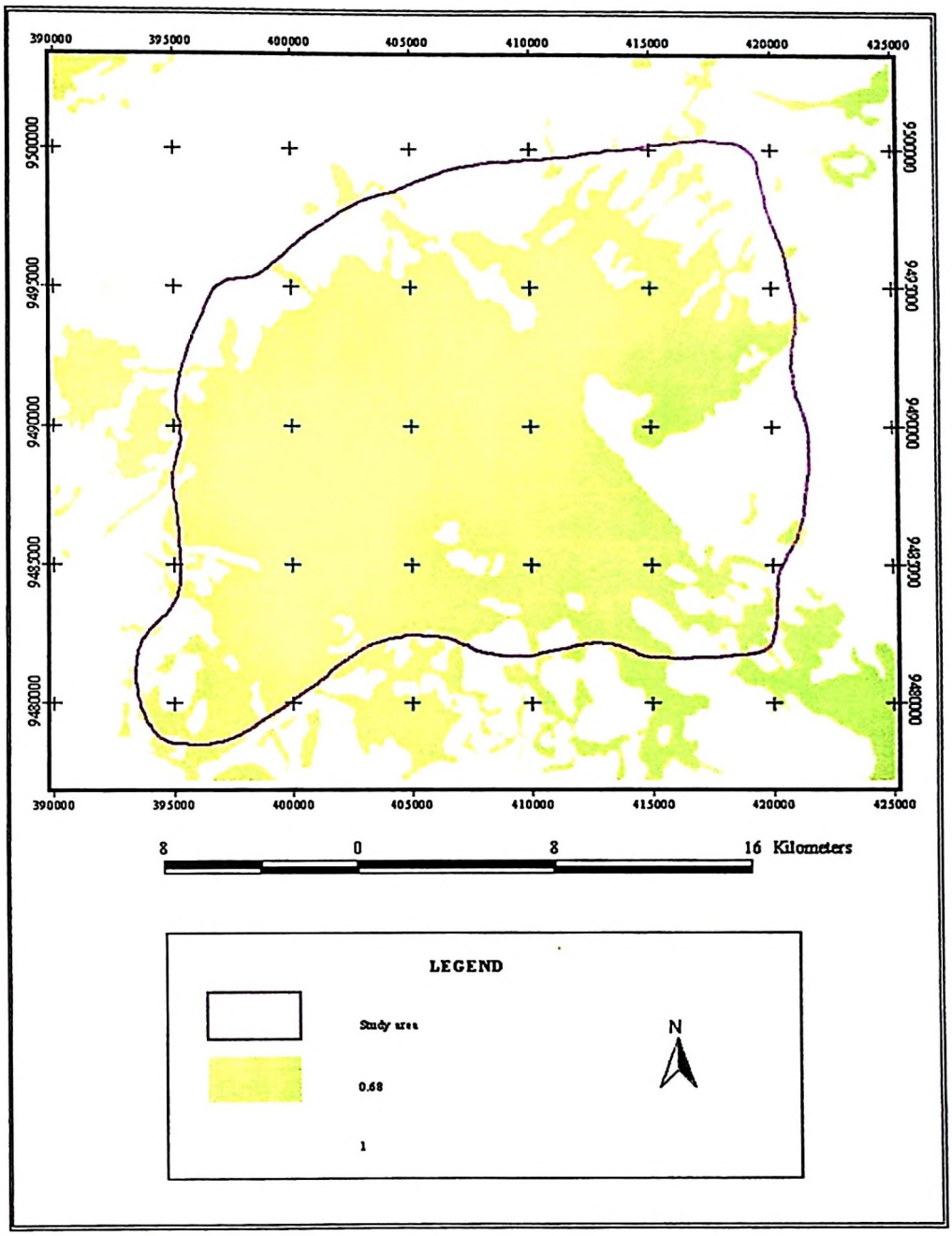
Appendix 28: Soil erosion loss risk map of 1984



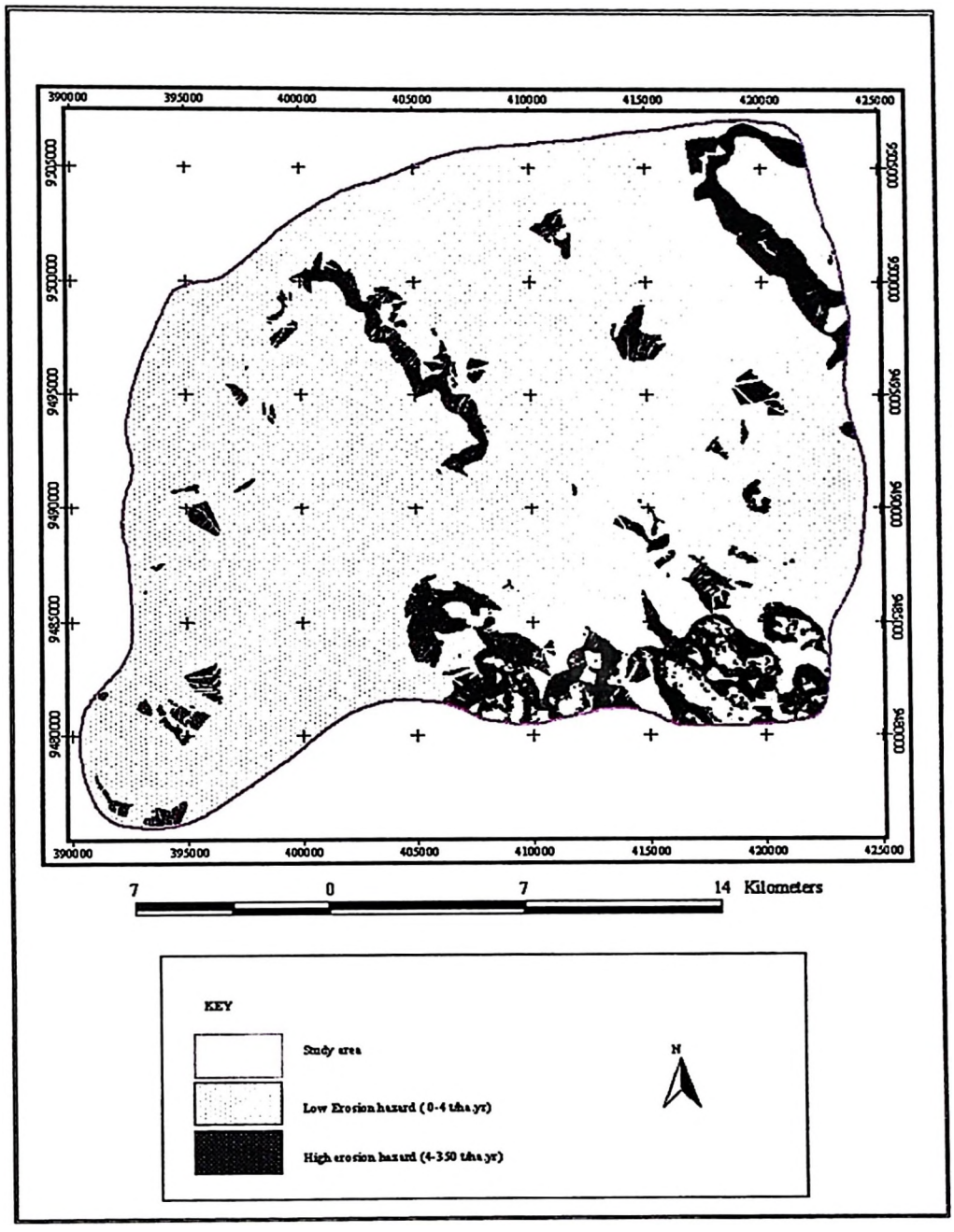
Appendix 29: C-Factor map of 1994



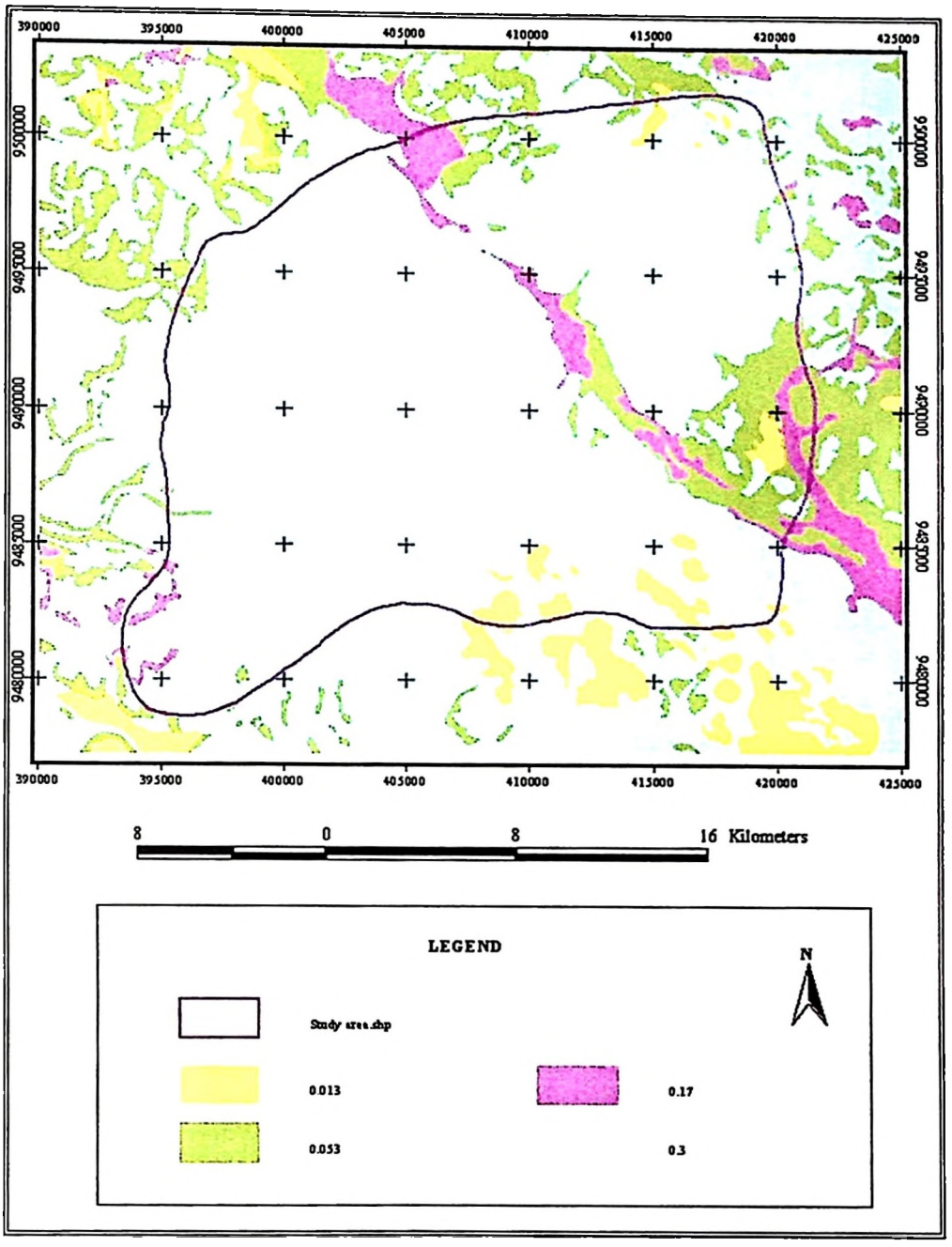
Appendix 30: P-Factor map of 1994



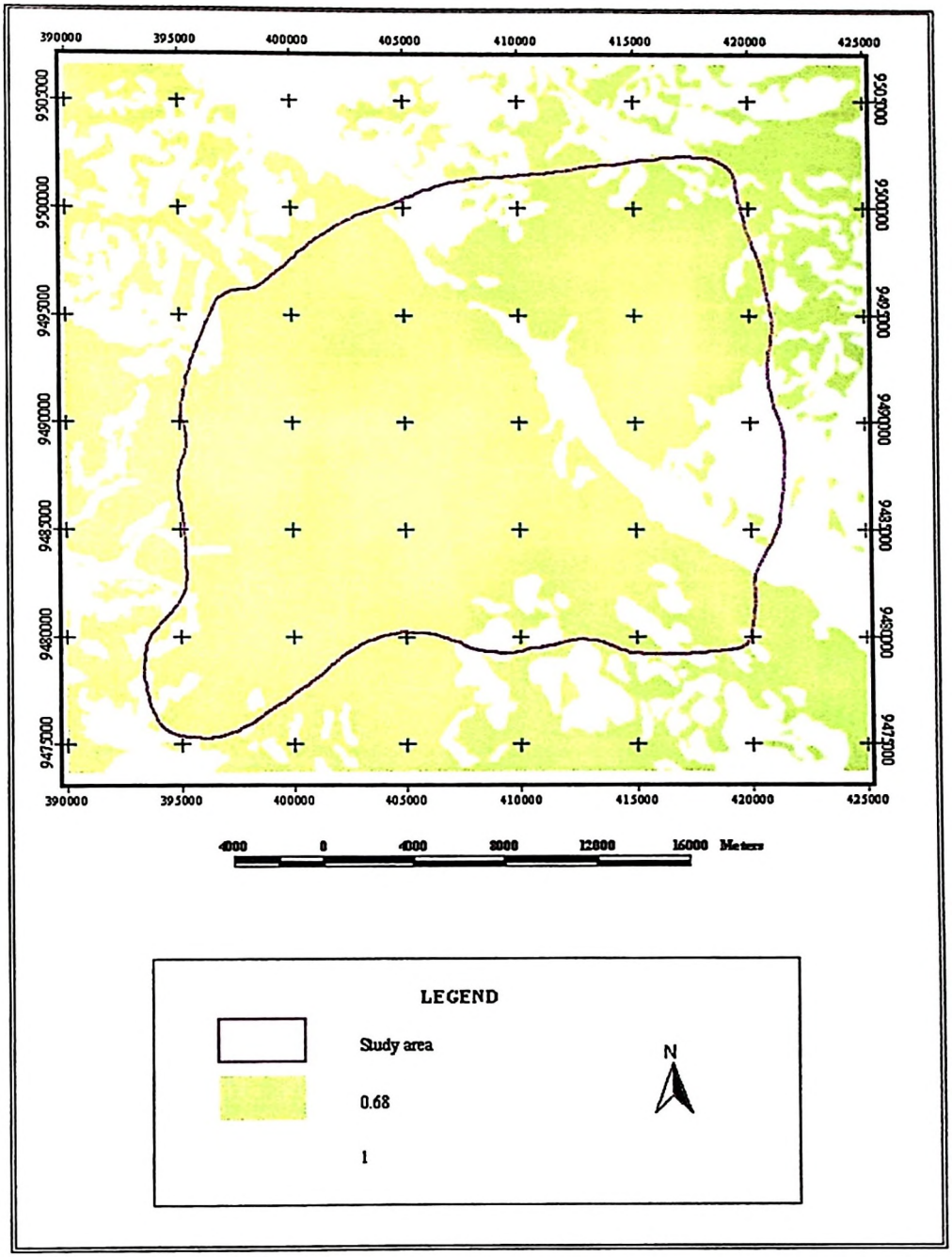
Appendix 31: Soil erosion loss risk map of 1994



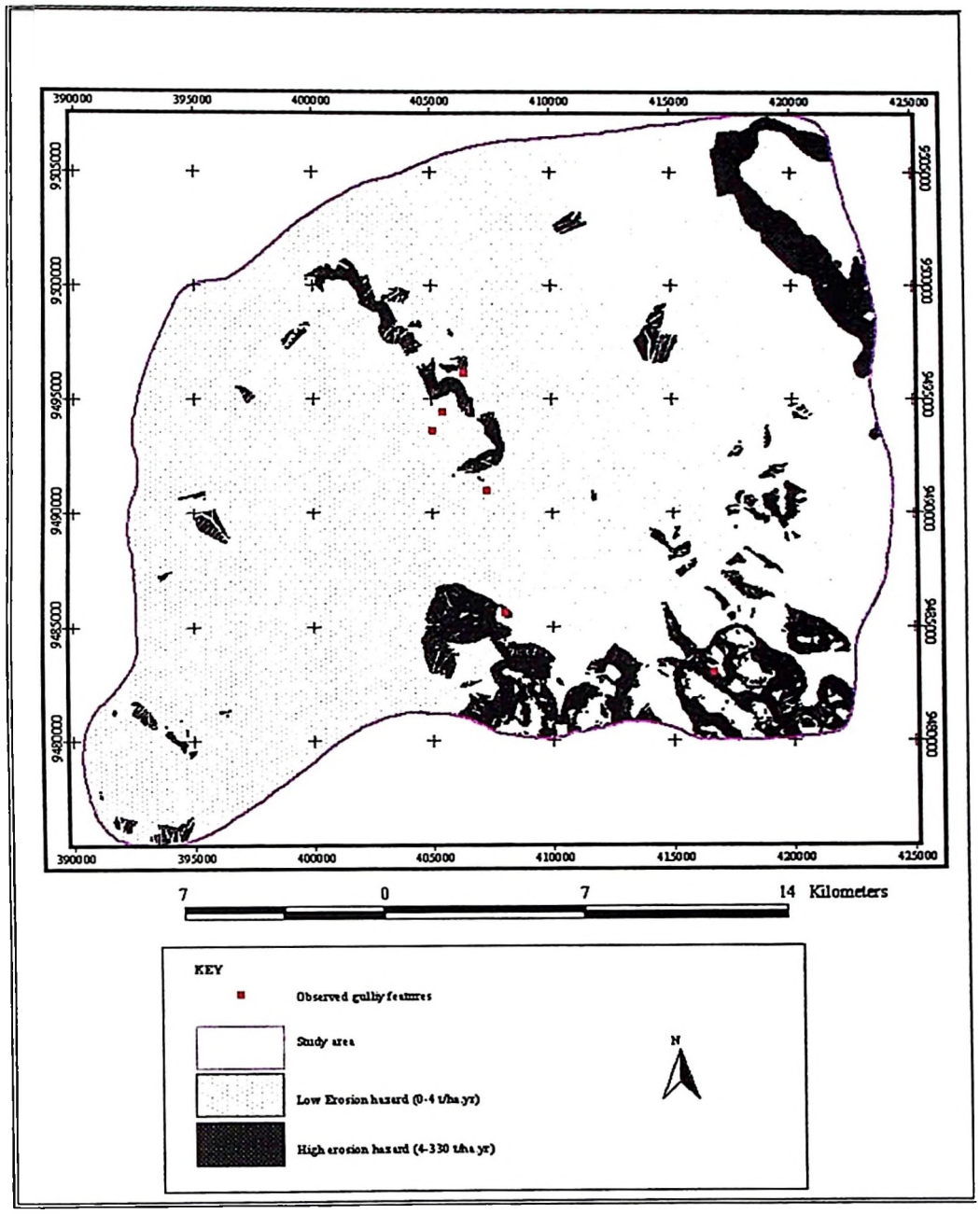
Appendix 32: C-Factor map of 2006



Appendix 33: P-Factor map of 2006



Appendix 34: Soil erosion loss risk map of 2006



Appendix 35: Land use/cover and soils types of sampling sites.

Sample sites	Land use/cover				Soils
	1978	1984	1994	2006	
P1	Bushland	Grasland	Cultivated land	Cultivated land	Ferralic Cambisols
P4	Bushland	Grassland	Cultivated land	Cultivated land	Dystric Gleysols
P10	Woodland	Woodland	Bushland	Bushland	Litholsols
P32	Bushland	Cultivated land	Cultivated land	Cultivated land	Cambic Arenosol

Source: Topo sheet map of 1978, Landsat TM of 1984, 1994 and Landsat ETM of 2001 and 1978 soils map.

Appendix 36: Rating soil fertility status

Type	Range	Classification
Soil Ph	< 4.5	extremely acid
	4.5-5.0	very strongly acid
	5.1-5.6	strongly acid
OC%	< 0.6	very low
	0.60-1.25	low
	1.26-2.50	medium
	2.51-3.50	high
N%	< 0.10	very low
	0.10-0.20	low
	0.21-0.50	medium
	0.51-1.00	high
mgP/kg (Bray-1	< 7	low
	7.1-20	medium
	> 20	high

Source: National Soil Service (NSS, 1990)

Appendix 37: Rating soils conditions according to pH values

Soil condition	pH value	pH Scale
Extremely acid	< 4.5	Low pH
Very strong acid	4.5-5.0	
Strongly acid	5.1-5.5	
Medium acid	5.6-6.0	
Slightly acid	6.1-6.5	
Neutral	6.6-7.3	
Mildly alkaline	7.4-7.8	
Moderately alkaline	7.9-8.4	
Strongly alkaline	8.5-9.0	
Very strongly alkaline	>9.1	High pH

Source: Kanyanjua *et al.* 2002