LAND USE AND LIVELIHOOD CHANGES IN THE MOUNT RUNGWE ECOSYSTEM, TANZANIA

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Dissertation presented for the degree of Doctor of Philosophy in the Faculty of Arts and Social Sciences at Stellenbosch University

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December 2013

DECLARATION

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ABSTRACT

The Mount Rungwe ecosystem (MRE) has unique mountain resources. Its biological, hydrological, economic and cultural endowments offer many development opportunities for Tanzania. Since the 1970s, the MRE has experienced change in land use and means of acquiring livelihoods, calling for scientific investigation into the extent, nature, and magnitude of land use changes and their implications for communities' livelihoods.

The aim of the study was to investigate the major changes in land use, to identify the drivers responsible for these changes and to establish the interrelationship between land use change and communities' livelihoods in order to suggest desirable management options towards improving rural livelihoods and the ecological integrity of MRE. A research design that integrates both qualitative and quantitative approaches was adopted. The fieldwork involved six villages representative of three ecological zones and 384 respondents were interviewed. Information on the past and present land uses, policies, institutions and processes that have influenced and are influencing land use change in the area was obtained through questionnaires, interviews, field observation, and analysis of documents. Satellite imagery of 1973, 1986, 1991 and 2010 were analysed for spatial and temporal statistics on land use and change.

The findings indicate that MRE is experiencing land conversions from one land use category to the other especially in villages of the highland zone. Government policies on the use of and access to forests, agricultural land and energy have contributed to the past and current land use changes. Demographic, cultural, economic and natural factors singly or cumulatively have also induced changes in land use in MRE. Most of the changes in land use were noted between 1991 and 2010. At the district level there was a significant decrease in natural vegetation, particularly bushland and woodland, and an increase in cultivated land. Intensification of agricultural land use was more in the villages of the highland zone than in the middleland and lowland zones. Villages of the lowland zone showed a decline of cultivated land area, particularly in the tree crops category, and a constant or declining trend of the natural vegetation coverage – especially grasslands and woodlands.

To reduce unplanned farm expansions into areas of natural vegetation, it is recommended that the Ministry of Agriculture should re-emphasise intercropping practices and provide extension services targeting crops such as potatoes and bananas which are now commercialised. This would be a step towards improving agricultural land productivity and addressing local food security. The ministry of Energy and Minerals could finance the ongoing tree planting efforts by local communities and enhance the use of more efficient charcoal stoves so as not only to protect the remaining forests but also as a way of diversifying the communities' livelihoods.

Key words: land use, land use change, livelihoods, driving forces, Mount Rungwe ecosystem, Tanzania, Landsat images, GIS.

OPSOMMING

Die Mount Rungwe ekosisteem (MRE) het 'n unieke berggebaseerde hulpbronbasis. Sy biologiese, hidrologiese, ekonomiese en kulturele erfenis bied vele ontwikkelingsgeleenthede vir Tanzanië. Sedert die 1970s het die MRE verandering in grondgebruik ervaar wat implikasies inhou vir bestaanswyses van sy bewoners. Daarom vereis die veranderingsverskynsel wetenskaplike ondersoek na die omvang en aard van grondgebruikveranderinge en die implikasies daarvan vir gemeenskappe se lewensbestaan.

Die doel van die studie was om ondersoek in te stel na die belangrikste veranderinge in grondgebruik en om die drywers verantwoordelik vir hierdie veranderinge te identifiseer en die onderlinge verband tussen die verandering in grondgebruik en gemeenskappe se lewensbestaan te identifiseer. Daaruit word wenslike bestuursopsies duidelik vir die verbetering van landelike bestaansmoontlikhede en die handhawing van ekologiese integriteit van die MRE. 'n Navorsingsontwerp wat beide kwalitatiewe en kwantitatiewe benaderings integreer is gekies. Vir veldwerk is ses dorpe in drie ekologiese sones ondersoek en 384 respondente is ondervra. Inligting oor die grondgebruike, -veranderings, beleide, instellings en prosesse wat die gebied beïnvloed het, is verkry deur middel van vraelyste, onderhoude, veldwaarneming, en dokumentontleding. Satellietbeelde van 1973, 1986, 1991 en 2010 is ontleed vir ruimtelike en temporale patrone van grondgebruik en verandering.

Die bevindinge dui daarop dat die MRE grondgebruik-omskakeling van verskillende kategorieë na ander in veral die hooglandsone ervaar. Regeringsbeleid oor die gebruik en toegang tot natuurlike woude, landbougrond en energiebronne het bygedra tot hierdie grondgebruike en hul veranderinge. Demografiese, kulturele, ekonomiese en omgewingsfaktore, enkel of kumulatief, het ook tot die veranderinge bygedra. Die meeste van die veranderinge in grondgebruik is tussen 1991 en 2010 aangeteken. Op distriksvlak het byvoorbeeld natuurlike plantegroei, veral bosveld en woud, beduidend oor die studietydperk afgeneem, terwyl die bewerkte grondoppervlak sterk toegeneem het. Intensivering van landbougrondgebruik was meer intens in die dorpe van die hooglandsone in vergelyking met die middelland en laer sones. Dorpe van die laer sone het weer 'n afname van bewerkte grond, veral boomagtige gewasse, en 'n konstante of dalende tendens van die natuurlike plantegroei ervaar – veral gras- en bosveld.

Om ongewenste plaasuitbreidings na gebiede van natuurlike plantegroei te voorkom, beveel die studie aan dat die landbouministerie weer klem plaas op praktyk vir tussenverbouing van gewasse en voorligtingsdienste voorsien vir die verbouing van gekommersialiseerde gewasse soos aartappels en piesangs. Dit sou die verbetering van die landbou-produktiwiteit en die verhoging van plaaslike voedselsekuriteit in die hand werk. Die energieministerie behoort origens deurlopende boomplant-aksies deur plaaslike gemeenskappe te stimuleer deur verskaffing van finansies en moet die gebruik van meer doeltreffende houtskool stowe aanmoedig. Dit sal die oorblywende woude help beskerm en is ook 'n manier om die gemeenskappe se lewensonderhoudstelsels te diversifiseer en te verbeter.

ACKNOWLEDGEMENTS

I thank the Almighty God for without his divine assistance this work wouldn't have been accomplished. My sincere gratitude goes to my supervisor Prof JH van der Merwe for his tireless guidance, constructive discussions and criticisms, which have made this study a reality. His extended care and support beyond academics made my studies and stay in Stellenbosch convenient and pleasant. Prof PS Maro, co-supervisor deserves special appreciation for his great contribution to my academic career since the days of my master's degree; his ideas shaped my thoughts and work.

I am indebted to the Graduate school, Stellenbosch University, that offered financial support to facilitate my studies. I extend my deep thanks to the University of Dar es Salaam, my employer, for granting me a study leave, research funds and clearance for undertaking my studies. I acknowledge the support of SSRC dissertation completion fellowship that was valuable regarding the writing, editing and production of the dissertation. I extend my gratitude to Dr Festo Ndumbaro, the Head of Department, and my colleagues in the Department of Geography at the University of Dar es Salaam for their facilitation and moral support of my study work. I acknowledge the technical assistance in the interpretation and analysis of satellite imagery I received from Ms Olipa Simon and Mr Stephen Kajula of the Institute of Resource Assessment, University of Dar es Salaam. I thank Mr Johnstone Andrea, in for his assistance during fieldwork.

I appreciate the support of Dr Cosmas Sokoni, Dr Emmiliana Mwita, and Dr Herbet Hambati whose devotion, interest in my study, guidance and encouragement have contributed to the completion of this work. I am grateful to Ms Joyce Manahiri for being close to my family during my absence. I thank my colleagues in ADA PhD students'2010 cohort, Erick Shartiely, Ernest Jakaza, Trynos Gumbo, Walter Musakwa and Evance Mwathunga for the way they worked as a team to motivate me to achieve success in my studies and in my social life.

Special thanks go to Mr Albert Mwandambo and his family for their kindness and support of my fieldwork in Rungwe by offering me an encouraging accommodation and work space. I also thank the Mbeya regional and Rungwe district administrative secretaries for offering me a research permit. I am grateful to the support and cooperation I received from officials of the Mount Rungwe Nature Reserve and the Rungwe District that facilitated my fieldwork. The study would not have been achieved without the support and cooperation of the key informants and respondents in the study villages.

I especially thank Phillip Pambe; my lovely husband who is the inspiration for my studies and my life. Because of his support and encouragement, I was able to work long hours and keep the home fires burning during the years that I devoted to my scholarship. Thank you from the bottom of my heart for being there for me.

The sacrifice, prayer, love and concern of my sons John Phillip and Emmanuel Phillip played a significant role in the successful completion of this dissertation. My young sister Magreth deserves a special appreciation for making a sacrifice in order to take care of my family during my absence without her help it would have been difficult for me to pursue my studies.

DEDICATION

This work is dedicated to the following:

My parents who brought up me, and provided every support I needed to achieve my educational dreams.

My loved sons John and Emmanuel, and my lovely husband Phillip for their support, care and love.

CONTENT

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ACRONYMS AND ABBREVIATION

AMA	African Mountains Association
CDE	Centre for Development and Environment
CMEAMF	Conservation and Management of the Eastern Arc Mountain Forests
EMA	Environmental Management Act
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agriculture Organisation
GIS	Geographical Information System
GIT	Geo-Information Technologies
GLOCHAMORE	Global Change in Mountain Regions
Ha	Hectares
HIV	Human Immunodeficiency Virus
ICIMOD	International Centre for Integrated Mountain Development
IGU	International Geographic Union Commission
IPCC	Inter-governmental Panel on Climate Change
LANDSAT	LANDSAT–Land Satellite
MA	Millennium Ecosystem Assessment
MDGs	Millennium Development Goals
MEs	Mountain Ecosystems
MRE	Mount Rungwe Ecosystem
MRI	Mountain Research Initiative
MSS	Multi Spectral Scanner
NAPA	National Adaptation Programme of Action
NASA	National Aeronautics and Space Administration
NEMC	National Environment Management Council
NGO	Non-Governmental Organisation
PCC	Post Classification Comparison
SAPs	Structural Adjustment Programmes
SES	Social Ecological System
SIC	Satellite Imaging Cooperation
SLC	Scan Line Corrector
SSDDP	Small-Scale Diary Development Project
TANU	Tanganyika African National Union

TaTEDO	Tanzania Traditional Energy Development Organisation
TDG	Tanzania Development Goals
TM	Thematic Mappers
TUWSA	Tukuyu Water Supply Authority
UNEP	United Nations Environment Programme
UNESA	United Nations, Economic and Social Affairs
UNCED	United Nations Conference on Environment and Development
UNITAR	United Nations Institute for Training and Research
UN	United Nations
URT	United Republic of Tanzania
VEO	Village Executive Officer
WEO	Ward Executive Officer
WCMC	World Conservation Monitoring Centre
WCS	Wildlife Conservation Society

CHAPTER 1 MOUNTAIN ECOSYSTEMS AND LAND USE CHANGE DYNAMICS

This chapter acts as an introduction to the study. A general overview is presented on mountain ecosystems (MEs) conceptually regarding their attraction as special areas of growing interest in the world; their significance for sustainable development and livelihood support in developing countries; the growing concern about land use change and its implication on livelihoods and the particular significance of Mount Rungwe ecosystem (MRE) in the national spatial context of Tanzania. The goal, structural elements of the research problem, aim and objectives for this study are explained followed by a description of the study area in terms of its geographical location, socioeconomic aspects and the sampled villages' characteristics. The structure of the dissertation concludes the chapter.

1.1 MOUNTAINS AS ECOSYSTEMS

In this subsection a general definition of mountains, their characteristics and social-ecological values is provided. International and local recognition of the need to conserve mountains, their potential attraction to human use and the support they provide to human livelihood is explained. An explanation on the extent of land use change in global and local mountains, pertaining to global and local policies is provided as well.

1.1.1 Definition of mountain ecosystems

Mountain ecosystems (MEs)[1] are unique features of the earth's surface (Beniston 2000), of different altitudes, with a great variety of shapes and climates and specific combinations of ecosystems and are found on every continent (Mountain Agenda 1999).

[1] The world's mountains do not lend themselves to a unifying definition and classification that goes beyond the simple combination of 'steepness of slope' and 'altitude'. It follows that several definitions, which are region-specific, are needed (Messerli & Ives 1997). UNEP-WCMC (2002) defines mountains as areas with an altitude of 2500 m or higher. Goudie (1985) defines mountains as substantial elevations of the earth's crust above sea level which result in localised disruptions to climate, drainage, soils, plants and animals. Browne, Fox &Funnel (2004) and Ives, Messerli & Spiess (1997) insist on the incorporation of local features such as climate, relief, geology, vegetation or accessibility criteria in delineating mountains from other landscapes. Meybeck, Green & Vörösmarty (2001) define mountains on relief roughness indicators and the maximum altitude at a resolution of 30' x 30'. Based on these two criteria these authors recognised 15 global relief patterns: plains (0-200 m), mid altitude plains (200-500 m), high altitude plains (500-100 m), lowlands (0-200 m), rugged lowlands (0-200 m), platforms (200-500 m), low plateaus (500-1000 m), mid altitude plateaus (1000-2000 m), high plateaus (2000-3000 m), very high plateaus (4000-5000 m), hills (200-500 m), low mountains (500-1000 m), mid-altitude mountains (1000-2000 m), high mountains (2000-4000 m) and very high mountains (4000-5000m). Following Browne, Fox & Funnel's (2004), Ives, Messerli & Spiess's (1997) and Meybeck, Green & Vörösmarty's (2001) definitions, MRE qualifies as a mountainous area. With regard to the four classes of mountains categorised by Meybeck, Green & Vörösmarty (2001) it falls in high mountains as it has an altitude of 2981 m metres above

There is no general consensus in mountain literature on the universally accepted definition of mountains. Ives (2001) points out that the inability of scholars to agree upon a rigorous definition that has universal application and acceptance has frequently led to time-consuming discussion with no satisfactory result. Thus, mountains definition has relied upon the simple combination of 'steep slope' and 'altitude' (Messerli & Ives 1997). Generally, if we use the definition of steep slope and altitude mountain areas cover 24% of the world's land surface (FAO 2000; UNEP-WCMC 2002), and are a home to 12% of the global human population (Huddleston & Ataman 2003), with a further 14% living in their immediate vicinity (Meybeck, Green & Vörösmarty 2001). Environmentally, mountains of the world range from extremely cold and sterile high ice (Antarctica and Greenland); high, dry, hypoxic and almost inhospitable (the south-central High Andes) to richly varied and even luxuriant ridges and valley systems of subtropical and tropical regions (the Himalayas, the Cameroon, the Ethiopian and the East African mountains) which are preferred as human habitat (Messerli & Ives 1997).

1.1.2 Characteristics of mountain ecosystems

Mountains, similar to other geographical features, offer goods and services to humanity. However, they are geographical features with special characteristics that separate them from plains or which they can share with, for instance, deserts as another form of 'special region'. According to Byers & Sainju (1994) and Jodha (1997) the special characteristics of mountains include:

- Inaccessibility – one of the most known features of mountain areas. Due to their steep slope, high altitude, difficult terrain, variable climatic conditions and natural hazards they are not very hospitable;
- Fragility – mountain ecosystems are fragile, due to steepness, low temperatures and isolation. Soils are thin, young and highly erodible;
- Marginality – mountain ecosystems are politically and economically marginalised in terms of the development of their resources and inhabitants compared to surrounding lowland areas and regional centres of power;

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sea level (URT 2011a). Various references to the terms mountains, mountain regions, mountain areas and highlands in this document are deemed to be referring to MEs.

- Diversity or heterogeneity – mountains are sources/reservoirs of natural biodiversity of species and ecosystems. In fact, as global gene banks, mountains represent food security and future resources for humanity. Due to their isolation, marginality, migration patterns and ecosystem diversity, mountains are also rich in traditions and cultural diversity of people, crops and livestock varieties;

- Natural suitability for some activities or products – mountains provide resource bases for typical mountain agricultural, pastoral and other economic systems. Traditionally they provide timber, fuelwood, bamboo, herbs, flowers, essential oils, and ceremonial, medicinal, and edible plants**;** they are exclusive beauty spots and sources of rare natural products such as honey and beeswax. Thus mountains are a source of livelihood[2] for multitudes in Africa;

- Mountains are essential water catchment areas, run off producers and ecological reserves.

1.1.3 Social-ecological values of mountain ecosystems

Mountains are as important as lowland areas though they have long been marginalized from the viewpoint of sustainable development. Mountains support not only human livelihoods but they also play a vital role in the global ecosystem and economy such as the tourism industry, for water catchment, and as storehouses of biological and cultural diversity (Funnell & Parish 2001; Körner & Ohsawa 2005; Spehn, Liberman & Körner 2006). MEs comprise potential supportive resources (water, food, minerals, woodland, fibre, non-timber forest products, scenic resources for tourism) for human development both in the highlands and lowlands and are fundamental constituents of our environment (Price & Butt 2000). Mountains, if well conserved in terms of their vegetation cover and composition, provide potential services such as maintenance of soil fertility and structure and the associated limitation of soil erosion; downstream movement of soil nutrients; avoidance of damaging impacts of disastrous events such as floods, landslides, avalanches; provision of landscape

[2] Ellis (2000) defines human livelihoods as the capabilities, assets and activities required for a means of living. The concept of livelihoods is diverse. DFID (1999) for example, provides a number of determinants according to which livelihoods can be measured: human, natural, financial, physical and social capitals/assets. This study focuses on the rural context where agriculture is the major means of livelihood. It follows therefore that for rural communities, livelihood is a manner in which persons obtain a living depending on what they have and hold which is more important than what they do not have. In this study the term livelihoods means any activity that earns a living.

amenity; maintenance of biodiversity; cycling and storage of carbon and soil nutrients; pollination of crops and natural vegetation and dispersal of seeds (FAO 2000; Messerli & Ives 1997). These goods and services provided by MEs are critical life supports upon which the well-being and livelihoods of hundreds of millions of people depend (Millennium Ecosystem Assessment (MA) 2005; Nogues-Bravo et al. 2006; Price 2007).

1.1.4 International recognition of the importance of mountain ecosystems

MEs are utilised for income generation and for sustainable livelihoods, however, they are amongst the most fragile environments due to steep slopes and shallow soils (Rashid, Robert & Neville 2005; Sharma et al. 2007). The fragile nature of MEs and the need for their better management have attracted great interests within development discourse and practice (Ives 1992). The interest in their fragility and management has been increasing due to their support for human livelihoods and the link with other important environmental issues like carbon stocks, climate change, land degradation and land related disasters such as flooding, landslides and soil erosion (IPCC 2007; Shigaeva et al. 2007).

The growing appreciation of MEs and their critical importance began after the 1992 Earth Summit in Rio de Janeiro that was instrumental in moving mountains up in the global environmental agenda. According to Ives (1992) and Stone (2002) MEs received particular attention during the United Nations Conference on Environment and Development (UNCED) held in 1992. The United Nations (UN) governing system formulated a mountain agenda with the goals of making an authoritative statement on the environmental status and development potential of the world's mountains; disseminating mountains status information in the widest possible form; and identifying problems and providing some guidelines for a practical response to the problems and challenges of mountains for consideration by world leaders. All these broad goals are recognised in Chapter 13 of Agenda 21 on "managing fragile ecosystems: sustainable mountain development". Chapter 13 of the agenda focuses on two programme areas: generating and strengthening knowledge about the ecology and sustainable development of MEs; and promoting integrated watershed development and livelihood opportunities (ICIMOD 2010).

The Food and Agriculture Organization (FAO) of the UN was given the role of task manager regarding the issues identified in Chapter 13 with a mandate to facilitate and report on the implementation of these two programme areas. In 1994, FAO convened a task force including NGOs (non-government organisations), development organisations, and UN agencies to coordinate the implementation of Chapter 13. During the decade following the Earth Summit, many specific initiatives by governments, international institutions, NGOs and scientific organisations emerged as a result of what was written in Chapter 13. One important initiative was the establishment of the Mountain Forum in 1995 as a global network for information exchange, mutual support, and advocacy towards equitable and ecologically sustainable mountain development and conservation (ICIMOD 2010).

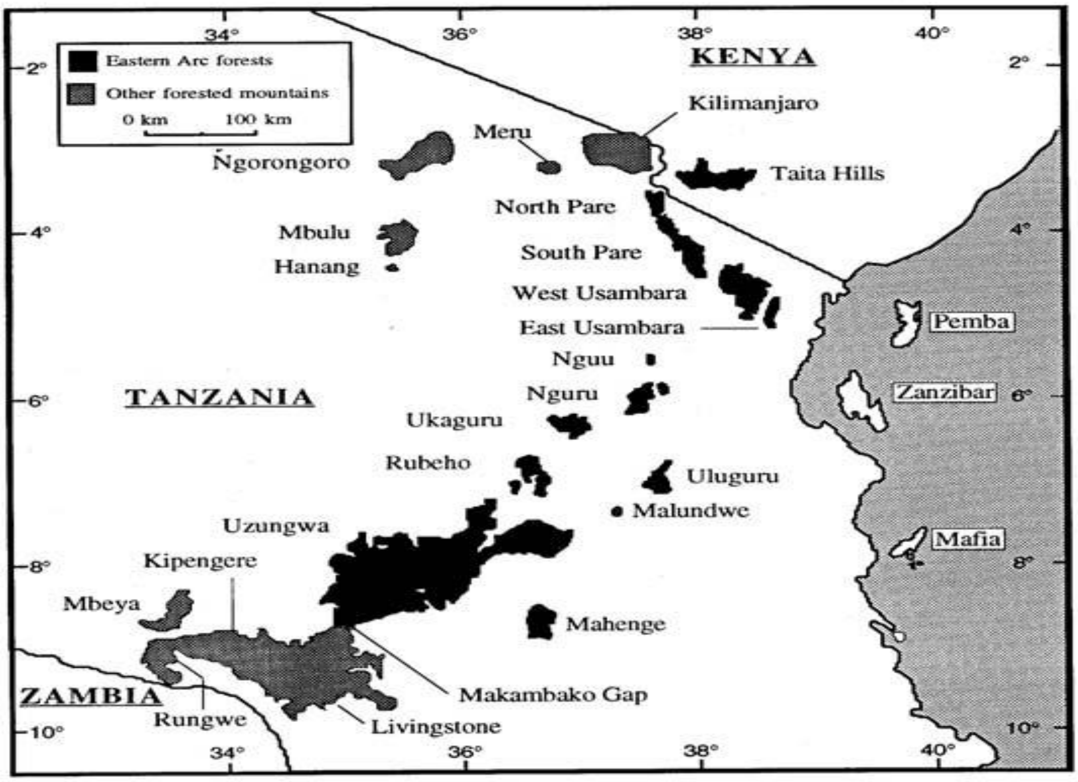
In 1998 the UN general assembly declared the year 2002 to be the 'International Year of Mountains' (FAO 2002; Sonesson & Messerli 2002), before commissioning the MA which was an international four-year (2001-2005) effort to assess the health of the earth's ecosystems including mountains (Alcano, Ash & Butte 2003). The International Year of Mountains aimed at increasing awareness of the global importance of MEs and the challenges faced by mountain people and to promote action (ICIMOD 2007).

Since the UN proclamation on the importance of conserving mountains various conservation programmes, commissions, associations and networks on mountains have been founded. For instance there is a programme of work for mountain biodiversity under the Convention on Biological Diversity and the inclusion of a chapter on mountain systems in the MA (Körner & Ohsawa 2005). The International Geographical Union (IGU) on Diversity in Mountain Systems, for example, was founded basically as a scientific union, the members of which are from the academic, professional societies, government and NGOs that represent the geographical discipline in their countries (Stoltman 1997). The International Centre for Integrated Mountain Development (ICIMOD) has also been founded (Gyamtsho 2006; ICIMOD 2006). ICIMOD's mission is to enable and facilitate the equitable and sustainable wellbeing of mountain peoples by supporting sustainable mountain development through active regional cooperation. Others include the SARD-M (Sustainable Agriculture and Rural Development in Mountains) project, the GLOCHAMORE (Global Change in Mountain Regions) project and the MRI (Mountain Research Initiative), which are open global network for mountain researchers (ICIMOD 2010). The African Highland Initiative (AHI) was also started in 1995 in East and Central Africa (Jeremia, Riziki & Ann 2007). In 2002, the Mountain Partnership was launched at the World Summit on Sustainable Development in Johannesburg to promote and facilitate closer collaboration between governments, civil society, intergovernmental organisations, and the private sector towards achieving sustainable mountain development (ICIMOD 2010). These organisations have provoked mountain researchers and scientists now carry out detailed investigations to determine the health of mountain ecosystems. Land use change is one of the problems facing mountain landscapes. Case based understanding of land use change is considered to be a prerequisite for the global assessment of mountain landscape dynamics with reference not only to their support of human livelihoods but also to their vital role in the global ecosystem and economy (Körner & Ohsawa 2005; Spehn, Liberman & Körner 2006). This study is one such specific case, which analyses the trend of land use change and identifies their associated driving forces in Mount Rungwe Ecosystem (MRE).

1.1.5 Recognition of mountains in Tanzania

Tanzania, like other countries in the world, is striving to ensure that her environment and ecosystems in general are managed sustainably. To ensure the sustainable management of her environment, Tanzania developed and adopted the National Environmental Policy (URT 1997a) and the Environmental Management Act (EMA) No. 20 of 2004 (URT 2004). EMA became operational in July 2005. Specifically, EMA gives due recognition to ecosystems issues and management as exemplified under Section 58. This section mandates government entities like the National Environment Management Council (NEMC), researchers and NGOs to identify and protect mountains, hills and landscapes that are at risk from environmental degradation. However, despite such due recognition of mountains, only a few mountains in the country have been studied with regard to their potential. Such studies include those on Mount Kilimanjaro (Mbonile, Misana & Sokoni 2003; Misana, Sokoni & Mbonile 2012; Soini 2002; 2005; William 2003); Usambara Mountain (Kaoneka & Solberg 1994). In terms of land use change a lot has been documented on Mt Kilimanjaro and thus it appears as if it is the only mountain in the country experiencing land use change among the mountains in the country. It is in this context that MRE has been selected for this study in order to balance the concern somewhat.

A number of conservation programmes enhancing sustainable use and utilisation of mountain resources are in place in the country. One example is the Conservation and Management of the Eastern Arc Mountain Forests (CMEAMF). The Eastern Arc Mountains comprise of 13 separate mountain blocks in Kenya and Tanzania, supporting around 3300 km^2 of sub montane, montane and upper montane forests. On the Tanzanian side the Udzungwa, East Usambara and Uluguru are the most important blocks with other important blocks being the Nguru and West Usambara (Burgess et al. 2007). Another programme is the Southern Highland Conservation programme that involves the southern highlands of Tanzania including Rungwe, Kitulo and Livingstone Mountains. These mountains are renowned in Africa for high concentrations of endemic species of animals, plants and birds (Burgess et al. 2007; Davenport 2006). The spatial distribution of these mountains is shown in Figure 1.1.



Source: Burgess et al. (2007: 211)

Figure 1.1 Mountains distribution in Tanzania

Towards the implementation of the MA in the Tanzanian context, a pilot study on integrated ecosystem assessment was done in the Livingstone Mountain Ranges (NEMC 2008). Among other things the objectives of the assessment were to assimilate the MA approach in the Tanzanian context; to analyse conditions and trends and identify drivers of change in the area; to develop scenarios that will help the local authorities and communities to conserve the Livingstone MEs for improved human wellbeing; and to build capacity among Tanzanians in carrying out integrated ecosystem assessments. However, this assessment was a pilot study in one mountain and the results cannot be generalised to MRE.

My study therefore uses Landsat and socioeconomic data to address some of the key goals of the MA initiative in the Tanzanian context – particularly documenting the nature and extent of land use change, identifying drivers of change and suggesting policy action for improved human wellbeing and the integrity of MRE in general.

The global and local initiatives have been founded on the one hand on the basis that during the previous decades changes occurred in natural mountain landscapes and land use[3], which need detailed and sophisticated investigation. On the other hand there is the realisation that MEs are particularly fragile, degrading rapidly and therefore there is a need of documenting natural degradation or restoration and land use patterns (Gyamtsho 2006; ICIMOD 2006). Again, the international, regional and local status of the mountains has been achieved through the recognition of the vital role mountains play in supporting human livelihoods (ICIMOD 2010; Nogues-Bravo et al. 2006). Current predictions of likely harmful global climate change have directed greater attention to MEs. People issuing such warnings consider MEs as areas where imprints of such manifestations will be apparent (Beniston 2000).

1.1.6 Direct utilization of mountain ecosystems

Human impact on MEs has a long and informative history, with periods of sustainable use and periods of deforestation and land use change. A range of factors drive people to use mountain areas as source of their livelihoods. The biophysical characteristics of mountains are in one part direct drivers of their utilization (Viviroli et al. 2007). In the developing world, habitable climate, abundant supply of timber and wood fuel, fertile soils, high productivity and biodiversity contribute to their utilization. Tropical African MEs, for example, are often agriculturally highly productive. Therefore they constitute a prime human habitat unlike temperate or boreal mountain ecosystems, which are frequently cold and less than habitable (MRI & CDE 2007; Nogues-Bravo et al. 2006). Tropical African mountains therefore accommodate a relatively higher number of people who live in these mountains

[3] There is a difference between land cover and land use. Land cover on the one hand refers to the biophysical attributes of the earth's land surface and the immediate subsurface, including biota, soil, topography, surface and ground water, crops and human structures. Land use, on the other hand, refers to the human purpose or intent applied to land cover (Braimoh 2004; Cihlar & Jansen 2001; Lambin, Geist & Lepers 2003). What is observed on satellite imagery and aerial photographs directly constitutes land cover. What the observer interprets that cover to represent can be termed land use. This study is concerned with assessing land use and associated land use changes by linking social survey information from land users within MRE to the observed land use changes and the implications of such changes to their livelihoods.

deriving much of their livelihoods from them through direct or indirect provisioning of goods and services such as water, forest products, biodiversity and soil nutrients. Increasing population and demand for food to feed the growing population in the developing world coupled with degraded lowlands are other forces that drive people to mountain areas.

Agricultural activities in most tropical African mountains, for example have benefited from the fertile volcanic soils found in some mountain ecosystems of Mt Kilimanjaro, Mt Kenya, Mt Elgon and the Ethiopian highlands. The fertile soils and benevolent climate conditions have fostered relatively high population densities both in the highland and lowlands of many mountain ecosystems in Africa. The slopes of Mount Kilimanjaro for example have a high population density of 300 persons per km^2 (Mbonile, Misana & Sokoni 2003). The lowlands and the highlands of Mount Kilimanjaro are both intensively cultivated, there has been encroachment into forest reserves and exotic trees have replaced natural vegetation in some areas. Despite the attraction of the mountains in Africa, they are increasingly becoming the most fragile ecosystems due to pressure from population encroachment. The pressure felt in the mountains is caused by demand for land, water, wood products and the entire mountainous biodiversity. Since mountains offer quite a number of livelihood activities, land use change dynamics are felt in these fragile ecosystems.

1.1.7 Land use change in global mountain ecosystems

Changes in MEs are brought about by natural and human interaction. However, the direct and indirect human impacts to ecosystems including MEs override natural impacts (Erich, Ulrike & Alexander 2005; Lambin, Geist & Lepers 2003; Rashid, Robert & Neville 2005). Activities such as land cultivation, livestock grazing, human settlement, infrastructure constructions, reserves and protected land reservation, timber extraction and introduction of exotic species have cumulatively transformed mountain landscapes in such a way that their ability to provide goods and services to communities dependent on them has been impaired (Hofer 2005). Case studies on land use change in mountain regions are minimal. Available literature however, shows that the rate of conversion of natural vegetation into cropland and grazing land in such environments is high. Land use change analysis in global MEs during the period 1700 to 1990 for example showed that 16% to 21% of the land was converted into cropland and grazing land (UNEP-WCMC 2002).

Another analysis of global MEs between 1990 and 2000 indicated that about 19% remains as forest, 78.3% remains as non forest, 2.3% has been deforested and only 0.4% reforested (UNEP-WCMC 2002). At a global level analysis in MEs indicates that in terms of percentage land area, conversion to grazing is highest in African mountains, whereas conversion to cropland is greatest in Australia and Southeast Asia.

The analysis of land use change in the Himalayan region, in the five selected watersheds in China and India, shows that natural forests decreased in both countries with the highest change of 20% in the Indian Mamlay watershed from 1988 to 1997(Sharma et al. 2007). According to Sharma et al soil loss recorded in these areas ranged from 250 to 616t/km^{-2} yr^{1}. Tiwari (2008) observes that in the Himalayas the landscape was transformed considerably; cultivated land, forests, pastures and rangelands deteriorated and were depleted steadily and converted into degraded and non-productive lands. According to Tiwari, extensive land use changes have left large areas exposed to erosion.

Mottet et al. (2006), studying land use change in one of the villages in the Pyrenees mountain landscapes, observed both intensification and extensification trends in the late 1980s and 1990s. They noted that agricultural intensification was related not only to the application of agri-environmental policies but also to specific local factors, in particular to the building of an access road to the highest part of the study area. In agricultural extensification, most of the croplands were converted into meadows where traditional mixed crop-livestock farming systems were progressively converted into specialised livestock farming systems with greater need for forage. In the same line Bender et al. (2005) also acknowledge the fact that conversion of croplands into meadows is a widely observed phenomenon in Mediterranean mountain areas. A number of factors including, demographic, socio-economic, political, technological, cultural and natural, drive land use change in global mountain areas (Bürgi, Hersperger & Schneeberger 2004; Hasselmann et al. 2010; MA 2005). These factors are explored in more detail in Chapter 2.

1.1.8 Land use change in African mountains

In African mountains the studies such as those of Liniger (1993) and Gichuki et al. (1998) have shown that there is extensive forest degradation and expansion of agriculture in Mount Kenya and Ethiopian mountains. These studies indicated that the observed soil loss was a significant consequence of human processes through both cropping and grazing. In eastern Africa, agricultural land has been expanding at the expense of decreasing forests. In some parts of the Ugandan Mountains, it is also reported that districts with high population densities experience expansion of areas under cultivation at the expense of forest reserves (Mugagga, Kakembo & Buyinza 2012).

Imbernon (1999) studying change in land use in the semi-arid and humid areas of Mount Kenya found that tree cover decreased from 26% in 1956 to 24% in 1995. The extent of perennial crops (tea and coffee) increased from 1% to 33% over the same period. Bushland, which covered about one-quarter of the area in 1958, no longer existed by 1995. In the highlands north of Nairobi, Ovuka (2000) also observed that in 1960 there was 15% fallow land but it decreased to 6% in 1996 whereas woodlots increased from 1 to 3% and coffee gardens from 0.2% to 12% over the same period. Areas without soil and water conservation practises increased from about 25% in 1960 to 70% in 1996.

Tekle & Hedlund (2000), analysing land use changes between 1958 and 1986 in the highlands of Kalu District, Ethiopia, observed a decrease in coverage by shrub, riverine vegetation, and forests while areas under cultivation remained more or less unchanged. It was concluded that land use changes were the result of clearing of vegetation for fuelwood and grazing. These findings on land use conversions are probably applicable to other African mountains including those of Tanzania.

1.1.9 Land use change in Tanzanian mountains

In Tanzania, studies on land use change on Mt Kilimanjaro and the Usambara Mountains focus on the biophysical aspects and their effect on natural forests, general biodiversity and soil degradation. The findings of various studies on Mt Kilimanjaro, including those of Misana, Sokoni & Mbonile (2012), Soini (2002) and William (2003) indicated that the area has experienced various land use change. William (2003), for instance, studying land use change around the Half Mile Forest Strip (HMFS) on the southern slopes of Mt Kilimanjaro using 1952 and 1982 aerial photographs and satellite imagery of 1999/2000, found that cultivated land expanded at the expense of forest and grazing land. The study further indicates that forest cover decreased by a quarter from 194.41 km^2 in 1952 to 155.8 km^2 in 1982. The impact of such land use change was the decreased number of plant species such as *Embelia* and disappearance of *Ocotea usambarensis* species in the HMFS.

Soini (2002), using aerial photographs for 1960 and 2000 found a general expansion of cultivated land, disappearance and fragmentation of natural vegetation and appearance and expansion of settlements on the southern slopes of Mt Kilimanjaro. He indicated that bushland decreased from 40% of the total area in 1960 to 11% and seven per cent in 1982 and 2000, respectively, and that the cultivated land increased from 41% in 1960 to 64 and 67% in 1982 and 2000, while settlements increased from 0.1 % in 1960 to 0.7% and 2.4% in 1982 and 2000 in that order. According to the author, the changes in land use were attributed to population growth. Another land use change analysis on the southern and eastern slopes of Mt Kilimanjaro from 1973 to 2000 shows an expansion of cultivation at the expense of natural vegetation, where the area under cultivation increased from 54% in 1973 to 62% and 63% in 1984 and 2000, respectively (Misana, Sokoni & Mbonile 2012). This is attributed to population growth, government policies, and economic factors, socio-cultural and technological change.

Another study in the Usambara Mountains in the Tanga region showed a drastic reduction in forest cover from 53 000 ha in 1965 to 30 000 ha in 1991, where about one-third of the natural forest was converted to plantations (Kaoneka & Solberg 1994). The main cause of the deforestation was the expansion of farmlands and settlements because of population increase (Kaoneka & Solberg 1994). In Kondoa Irangi Hills, Central Tanzania, it is reported that in 1977 the land was completely wooded but by 1992 most of the land had been converted into agriculture (Kangalawe 2010). The results of this study show that cultivated land increased from 31% in 1977 to 35% in 1992 of the total area; particularly along water courses that decreased by 55% and the area covered with natural vegetation increased due to soil conservation measures that were implemented in the Irangi hills.

1.1.10 Land use change in Mt Rungwe ecosystem

Land use and livelihoods in MRE have been influenced by national policies[4] as well. During the colonial period in 1949, Mount Rungwe Forest Reserve was gazetted and access to forest resources was restricted (McKone & Walzem 1994). In the early 1970s, the Kiwira forest plantation project was established through conversion of part of the natural forest around Mt Rungwe (URT 2011a). The establishment of the Kiwira forest plantation reduced the amount of land available to local communities for grazing and farming. In a way it also

[4] The various policy regimes and processes and how they are related to resource use, access, management and resultant land use change countrywide are explained in detail in Chapter 2 of this dissertation.

accelerated the clearance of bushlands and woodlands for establishing farms. The gazetting[5] of Mount Rungwe Forest Reserve and the establishment of the Kiwira forest plantation were in line with the forestry policy on gazettement of natural forests and establishment of forest plantations (URT 2005).

Mashalla (1988), studying the human impact on the natural environments in the Southern highlands (including Rungwe) points out that during villagisation[6] in 1975 rural settlements in some parts of Rungwe were reorganised into nucleated settlements. According to this author the concentration of people into Ujamaa villages in Rungwe resulted in clearance of forests and woodlands for cultivation, overgrazing and extensive wood cutting. Mwakalobo (1998), investigating the effects of price reform measures on smallholder production systems, responses and changes that have taken place in smallholder agricultural production systems in Rungwe district following the institution of price reform policies in Tanzania, revealed that some farmers have abandoned growing some crops that required fewer or lower inputs (e.g. tea). Results from the same study indicate that some farmers failed to expand the area under cultivation of some crops, which yielded good profit because, of high population density, increased cost of production and delay in payment for crops sold in that particular cropping season. These results suggest a change in land use and cropping patterns. However, information on the nature, extent of land use change and their implications on their livelihood systems are scarce, except for a number of ecological studies (Kurita 1993; Mwamfupe 1998a).

Specifically, researchers such as Davenport & Jones (2005), Davenport (2006) and Machaga, Massawe & Davenport (2005) have conducted studies that specifically link land degradation in terms of deforestation to loss of biodiversity. Other studies, including those of Gwambene (2007) and Majule, Williamson & Mwalyosi (2007), focused on climate change and found variability and decline in land productivity in some parts of Rungwe. Mwakalobo

[5] The term is used here to refer to the Act of an official declaration or publication through a government order or notice. Mount Rungwe Forest Reserve was gazetted (declared or published) in 1949. The gazetting was carried out through the declaration order GN 773 of 26/5/1949. There have been various orders namely the GN 54 and 55 of 20/2/1953 since its establishment. The current status is that in 2009, the Forest Reserve was declared a Nature Reserve through a declaration order GN 56 (URT 2011a).

[6] Villagisation has been defined as the grouping of people into centralised planned settlements (Kikula 1996; Nyerere 1968). The term is frequently confused with resettlement as the two policies often occur at the same time and may overlap. In Tanzania villagisation with its famous concept of Ujamaa (which means 'family hood' in Swahili) was a policy from 1973 to 1976 that involved the concentration of the population aimed at improving the standards of living of people through increased agricultural productivity and provision of various centralised social amenities.

(1998) focused on the detrimental impacts of structural adjustments on smallholder farmers while Mwakalobo (2007) focused on the heavy impact of HIV in some villages in Rungwe. With respect to land use changes, a study has been conducted by Majule & Muganyizi (2009), establishing land use changes using GIS and participatory approaches in two villages of MRE. In this study it was found that land use change is a reality in the study villages and different natural and socioeconomic factors that were considered likely to influence changes on land use were identified. These activities included expansion of agriculture, growing of tree plantations and urbanization. This is, however, a one-way link of human activities to land use change, neglecting the reverse link describing development-environment interactions taking place in a specific ecosystem. There is a need for examining the relationship between land use and livelihood changes in the area. In particular, an understanding of the nature and extent as well as the driving forces behind changes in land use is required for establishing how such changes offer opportunities or constrain people's livelihoods.

1.2 RESEARCH PROBLEM AND RESEARCH QUESTIONS

MRE has unique resources and offers many opportunities for the development of Tanzania through its biological, hydrological, economic and cultural roles. Biologically the mountain is home to many rare and endemic plant species such as *Exotheca Abyssinica, Andropogon, Eragrostis, olea capensis* and mammalian species such as the black and white colobus (*Colobus sharpie*), Abbotts duiker and kipunji (*Rungwecebus kipunji*) (McKone & Walzem 1994; Machaga, Massawe & Davenport 2005). Hydrologically the ME is important for its water catchment value. The mountain feeds numerous villages and towns from Kiwira, Katumba, and Tukuyu to Kandete towns, and nourishes the rich agricultural lands of the Kyela valley. The ME is the catchment for rivers such as Kiwira, Suma, Mbaka, Kilasi, Marogala, Mrombo, Mulagala, Sinini and Mwatisi Rivers, which flow into Lake Nyasa[7] (McKone & Walzem 1994; URT 2011a). The mountain's economic value includes its contribution as a water catchment, its provision of forest resources, land for agriculture and its potential for tourism. The mountain is also of great importance to the local communities in the area as a source of medicine, fuelwood, building materials and sacred forest area for worship and performing rituals (URT 2011a).

[7] The Lake is shared by Tanzania, Malawi and Mozambique. In Tanzania it is called Lake Nyasa while in Malawi it is called Lake Malawi.

Despite the value of MRE, changes in land use patterns resulting from increasing population needs and demands on land and forest resources threaten the socio-economic and ecological functioning of the ecosystem. Land in MRE is a major natural resource on which economic, social, infrastructure and other human activities are undertaken. The users of the land put it into various uses in order to meet their daily needs. Agriculture and settlements in some village areas, for example, have replaced natural vegetation while areas that were set aside for grazing have been converted into other uses due to the increasing human population.

In the MRE there are also different forms of encroachment, mostly the use of the forest reserve for agriculture, illegal logging, charcoal making and firewood collection. There is a decrease in crop farming areas and an increase in areas planted with pine trees. Cumulatively or singly the utilization of the resources has caused changes in land use patterns and change in the means of making a living in the area. In terms of livelihood adjustments there is a shift in some crop varieties grown and livelihood activities. Changes in land use associated with various driving forces[8] threaten the provision of ecological and other services provided by this mountain that are likely to affect people's livelihoods. Land use change in MRE however, is not a current phenomenon; it dates back to the 19th century (Mbonile 2000). The future capability of MRE to provide services such as biodiversity, food, water, carbon sequestration and recreation is determined by changes in the physical and socio-economic characteristics. There is however, little or no analytical research that has been done linking land use change and communities' livelihoods in MRE. Furthermore, the driving forces of landscape patterns are often region-specific as a consequence of different contextual conditions, specific variation in the socio-economic and biophysical conditions and the influence of land use history and culture. Thus a similar driving force may behave differently in different locations. It is therefore the purpose of this research to provide baseline information on patterns of changes in land use in the MRE over a 37 year period (1973-2010) and their implications on communities' livelihoods. The study also aims to identify broad

[8] The term 'driving forces' is complex and there are numerous definitions. Bürgi, Hersperger & Schneeberger (2004) define driving forces as factors that cause observed landscape change, while Braimoh (2004) refers to them as any factors that influence human activity. Other researchers call driving forces key processes (Marcucci 2000), drivers (Wood & Handley 2001; MA 2005) or causes of land use change (Lambin, Geist & Lepers 2003). Their categorisation is also different. Some authors categorise them into direct and indirect (MA 2005); proximate and underlying (Lambin, Geist & Lepers 2003; Rowcroft 2005). In this study the term drivers, driving forces and causes of land use change are used interchangeably to refer to any factors that influence decisions on land use.

drivers of land use change based on the common findings of a number of other studies around the world. Therefore, my research questions are:

1) What is the extent and nature of land use change in MRE from 1973 to 2010?
2) Which drivers have been instrumental for the land use changes in the MRE?
3) What is the relationship between land use change and local communities' livelihoods?

1.3 AIM AND OBJECTIVES OF THE STUDY

The researcher aims to investigate the major changes in land use, to identify the drivers responsible for these changes and to establish the interrelationship between land use change and communities' livelihoods in order to suggest desirable management options towards improving rural livelihoods and the ecological integrity of MRE. In this context, the specific objectives are to:

(1) Identify and map land use in the MRE from 1973 to 2010;
(2) Analyse land use change in the MRE over 37 years (i.e. from 1973 to 2010);
(3) Identify and evaluate instrumental drivers (political, social, economic and natural process) in the MRE; and
(4) Establish the relationship between land use change and people's livelihoods in the area to enable future development prediction.

1.4 RESEARCH RATIONALE AND SIGNIFICANCE

MEs in Tanzania have been accorded priority due to their role and were identified as focus areas as articulated in the Environmental Management Act (EMA). Furthermore, the southern highlands including MRE form a major catchment area for Lake Nyasa and contain unique biodiversity. MRE is located in a major grain producing region in Tanzania. Thus, the threats of degradation in MRE need prompt attention in order to sustain food security for the country.

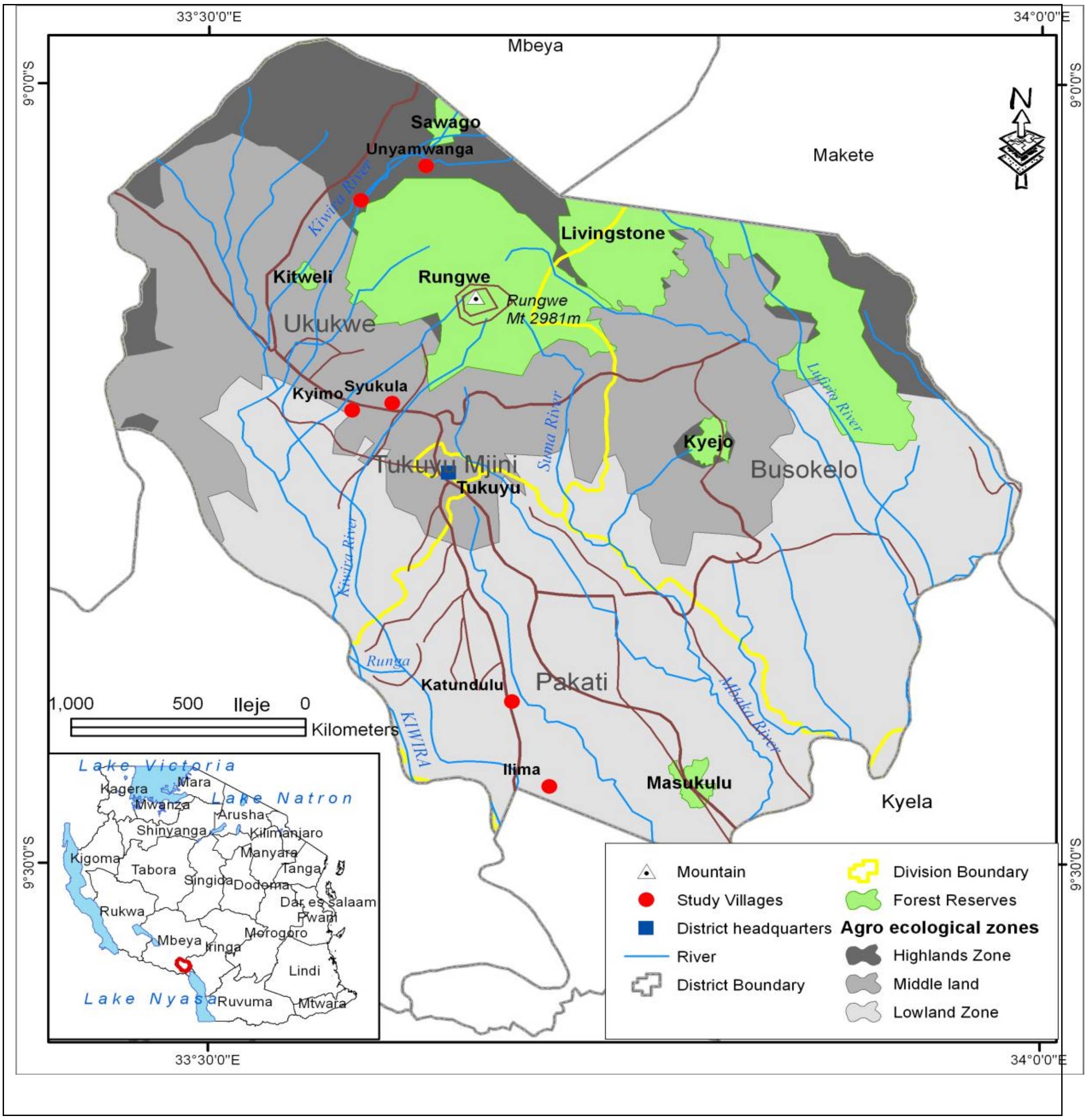
This study assesses prevailing land uses, their historical changes and their associated socio-economic impacts. At the theoretical level the study contributes to the debate on global environmental change and its impact on ecosystems and people's livelihoods especially in Sub-Saharan Africa. It also supports and strengthens applied uses of geoinformation technologies (GIT) in land use change analysis. At the practical level the study gives site specific information and suggests locally suitable measures that are beneficial to various stakeholders for conserving the integrity of MRE. Furthermore, the study generates information that helps to harmonize conservation programmes and community activities. The local communities, who are the resource users, could gain a better understanding of the way their activities impact the natural environment and their livelihoods and of how the solutions to MRE problems lie in the way they value and use land resources. Since mountains do not exist in isolation, lessons drawn may be applicable to similar mountain regions elsewhere.

1.5 STUDY AREA

In this section I present detailed information of the study area, the Rungwe district. In the first section the location and boundary delineation of the study area are given. Then a description of the general bio-geophysical and socio-economic characteristics of the study area follows. Thirdly, specific chosen villages as case studies are described in terms of their human composition and economic development.

1.5.1 Geographical location of the study area, Rungwe district

For the purpose of this research MRE is considered as an open system that allows interactions within and outside its boundaries. For the study to be manageable, a demarcation based on a political boundary of the district was considered for the survey and the land use change analysis. The Rungwe district is in Mbeya region located between Latitude 8° $30^{'}$ S and 9° $30^{'}$ S and Longitude 33° E and 34° E in southwest Tanzania. Rungwe district borders Kyela district in the South, Ileje district in the West, Makete district in the East and Mbeya district in the North. The district seat, Tukuyu, is located roughly at the centre of the district and it is about 72 km from Mbeya city. Figure 1.2 shows the location of the Rungwe district, the selected study villages, the three agro-ecological zones and the six reserved forests in the district.



Source: Adopted from URT (2010)

Figure 1.2 Location of Rungwe district

The district occupies an area of 2211 km^2 of which 1668 km^2 (75%) is suitable for agriculture. The remaining 45 km^2 (2%) is covered by forests and 498 km^2 (23%), comprises mountains and residential areas. Regionally, Rungwe is one of the smallest districts comprising only slightly more than 3% of the total Regional land area, which is 63 617 km^2. Rungwe district consists of four divisions namely Ukukwe, Busokelo, Pakati and Tukuyu. During the time this study was conducted the four divisions were subdivided into 30 wards in which 162 individually recognised villages are located (URT 2003a; 2010). The map shows the highland area in the central north, sloping towards the south with many rivers draining towards Lake Nyasa in the south eastern vicinity. From it the spread of the study villages representative of the three recognised agro-ecological zones is apparent.

1.5.2 Geography of the study area

In this subsection, the topography, climate, geology and soils, vegetation and wild animals of MRE are described. The human population, economic activities and social services in the district are also presented.

1.5.2.1 Topography

The Rungwe district is generally mountainous, with average height above sea level ranging between altitudes of 772 metres to 2981 metres. Mount Rungwe is composed of 10 or more dormant volcanic craters and domes. The topography varies from hilly to steeply dissected, with elevation ranges between 1500 metres in the south and 2981 metres at the summit (URT 2011a). Steep sides of the mountain ranges are characterized by numerous small streams which together drain to major rivers such as the Kiwira, Lufilyo, Mwalisi and Mbaka. The Kiwira, Mwalisi and Mbaka rivers originate from the Rungwe Mountain while Lufilyo River originates from the Livingstone Mountain ranges beyond the study region in the north east. These rivers are adjoined by other small streams, which pour their waters into Lake Nyasa in Kyela District (URT 2010; 2011a).

1.5.2.2 Climate and agro-ecological zones

The simultaneous consideration of thermal, moisture, soil and topography characteristics permits the definition of broad agro-ecological zones. These classifications are useful in assessing the potential for crop cultivation. According to URT and World Bank (1994) agro-ecological zones classification in Tanzania, Rungwe falls under zone V (southern, south-western and western highlands). This zone is characterised by having high altitude plateaus with volcanic and pre-Cambrian metamorphic rocks with soils of low to moderate fertility, rainfall in the southern and south-western areas are generally reliable and unimodal (800-1400 mm per year). In the western areas rainfall is bimodal and higher (1000-2000 mm per year). The district is divided into three distinct sub agro-ecological zones: the highlands, middlelands and lowlands as shown in Table 1.1 and Figures 1.2 and 1.3. They differ quite significantly in terms of the topographically determined annual and seasonal rainfall and temperature regime experienced. While the spatial variations in rainfall and temperatures

Table 1.1 Classification of agro-ecological zones in Rungwe district

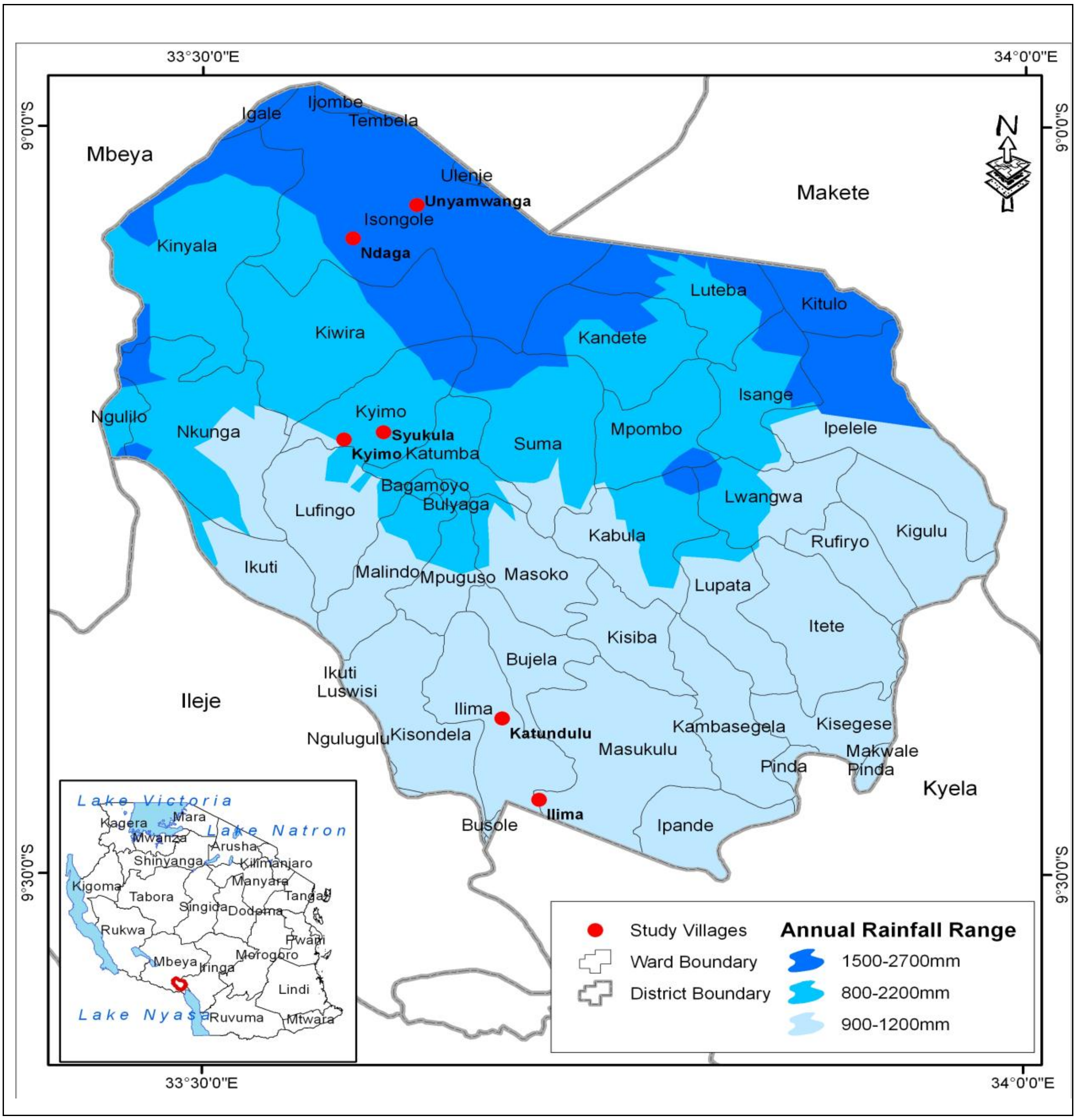
Zone	Altitude (metres asl)	Description	Average Rainfall (mm/yr)	Annual average temperature	Main crops and vegetation
Highland	2000-2265	Continuation of Uporoto mountains from Mbeya rural district, covers the whole area of Isongole ward	1500-2700	5°C - 18°C	pyrethrum, Irish potatoes[9], maize, beans, pines, Ficus
Middleland	1500 - 2000	This zone occupies most of Ukukwe, Tukuyu and Busokelo divisions	800 - 2200	16°C - 28°C	bananas, tea, coffee, maize, beans, cardamoms, groundnuts; Ficus, Grevillea
Lowland	772 - 1500	Lies to the south of the district in Pakati division mainly Ilima, Masukulu, Itete, Kambasegela and Kisegese wards.	900 - 1200	20°C - 30°C	paddy, maize, beans, cocoa, bananas miombo, Albizia, Ficus

Source: URT (2003a; 2010)

are not pronounced, they do make the district uniquely suitable for producing a variety of crops and they determine the type of agriculture that is undertaken within a particular zone in the district.

On average the rainfall ranges from 900 mm in the lowlands to 2700 mm (three times higher) in the highlands. Temperatures are generally modest and range from 18^0C to 25^0C all the year round (URT 2003a; 2010). An annual dry season is mainly experienced from June to October. Adverse climatic events, mainly droughts, have been recorded regularly (1962, 1963, 1974, 1979, 1982, 1983, 1993, 2005 and 2006) and flooding events are remembered to have hit the area in 1997, 1998, 2004 and 2005 (Mzara 2011, pers.com). The two types of disaster resulted in destruction of crops, soil erosion, crop failure, pest invasion, hunger and human diseases. Despite such climatic events, in summary, it can be said that in general the study area experiences relatively mild climatic conditions, devoid of extremes and offering a pleasant and productive living environment.

[9] This is the English language name commonly given to potatoes (solanum turberosum) in markets in Tanzania and other parts of East Africa. In this document the term potatoes is used referring to the Irish potatoes in the study area.

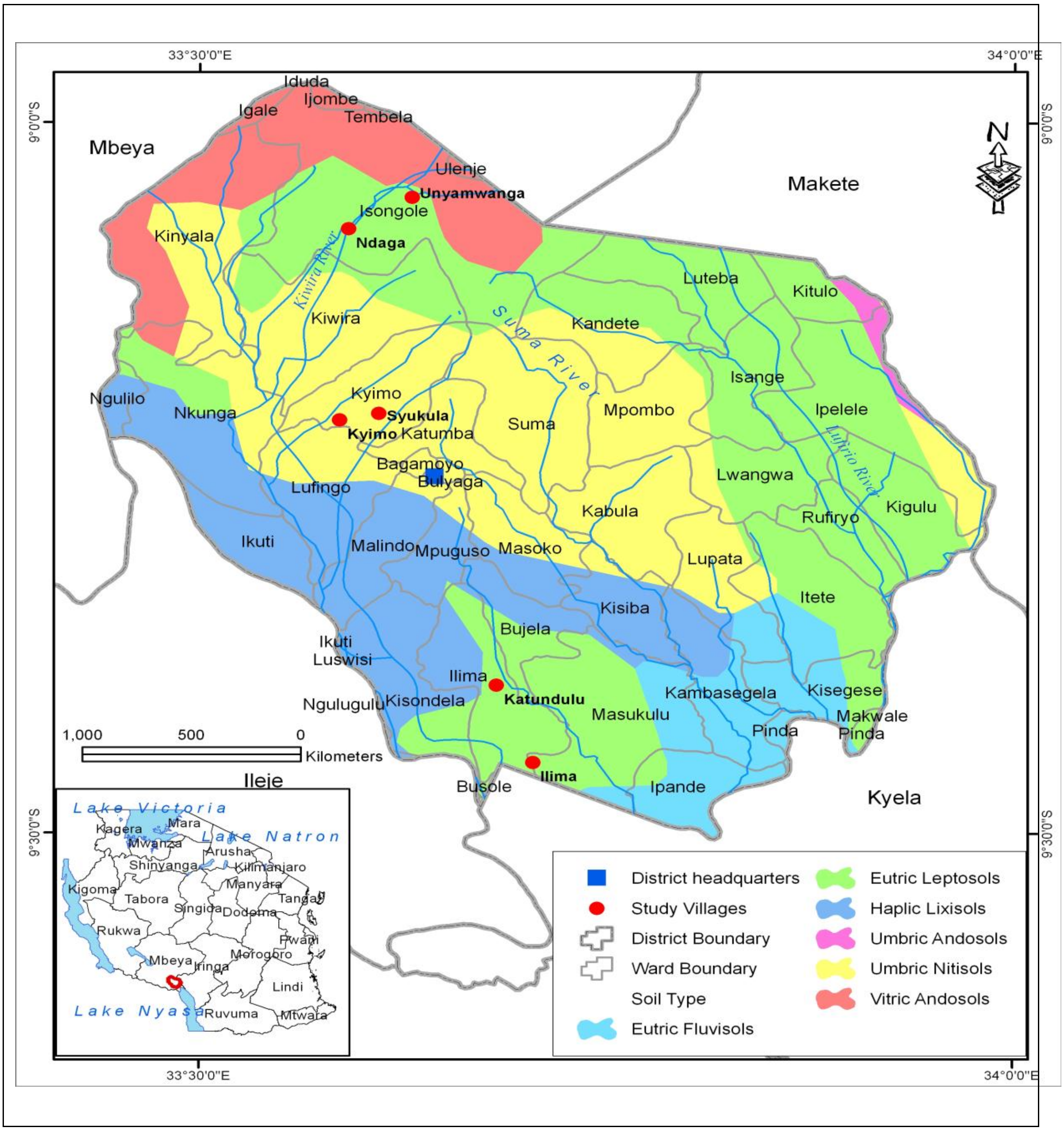


Source: Adopted from URT (2003a; 2010)

Figure 1.3 Agro-ecological zones and rainfall amounts

1.5.2.3 Geology and soils

Mt Rungwe is a dormant volcano built up mainly of phonolitic-trachyte lavas and tuffs, olivine-basalts, phonolitic trachyte lavas, pumice and ash from a nest of conelets within the Rungwe caldera (McKone & Walzem 1994; Mshiu 2011). The parent material is volcanic ash and pumice. Figure 1.4 shows the various soil types derived from these geological bedrock materials of the MRE. The soils are typically well drained and have low bulk density. Topsoil is black to brownish-gray. Subsoil consists of alternating layers of pumice-gravel and soil.



Source: Adopted from URT (2006a)

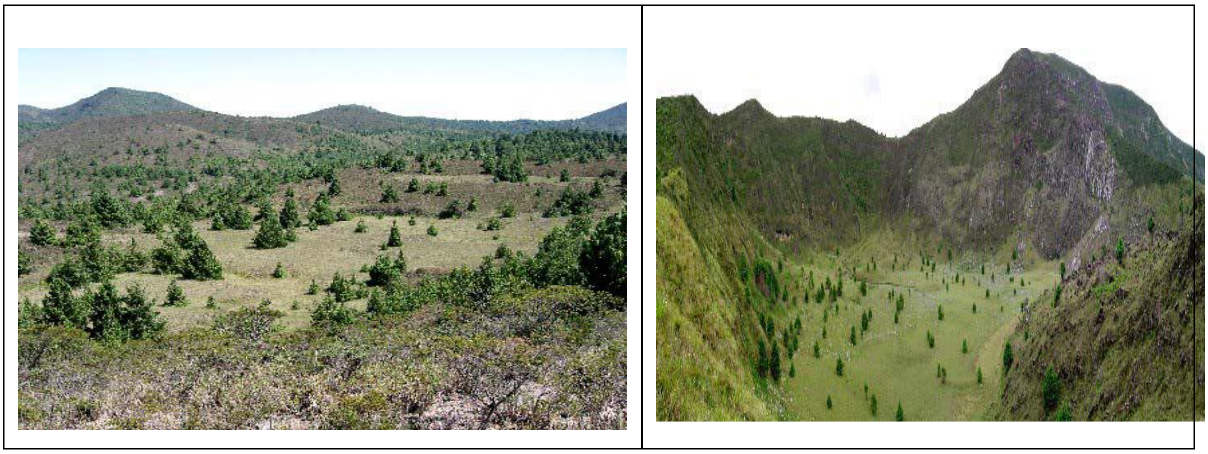
Figure 1.4 Soil types in MRE

Soils in the high grasslands are thin and quite rocky (McKone & Walzem 1994; URT 2011a). On the steep slopes of Mt Rungwe, soils are predominantly dark greyish and dark brown as well as dark-yellowish-brown with sandy and clay loams (McKone & Walzem 1994). The soils of the main arable lands are of medium fertility, coarse or medium textured, ranging from sandy loams to alluvial, conducive for growing bananas, beans, maize, potatoes, tea, coffee, paddies and small woodlots.

1.5.2.4 Natural vegetation

MRE has rich and diversified natural vegetation due to variation in climate, soils and topography. Mt Rungwe Forest Reserve is made up of Montane forest, Upper Montane forest and grassland with lesser amounts of bushland and heath zone, which is generally a transition zone between the forest and upper grasslands (URT 2011a). The forest is mainly composed of *Aphloia theiformis*, *Ficalhoa laurifolia*, *Maesa lanceolata*, *Trichocladus ellipticus*, *Albizia gummifera* and *Bersama abyssinica*. There are more than 550 plant species out of which approximately 400 are used as traditional medicines by the residents of Rungwe, Mbeya and Kyela districts. These species include *Juniperus procera*, *Erica aborea*, *Olea capensis*, *Albizia* sp. and *Musa isente*. Mountainous grasslands and forests occur above 1300 metres above sea level. Bamboo (*Arundinaria alpina*) vegetation also occurs in the highland zones (URT 2011a). The district also has six gazetted catchment forest reserves shown in Figure 1.2, and including the Livingstone which is situated on the northern and north-eastern slopes of the Lake Nyasa trough; Kyejo, which is on Kyejo Mountain; Rungwe that covers most of Rungwe Mountain; Kitweli which is situated on the west of Mt Rungwe; Sawago which is north of Rungwe and Masukulu which is a woodland reserve on the interfluves that drop down to Lake Nyasa (McKone & Walzem 1994). All of these forest reserves' waters contribute to the rich agricultural lands in Kyela and Rungwe districts, before emptying into Lake Nyasa.

All of the natural vegetation groupings experience heavy grazing, illegal lumbering, charcoal production, fuelwood collection and beekeeping. The forests are prone to natural dry seasonal grass fires. Cultivation and bamboo collection is carried out, even in these reserves (McKone & Walzem 1994; Davenport 2004). Farmers cultivate the slopes of the mountains beyond and despite reserve boundary beacons, causing deforestation of the forests. Additionally, exotic pines spreading from plantations have replaced natural vegetation in some areas. In Mt Rungwe Forest Reserve for example, natural grasslands have been colonised by the exotic species *Pinus patula* that threaten their existence (McKone & Walzem 1994; Davenport 2004). Figure 1.5 shows the extent of pines invasion in some parts of the MRE. The planting of exotic species in cultivated and uncultivated areas in the MRE have also resulted in changes in agro-forestry ecosystems where indigenous plants are colonised by exotic *Pinus patula* species (McKone & Walzem 1994).



Source: Davenport 2004

Figure 1.5 Pines invasion in MRE

1.5.2.5 Wild animals and birds

Wild animals occurring in the MRE include *Colobus* monkeys including the newly discovered Kipunji (*Rungwecebus kipunji*) named after Mt Rungwe where it was first discovered (Davenport & Jones 2005). Mount Rungwe is also rich in small game and numerous bird species and is hence an important Bird Area (IBA No.64) with two species listed as vulnerable (Machaga, Massawe & Davenport 2005). Generally, the ecosystem harbours a range of endemic mammalian species of particular conservation concern. It is a home to almost 100 species of mammals, over 230 species of birds, 34 species of reptiles, 45 species of amphibians and 10 species of fish (URT 2011a). Destruction of such an ecosystem and habitat may therefore lead to serious species losses.

1.5.2.6 Ethnicity and human population

The dominant ethnic groups in the MRE are the Nyakyusa and the Safwa, while Ndali, Malila and Bena are minorities. According to the national population census of 1978 and 1988 the district had 235 314 and 271 432 people respectively (a 1.53% annual growth rate). According to the 2002 population census, Rungwe district had 307 270 people of which 145 257(47%) were males and 162 013 (53%) were females with the projected annual growth rate now more stable at 0.9%. The slight gender imbalance can be attributed to a gender based death/survival rate differentials or male labour migration. Based on the 2002 population census data as a base year and the annual growth rate of 0.9%, the district's population is projected to reach 336 207 in 2012. This indicates an addition of 28 937 people in 10 years' time. The stable growth rate at 0.9% per annum and the slight difference in population growth between 2002 and 2012 is probably due to outmigration in some villages as indicated later in Table 5.1 in Chapter 5, where some villages' population for 2002 is slightly lower compared to that of 1988 census data. The national census survey that was conducted in October 2012 however, is expected to provide accurate figures on population growth rate of the area. Overall, the average population density is 152 people per square kilometre, being above the regional average of 34 people per square kilometre and national average of 39 persons per square kilometre (URT 2010) but slightly lower than the average population density on the slopes of Mount Kilimanjaro which was over 200 people per square kilometres in 2002 (Soini 2005).

The average household size in the district is a relatively small 4.1 persons. The active working group constitutes of 49.2% of the total, the children under 15 years comprises 41.9% while the old folk above 60 years comprises 8.9% of the population, denoting a tolerable dependency ratio. With regard to the projected population and the available arable land this implies that on average each person has about 2.0 ha, this being somewhat below the regional average of 2.5 ha and the national average of 3.0 ha of the land available for agriculture (URT 1997b; URT 2007). The Rungwe district though has a stable annual growth rate and is recognised as one of the more populated areas in the Mbeya region followed by Mbozi and Mbeya rural districts (URT 1997b). Generally, the growing human population in the area gives rise to increased demand for land, water, wood products and the entire mountainous biodiversity. Land shortages in turn have led to conversion of natural vegetation, more intensive agricultural practices and considerable outmigration (Charnley 1997) especially of young persons or families in an attempt to acquire land elsewhere. The major population movements are directed to major urban centres within the region and to other regions in the country, especially Dar es Salaam (Mbonile 2005). The main denominations in the area are Christianity[10] and Islam.

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[10] Although these are the main religious denominations, there are several others. People of different religions live side by side without acrimony respecting each other and cooperating in social events and activities. It is uncommon in Tanzania to use or exploit ethnicity or religious identity for political or economic gains. Thus in most cases data on religious groups is not officially recorded. On these grounds, this study did not get data on population size and distribution of religious denominations. Countrywide, religious surveys were eliminated from government census reports after 1967 (US Department of State 2007). There are however estimates from different sources. Religious leaders and sociologists estimate that the *Christian* and *Muslim* communities are approximately equal in size, each accounting for 30 to 40 percent of the population, with the remainder consisting of practitioners of other faiths, *indigenous religions* and people of *no religion* (US Department of

1.5.2.7 Primary resource exploitation

Primary economic activities include *agriculture* as the major economic activity in the district, employing about 90% of the economically active population, while the remaining 10% are civil servants (URT 2010). The main cash crops grown are tea, coffee, cocoa, bananas, rice, potatoes and maize and vegetables while bananas, pineapples and avocados are the major commercial fruits. However, the growing of banana and potatoes as cash crops by some farmers has started in recent years (Mwakalobo 1998). Recent production trends for these main crops are reflected in Table 1.2, demonstrating that banana, maize and potatoes production are dominant in volume and all are fast growing in output, while more stable figures are recorded for the other commodities.

Table 1.2 Crop production trend in Rungwe district

Year	Production in tonnes per crop						
	Banana	Maize	Potatoes	Cocoa	Coffee	Tea (green leaves)	Rice*
2004	230 000	55 400	75 000	852	294	13 496 297	2015
2005	250 000	58 700	72 000	1036	775	15 450 085	2399
2006	264 513	55 218	81 215	1198	231	11 618 134	1273
2007	298 819	68 492	112 300	1709	552	16 677 184	1709
2008	331 217	70 237	122 300	1772	191	17 393 582	2015
2009	379 212	123 589	143 306	2006	447	18 741 692	-
2010	473 611	125 289	100 000	1017	447	17 629 453	-

Source: DALDO's office report (2010)

* In the report there was no data on rice production for 2009 and 2010'/

In the highland and middleland zones crop production is fully rainfed. In the lowland zone the rainfall pattern is unimodal with one rainy season; hence, irrigation is essential for crop production. The district has five irrigation schemes namely Kasyabone, Mbambo, Kikole, Kifunda and Kisegese – all in the lowland. To date 150 ha of paddy are under irrigation by traditional canals. The only fairly large *industries* in the district process these primary products: tea at Katumba and Mwakaleli tea factories, and gas at the Kyejo plant. Small plants process grains (milling) and timber (carpentry, mills).

State 2007). The study of the United States Bureau of Democracy, Human rights, and Labour for 2009 suggests that 62% of the population of Tanzania is Christian, 35% is Muslim, and 3% are members of other religious groups (US Department of State 2009). The CIA World Factbook states that 30% of the population is Christian, with Muslim being 35% and indigenous beliefs 35%.

Lumbering is also common particularly in the Mt Rungwe Forest Reserve (McKone & Walzem 1994). Generally the district is estimated to have a total of 43 749 ha of forest reserves of which 97% includes natural forests and 3% district forest plantations. The Livingstone Forest Reserve is the largest with 62% followed by Rungwe Forest Reserve covering 32% of the total reserved land. With regard to the district forest plantation, the Kiwira forest plantation is the largest comprising 95% of the forest plantations in the district. *Beekeeping* is widely practised in some parts of Rungwe district and produces about 3% of the total honey produced in the Mbeya region (URT 2010). The main products obtained include honey and beeswax, which are exploited for commercial purposes. *Mining* is practised on a limited scale. The district is endowed with carbon dioxide gas and gold, though in small quantities. Carbon dioxide gas is extracted at Kyejo and is sold out of the district by Tanzania Oxygen Limited. Both the carbon dioxide gas and gold are small scale plants.

While actually tertiary in nature, *tourism* as an economic sector exploits primary resources. Rungwe district is endowed with many beautiful sites of considerable potential as tourist attractions. These include: Mt Rungwe, Kyejo and Livingstone; there is also the Giant Mvule Tree situated at the Lugombo village, Masoko – named 'Katembo' by the local villagers, it is estimated to be 250 years old, has the scientific name *Miliciaexcelsa* or Mvule Tree (in Swahili) and Mwale (in Kinyakyusa), and rises to approximately 40 metres, with a circumference of some 18 metres; then there are volcanic Crater Lake known to some as Masoko and others as Kisiba (Kisiba means lake in Kinyakyusa); Ngosi crater lake; the Kajala and Kalambo hot-water springs; Kaporogwe Falls and Daraja la Mungu (God's Bridge) or Kibwe Natural Bridge which was reputedly formed by a water-cooled lava flow from Mt Rungwe (URT 2010). Despite such special sites and features that provide opportunities for income generation that can benefit the national economy, the district tourism industry is not well developed, thus there were no supporting data on the number of tourists and income generated from tourism activities in the district. Currently, the Mount Rungwe Nature Reserve management is trying to develop tourism related structures in order to create opportunities for cultural and eco-tourism. Such development could facilitate the conservation of important natural resources (especially natural forests) by providing alternative sources of income to villages adjacent to tourism potential areas.

1.5.2.8 The service sector

Rungwe district attaches great importance to *education* alongside other social services. In 1965 the district had only 86 primary schools with an intake of 18 246 pupils (URT 2010). These schools catered for the district, which incorporated Kyela and Ileje before they became separate districts in 1972 (for Kyela) and 1975 (for Ileje). Currently the district has 197 primary and 46 secondary schools. There are 174 nursery schools of which 82 are owned by private institutions. The district has two colleges of education: Tukuyu and Mpuguso, one nursing training college and two vocational training centres.

The traditional sources of *water* for the district are springs and streams, which flow down the slopes of Mount Rungwe and Livingstone Ranges. Due to the topographical features of the district, human settlements are located on the top of ridges and so, to ensure availability of water there, the government in collaboration with various development partners, has constructed gravity water schemes. Some 46% of Rungwe residents (140 935) have access to piped water supply (URT 2010). The Council has established a water board (Tukuyu Urban Water Supply Authority–TUWSA) to provide sustainable water services for almost 21 800 inhabitants in Tukuyu township.

Rungwe district is fortunate to have *health facilities* spread within easy reach of households. The district has one district hospital, two faith-based hospitals, five rural health centers, 33 government dispensaries and 16 charitable/private dispensaries. The district also has a fairly good *transportation network* of 1033.3 km of which 67.7 km are tarmac, 291.7 km gravel and the remaining 673.9 km are earth roads. The district's feeder roads system of 422 km is maintained by the district and the community. Concerning *financial* services there are two commercial banks, namely National Microfinance Bank (NMB) and National Bank of Commerce (NBC) located at Tukuyu town with ATM services operating 24 hours a day. Also, there is a branch of Tanzania Revenue Authority (TRA).

The information and *communication* technology (ICT) that is available in the district includes Tanzania Telecommunication Company Limited (TTCL), offering more than 169 lines, the post office and there are also sub-branches of the cellular phone operators like TIGO, ZAIN, VODACOM and ZANTEL (URT 2010). In addition, a considerable number of people in the town own television sets, radios and there are internet cafés. The district is connected to the National Electricity Grid. However, as the problem of electricity in Tanzania is characterised by frequent power cuts and sometimes power rationing, this affects the performance of the economy, including ICT use.

1.5.3 Villages selected as case studies

It was previously pointed out that the district has three agro-ecological zones. Before selecting the villages for change analysis and household surveys, the first step was to perform a land use change analysis of the whole district to see which villages experience change and which ones do not. The analysis showed that the entire ecosystem was experiencing land use change. Secondly, since all villages experience change, two villages were selected from each zone In the highland zone of MRE the villages chosen were Unyamwanga and Ndaga, in the middlelands Kyimo and Syukula while in the lowlands Ilima and Katundulu were selected. All six villages were randomly selected in each of the agro-ecological zones (see Chapter 3, Section 3.3.6.2 on the methods used). Their socio-economic characteristics pertaining to the nature of climate, agricultural calendar, social services available in a particular village and the total number of human population per village are summarized in Table 1.3.

Table 1.3 General characteristics of the selected villages

Zones	*Village name*	*Climate/soils*	*Agricultural calendar of main cash crops*	*Social services*	*Population number per 2002 census*
Highland	Unyamwanga	Cool climate, high rainfall and volcanic soils	April-July (potatoes 1st season) October-February (potatoes 2nd season) July-February(maize season)	A primary school, private secondary school, piped water, churches and kiosks, no daily or weekly market, no reliable transport, no electricity, no dispensary	1436
	Ndaga			Has a primary school, health centre, piped water, bars, guest houses, butcher, shops, tea rooms and kiosks	3884
Middleland	Kyimo	Cool climate, high rainfall and fertile volcanic soils	July-February (maize season)	Primary school, dispensary, shops, bank, electricity, butcher, guest houses, pharmacy, restaurant, social hall, bars, weekly market and piped water	2448
	Syukula	Cool climate, high rainfall and fertile volcanic soils		Two primary schools, motor cycles, No electricity, piped water, dispensary, market	4407
Lowland zone	Katundulu	Hot weather, volcanic soils	November-March (maize season)	Primary school, small kiosks, no electricity	1913
	Ilima			No electricity, safe water, shops, butcher, dispensary, has a primary school	952

This table basically illustrates that villages in the highland and middleland zones have mild climatic conditions, more developed social services and are sparsely populated compared to the two villages in the lowland zone. The villages of the highland zone are also peculiar in terms of crops grown, for example, only potatoes are grown in this zone.

1.6 STRUCTURE OF THE DISSERTATION

This dissertation is structured in seven chapters including this introductory chapter in which a general conceptualisation of the research problem, aims and objectives and significance of the study are explained. The chapter also describes the study area, emphasising the socioeconomic characteristics of the area. In Chapter 2 a literature review of land use change as a phenomenon is presented. The review is based mainly on various theories that have evolved in an attempt to understand the causes of land use change. The chapter starts with a brief review of such theories in explaining the underlying causes of land use change. Then follows a discussion on the nature of land use change, citing examples, from global, regional and local experience. In the chapter the various driving forces of change are highlighted and a link is drawn between land use change and peoples' livelihoods. At the end emphasis is placed on the policy shifts in Tanzania and how they are related to land use change in the country.

Chapter 3 starts by highlighting the differences between research methodology and research methods and the reasons for adopting the mixed methodology used in this study. The conceptual framework for analysing the drivers of change in the study area is presented. The research methods and materials used during data collection are discussed, preceded by a detailed research design adopted for the study. The justification for using imagery over other data sources and the periodisation of the selected images is provided. The chapter also points out the limitations of the study and the various ways employed to overcome them.

In Chapter 4 the empirically derived discussions of the mapped land uses and the inherent changes based on the 1973, 1986, 1991 and 2010 satellite imagery, are presented. The presentation starts with a broad coverage of the use and change categories at the district level and then scales down to the six selected villages. In Chapter 5 an explanation of the drivers of the change in land use in the study area is given. An account of a number of direct and indirect drivers is also given in this chapter. In Chapter 6 there is an explanation of the linkages between the observed land use change and their implications on people's livelihoods as derived from the perception survey of wellbeing and the livelihood of people.

In Chapter 7 there is a summary of the study findings, possible policy recommendations are made and areas which may be incorporated in future studies on this theme are highlighted. The appendices to the dissertation include a copy of research permit letters, the questionnaire, and some data tables deemed of relevance to the discussions presented in the main text.

CHAPTER 2 LAND USE AND LIVELIHOOD INTERFACE: AN OVERVIEW

In this chapter different themes on the land use and livelihood interface, with particular emphasis on MEs are examined. The major themes presented include theories related to the causes and the implications of land use change, the nature and scope of land use change, land use and livelihoods linkages, types of driving forces of land use change and policy issues related to management of natural resources specific to Tanzania.

2.1 THEORETICAL UNDERSTANDING OF THE CAUSES OF LAND USE CHANGE

In Chapter 1 the difference between land use and land cover is pointed out. Land use normally relates to the manner in which the biophysical assets are used (Cihlar & Jansen 2001). In most cases land use is determined through direct examination and interpretation of observed land cover only. Since use depends largely on the land characteristics (i.e. cover, form, position, substratum), there is a close relationship between land cover and land use. Inherently land cover can stand alone but land-use in general cannot and must be inferred from land cover and patterns thereof (Jansen & Di Gregorio 2003). However, land cover observation does not automatically mean land use definition because land cover and land use, though interrelated, are not identical. Individuals or land users choose a land use type from which they expect to derive benefits, in the form of goods and/or services, considering their aims, available means, possible constraints and the given set of biophysical parameters. In addition, there are determining factors such as the institutional and cultural setting, the legal attributes of the plot (e.g. land tenure) and the broader socio-economic environment (Cihlar & Jansen 2001). The land use choices made by land users therefore will vary in space and time and so will the resulting land use changes. There are controversies surrounding the causes of land use change, which are viewed from different perspectives, and so on the subject of land use change there has been no single theory that explicitly explains its nature and causes. As a result a number of often conflicting or opposing theories and concepts provide explanations for land use change, addressed here chronologically according to when they were formulated.

2.1.1 Malthus' theory

Malthus' theory focused on the relationship between land use change and population growth. Malthus stated that "the populations of the world would increase in geometric proportions and that the food resources available for them would increase only in arithmetic proportions" (Malthus 1967:8). In other words he believed that the power of the population to grow when unchecked is indefinitely greater than the power to produce subsistence for mankind. Malthus argued that as rural population grows, land per capita diminishes and household food security becomes threatened. Any further increase will lead to a population crash caused by natural calamities like famine or diseases. The most important element in the Malthusian theory that is directly related to land use change, is population density. For him agricultural extensification was a response to population pressure leading to cultivation of marginal lands, land fragmentation, decreasing productivity and famine, all related to poverty and environmental degradation. Braimoh (2004) also asserts that the increase in population exerts pressure on land in that frequency of cultivation increases, thereby shortening fallow periods needed to rejuvenate the soil fertility, thus productivity drops, which, in turn leads to food scarcity.

It should be emphasized here that Malthus held a negative perception on the relationship between agricultural and population growth. The applicability of this theory in the developed world may be insignificant due to advanced population control mechanisms and financial schemes such as farmers' compensation schemes. In a way his theory also ignored the role of technological advances in improving agricultural production to sustain the needs of the growing population, particularly in the developed world. He also did not consider the role of income or livelihood diversification, as with increasing population there is the possibility that some households will diversify to non-farm incomes as well as migration to other areas for better livelihood opportunities, a phenomenon which is common nowadays in developing countries. Anseeuw & Laurent (2007), Elmqvist & Olsson (2006), Hesselberb & Yaro (2006), Iiyama et al. (2008), Sharma et al. (2007) and Soini (2005), among others, highlight the importance of off-farm activities as an additional source of income, especially in cases where there is a discrepancy between available resources and the resources needed to develop commercial farming activities. These authors contend that adaptation through non-farm diversification is an important contribution to rural livelihood security, since farm income consistently fails to cover household expenditures. In a study by

Davis et al. (2007), for instance, it is reported that in four African countries non-farm employment due to various reasons contributes between 22% and 53% of total income.

Malthus's views on resource scarcity as well as the effect of population growth on environmental resources, however, cannot be ignored in understanding the causes of land use change and resources degradation in many developing countries, including Tanzania, which are lacking in technology. In Africa, and Tanzania in particular, natural population growth rates are still high. According to a World Bank report, Africa is the second most populated continent after Asia with around one billion people or 15% of the world's population (UN 2009). According to this source, the population density for the African continent is 32.7 inhabitants per km^2. Tanzania's population has grown from 10 million in 1960 to approximately 45 million in 2010 (UNESA 2010). The projected population for 2015 is 52 million, by 2030 it is expected to be 75 million and by 2050 it is projected to reach 109 million (UNESA 2010) with a growth rate of 3% being higher than the global rate of 1.1%. Natural population growth in Africa and in Tanzania in particular is accompanied by expansion of subsistence farming, increasing demands on the land and volume of fuelwood consumptions for household usage and is perhaps the primary driver of land use change (Geist & Lambin 2002). It is worthwhile noting that Malthus's views raised awareness not only on resource scarcity and that at some point in time resources may become depleted in quantity and quality. It also led to the recognition of the processes which contribute to scarcity of resources. This raises the need for conservation and sustainable use of environmental resources, especially in fragile environments such as MEs.

2.1.2 Boserup's theory

Malthus' predictions provoked alternative views such as those of Boserup, who related population growth to agricultural intensification. Boserup (1965) focused on the role of high population growth in stimulating agricultural intensification, which entails more intensive use of existing lands and the adoption of new technologies. She argued that demographic pressure acts as a catalyst in compelling farmers to adopt intensification of agriculture. This is because as population pressure increases, arable land becomes scarce and this necessitates people to intensify agricultural production to meet the needs and demands of the growing population. Netting (1993), holding similar views, noted that population growth or attraction of people to market centres, the desire to increase farm output per unit area and higher population density, compel farmers to follow an intensification process.

Intensification may be achieved through increasing output from limited land by development and adoption of new technologies, use of more input such as labour and fertilizers, more frequent cropping, or investment of capital for long term land improvement (Boserup 1965; Netting 1993; Soini 2005). In European landscapes for example Vos & Klijn (2000) recognised intensification and scalar increase in agricultural production that transformed wetlands and natural areas into agricultural lands. The study noted that intensification was a phenomenon particularly in densely populated areas.

Although some case studies in Tanzania and Africa in general have shown that in general agricultural systems are intensifying, therefore improving ecosystem and crop yielding (Mbonile, Misana & Sokoni 2003; Soini 2005; Tilman et al. 2001) the situation however, is not comparable in all African countries. Ponte (1998) points out that lack of efficient markets for crops and capital to invest in agriculture has led to failure in agriculture intensification in many African countries. In Tanzania, for example, the removal of subsidies for agriculture inputs[11] and liberalisation of crop markets as a result of structural adjustments has hit most smallholder farmers who could not withstand the scourge of market forces. This resulted in a drop in agricultural production especially of the four regions in Tanzania (Iringa, Mbeya, Rukwa and Ruvuma), referred to as the 'big four', because of inadequate inputs (Mariki 2002). This has led to most farmers reverting to traditional farming systems which have manifested poor productivity and degradation of land resources (Mariki 2002).

Malthus' and Boserup's theories have been criticised for undermining the linkages of the households' mode of production to the external markets (Bockstael & Irwin 2000; Ellis 1998; Netting 1993). Even though Boserup later considered market development to influence land use change, she viewed it as an endogenous factor stimulated by population growth (Boserup 1981; 1990). She argued that as population increases there will be intensive land use with most of the land between villages inhabited. In such a situation, where population density is high, small markets and urban centres emerge and agricultural land use would be intensified around such centres.

[11] Agricultural inputs generally refer to partial measures or physical inputs to agricultural productivity. Such physical indicators include land, labour, fertilizers, pesticides, herbicides and agricultural machinery. The appropriate level and application rate of these inputs however vary by country and over time, depending on the type of crops, the climate and soils, and the production process. In this study agricultural input is used to refer to fertilizers and pesticides.

Criticising this view, Ellis (1998) argues that in the contemporary world most households produce both for domestic use and surplus for market. Similarly, it has been argued that smallholder farmers do not live in isolation from larger networks of economic exchange or political organization, and that their desire for goods and services as well as their scarcity link them to external relationships (Netting 1993). Therefore, other factors such as land tenure systems, fluctuation in the physical environmental conditions, government policies and market conditions may have an influence on land use change, suggesting that population pressure is not the only stimulus for land use change (Tiffen, Mortimore & Gichuki 1994). Nevertheless, agricultural intensification provides an insight to drivers of change as a result of population increase. Despite the drawbacks associated with population and intensification linkages an argument is generally made that a growing population or new markets will pressurize farmers to increase production through one of these options: extensification where land is abundant and intensification where land is scarce to accomplish higher returns per area of land (Ningal, Hertemink & Bregt 2008; (Ramankutty, Foley & Olejniczak 2002). Stone (2001) contended that rising population pressure on resources frequently does force farmers to alter their production tactics, often demanding greater inputs in the process, and that this is often predictable.

2.1.3 Market demand theory

The other theoretical understanding of land use change is based on market demand. This theory explains land use change from the viewpoint of individual landowners who make land use decisions with the objective to maximize expected returns (Bockstael & Irwin 2000). It recognizes small scale farmers as risk takers and profit maximisers driven by the desire for higher income through maximized production, and who respond efficiently to farm market innovation, risks and stimulations in allocating their land and labour sources to farming (Reardon et al. 1999). Pensuk & Shrestha (2008), for instance, report that in Southern Thailand an increase in rubber price over paddy was one of the driving forces of land use change and that those who switched to rubber plantations were better off financially than rice-based households due to the higher price of rubber compared to rice. In the same vein Braimoh (2009), shows that the domestic cropland expansion rate of rice and the creation of new plots were driven by marketing considerations. In a similar case study undertaken by Mwakalobo (1998) in some villages in Rungwe, it was found that bananas that were mainly cultivated as food crops in the district became a prominent cash crop following the implementation of price reforms in the early 1980s. Thus, it's clear that changes in market in terms of price incentives create changes in land use.

2.1.4 Von Thünen's model

The role of the market in agricultural intensification has also been demonstrated in *Von Thünen's model* of the "isolated state" (Dicken & Llyod 1990). The model shows how market processes can influence land use in different locations. The model assumes that land use close to the market will be highly intensified with high frequency of cultivation associated with production of high value products and perishable crops. The idea behind this is that the extent of intensification increases near to the market to support high population demand and it decreases as farms are situated further away from the market, depicting zones of different land use intensity. The model's assumption seems to be over simplified to the real situation yet, one can acknowledge a strong relationship between transport systems and agricultural land use patterns. Within the city, for example, land is more expensive than in the periphery. Thus, the land will be used for activities that bring the most profit. On the other hand, at times development in transport and infrastructure has facilitated movement of goods and services.

Currently markets are much less centralised or clustered and very often farmers have access to small-scale road-side markets where they can easily sell their produce at lower marketing cost. Consumers can also pick products from where they are produced. From the above discussion, it is obvious that the market is not the only factor that explicitly provides an explanation for land use changes. Braimoh (2009), assessing land use change in Ghana, contends that the change in land use was associated with both population growth and market incentives. The biophysical factors such as soils, seasonality of rainfall and accessibility of irrigation facilities may also have an influence on land use changes. These factors may act as constraints or opportunities to intensification. The theories explained herein nevertheless provide a basis for understanding interactions of different factors and their implications for land use and land use change in the MRE, the results of which are discussed in the results chapters.

2.2 THE NATURE OF LAND USE CHANGE

Land use changes are a problem facing both developed and developing countries and they are a function of increasing demand for ecosystem services (MA 2005). Land use changes are diverse and may be explained in terms of temporal and spatial aspects. Land use change may involve the complete transformation of some land use type into other land use types. The transformation may be in the form of replacement of, for example, forestry by agriculture or grazing and agriculture by settlement development. Land use change may also involve partial transformation of land use type into other forms while retaining their primary status such as rainfed agriculture to irrigated agriculture or natural vegetation to exotic vegetation. The principal modifications of land use that have occurred at the global scale include conversion of forests to cropland and grazing land, intensification of agriculture, tropical deforestation, pasture expansion and urbanization (Lambin, Geist & Lepers 2003; Mbonile, Misana & Sokoni 2003). Additionally, land use change may involve change in cropping systems, extensification and intensification. It may also include practices that conserve or replenish soils.

Understanding land use changes and the processes underlying them, is pivotal to not only understanding land use change in a particular ecosystem, but also the subsequent impacts on the natural ecosystems and eventually on communities' livelihoods (FAO 2009). This is so because land use change has both positive and negative impacts. The positive impacts include increase in food and fibre production, resource use efficiency, and building wealth and social well-being in some parts of the world (Foley et al. 2005). Some of the negative impacts associated with land use change include soil erosion, decline in soil fertility and loss of biodiversity (Antrop 2005; Ellis 2010; Foley et al. 2005; Geist et al. 2006; IPCC 2007; Olson et al. 2008). Details of these impacts of land use change and how they influence human wellbeing are elaborated in later sections.

2.3 DRIVING FORCES OF LAND USE CHANGE

The driving forces of land use change are many, complex and interlinked (Rowcroft 2005). Moreover, the driving forces of land use change vary and operate at a range of scales from local resource governance and use to national policy to global trends such as international markets and global climate change (Antrop 2005; Bürgi, Hersperger & Schneeberger 2004; Hasselmann et al. 2010; Olson et al. 2008). Some drivers have direct influence on the ecosystems, while others have a more indirect effect by influencing the political, social or environmental climate in which the poor seek to benefit from ecosystem services (MA 2005).

As noted earlier, there are controversies surrounding the causes of land use change which are viewed from different perspectives; similarly, the identification and classification of drivers are also problematic (Olson et al. 2004). The lack of universal theory has resulted in the application of different conceptual frameworks to explain the drivers of land use change at global, regional or local scales. Although there is no universal theory explaining land use change, a common methodological approach to identify the driving forces has evolved despite the fact that in the so-called common approach some researchers differentiate between direct and indirect drivers while others differentiate between immediate/proximate and underlying drivers (Olson et al. 2004). According to Rowcroft (2005) and Blaikie (1985) one of the explanations for the challenges to adequately identify drivers of change is not only that drivers are numerous, stemming from different angles and are interdependent, but also that different models and methods are used to identify drivers of change – some of which rely on Landsat imagery and then employ geographic data and limited secondary socioeconomic information in areas experiencing land use change. From the literature, however, population growth, national policies, globalisation, socio-economic, technological, cultural and natural factors are the commonly identified driving forces of land use change (Bürgi, Hersperger & Schneeberger 2004; Geist & Lambin 2002; Hasselmann et al. 2010; Lambin, Geist & Lepers 2003; MA 2005; Ningal, Hertemink & Bregt 2008; Schoorl &Veldkamp 2001; Ramankutty, Foley & Olejniczak 2002). Despite the challenges elaborated here, many of the common drivers that have been identified by various researchers might also be evident in the MRE (as highlighted in Chapter 5). Each one is described in more detail below.

2.3.1 Demographic factors

Literature has shown that there exists a positive linear relationship between high population growth and land use change (Boserup 1965; Goudie 1981; 1992; Ningal, Hertemink & Bregt 2008). This is because high population growth in a particular ecosystem exerts pressure on environmental resources in the form of demand for land, food, water, and biomass energy. This leads to land use change and change in resources use patterns either in the form of intensification or extensification of the available land; introduction of new crops and or mixed cropping practices. High population growth causes land use change as a result of the need to meet the demand for agricultural commodities that entail increasing areas of land under cultivation, which is sometimes achieved by encroaching on forest resources and marginal lands (Geist & Lambin 2002; Kangalawe & Lyimo 2010).

The relationship between population growth and land use change, however, is much debated (Carr, Suter & Barbieri 2005; Hartemink, Veldkamp & Bai 2008). This is due to the fact that although at global and supra national scale population growth is often used as a proxy for land use change (Kok 2004; Ningal, Hartemink & Bregt 2008; Ramankutty, Foley & Olejniczak 2002) at local scales a set of complex drivers is important (Lambin, Geist & Lepers 2003). Despite the debate, the effects of population growth on deforestation and grassland conversions as well as agricultural intensification have been well documented. During the 20th century, global croplands expanded by 50% from roughly 1200 million ha in 1900 to 1800 million ha in 1990 (Ramankutty, Foley & Olejniczak 2002). The cropland expansion was directly linked to the world population that more than tripled from 1.5 billion in 1900 to 5.2 billion in 1990 (Ramankutty, Foley & Olejniczak 2002). Currently, the world population is 7 billion and is expected to reach 10 billion by 2050 (UN 2009). The developing world accounts for 95% of the population growth –Africa being the world's fastest growing region (Hartemink, Veldkamp & Bai 2008; UN 2009). The growing population implies an increase in agricultural production to meet food demand. This demand can only be met by expansion of agricultural land or by intensification of existing systems.

Lambin, Geist & Lepers (2003), summarising changes in global land use, showed that the area of cropland increased from 300 - 400 million ha in 1700 to 1500 -1800 million ha in 1990. In the same period area under pasture increased from 500 million ha to 3300 million ha. These increases led to clearing of forests and the transformation of natural grasslands, steppes and savannas. Forest area decreased from 5000-6200 million ha in 1700 to 4300-5300 million ha in 1990, while area under steppes, savannah and grasslands declined from 3200 to 2700 million ha, respectively. These changes in land use were also attributed to population growth. Similarly, Ningal, Hartemink & Bregt (2008), assessing land use change in the Morobe province of Papua New Guinea, observed an increase of 58% in the conversion of forests to agricultural land use. The increase in cropland from 2.3 million in 1975 to 5.2 million in 2000 was attributed to population growth by 99%.

Population growth is also associated with increases in landlessness and smaller farm sizes. In India, average land holding size fell from 2.6 ha in 1960 to 1.4 ha in 2000 and it is still declining (World Bank 2007). In Bangladesh, the Philippines and Thailand, over a time period of roughly 20 years, average farm sizes have declined and landlessness has increased (World Bank 2007). In Cambodia as well, rural landlessness increased from 13% in 1997 to

20% in 2004 (Shalmali 2006). Similarly, in Eastern and Southern Africa, cultivated land per capita has halved over the last generation and in a number of countries the average cultivated area today amounts to less than 0.3 ha per capita (Carr, Suter & Barbieri 2005).

Likewise, Kangalawe & Lyimo (2010), Maruo (2007), Mbonile, Misana & Sokoni (2003) and Mwakalobo (1998), observed that population growth was a major factor for land use changes in some parts of Tanzania. The result is the expansion of agriculture into marginal areas and deforestation leading to environmental degradation. Population statistics for Rungwe district show that it is among the districts with lower population growth rates (URT 2003a). For some recent historical periods it is however, a densely populated district with the major population issue being in-migration (Maruo 2007), a practise which has led to drastic impact on the environment. According to Mwakalobo (1998), the increasing population growth in Rungwe district has resulted in land subdivision and fragmentation. The extent of this observation is explored in detail in Chapter 5 of this dissertation.

2.3.2 Socioeconomic factors

The socioeconomic driving forces are primarily rooted in the market economy and mainly influenced by the forces of globalisation which are exogenous to the local communities managing their land (Antrop 2005; Bürgi, Hersperger & Schneeberger 2004; Braimoh 2009; Lambin et al. 2001). Globalization is the set of processes by which places across the globe are joined into social, economic, and environmental networks of interaction (Held & McGrew 1999; Lambin & Meyfroidt 2011) and very often these processes break the intimate relationship a local society has with its land. Globalization processes evolve as more places become more interconnected, as barriers to interconnectedness are removed, or as flows of information increase between places (World Bank 2005). Some notable land use outcomes of globalization processes include international environmental agreements to regulate shared water or air resources; imposed structural adjustments that lead to changes in the intensity of agricultural production; increased transportation and financial accessibility to remote places of the globe; the relocation of large human populations; and the accelerated growth of cities, leading to spatial changes in resource use (Currit & Easterling 2009; Lambin & Meyfroidt 2011). Land use change depends on the interaction between these exogenous forces and the socioeconomic conditions of the land managers (Merterns et al. 2000) Globalisation is also considered as a driver of land use change as it accelerates the impact of the other driving forces such as cultural factors, political, demographic and technological factors (Braimoh 2009).

Currit & Easterling (2009), for example, showed that Mexico is experiencing rapid land use changes due to economic globalisation through the emergence of Mexico's Maquiladora (an industrialisation) programme. Braimoh (2009), also contends that land use change in Ghana is driven by economic policies formulated in response to the forces of globalisation – particularly the market and trade liberalisation during and after the implementation of structural adjustments. Braimoh (2009) found that macroeconomic changes increased the commercial orientation of farming as the sources of food supply changed from import to domestic production (import substitution). Braimoh (2009) also found that interest rate liberalisation increased the use of labour at the expense of fertilizer and other complimentary inputs.

Bakker et al. (2008), assessing land use change in the European mountains, revealed that market forces as well as national and European policies on the one hand influenced land use changes in the area particularly on crop and livestock choices. The agricultural policy on the other hand, with support from the EU, influenced massive expansion of commercial forest plantation. Generally, the study reported that market forces as well as these policies led to a decline in arable land in the region since it was planted with forest, for which subsidies could be collected from the EU. Nevertheless, the land could still be used for grazing, beekeeping or other practices while arable cultivation was abandoned.

Despite their environmental effects on macroeconomic policies and trade liberalisation, internal trade and other forms of globalisation can improve environmental conditions through green certification and ecolabelling, wider and more rapid spread of new technologies, better media coverage allowing for international pressure on states that degrade their resources, and free circulation of people, which leads to better education and employment opportunities (Lambin, Geist & Lepers 2003). In most African countries globalisation has negative effects on the environment. It has been observed though that in most African countries and the Southern Africa region in particular, economic/cost effective policies are now applied to ecosystem management. It is therefore argued that effective economic policies such as payment for ecosystem services and other economic instruments need to be effectively implemented in most African countries – including Tanzania – for sustainable resource use and management since globalisation is set to persist.

2.3.3 Political factors

Socioeconomic needs are expressed in political programs, laws and policies, and thus the socioeconomic and political driving forces are strongly interlinked (Bürgi, Hersperger & Schneeberger 2004). National and local policies, however, are among the drivers of land use change in agricultural dominated countries. Access to land, labour, capital, technology and information, for example, are structured by local and national policies and institutions (Batterbury & Bebbington 1999). Examples of policies that influence land use change are the state policies to attain self-sufficiency in food (Xu et al. 1999); taxation, fiscal incentives, subsidies and credits (Deininger & Minten 1999); price controls on agricultural inputs and outputs (Deininger & Minten 1999); decentralisation (Xu et al. 1999); infrastructure support, low investments in monitoring and formally guarding natural resources (Agrawal & Yadama 1997); resource commodification (Deininger & Minten 1999); land consolidation, nationalisation and collectivisation (Imbernon 1999; Xu et al 1999); and structural measures and international agreements (Mertens et al. 2000). These national policies, singly or in combination, may either facilitate or lead to over use of the resources in relation to community access, use and management of the resources.

Many of the national policies related to natural resources management in African countries have been associated with land use change, and Jepson et al. (2001), contend that many land use changes are due to ill-defined policies and weak institutional enforcement. Absence of clearly defined and secure property rights, lack of clear environmental policy goals, poor enforcement of existing regulation, corruption, lack of political will and lack of institutional capacity are examples of failing governance that leads to ecosystem degradation in African countries (Assan & Kumar 2009; Bürgi, Hersperger & Schneeberger 2004). Clover & Eriksen (2009) made it clear that change of land tenure has been among the major social and environmental transformations facing the Southern African region over the past century. These authors add that weak institutions of governance are often responsible for the failure to address land access and tenure problems. But equally important are the use of normative discourses and the way the social and political contexts interact with economic factors in determining issues of access, distribution, security of tenure, and management of land. On the other hand, recovery or restoration of land use change is also possible with appropriate land use policies. A study by Bray et al. (2004), on land use change in Mexico for instance, indicated that institutional innovations such as sustainable forest management have driven the outcome of low net deforestation of only 0.01% for the 1984-2000 period, the lowest recorded deforestation rate for Southern Mexico.

2.3.4 Technological factors

Technology is another important factor that must be taken into consideration when discussing the driving forces of human induced land use change (Hasselmann et al. 2010). The term encompasses, for example, agricultural production methods, infrastructure systems, artefacts such as building materials, as well as embedded knowledge systems. In a study by Bender et al. (2005) it was indicated that the conversion of croplands into meadows in Mediterranean mountain areas was a result of general development in agriculture, such as modernisation of cultivation tools, mechanisation and specialisation of agricultural activities. The variable impact of technological factors, however, depends on how the new technologies affect the labour market and migration, whether the crops are sold locally or globally, how profitable farming is, as well as on the capital and labour intensity of the new technology (Angelsen & Kaimowitz 2001). It remains to be seen how prominent this factor is in the African context.

2.3.5 Cultural factors

There are, a number of cultural factors, which are among the most complex dimensions of environmental change that influence decision making on land use and leave a deep imprint on landscapes (Bürgi, Hersperger & Schneeberger 2004; Lambin, Geist & Lepers 2003). Cultural factors such as agricultural practices depending on locally prevailing customs allow different land uses to be practised on the same type of land in different areas. In a study by Ochola, Muhia & Mwarasomba (2000), for instance, it was found that land use choices of the Luo in Kenya were culture bound. Different land use options were preferred, depending on the village history, traditions and religion. In this same study it wa found that culture also fostered diverse forms of learning about and adapting to ecosystem changes as seen in the traditional conservation of sacred and protected sites by managing and protecting the cultural and spiritual values assigned to natural resources (Ochola, Muhia & Mwarasomba 2000). In general terms, land users’ and managers’ attitudes, values, beliefs and perceptions may influence land use decisions, and also can explain the management of resources, adaptive strategies, compliance with or resistance to policies and therefore social resilience in the face of land use change. In some societies, culture is also sometimes linked with political and economic inequalities (e.g. the status of women or ethnic minorities) that affect resource access and land use (Leemans et al. 2003).

2.3.6 Natural factors

Land use change is a result of not only human activities but also natural factors. Natural factors such as rainfall variability, land and soil quality and topography can cause land use change. Pensuk & Shrestha (2008), studying change in land use in Thailand found that land and soil quality were among the reasons for 10.5 % of the farm households changing their land use from paddy to rubber production. Bakker & Van Doorn (2009), also showed that soil quality and slope were factors for land use change in the Mertola Municipality in the Alentejo region in south-east Portugal. The authors contended that frequent afforestation and abandonment of arable cultivation occurred much more often on steeper slopes and poor soils; that is: arable cultivation was maintained longest on better soils while with poor, less productive soils, alternative land uses (afforestation or abandonment) appeared to be an option for most farmers surveyed.

2.4 LINKAGES BETWEEN LAND USE AND LIVELIHOOD

Livelihood change affects the environment in terms of land use, and vice versa, ultimately leading to effects on livelihood (Dupar & Badenoch 2002; WRI 2001). McCusker & Carr (2006) argued that a link between livelihoods and land use change is not a simple causal relationship, but rather one where each constantly influences the other. Livelihood changes may superficially drive land use change and the existing land use may drive livelihoods change, hence posing a threat to local livelihoods. A land use and livelihood linkage is explored in the following subsections through the impacts each transmits to the other.

2.4.1 Negative impacts of land use change

One of the most prominent interfaces between human activities and environmental change in natural ecosystems including mountain areas is land use change (Steffen et al. 2004). Land use change is a dynamic, widespread and accelerating process, which in turn drives changes, that impact natural ecosystems and hence impairs their ability to provide ecosystem goods and services, such as the provisioning of food, fuel and shelter for humankind (MA 2005; Turner & MacCandless 2004). Generally, land use change influences the vulnerability of places and people to climatic, economic, or socio-political perturbations (Kasperson et al. 1995). When aggregated globally, land use change significantly affects central aspects of earth system functioning (Lewis 2006). Land use change and the related negative impacts thus create many challenges and opportunities for future livelihoods and there is a growing concern about their negative impact on human wellbeing and livelihoods (MA 2005; UNEP 2004). Of primary concern are impacts on biotic diversity worldwide, soil degradation and the ability of biological systems to support human needs (Soini 2005; Turner & MacCandless 2004; UNEP-WCM 2002; Verburg et al. 2002). Some of the global and national negative impacts are explained in the next subsections.

2.4.1.1 Climate change

Land use change plays a major role in climate change at global, regional and local levels (Ellis 2010; Foley et al. 2005; IPCC 2007). At global level, land use change is responsible for releasing greenhouse gases to the atmosphere, thereby driving global warming. According to IPCC (2007), land use change is considered the second largest source of greenhouse gas emissions, after the burning of fossil fuels, and hence a major driver of global warming that leads to climate change. For instance, it is acknowledged that since 1850, roughly 35% of anthropogenic carbon dioxide (CO_2) emissions resulted directly from land use change (Foley et al. 2005) of which urbanized areas contributed 97% of global anthropogenic CO_2 emissions (Svirejeva-Hopkins, Schellnhuber & Pomaz 2004). According to IPCC (2007) CO_2 is the major greenhouse gas responsible for global warming. In relation to CO_2 emissions, Shemsanga, Omambia & Gu (2010) show that land use change and forest degradation are among the major contributions to emissions of greenhouse gases in Tanzania.

The MA (2005) and the IPCC (2007) assessments show that environmental conditions and climatic patterns are changing and directly affect the livelihoods of the poor and undermine the constituents and determinants of livelihood security. The IPCC assessment shows that climate change will affect land-based rural livelihoods. This is particularly so in developing countries and in deprived sub-humid, semi-arid and arid regions in particular, where agriculture is largely rain-fed. Assan, Caminade & Obeng (2009), argue that for land-based livelihoods and agricultural production, the total amount of rainfall might not matter as much as its distribution over the period of the rainfall. In such a changing environment the world's poor are facing an even more pressing concern: sustaining their livelihoods and making a living in vulnerable environments such as mountains (Hurni 2008; FAO 2008).

2.4.1.2 Biodiversity loss

Literature shows that land use change reduces global, regional and local biodiversity at a considerable rate (Ellis 2010; Foley et al. 2005). When land is transformed from a primary forest to a farm, the loss of forest species within deforested areas is immediate and complete. Biodiversity loss occurs even when relatively undisturbed lands are transformed to more intensive uses, including livestock grazing, selective tree harvest and even fire prevention. This is because habitat suitability of forests and other ecosystems surrounding those under intensive use are also impacted by the fragmenting of existing habitat into smaller pieces which exposes forest edges to external influences and decreases core habitat area (Ellis 2010). According to Chapin et al. (2000), land use change is involved in the 5-20% of global species of birds, mammals, fish and plants threatened with extinction. Conversion from forest to cropland or grazing land greatly reduces species and structural diversity. Biodiversity loss is likely to be more pronounced in mountain regions due to their fragile nature and accelerated exposure to climate change.

It is widely acknowledged that mountain ecosystems are characterised by a high biological richness in terms of both species diversity and endemism (IPCC 2007; Körner 2009) and that they support about half of the world's biological diversity and nearly half of the world's biodiversity hotspots (Hassan, Scholes & Ash 2005). Mountain species moreover, are very sensitive to climate warming because they are adapted to specific altitudinal zones and microclimatic conditions (Hassan, Scholes & Ash 2005; IPCC 2007; Thomas 2009). With rising temperatures, therefore, upward shifts of vegetation belts to higher elevations and northward advances in the geographical ranges of species in the northern hemisphere are expected. Changes in the species composition of communities are also likely (Nogues-Bravo et al. 2006). Global warming is furthermore thought to have negative impacts on mountain species distribution and abundance, especially in tropical cloud forests, which are defined by constant interception of atmospheric moisture. In Costa Rica, 20 out of 50 species of frogs and toads in a 30 km^2 study area have disappeared since 1987, a phenomenon thought to be the result of drastic environmental changes associated with atmospheric warming (Pounds, Fodgen & Campbell 1999).

These processes should not, however, only be regarded as negative. They may also bring new opportunities. Because temperatures decrease with altitude, mountain species are in the privileged position of being able to migrate upwards into cooler areas, whereas lowland species usually have no other option than to adapt to higher temperatures, which is much more challenging (Körner 2009). Thus, mountains can serve as refuges for species which can no longer survive in the lowlands and which need to migrate to cooler areas (Singh, Singh & Skutsch 2010). However, some mountain species are likely to become losers. These include large territorial animals, late successional plant species, restricted populations and species confined to summits (Körner 2009).

2.4.1.3 Recession of glaciers on mountain ranges

Another noticeable impact of land use change in mountains in relation to climate change is the recession of glaciers. According to a publication by United Nations Environment Programme (UNEP) and the World Glacier Monitoring Service (WGMS) the ongoing trend of global and rapid, if not accelerating, glacier shrinkage on the century timescale is of non-periodic nature and may lead to the deglaciation of large parts of many mountain ranges in the coming decades (UNEP-WGMS 2008). Central Asia is among the regions of the world that have experienced the greatest glacial retreat in recent decades (Thomas 2009). Research conducted by the NCCR North-South found that glaciers in the northern Tien Shan (Kyrgyzstan) lost 28% of their surface area between 1963 and 2000 (Thomas 2009). Projections show that the glaciers will shrink to half of their current size by 2050 (Thomas 2009). In China, the glacier area has decreased by 25% in the last 200 years (ICIMOD 2010). On the Tibetan Plateau, the glacial area has also decreased by 4.5% over the last twenty years and by 7% over the last forty years because of global warming (ICIMOD 2010).

In the European Alps, the Alpine glacier cover is estimated to have diminished by about 35% between 1850 and the 1970s and by a further 22% by 2000 (UNEP-WGMS 2008). In the Canadian Rockies, glaciers lost at least 25% of their volume during the 20th Century (Luckman & Kavanagh 2000). In the Himalayas, glaciers appear to have receded relatively faster than the global average (Dyurgerov & Meier 2005). The rate of retreat for the Gangotri Glacier over the last three decades has been more than three times the rate during the preceding 200 years (Srivastava 2003). Most glaciers studied in Nepal are also undergoing rapid deglaciation (Fujita, Kadota & Rana 2001; Kadota et al. 2000; Seko et al. 1998). In the last half century, 82.2% of the glaciers in western China have retreated (Kang et al. 2010; Liu, Ding & Li 2006). In South America, the Northern Patagonian Ice Field lost about 3.4% or 140 km² of its area between 1942 and 2001 (Thompson et al. 2009).

In Africa, some 85% of the total ice volume of the plateau glaciers of Mount Kilimanjaro disappeared between 1912 and 2000 (Thompson et al. 2009). Other consistent trends are that the degradation of permafrost is accelerating, with the active layer becoming thicker due to surface warming, and that most snow and ice caps across the world are shrinking at increased rates. The disappearance or alteration of glaciers on mountains are already leading to changes in land surface characteristics and drainage systems and are very likely to have significant repercussions on water availability for mountain and downstream communities and is likely to force change in land use (Stern, Peters & Bakhshi 2006).

2.4.1.4 Soil degradation

Deforestation or vegetation removal leaves soils vulnerable to massive increases in soil erosion by wind and water, especially on steep terrains. This not only degrades soil fertility over time, reducing the suitability of land for future agricultural use, but also causes slope instability, releases huge quantities of phosphorus, nitrogen, and sediments to streams and other aquatic ecosystems, causing a variety of negative impact and hence decreasing the resilience and ability of the land to absorb shocks, which might affect the wellbeing of local communities (Ellis 2010). All of these outcomes have implications to human livelihoods. Tiwari (2008), for example, observed that indiscriminate deforestation and degradation of land resources in the Himalaya had not only disrupted the fragile ecological equilibrium in the mountains but also had significant and irreversible adverse impacts on the rural economy, society, livelihoods and life quality of mountain communities. Such degradation of resources forced local people to look for alternative means for livelihood support. Soil overuse on the other hand leads to irreversible degradation involving complete soil loss due to accelerated erosion. In East Africa, for instance, soil erosion and nutrient wash out are reported to reduce crop yields, forcing people to cultivate more and more land to meet their needs (Kaihura & Stocking 2003).

In a study by Fasona & Omojola (2009), it was found that there was an increased trend in human-induced land use change with notable severe negative impacts on ecosystems and livelihoods in Nigeria. Loss of fragile ecosystems including marshland (from 7.7% of total area in 1965 to 1% in 2001) and mangrove (from 14.6% of total area in 1965 to 3.1% in 2001) was intense, while over 300 ponds and small lakes, which are important for the local fishing economy, have disappeared. About eighteen communities were also dislocated by erosion in a section around the south-eastern parts of the coastline.

2.4.1.5 Disaster generation

In mountain areas land use change can also cause catastrophic land related disasters, e.g. flooding, windstorms and landslides and hence displacement of people (IPCC 2007; Kohler & Maselli 2009). In 1997, for instance, landslides had a disastrous impact on the livelihoods of the local community at the foot slopes of Mt Elgon in Eastern Uganda. Knapen et al. (2006) indicated that following the landslide in the Manjiya area, 48 people were killed, crops and dwellings of 885 families disappeared from the map of the area and 5600 people became homeless. Another incident occurred in 2004 where about 15 000 people were displaced and made landless as a result of landslides in Bududa, an area that lies on the steep slopes of Mt Elgon in Eastern Uganda (Kitutu et al. 2009). Such forced displacement jeopardizes people's wellbeing and livelihoods as the land that is a major natural resource on which their economic, social and other human activities depend is reduced, causing land scarcity, destruction of crops and dwellings and water pollution.

The IPCC (2007) report indicates that the intensity of precipitation events will increase, as a result of climate change, especially in the tropics and at higher latitudes where an increase in overall precipitation is expected. More intensive precipitation events could trigger flash floods and landslides in mountainous terrain and this is likely to have significant implications for fragile mountain ecosystems as well as for mountain livelihoods and infrastructure (IPCC 2007).

2.4.1.6 Pollution

Change in land use is an important driver of water, soil and air pollution, particularly through land clearing for agriculture and the harvesting of trees and other biomass. Modern agricultural practices, which include intensive inputs of nitrogen and phosphorus fertilizers and the concentration of livestock and their manure within small areas, substantially increase the pollution of surface water by runoff and erosion and the pollution of ground water by leaching of excess nitrogen (Ellis 2010; Foley et al. 2005). Other agricultural chemicals, including herbicides and pesticides, are also released to ground and surface waters by agriculture and in some cases remain as contaminants in the soil. Tilman et al (2001), for example showed that during the past 40 years, there has been a ~700% increase in global fertilizer use and this has led to degradation of water quality (coastal and fresh water) in many regions.

2.4.1.7 Invasive species and diseases

Research demonstrates that species invasions by non-native plants, animals and diseases may occur more readily in areas exposed to land use change, especially in proximity to human settlements (Ellis 2010; Foley et al. 2005). Apart from land use change, species invasions are also related to climate change. Malcolm et al (2002), for example, asserted that invasive species tend to adapt better to changing climate. Habitat modification, road and dam construction, irrigation, increased proximity of people and livestock, and the concentration or expansion of urban environments all modify the transmission of infectious disease and can lead to outbreaks and emergence episodes (Patz et al. 2004). For example, increasing tropical deforestation coincides with an upsurge of malaria and/or its vectors in Africa, Asia, and Latin America, even after accounting for the effects of changing population density (Patz et al. 2004). In Tanzania in recent years more cases of malaria have been reported due to continuing warming up across the country, including the highland areas (URT 2007). The report adds that cases of malaria are becoming common in mountainous areas (e.g. East Usambara Mountain Ranges and Kilimanjaro) where a few years ago it was not a problem. Yanda, Kangalawe & Sigalla (2005), studying the climatic and socio-economic influences of malaria in Lake Victoria Basin, showed that malaria in Tanzania is creeping from the lowlands to the highlands. According to these authors climate change, land use change and increasing human population are closely related with increasing malaria outbreak. In general, land use and climate change interactions can have a negative impact on people’s livelihoods that are directly or indirectly dependent on mountain resources.

2.4.2 Positive impacts of land use change

Despite the many negative effects of land use change, such as degraded ecosystems, eroded soils, depleted soils, loss of native species, poor crop production and added carbon release, it must be acknowledged that many forms of land use change lead to an increase in food and fibre production, resource use efficiency, and the building of wealth and social wellbeing in some parts of the world (Foley et al. 2005; Geist & Lambin 2002). Changing land use practices have enabled world grain harvests to double in the past four decades, so they now exceed ~2 billion tons per year (Foley et al. 2005). According to these authors some of this increase can be attributed to a ~12% increase in world cropland area, but most of these production gains resulted from ‘‘Green Revolution’’ technologies, including high-yielding cultivars, chemical fertilizers and pesticides, and improved mechanization and irrigation and the fact that during the past 40 years, there has been a ~70% increase in irrigated cropland area. In their case study Geist & Lambin (2002) also noted that the replacement of natural forest by plantations provides employment and timber trade to local communities in ways that can sustain their livelihoods. Geist & Lambin’s study also indicated that an enormous increase in the production of farm and forest products had brought greater wealth and more secure livelihoods for communities, though at the cost of land degradation, biodiversity loss and the disruption of biophysical cycles, such as the water and nutrient cycles. Although modern agriculture has been successful in increasing food production, it has also caused extensive environmental damage. In short, the negative impacts of land use change on ecosystems, including many that are important to agriculture, exceed its advantages.

2.4.3 Land use and livelihood change adaptation strategies

Land use change is considered as one of the important factors influencing livelihoods of farmers particularly in developing countries like Tanzania, where a substantial area of the country is under agriculture, employing a majority of the population (Makalle, Obando & Bamutaze 2008; Soini 2005). As a result of land use change and their associated impacts, particularly on agriculture, small-scale farmers are diversifying their economies through non-farm activities.

Lyimo (2010), assessing land use change and livelihood diversification in the Usangu plains in Tanzania, notes that the plains experienced changes in land use towards agricultural land use intensification due to high population growth, market demand for rice and the impact of liberalisation policies. Households in the plains are diversifying their livelihoods depending on the access to livelihood assets. The study also shows that well-off households are heavily involved in commercial rice production and diversification to high capital investment. Intermediate households with fewer livelihood assets are restrained from commercial rice production and have diversified to alternatives demanding less capital investment. Poor households diversified to activities requiring non-cash investment. All these trends prove that land use change can be a constraint or can be seen as an opportunity to diversify. The change in farming system manifesting as land use change, can affect farmer livelihoods and farmer's livelihoods strategies (Soini 2005). The FAO (2009) also contends that land use change has potential impacts on the natural ecosystems and eventually on communities' livelihoods. Davies & Bennett (2007), however, argued that, although livelihoods are diversified in developing countries and adapted to cope with uncertainty such as land use change, yet change can undermine such adaptation.

2.4.4 Livelihood changes and their impact on land use

Changes in land use can often cause substantial pressures on soil, water and vegetation resulting in increasing environmental and socioeconomic problems. By altering ecosystem services, land use change affects the ability of biological systems to support human needs (Rowcroft 2005). This is linked to the fact that people's livelihoods depend on both the internal and external contexts in which livelihood strategies are pursued. The internal factors on the one hand include access to livelihood capital assets including human, natural, physical, financial and social capital. On the other hand the external context of livelihoods includes factors such as natural resource management, natural disasters, economic crises, macroeconomic structural adjustments, change in regulation of natural resource management and decentralisation. The change of these contexts can provide opportunities or constraints to people regarding greater access to natural and physical assets, hence affecting the internal factors of livelihoods and livelihood strategies at the household level (O'Connor 2004).

Population dynamics can also lead to changes in people's livelihood strategies. Mwamfupe (1998b) reports that traditionally the Ngorongoro Maasai of Tanzania used to satisfy all their grain needs through the sale of livestock and livestock products to their agriculturalist neighbours. However, the incidence of cattle disease among the herds prevented cattle numbers from keeping pace with the human population growth. As a result, most Maasai households have recently taken up cultivation as an alternative survival strategy. Such an adoption of crop cultivation as a new strategy requires land. This has resulted in the conversion of marginal lands and encroachment on the protected areas of the Ngorongoro crater.

Land alienation and the use of land for building infrastructure, urban development projects, conservation programmes and large scale farming can also lead to livelihood and land use changes. The Barabaig[12] of Northern Tanzania for example lost access to their traditional lands as a result of nationalisation of land, as about 40 000 hectares of their grazing land was taken by the government for the Canadian International Development Agency wheat programme (Lane 1994). In the early 1970s, as part of an effort to increase wheat production in Tanzania, a large-scale wheat scheme was introduced in the area. The wheat farms, where monocropping with hybrid varieties and capital-intensive farming techniques is practised, have meant the loss to the Barabaig of the greater part of a particular type of grazing land, which had played a key role in their traditional seasonal grazing rotation. The project had displaced the Barabaig and made their traditional way of life untenable. It had caused soil erosion and had eliminated from the area the types of local grasses most suitable for grazing; hence, land pressure forced them to invade other areas including protected and conservation areas (Mwamfupe 1998b).

A similar case of land alienation was observed by Sulle & Nelson (2009), in the Rufiji, Kisarawe, Kigoma, Kilwa and Bagamoyo districts of Tanzania. In these places the government of Tanzania had allocated about 640 000 ha of a four million total hectarage to companies for biofuel production. Most of the allocated land was village land that was used for forest-based economic activities and harvesting products such as traditional medicine, mushrooms, fuelwood and building materials. Such areas provide a major part of local community livelihoods. Land alienation undermines future development options for local communities and it can have major adverse short and long term impacts on local livelihoods. Khagram, Clark & Raad (2003), point out that environmental sustainability and access to resources are critical for the livelihoods of poor populations, as well as providing opportunities for the realisation of basic rights and increased human capabilities.

Kusiluka et al. (2010), report a similar case of land alienation in Morogoro. The authors found that due to expansion of the Morogoro urban area around Uluguru Mountain many indigenous landholders were forced to sell their holdings wholly as farms or in small pieces at a time. These authors also noted that loss of land, loss of means of livelihood, disruption of economic activities, persistent land-related conflicts, relocations to poorly developed areas, inadequate and late compensation and environmental degradation were

[12] The Barabaig are a semi-nomadic pastoralist group and a sub-section of the wider ethnic and large group called Tatogo (Nilotes) in Tanzania. They occupy the plains of Mt Hanang in Hanang district of Arusha region in north central Tanzania.

some of the negative outcomes the indigenous people normally face in land acquisition programmes. Generally, land transfer from the village to the general lands category, removes natural resources from the village domain on a permanent basis. This leads to loss of livelihoods, which in turn can cause environmental degradation, though there appears to be a cumulative causation wherein poverty, high fertility rates and environmental degradation feed upon one another.

2.5 POLICIES ON LAND USE AND RESOURCES MANAGEMENT IN TANZANIA

In Tanzania as it is elsewhere, land use and livelihood changes are linked to national policies on land use and resources management, although demographic, socioeconomic, technological and natural factors have also significant influence. Tanzania has experienced major changes in her socioeconomic system since independence. This has involved change in policies that influence land use and livelihoods. In this section such policies are reviewed. The discussion is structured chronologically starting with the Arusha Declaration[13] and the pre-forced villagisation era (1967-1972), followed by the forced-villagisation and post-villagisation era (1973 to early 1980s) and lastly by the era of structural and post structural adjustments (mid-1980s to the present). These three periods encompass the operational dates considered for this study, i.e. from 1973 to 2010.

2.5.1 Arusha Declaration and pre-forced villagisation era

Tanzania was under the British colonial government from 1920 until independence in 1961. During the colonial period resource use and access were controlled by the colonial government. After independence, particularly in 1967, a socialist policy was adopted in the country. The official name of the policy was Socialism and Self-Reliance (Ujamaa na Kujitegemea in Swahili). Under the Ujamaa policy, a villagisation programme was implemented as part of a national strategy for development. As part of the implementation of

[13] The Arusha Declaration refers to the policy blue print that was passed by TANU (Tanganyika African National Union – that was the principal political party in the struggle for sovereignty in the East Africa state of Tanganyika, now Tanzania) in January 1967 (TANU 1967). The Declaration was geared by Mwalimu Julius Nyerere, the former Tanzanian president. In 1977, TANU merged with the ruling party in Zanzibar, the Afro-Shirazi party (ASP) to form the Current Revolutionary State Party or Chama Cha Mapinduzi (CCM) – the current ruling party. The Arusha Declaration was passed in Arusha region, and hence it was named after the place (Arusha region). The declaration, apart from explaining the meaning of Socialism and Self-Reliance, and their relevance to Tanzania, also outlined the long-term Tanzanian government policy on economic and social development (Kikula 1996; Mwakaje 1999; TANU 1967), with villagisation as an important component. For details on the Arusha Declaration see Coulson (1982) and TANU (1967).

the policy, Mwalimu Julius Nyerere, the "father" of the Tanzania nation, was the architect of Tanzania's villagisation programme that transformed rural settlements of Tanzania from scattered homesteads to nucleated villages. The Arusha Declaration of 1967 marked the commencement of voluntary spontaneous resettlement of households into Ujamaa nucleated villages. The Arusha Declaration aimed at providing social services to a large population and emphasised the need to reorganise rural settlements based on principles of socialism.

The Arusha Declaration of 1967 therefore, apart from putting Tanzania on the path towards Socialism and Self-Reliance; also marked a shift from the colonial free market economy to a state-controlled economy guided by the policy of Socialism and Self-Reliance. Under this policy the state controlled resources, their use in production and the marketing and distribution of resources for and outputs from production. From 1967 to 1972 it was a period of voluntary resettlements into the villages. The government supported rural households that voluntarily agreed to move and start new Ujamaa villages by providing resources for housing and establishing agricultural activities. In some parts of the country the resettlement of people into Ujamaa villages was associated with change in land use including deforestation and settlement patterns from scattered to nucleated patterns, mostly located along roads (Kikula 1996; Mashalla 1988; Mbonile, Misana & Sokoni 2003).

2.5.2 Forced villagisation and post-villagisation era

After the first six years (i.e. 1967-1972) of experimenting with voluntary resettlement the villagisation program was perceived to progress too slowly and the regime decided to speed up the process through a national operation of rural settlement reorganisation ('Operesheni Vijiji') in which some force was used. The aim still was to re-organise the scattered rural homesteads into nucleated Ujamaa villages where collective ownership of resources and agricultural production were encouraged. Thus in 1973 the government made it compulsory for all rural people to live in registered Ujamaa villages (Kikula 1996; Lane 1994). From 1973-1976 all rural Tanzanians were supposed to settle in registered villages that consisted of between 200 to 600 households (Kikula 1996). To date the exact number of people relocated is not well documented. The government, for example, claims that 13 million or 90% of the rural population had moved into Ujamaa villages by 1976 (Lappé & Beccar-Valera 1980). Other estimates show that around five million rural people were resettled (Hyden 1980). Tsikata (2001) showed that more than 9 million peasants and pastoralists were resettled in old or newly formed villages, which implies the establishment of more than 7000 villages. Under the Ujamaa village Act of 1975, land was allocated to each village and the village traditional rulers (chiefs[14]) and village councils were given power to allocate village land for communal and individual use (UN_HABITAT 2002). Women's right to land was affected by the enactment of the Ujamaa village Act of 1975 which provided for allocation of land to the heads of household or family unit. Women lacked access to land at that time (UN_HABITAT 2002). Shivji (1998) pointed out that rural Tanzanians were not only relocated without formally reconciling their forced moves with existing patterns of land rights and tenure, but villagisation also excluded land users from their traditional access to resources and the culture and custom in which they were rooted.

One of the expectations during the villagisation process was that through provision of social services, farmers' productivity would rise. There was, however, no direct link with agricultural development and that is why during this era most investment was in health, education and water provision. Also during the villagisation process the focus was not on protecting environment and improving food production. In some parts of the country the process had a noticeable impact on forests, woodlands and bushes. Villagisation as such has been associated with increasing land use change, change in human resource use systems and environmental degradation near village centres due to increasing pressure on environment for agricultural land, and resources for energy, water and building materials (Kikula 1996; Mashalla 1988; Mbonile, Misana & Sokoni 2003).

In some areas land that was once cultivated was abandoned and allowed to revert to bush when people moved to new villages. Land previously used for grazing was used for settlement and crops such as maize, cassava and sorghum replaced natural vegetation (Kikula 1996; Mbonile, Misana & Sokoni 2003). Similarly, there was a change from traditional, scattered, semi-permanent settlements to the adoption of concentrated and permanent settlements. This was accompanied with a change from shifting cultivation to permanent intensive cultivation and livestock keeping – all implemented under the guidance of the

[14] The establishment of indirect rule in 1926 by the British colonial government sanctioned the nomination of several traditional rulers (chiefs). This role was strengthened by the African Chiefs Ordinance of 1953. The first post-independence amendment of local government was made in 1962, amending the Local Authority Ordinance of 1953. This amendment abolished the chiefs' roles and functions completely and left them powerless regarding control of natural resources. They were then only concerned with traditional issues. Their role was replaced by government bureaucrats and party authorities through a decentralisation process that was implemented between 1972 and 1982 and in 1984 (Oyugi 1998; Mukandala 1998) by the Decentralisation Government Act of 1972 and the Local Government Act No 5 of 1984.

Ujamaa Village Act of 1975 (Kikula 1996; Lane 1994). Land use in these registered villages therefore became a mixture of individual tenure and communal plots or block farms. Since all village land was allocated to different uses the result was often severe land degradation and deforestation because most people settled in new areas and required building materials. Villagisation furthermore increased the distance to farms from the new villages as the process was implemented irrespective of the consequences for agriculture. For example, the situation of villages near roads (Hyden 1980) led to many problems. In some circumstances people were obliged to go back to their deserted former fields/homesteads for cultivation, which imposed difficulties on the farmers. They had to walk long distances to their fields and it was difficult to protect crops from vermin and theft.

In addition, during this era, many parts of the country saw establishment of national parks, forest reserves and exotic forest plantations (such as Kiwira Forest plantation and Kilimanjaro National Park) that replaced indigenous forests that dominated the landscapes during the colonial era. The gazetting policy denied communities access to resources in the forest reserves. In other places, land was alienated from tribal ownership for large-scale wheat farms, sisal and beef ranches thereby reducing the land available to the local population for cultivation and grazing. The pastoral Barabaig land, for example, was converted into large-scale wheat farms that resulted into land use change and loss of community livelihoods (Lane 1994). During villagisation, private lands (agricultural estates), industries and service sector enterprises were also nationalised by the government, while customary land institutions and practices were greatly weakened by the villagisation campaigns of the mid-1970s.

In the early 1960s, the government replaced and disempowered the chiefs who had been custodians of natural resources since colonial times. The abolition and disempowerment of the chiefs left control of natural resources in the hands of non-stakeholders (Oyugi 1998) and this changed the structure of the traditional land tenure systems. Over time the state was unable to manage the vast natural resource base, such that these resources became ‘open access’ areas where the underlying social dynamics of the mismatch between government and public interests is famously captured in Hardin’s “tragedy of the commons” phrase (Geoffrey et al. 2001). The consequences included unsustainable land use practices, biodiversity loss and a decline in the quality of the environment.

Ujamaa policy also emphasized the role of cooperatives in produce marketing and input supply. The policy facilitated intensification by supporting farmers in terms of providing inputs and making markets available. However, in 1976 most cooperative societies in the country were abolished and this affected most cash crop producers since farmers could no longer buy agricultural inputs. A decline of cash crop production (such as coffee, pyrethrum and cotton) followed, because many farmers abandoned their farms. Some became bush-infested while other farmers switched to other crops such as bananas, maize, vegetables and flowers (Misana, Mbonile & Sokoni 2003; Mwakalobo 1998). During the Ujamaa period, the state had command over natural resources (such as forestry) and local communities were excluded from participating in the protection and management of the resources. Weaknesses of state control under the Socialism and Self-Reliance policy, led to decline in agricultural productivity and to economic crises that compelled a change back to a market economy.

2.5.3 Structural and post structural adjustment era

In the mid-1980s the country faced social and economic problems including food crises and monetary budget constraints. Economic liberalisation was thus forced on Tanzania as a consequence of a severe economic crisis of the 1980s in the course of which GDP is thought to have contracted by about 10% (World Bank 1984). As a consequence, since the 1980s, the government of Tanzania has implemented a number of policy reforms. The main objectives of the reforms have been and continue to be to achieve economic growth, to reduce dependence on external balance of payment support, to reduce inflation, to improve social services and economic infrastructure, to alleviate and ultimately eradicate poverty, to manage the ecosystem, and to use natural resources sustainably (URT 2002). These reforms are being implemented together with equally significant political and social reforms. Sectoral policy changes have been introduced in order to orient production and resource management to the market economy. Examples of such policy changes that related to land use and natural resource use and management among others, are the Land Policy of 1995; Land Act of 1999; Village Land Act of 1999; Agricultural Policy of 1983 and its revision of 1997; Forest policy of 1998; Forest Act of 2002; National Environment Policy of 1997; Environmental Management Act of 2004; Energy Policy of 2003; Rural Electrification Policy of 2003 and the Tanzania Development Vision 2025. A summary of some of these policies and reforms with regard to aims, affected sectors and success since their inception are summarised in

Table 2.1, whereas their effect to change in land use are elaborated on in the next four sections.

Table 2.1 Selection policies and laws affecting land use change and livelihoods in Tanzania

Policy/Law	Sector affected	Aims, objectives and policy thrust	Outcomes
Land policy (1995); Land Act (1999); Village land Act (1999)	Land	• Promote and ensure equitable distribution of and access to land by all citizens (empowering women to own, access and use land); • Recognises, clarifies and secures in law existing land rights; • Encourages optimal use of land resources; • Facilitates broad-based social and economic development without upsetting or endangering ecological balance • Recognition of communal village land and customary rights of occupancy • Translation of land legislations into Swahili language	• Increased right to access and own land by both men and women at local levels; • Recognised customary land rights and legally documenting such land under the “Hati ya Kumiliki Ardhi ya Mila; • Land Planning Bill passed by parliament in 2006; • Village land Act and village land regulations have already been translated; • Land allocation committees established at the district and urban authority levels; • Village and district land registries in process; • Committees and national land advisory council formed; • Ongoing education campaign to sensitize public to provisions of the new land Acts regarding legal and physical access to land.
Agricultural and livestock policy (1997); Agricultural Sector Development Strategy (ASDS– 2001); Kilimo Kwanza Strategy (2010) –(“Agricultural first initiative’)	Agriculture	• Government withdrawal from direct production, but remaining supervisor; • Provide competitiveness among producers; • Assure basic food security to the nation; • Improve standards of living in rural areas through increased income from agriculture and livestock; • Increase foreign exchange earnings; • Produce and supply raw materials for local industries; • Develop and introduce new technologies; • Promote integrated and sustainable use and management of resources; • Provide agricultural support services; • Promote access to land, credit, education and information by women and the youth;	• Self-sufficiency in food production since 2005 with 2007 peak; • About 23% of all households in rural mainland Tanzania are food secure; • Smallholder participation in out-grower schemes, access to irrigation, credit and diversification into non-farm activities; • Resettlement of livestock keepers from overgrazed areas to lower-stocked parts of the country; • Promising developments in SAGCOT[15]; • A bill on establishment of cereal and other produce board passed by parliament in 2010; • Launch of the national Agriculture Input Voucher Scheme[16] (NAVS) programme in 2009

[15]The Southern Agricultural Growth Corridor of Tanzania (SAGCOT) is a large-scale, public-private partnership to develop the southern region’s agricultural potential. Both the SAGCOT and the Tanzania Agriculture and Food Security Investment Plan initiatives ensure that more benefits accrue to smallholder farmers and food-insecure households.

[16]The national Agriculture Input Voucher Scheme[16] (NAVS) programme was launched in Tanzania in response to the high food and fertiliser prices prevailing in 2007-2008. The government therefore urged that the best way to improve national food security in the face of high international food prices was to promote the use of agricultural inputs to raise productivity (DANIDA 2011/2)

		• Provide liberal markets farm products, farm incentives, better prices and remove government market monopoly	
Energy policy (2003); Rural electrification policy (2003)	Energy	• Establish efficient energy production, procurement, transportation, distribution and end-use system in an environmentally sound manner; • Diversify energy sources by exploiting renewable and alternative energy sources: biofuels, wind, solar, small hydropower, coal, liquefied petroleum gas and natural gas; • Provide electricity to rural areas and arrest fuelwood use	• 92% of energy still biomass based and 8% energy from electricity and petroleum; • 80% biomass based energy consumed in rural areas; • Tanzanian power grid reaches the main urban centres but only 15% rural community; • Coal, solar, wind, biogas are still insignificant sources
National environmental policy (1997); Environmental Management Act (2004)	Environment (cross-cutting all sectors)	• Sustainable and equitable use of resources; • Prevent and control degradation of resources; • Conserve and enhance natural and man-made ecosystems; • Raise public awareness of the essential linkages between environment; • Promote individual, private and community participation in environmental action; • Recognise ecosystem issues and management	• Empowered local communities and private sector in managing and sharing accrued benefits from resources for improved livelihoods; • Recognition of neglected ecosystems such as mountains; • Two-yearly comprehensive assessment and publication of current state of the environment at local and national levels; • Environmental impact assessment required for development project proposals.
Forest policy (1998); Forest Act (2002)	Forest resources	• Enhance contribution of the forest sector to sustainable development of Tanzania; • Encourage sustainable use of forest resources; • Emphasize participation and effective involvement of communities in managing forest resources;	• Established forest management programs such as participatory forest management, joint forest management and community based forest management programs for ensuring equity in benefits sharing;
Tanzania Development Vision (2025)	Cross-cutting	• Achieve high quality livelihoods • Country status as, sustainable semi-industrialised and middle income by 2025; • Meet Millennium Development Goals target of poverty reduction by 2015; • Emphasise good governance, transparency, power devolution and appropriate balance between public and private institutions.	• Economic growth rate of 7% over the last 10 years; • Agriculture outpaced by service, manufacturing and construction sectors; • No significant reduction in income poverty; • About three-quarters of the population still dependent on smallholder agriculture for their livelihoods; • Life expectancy increased from 51 in 2002 to 58 years in 2010; • Literacy rate has improved; • Some improvement in national governance and devolution of power to local government.

Source: EAFF (2011); DANIDA (2011/2); URT (2011b)

The influence of these policies on land use change in the study area is discussed in Chapter 5 of this dissertation.

2.5.3.1 Privatisation and market liberalisation

Although the Structural Adjustment Programmes (SAPs) were aimed at shaping the national economy, it was not very advantageous to smallholder farmers who constitute the majority of agricultural producers in Tanzania. This was the case because SAPs were achieved through a number of liberalisation and privatisation measures. The removal of subsidies for agricultural inputs, for example, led to low productivity and low quality of export crops (Mariki 2002; Misana, Mbonile & Sokoni 2003; Mwakalobo 1998). The privatisation of parastatals and cooperatives and the liberalisation of markets for both food and cash crops and the participation of private traders in the marketing systems hit the smallholder farmers who could not withstand the impacts of market forces. Under this new marketing system, farmers were subjected to market forces inherent to the system that resulted not only in low productivity and low quality of agricultural produce, but also affected rural land use and livelihoods (Topp-JØrgensen et al. 2005; Sokoni 2008). It is during this time that in most parts of the country farmers switched from permanent cash crops to annual cash crops, from crops requiring high input to those requiring low input use. Such a change in farming systems has been described by Ponte (1998) as a change to fast crops, fast cash. This was observed in the Morogoro and Songea districts of Tanzania. In fact, the removal of agricultural subsidies, market conditions and fluctuating prices in turn influenced farmers to abandon farms, adopt other crops or intensify farm use, ultimately leading to change in land use and forest degradation (Mariki 2002).

2.5.3.2 Land policy

Market liberalisation has enhanced the process of land and smallholder commercialisation. Commercialisation of land has further been enhanced by changes in the country's land policy in 1995, which now encourages legal ownership of land by individuals, the private sector, communities and villages in order to attract private investment in the agricultural sector. Although this was meant to reduce land use conflicts and increase the value of land, it has created new competition over land resources between large-scale farmers and smallholders, between pastoralists and cultivators, and between foresters and lumber business interests (Sokoni 2008; URT 1995). Under the land policy and market liberalisation, smallholder farmers need transformation from subsistence production to market-oriented production and a change from non-monetary systems of access and use of resources to market exchange (Sokoni 2008). It is worth noting here that commodification of land and smallholder commercialization has been accompanied by land use change and change in human resource use systems. Sokoni (2008), for example, points out that, due to market liberalisation, the community-based resource management system has been replaced by more individualised social relations. Through commercialisation, farmers' access to land is increasingly becoming monetised and that high levels of contractual agreements proliferate, unlike in the 1970s when traditional social negotiation over access to resources such as land, labour markets and food was still common practice (Kurita 1993; Ponte 2000). Allocation of land to villagers by village governments, which was a common practice during the Ujamaa era, is no longer practised. Through commercialisation, many villages have lost communal land by selling or hiring it out to private developers (Sokoni 2008; Sulle & Nelson 2009). Also, access to land through market mechanisms has involved farmers seeking land outside their own village boundaries. This has increased distance to fields and further complicated land management. Generally speaking, replacement of traditional systems of resource management has not always been supported by market mechanisms that enhance better resource management and higher agricultural productivity. Land use change occurring in the MRE may be an indication of inadequate access by local communities to the resource, and of development initiatives in disharmony.

2.5.3.3 Agricultural policy

The government of Tanzania has had a National Agricultural Policy in place since 1983. The emphasis of the Agricultural Policy of 1983 has been on: increased output and efficiency of agricultural production at the village level; timely delivery and efficient use of energy inputs into agriculture; increase in use of tractors and/or animal-drawn implements for farming; introduction of village-level transport and the use of small-scale human or draught-animal powered technologies; use of renewable energy resources; and introduction of improved efficiency barns for curing tobacco, drying tea, and smoking fish to reduce the use of wood fuel (URT 1983). As a result of such liberal economic policies, the 1997 Agricultural Policy also emphasises and promotes foreign investment in the agricultural sector.

As the sector was still the backbone of the economy, in 1997 the Agricultural Policy was revised in order to orient agricultural production in the country. Four reasons necessitated the revision of the policy: to merge and consolidate into one document the agricultural and livestock policies of the 1983 (were two separate policies); the economic scene of the country had drastically changed in the last decade; existence of the new national land policy meant that farmers could not continue to use land for crops and livestock the way they used to; and the fact that agriculture operates in a delicate natural environment which requires proper management and protection.

In its 1997 revised form, the Agricultural and Livestock Policy also underscored the promotion and adoption of environmentally friendly technology and methods through collaboration with other ministries and institutions, enhancing environmental awareness through extension services, and undertaking further research and dissemination of sustainable agricultural practices (URT 1997). The National Land Policy (1995) reinforces the objectives of the agricultural and livestock policy (1997), especially in the treatment of shifting cultivation which contributes to land and soil degradation (URT 1995; 1997). Like the former policy, the 1997 Agricultural and Livestock Policy encourages and promotes private investment in the sector. This has had significant impacts on the sustainable management of resources for agricultural production and standards of living in rural areas of Tanzania.

As such, agricultural and policy reforms have been an act of excluding communities from their land and opening it to others. Collier & Dercon (2009), for example, contend that current agricultural policy reforms neglected the social reproduction requirements of African peasantries and pastoralists, ironically using the food deficits to justify the current land grabbing and creation of large-scale farms. Moyo (2008), supporting this view, contends that land grabbing in most African countries in the name of investment, is done in collaboration with African political leaders and foreign capitalists/investors.

From the foregoing discussion it is argued that policy changes and reforms related to land tenure, produce marketing and management of natural resources, are likely to have influenced land use and livelihoods in the country. Liberalisation, in particular, has undermined dependence on traditional cash crops. The result in most parts of the country has been changes in crop composition (preference for fast growing crops), cropping intensity and planting frequency (Ponte 1998) and extending farms into virgin lands including stream valleys and onto land yielding natural resources. These changes have implications in terms of lower productivity and ability to enhance sustainable usage of resources. The process of policy reforms is ongoing and is positioned to continue during this era of globalisation as a desired option for transformation of the rural economy, not only in Tanzania but also in other sub-Saharan countries. Thus perceived effects may dominate as Lambin & Meyfroidt (2011) contend that in a more interconnected world, agricultural intensification may cause more, rather than less, cropland expansion.

2.5.3.4 Decentralisation

To conserve and protect ecosystems in Tanzania, as it was elsewhere in developing countries in the late 1980s and 1990s, much emphasis was placed on participatory approaches that have brought a shift towards more decentralised and inclusive modes of resource use and management (Swiderska et al. 2008). It was during this era when the “top-down” technocratic approaches to resource use and management started to be replaced by “bottom-up” approaches. Decentralizing government activities are currently being implemented with the aim of transferring authority and functions to lower levels of administration (districts), which are closer to the people and, therefore, will be more effective and efficient in the management of sustainable development activities.

Generally, Tanzania has made substantial policy reforms since the mid-1980s to the present of which some may have altered resource use patterns and land use change in the study area. In Chapter 6 of this dissertation it is illustrated how these policies and the processes that underpin them have operated in the study area and resulted in land use change as well as their implication for communities’ livelihoods.

2.6 CHAPTER SUMMARY

This chapter has presented a literature review of land use change specifically with reference to relevant theories on the causes of land use change. It has explained a number of opposing theories including intensification theory, economic theory and other theories and concepts used to understand the causes of land use change. In most of these theories it is acknowledged, however, that humans are at the centre of land use change as a result of their desire to meet their fundamental needs.

CHAPTER 3 EMPIRICAL RESEARCH METHODOLOGY

Paltridge & Starfield (2007) distinguish between research methodology and methods. The former refers to the theoretical paradigm[17] or framework or approach in which the research is embedded (e.g. choosing a qualitative or quantitative paradigm), placing research into appropriate theoretical frameworks, hypotheses or research questions and the argument to justify such choices. According to Paltridge & Starfield (2007) the methodology should give an explanation as to why certain research methods have been chosen.

The methods, on the other hand, refer to the actual research instruments and materials used. Similarly, the justification of the chosen methods over others should be given using the literature (Paltridge & Starfield 2007). Basing this section on the Paltridge & Starfield (2007) notion of a research methodology and research methods, a description of the process by which the research activities were executed to address the research aim and research questions is provided. The first main section elaborates the motives for selecting the particular research methodology, while the second section explains the research framework adopted for this study and the third section details the research methods followed. The third section includes the research design for this study and specific technicalities concerning the research instruments used in the study.

3.1 SELECTION OF THE RESEARCH METHODOLOGY

Creswell (2009) identified three research methodologies: qualitative, quantitative and mixed methodologies. According to him these typologies are also referred to as research designs. In the literature different terms are used for the mixed approach: *integrating, synthesis, quantitative and qualitative methods, multimethod and mixed methodology*, but recent writers use the term mixed methods (Bryman 2006; Creswell 2009; Tashakkori & Teddlie 2003). Other authors and or researchers including McCusker & Ramudzuli (2007), Olson et al. (2004) and Rubin & Babbie (2007) refer to a mixed methodology as triangulation. The three research methodological designs or paradigms (qualitative, quantitative and mixed) are explained below.

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[17]Paradigms are described as overarching sets of ideas constituting the conceptual basis of a specific domain. A paradigm reflects the deep structure of the domain in that it consists of ideas, perceptions, views and the underlying assumptions (Frantzeskaki et al. 2010).

Quantitative methodologies typically seek to produce precise and generalisable findings (Rubin & Babbie 2007); they examine relationships among variables, which can be measured so that numbers can be analysed using statistical procedures (Creswell 2009). Additionally quantitative design provides rigorous, reliable, verifiable large aggregates of data and statistical testing of empirical hypotheses (Berg 2009).

A qualitative methodology is basically used to explore and understand the meaning individuals or groups ascribe to a social or human problem (Berg 2009; Creswell 2009), and it permits the use of subjectivity to generate deeper understanding of the meanings of human experience (Rubin & Babbie 2007). The qualitative methodology is more flexible by allowing the research procedures to evolve as more observations are gathered and it typically permits the use of subjectivity to generate deeper understanding of the meanings of human experience and explores how people structure and give meanings to their daily lives (Creswell 2009; Rubin & Babbie 2007). A *mixed methodology* blends or combines both quantitative and qualitative approaches (Creswell 2009; White 2002; Yoshikawa et al. 2008). The epistemological assumption in a mixed methodology is that the world is not an absolute unity, it can be represented through both numbers and words and that the numbers and words should be given equal status in scientific endeavours (Creswell 2009; Yoshikawa et al. 2008).

In this study a mixed methodology was employed in order to answer the research questions. This study is basically focusing on exploring human-environment interactions leading to land use change and its implications for people’s livelihoods. The use of the mixed methodology was three fold. First, the research problem calls for an exploration and description of land use and land use change at a specific time frame (Question 1). Exploratory research can use qualitative or quantitative techniques to gather data that may lead to insight and comprehension of a phenomenon (Babbie & Mouton 2001; Rubin & Babbie 2007; Neumann 2006). Descriptive research which is mostly qualitative, can be also quantitative or both with the primary purpose being to ‘paint a picture’ using words or numbers and to present a profile, a classification of types or an outline of steps to answer questions such as who, when, where and how. Second, it calls for identification and explanation of factors behind land use changes (Question 2). Third, it calls for explanation of the relationship between land use change and people’s livelihoods (Question 3). The primary purpose of explanatory research is to explain why events occur. It builds on exploratory and descriptive modes and it goes on to identify the reason why something occurs. It looks for causes and reasons (Neumann 2006).

In line with the identified purposes of social scientific research, this study addresses the three purposes of scientific research as categorised by Babbie & Mouton (2001), Rubin & Babbie (2007) and Neumann (2006). The study therefore is exploratory, descriptive and explanatory in nature and these research purposes require the mixing of both quantitative and qualitative methodologies (Creswell 2009; Neumann 2006; Rubin & Babbie 2007). In using the mixed methodology, however, quantitative design formed the core part of the study for collecting primary data pertaining to land use changes. The qualitative design was used to supplement quantitative design in acquiring in-depth information on land use and land use changes and their linkages to people's livelihoods.

3.2 DETAILED RESEARCH FRAMEWORK FOR THIS STUDY

Various analysts and organisations (such as Geist & Lambin 2002; MA 2005; Ostrom 2009; Parker, Berger & Manson 2002) have attempted to provide conceptual frameworks or models to capture the dynamics of social ecological systems[18] (SESs). The MA (2005), for example, introduced a new framework for analysing SESs that had a wide influence in the policy and scientific communities. Studies after the MA are taking up new challenges in the basic science needed to assess, project and manage flows of ecosystem services and effects on human wellbeing (Carpenter et al. 2009; Costanza, Graumlich & Steffen 2007; Daily & Matson 2008; Ostrom 2009; Turner, Lambin & Reenberg 2007). Ostrom's conceptual framework for example, considers four interacting parameters: the resource system, the resource unit, governance and users as factors for the sustainability or unsustainability of ecosystems. In many empirical studies the choice of relevant conceptual frameworks, however, depends on the particular questions under study, the type of SES and the spatial and temporal scale of analysis (Ostrom 2009). In this study land use change and the driving forces of change are assessed. In order to understand the dynamics of land use change in the MRE, and to accommodate the objectives of the study adequately, the ecosystems approach is adopted.

[18]Ecological, economic and social systems affect one another so strongly that they are best viewed as socio-ecological systems (Berkes, Colding & Folke 2003; Clark & Dickson 2003) or as coupled human environment systems (Turner et al. 2003). They reflect the interactions of the physical, ecological and social process.

3.2.1 The ecosystem approach

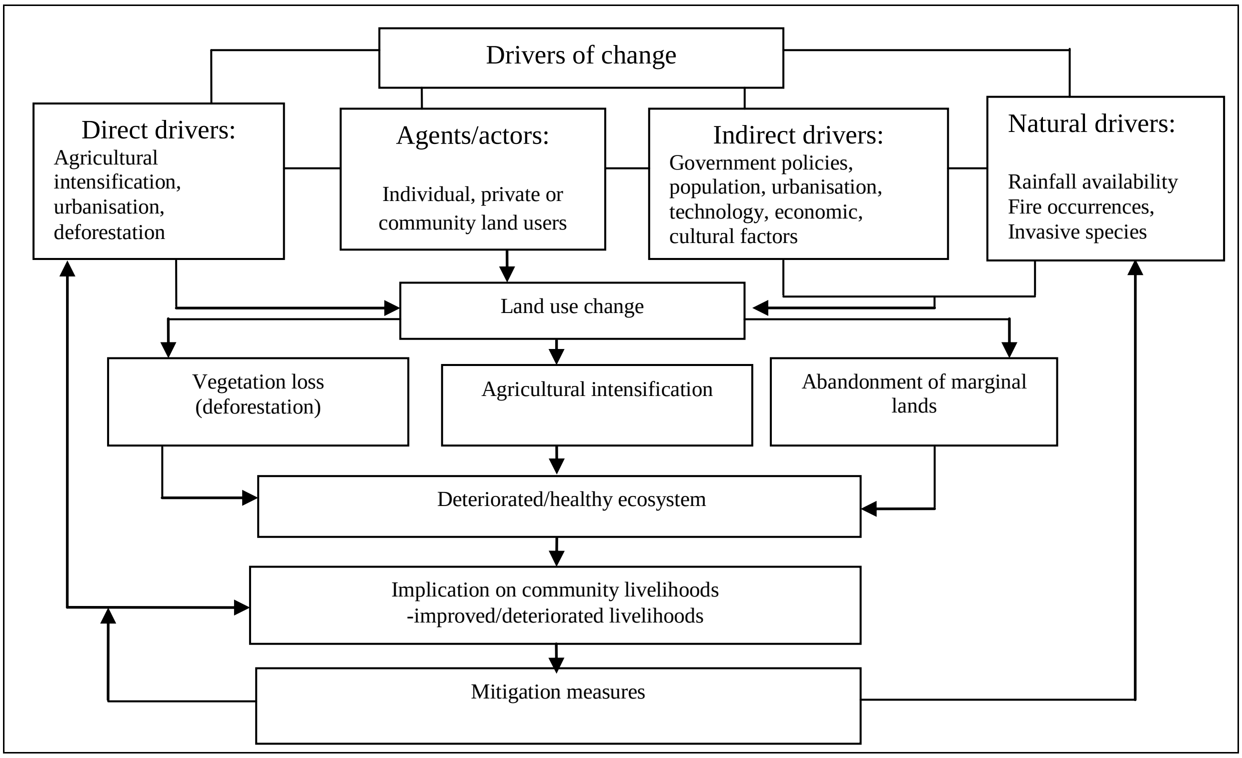
The ecosystems approach conceives mountains on the one hand as open systems allowing interactions between spatial patterns and social ecological processes, and on the other hand as a category of systems with special characteristics: inaccessibility, fragility, marginality, diversity or heterogeneity and natural suitability for some activities or products (UNEP 2009). The ecosystem approach also recognises people and their institutions (being integral components of the mountain ecosystem) while valuing the active role of human beings in achieving the goals of ecosystem sustainability (Armsworth et al. 2007; UNEP 2009). In this context mountains should be treated as social ecological systems (SESs) rather than simply service providers to human societies that derive services such as clean water and air, food production and fuel from the ecosystem they inhabit (Chapin 2007; Folke 2007; Liu et al. 2007; Ostrom 2009; Rescia et al. 2008; 2010). By virtue of being integral components of the system, humans are agents of change and should not be treated as external drivers or just users of the ecosystem services without influencing them. Thus, land use changes are the direct and indirect consequences of the human actions to secure essential resources. The ecosystem approach proposes ways of restoring degraded landscapes which emphasises the importance of promoting total system stability. In the next subsection the specific elements of the conceptual framework considered in this study, are detailed.

3.2.2 Elements of the framework

The conceptual framework in Figure 3.1 is modified to suit this study. The modifications are made on the drivers of change by including the aspects of agents and natural drivers. Also included in the model are the implications of land use change on community livelihoods and mitigation measures for sustainability. The conceptual framework in Figure 3.1 shows that land use change is caused by the interaction of a number of driving forces that are mediated by human agents. Conceptually, these driving forces of land use change form a complex system of dependencies and interactions between and among themselves (Bürgi, Hersperger & Schneeberger 2004). Land use change therefore may present an opportunity or limitation to ecosystem’s health and human wellbeing. The elements in the framework are explained in detail below.

3.2.2.1 Agents

Agent refers to the human actor or actors (an individual, household, or institution) that all play a certain role in land decision making (Bakker & Van Door 2009, Farmer-Bowers et al. 2006, Ostrom 2009, Parker, Berger & Manson 2002; Rowcroft 2005). The agent may also be a land manager who combines individual knowledge and values, information on soil quality and topography (the biophysical landscape environment), and an assessment of the land-management choices of neighbours (the spatial social environment) to calculate a land use decision. Similarly, the agent may represent higher-level entities or social organizations such as a village assembly, local governments, or a neighbouring country whose decisions of which may influence land use change.



Source**:** Modified from Geist & Lambin (2002); Ostrom (2009); Parker, Berger & Manson (2002)

Figure 3.1 Drivers of land use change in an ecosystem

These agents take specific actions according to their own decision rules and these drive land use change (Parker, Berger & Manson. 2002; Rowcroft 2005). These agents are also engaged in a very complex interchange in which they evaluate economic and non-economic alternatives based on their own characteristics (background, preferences and resource endowments) and on decision parameters such as prices, technology and management practices, institutions, and access to information, services and infrastructure (Parker et al. 2003). Together, these factors determine the set of available choices and the incentives for different choices.

The underlying hypothesis is that "agents, such as individuals, households, and firms as land users take specific actions according to their own decision rules that drive land use change" (Rowcroft 2005). In the land use change context, shared resources such as land through which agents interact and where the actions of one agent can affect those of others is likely to be a unifying environment. Literature suggests that a wide range of self-organising mechanisms may evolve to informally coordinate the actions of multiple resource users, public and private, governmental and non-governmental (Ostrom 2009). Berardo & Scholz (2007), for instance, point out that in commonly owned resources (such as forests and agricultural lands) it is possible for individual actors to find themselves in a repeated "tragedy of the commons" game, where a myriad of uncoordinated individual choices evolve and actors constantly seek new uses of the resources while dropping old ones in order to cope with the most pressing problems of the day. In general, agents have goals that relate their actions to the environment. With respect to this study, agents here include land users (farmers and pastoralists) and government entities that all play a role in land use decision making.

3.2.2.2 Direct drivers

These are factors that have a direct influence on ecosystems. They are factors that affect decisions at household or community level and are related to agents' socio-economic characteristics, to their physical, natural, social and political capital endowment and to their access to markets and technology (Geist & Lambin 2002; Lambin, Geist & Lepers 2003; Rowcroft 2005). In fact, human activities or immediate actions such as agricultural expansion, technology adaptation and species introduction or removal directly impact on land use (Ellis 2010; Lambin, Geist & Lepers 2003). Such direct factors determine how agents respond to broader macro-economic and policy forces (Farmer-Bowers et al. 2006). Generally, the decisions people make about land use and the land use change associated with them are made against a background of myriad interconnected social, political and economic factors that determine strategic thinking, define the relationships people share with one another and their resources, and which influence choices with respect to resource exploitation and management (Ostrom 2009; Rowcroft 2005).

3.2.2.3 Indirect drivers

These are factors that have an indirect effect on ecosystems by influencing the direct drivers. In most cases the indirect drivers originate in spheres that may be quite distinct from, and apparently unrelated to, decisions by the main agents (Farmer-Bowers et al. 2006; Rowcroft 2005). Macroeconomic policies for example, contribute to changing the structure of economic and political power of society and create changing relationships between humans and natural resources (Rowcroft 2005). Some indirect drivers may even originate in other countries and transmit their influence through trade or the action of international agencies and transnational or multinational corporations. Farmar-Bowers et al. (2006) calls this category of drivers mega drivers i.e. they are external to the agents. In fact, the indirect drivers are more contextual and constitute developmental background factors embraced under the broader social, economic, political and ecological contexts in which land use change occurs. Müller (2002; 2003) points out that such indirect driving forces influence agents' decisions through several channels including the market, the dissemination of new technologies and information, the development of infrastructure and institutions, in particular the prevailing property regime.

3.2.2.4 Implications

The interplay between the direct and indirect driving forces, result in the modification of land uses and composition of the natural environment. Urbanization and depopulation of rural areas, for example, is accompanied by intensification of agriculture, vegetation loss and abandonment of marginal lands (Ellis 2010). According to Foley et al. (2005) and Geist et al (2006), land use change practices on the one hand are essential for humanity because they provide critical natural resources and ecosystem services such as food, fibre, shelter and fresh water. On the other hand, some forms of land use are degrading the ecosystems and services upon which humanity depends. As a result various resources such as land, fuelwood, water, and income generated from selling various resources such as timber and honey are affected. Likewise, when humans are affected, they respond by modifying the direct and indirect driving forces. Responses might take the form of individual management action, e.g. in changes in land use or investment patterns or collective management action (Müller 2002; Ostrom 2009).

The change in land use, which is the broad focus of this study, is driven by both human actions and management, which may be determined by local and global policies and which may provoke new patterns of land use and management. At the household level, for example, land use decisions are shaped by many factors including land characteristics, ownership, demographics and institutions that present opportunities or limitations for particular land use activities. Local policies, particularly land tenure policies, play a big role in influencing land use changes. Mvula & Haller (2009), for example, pointed out that land tenure policies have yet to provide successfully an adequate level of security to induce farmer investment in ecological protection in some countries. Chambers, Leach & Conroy (1993) also argued that unless they have secure rights to the resources they use, people will not be motivated to manage and protect them. Accordingly, with secure title and control over land resources linked to improved economic opportunities, a decreased probability of land degradation among households with titled land is expected.

Using the conceptual framework in Figure 3.1 and satellite images for different years (1973, 1986, 1991 and 2010), changes in land use over 37 years within MRE were recorded and described in this research. The direct and indirect drivers of land use change were identified by linking remotely sensed data and household socio-economic and policy data. Bürgi, Hersperger & Schneeberger (2004), and Rowcroft (2005), on one hand, however, asserted that driving forces of land use change are numerous and complex and interact at different levels. Blaikie (1985) on the other hand, showed that the complexity and interconnectedness of the driving forces of land use change make it difficult to analyse and represent them adequately. In this study, a number of direct and indirect drivers were identified as explained in Chapter 6.

3.3 RESEARCH METHODS

Creswell (2009) identifies three data collection methods in a mixed methodology: sequential, concurrent and transformative mixed methods. *Sequential mixed methods* are used when one seeks to elaborate or expand on the findings of one method with another method.

Concurrent mixed methods are those in which the researcher converges or merges quantitative and qualitative data in order to provide a comprehensive analysis of the research problem. In this design, the investigator collects both forms of data and integrates the information in the interpretation of the overall results. In this respect the qualitative data address the process while the quantitative addresses the outcomes.

Transformative mixed methods are those in which the researcher uses a theoretical lens as an overarching perspective within a design that contains both qualitative and quantitative data. The lens provides a framework for topics of interest, methods for collecting data and outcomes or changes anticipated by the study.

In this study the concurrent embedded mixed method in which both qualitative and quantitative data were collected and integrated in the interpretation of the overall results, was employed. The qualitative data was embedded in the quantitative design during discussion in order to provide the overall composite assessment of the problem studied. In the analysis the qualitative data from interviews were complemented with data from satellite imagery interpretation and analysis. During sample selection the respondents (key informants) for qualitative in-depth interviews were drawn purposively based on the set criteria, (such as age, zonation and/or being a district official) and these key informants were nested in the quantitative sample design. One of the advantages of a nested design is that generalisation from one sample to the other can be done easily (Yoshikawa et al. 2008). Data collection in this study relied heavily on Landsat imagery, semi-structured interviews, in-depth interviews, field observation and documentary analysis as explained in sections below.

Within the context of the research methods, a research design for this study is first presented and then an explanation on the specific research methods and materials follows in the subsequent sections.

3.3.1 Research design

Mouton (2001) conceives a research design as a plan or blueprint of how to conduct a research study whereas Henning, Van Rensburg & Smit (2004) conceive a research design as a reflection of the methodological requirements of the research question and therefore of the type of data that will be elicited and how the data will be processed. A research design therefore consists of the steps for systematic, methodological and accurate execution of the research process. In a research design, various methods and tools to perform different tasks are specified in a logical execution sequence as exemplified in Figure 3.2.

Figure 3.2 shows the research design for this study indicating various tasks that eventually led to achieving the set objectives. Three parallel components of research processes were involved: Land use, livelihoods and policy analyses. In the first component of the analysis, remote sensing (RS) and Geographical Information System (GIS) methods were used to acquire and analyse data on land use and land use change in the study area in time sequence for the years 1973, 1986, 1991 and 2010. The data and techniques for this analytical stage depended on remotely sensed images (Landsat) and GIS analysis. The second component of the analysis involved a socioeconomic survey in the selected villages of MRE. The aim was to collect information on the livelihood activities and the causes of land use changes observed on the images.

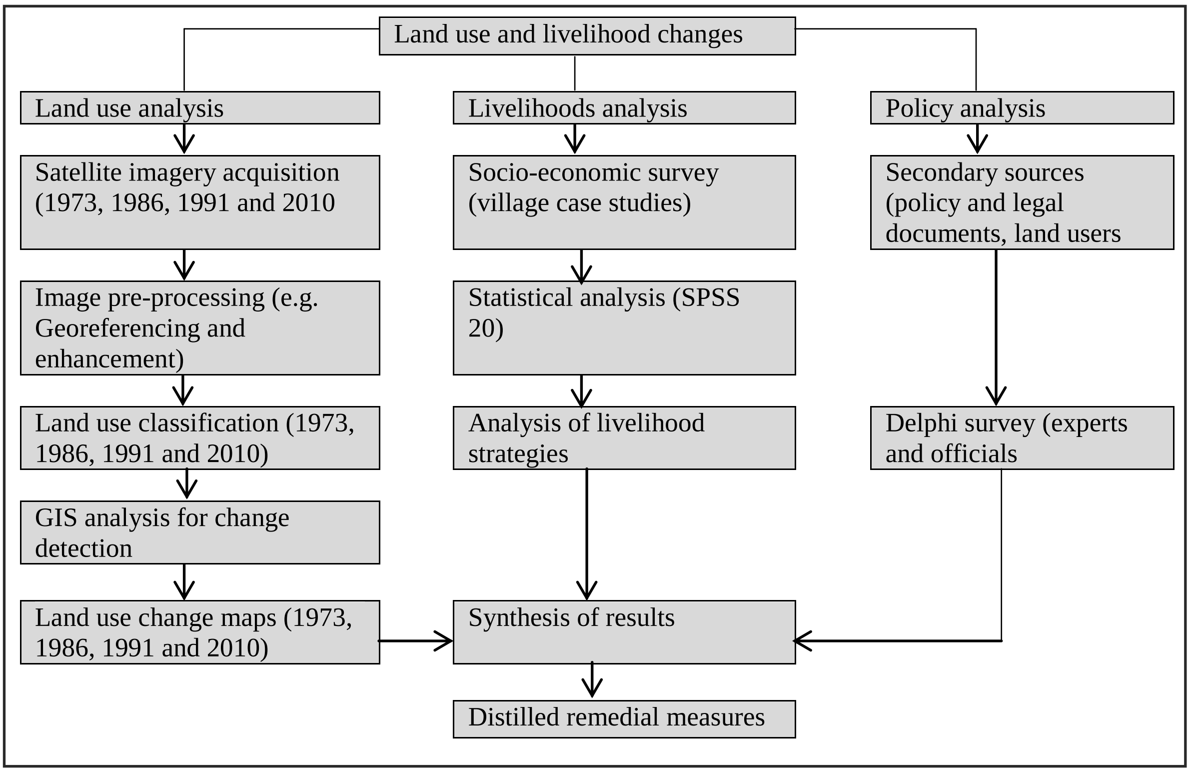


Figure 3.2 Detailed research design for this study

Selected respondents completed a questionnaire via a face to face interview while in-depth interviews were conducted with selected key informants. This part of the analysis relied on survey questionnaires, the delivered data analysed by statistical software (SPSS 20) and results summarized and presented quantitatively in frequencies, percentage distributions, figures, charts and tables.

The third component of the analysis involved policy analysis from available literature and Delphi surveys of government and officials. In this stage, both secondary information and in-depth interviews were used to solicit information. The results were presented in the qualitative form of quoted narratives on important events concerning the history of land use and land use change. The results of the three levels of analysis are presented in Chapters 4, 5 and 6.

3.3.2 Landsat data

Obtaining accurate and timely information on land use is crucial for land use change analysis (Chen & Stow 2003; Giri, Zhu & Reed 2005; Lu et al. 2003). Various methods can be used to collect information on land use change but the use of satellite remote sensing technologies greatly facilitates the task (Fazal 2005; UNITAR 2001). Satellite remote sensing in conjunction with GIS, has been widely applied and recognised as a powerful and effective tool in detecting land use change (Fazal 2005; Mapedza, Wright & Fawcett 2003). Remote sensing provides valuable multi-temporal data for monitoring land use patterns and processes. GIS enables the spatial analysis and mapping of land use patterns. It also allows for detection of land use change over time as well as evaluating the kinds of change occurring. Results from land use change analysis support policy decision making (UNITAR 2001). Generally, unlike the traditional ground-based surveys, satellite remote sensing for region sized areas provides area-wide or synoptic information on the geographic distribution of land use at a relatively low expenditure of money and time (Rogan & Chen 2004; Yuan et al. 2005). In the next sections an explanation of the images selected in terms of their sensor characteristics, the techniques involved in the pre-processing stage, interpretation, land use classes delineation and change detection are elaborated.

3.3.2.1 Image selection

Landsat provided the first ever full coverage of the earth's surface for measurements and observations on temporal and spatial scales (Rogan & Chen 2004; Satellite Imaging Cooperation (SIC) 2012). Previously, surface features were mapped from aerial photographs and by traditional methods of field survey. This study used Landsat images on three grounds: firstly, it was because of the size of the area in which the analysis was carried out. The district's total area of 2211 km^2 is covered by a total of four Landsat TM scenes, so that spatial coverage and image availability made Landsat the optimal data set to use. Secondly, the Landsat spatial resolutions are good for mapping natural environment such as land use/cover (Jensen 2000; Franklin et al. 2003). Thirdly, since the purpose of the research was to map all the broader land use categories of the study area at different time stages, Landsat imagery provided the preferred temporal resolution data for the study (i.e. 1973, 1986, 1991 and 2010).

The selected four periods (1973, 1986, 1991 and 2010) correspond approximately to different levels of socio-political and economic policy regimes in the country related to resource access, resource use and resource management practices. It therefore follows that historical land use change is traced from the periods that represent important milestones of immediate post independent Tanzania history. The study for that reason divides the four periods (1973, 1986, 1991 and 2010) into three operational periods and for the purpose of this study the periods are named as follows: the Arusha Declaration and pre-forced villagisation era (1967-1972), forced villagisation and post-villagisation era (1973-early 1980s) and the structural adjustment and post-structural adjustment era (mid 1980s to present). Satellite imagery was preferred over aerial photographs due to the fact that the historical range of the Tanzanian map archive is poorer than that of the satellite archive. For this reason, aerial photos and thematic maps were used for spatial referencing and accuracy assessment only.

The study area is always affected by cloud cover due to the prevailing climatic conditions of the area. Cloud-free windows in time are severely limited. Lu et al. (2008) point out that persistent clouds and rain limit clear remotely sensed views of the earth's surface and thus prevent platforms from obtaining good quality images. Fortunately, sufficient cloud free images for the target study periods could be acquired for analysis, although not for the same month for all four dates over the 37 year period – causing a slight seasonality problem. To avoid major differences in phenology, all images obtained were at least for the dry season (see Table 3.1). Following the decision to use Landsat images rather than aerial photographs, the scale and resolution of the images had to be determined. Landsat Multi Spectral Scanner (MSS), Thematic Mappers (TM), and Enhanced Thematic Mapper Plus (ETM+) were used to identify the land use and land use change for the specified periods. All Landsat images were downloaded from Earth Resources Observation and Science (EROS) at (http://glovis.usgs.gov) of the Geological Survey of the United States of America. In the next section a detailed description of the basic characteristic features of the various sensors is provided.

3.3.2.2 Sensor characteristics

Table 3.1 presents a summary of the key characteristics regarding the spectral[19], spatial[20] and temporal[21] resolution of the satellite sensors deployed during the capturing of the target imagery. The first Landsat MSS started to operate in 1972 and continued up to 1983 (Rogan & Chen 2004; SIC 2012). The MSS sensor imaged a swath of 180 km wide. Each pixel of the MSS sensor represents an 80 m x 80 m ground area and the approximate scene size is 170 km x 185 km. The MSS sensor recorded 4 spectral bands that simultaneously record reflected radiation from the earth's surface in the green (Band 1), red (Band 2) and near-infrared (Bands 3 & 4) portions of the electromagnetic spectrum between 0.5-1.1 µm. In this sensor, bands 1, 2 and 3 were used for the analysis.

Table 3.1 Characteristics of selected satellite sensors

Sensor	Launch year	Spectral resolution (µm)	Spatial resolution (meters)	Temporal resolution (days)	Swath width (km)	Scene size (km)	Path/row	Date image acquired	Season image acquired
MSS (Landsat 1-4)	1972-1983	Limited (4 bands)	Low resolution (80 m)	18	180	170 km x 185 km	181/066 and 181/067	22/09/1973	Dry
TM (Landsat 4-5)	1982	Limited (7 bands)	Medium resolution (30 m)	16	185	170 km x 183 km	169/66	12/10/1986	Dry
TM (Landsat 4-5)	1982	Limited (7 bands)	Medium resolution (30 m)	16	185	170 km x 183 km	169/66	22/08/1991	Dry
ETM+ (Landsat -7)	1999	Low (7 bands)*	High (15 PAN) Medium: (30 MS) (60 TIR)	16	185	170 km x 183 km	169/66	18/08/2010	Dry

Source: Rogan & Chen (2004); Weng (2012)

*Band 6 on Landsat 7 is divided into two bands, high and low gain

These visible bands were used in this combination for two reasons: first, the ground features appear in colours similar to their appearance to the human visual system, and are

[19]Spectral resolution refers to the number, locations and bandwidths of spectral reflectance bands captured by the sensor. It can range from a limited number of multispectral bands (e.g. 4 bands in Landsat MSS and 7 for Landsat TM and ETM+) to a medium number of multispectral bands (e.g. ASTER with 14 bands) to hyper-spectral band data (e.g. AVIRIS with 224 bands) (Weng 2012).

[20]Spatial resolution refers to the cell size of individual pixels capturing reflectance values during earth surface scanning from the satellite sensor. It is a function of sensor altitude, detector size, focal size and system configuration (Jensen 2005). It defines the level of spatial detail depicted in an image, and it is often related to the size of the smallest possible features that can be detected from an image. It also means that a ground feature should be distinguishable as a separate entity in the image. In short, it refers to both detectability and separability of features in an image (Weng 2012).

[21]Temporal resolution refers to the amount of time it takes for a sensor to return to a previously imaged location, commonly known as the repeat cycle or the time interval between acquisitions of two successive images (Weng 2012).

thus necessary for the visual interpretation of images and, second, they are standard for visual interpretation of vegetation mapping in the tropics (Trotter 1998).

Landsat TM is an advanced, multispectral scanning earth resources sensor designed to achieve higher image spatial resolution, sharper spectral separation, improved geometric fidelity and greater radiometric accuracy and spatial resolution (30 m) than the MSS sensor (National Aeronautics and Space Administration-NASA 2003). The TM sensor mission began in 1982 with Landsat-4 and has continued to the present with the Landsat-7 mission. The pixel in a TM scene represents a 30 m x 30 m ground area and a swath of 170 km x 183 km. The TM sensor has 7 bands that simultaneously record reflected or emitted radiation from the earth’s surface in the visual blue (Band 1), green (Band 2), red (Band 3), non-visible near-infrared (Band 4), mid-infrared (Bands 5 & 7) and the thermal-infrared (Band 6) portions of the electromagnetic spectrum between 0.45-2.35 µm (NASA 2003; Rogan & Chen 2004; SIC 2012). Bands 3, 4 and 5 were used for the analysis.

The Enhanced Thematic Mapper Plus (ETM+) sensor was launched in 1999 on the Landsat-7 mission (NASA 2003; Rogan & Chen 2004; SIC 2012). The sensor records data using the same 7 bands as the TM sensors. There are two advanced features of this enhanced sensor. One is the addition of a panchromatic Band 8 with 15 m spatial resolution at a bandwidth between 0.52-0.92 µm. Second is the increase in spatial resolution of the thermal Band 6 from 100 m to 60 m. The overall spectral range of the ETM+ sensor is between 0.45-2.35 µm of the electromagnetic spectrum. With ETM+ bands 3, 4 and 5 were used for the analysis.

Generally, the main differences among the Landsat data are the resolution, e.g. MSS (80m), TM and ETM+ (30 m), the number of bands and the technological advances in data capturing technology of the TM sensors. Despite their differences, all Landsats entail similar analytical procedures such as pre-processing and processing of the images before performing the actual analysis of which specific procedures are indicated in Figure 3.3.

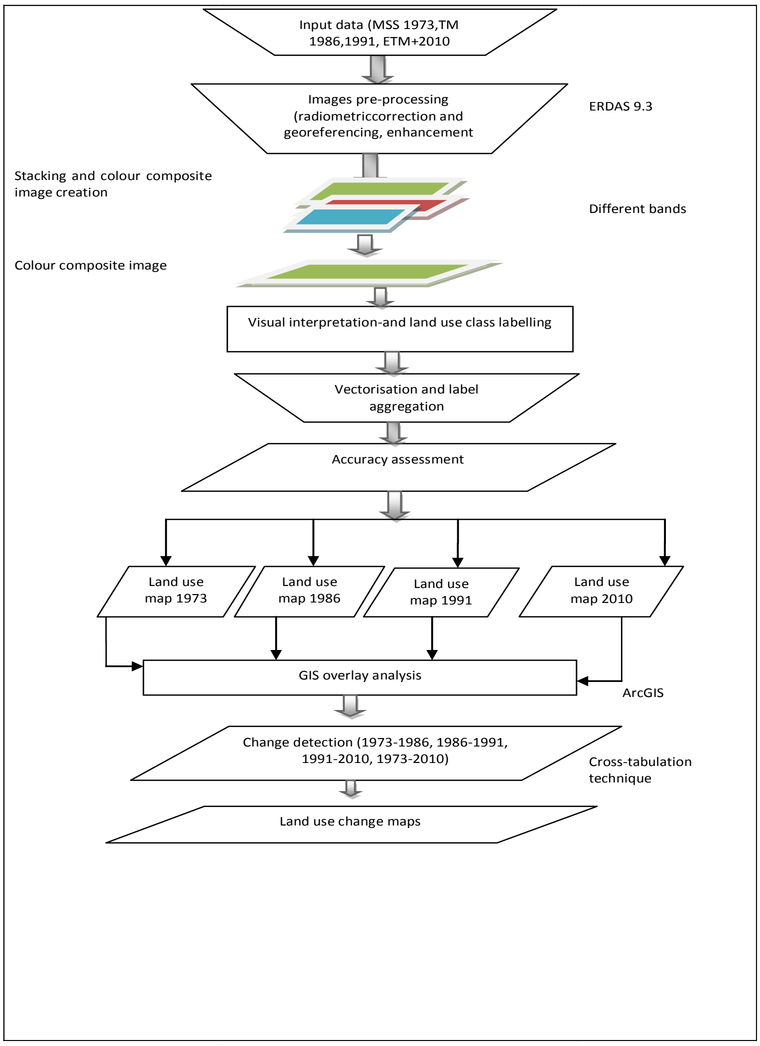


Figure 3.3 Methodological flow chart for land use and land use change analysis

The technical procedures (summarised in Figure 3.3) used in this study for extracting information on Landsat images and a detailed explanation of what was exactly done in each of the stages are given in the later sections.

3.3.2.3 Image pre-processing

In May 2003, a Scan Line Corrector (SLC) instrument on the Landsat-7 satellite failed. Subsequent efforts to recover the SLC were not successful, and the failure appears to be permanent (NASA 2003). As a result, all Landsat-7 scenes acquired since have pixel gaps and are only able to acquire image data in the “SLC-off” mode. All Landsat 7 SLC-off data however, are of the same high radiometric and geometric quality as data collected prior to the SLC failure (NASA 2003). In order to do the analysis there was a need to fill the pixel gaps in the 2010 image using the *frame_and_fill 1.0* program. The purpose of the *frame_and_fill* program is to first align multiple ETM+ Landsat scenes to a common frame of reference and then fill the gaps caused by the 2003 SLC failure (NASA 2003).

After gap filling procedures on the 2010 image, all images (1973, 1986, 1991 and 2010) were firstly radiometrically corrected in ERDAS 9.3, and georeferenced in ArcGIS to Universal Transverse Mercator (UTM), World Global System (WGS 84), North of the Equator standard. Georeferencing was done using the cubic convolution interpolation technique (Keys 1981). The cubic convolution method is more accurate (in terms of reconstruction of any second degree polynomials and convergence approximation rates) than the nearest neighbour algorithm or linear interpolation method, though not as accurate as a cubic spline approximation (Keys 1981). Additionally, cubic convolution interpolation can be performed much more efficiently (Keys 1981). Secondly, for the purpose of accuracy of the projection and the fact that Tanzania is South of the Equator, the images were re-projected using a modified Clarke 1880 Spheroid, Arc1960 Datum, UTM Zone 36 South. Thirdly, the images were enhanced and stacked to create composite images for visual interpretation.

The visual analysis to delineate land use classes relied on the fullest use of the distinguishing capabilities of the human eye and therefore the images were firstly enhanced to increase the apparent distinction between the features on the images. Contrast stretching was applied on the images to produce colour composite images for the visual interpretation. The colour composites were generated through a combination of three selected bands on each image and the printer assigned the Red, Green and Blue (RGB) to the individual specified bands. With Landsat TM and ETM+ the colour composite image was created by assigning the colour blue to band 3, red to band 4 and green to band 5. In Landsat MSS the composite image was created by assigning blue to band 1, green to band 2 and red to band 3. ArcGIS 10 was used to construct three-band composite images for 1973, 1986, 1991 and 2010. The bands used in this combination were sufficient in delineating the different land uses of the study area.

3.3.3 Land use mapping

With the images prepared, the mapping process of land use patterns could commence. The process was started by defining a meaningful land use classification scheme, after which the actual mapping and assessment of accuracy could commence. These procedures are elaborated on in this section.

3.3.3.1 Land use classification scheme

Landsat images of the four years were visually interpreted and the patterns mapped. Before mapping of the land uses commenced, the images were printed. A classification scheme was then prepared, after which hand drawn boundaries were used to delineate each of the observed land use classes, which were later digitized onscreen. Lyon (2001) contended that preparation of a scheme is a prerequisite in the classification process. Similarly, Thapa & Murayama (2009), add that classification schemes provide frameworks for organizing and categorizing information that can be extracted from image data. The general objective of the classification procedures is to categorize each pixel of an image into one of the various land use classes or themes (Lillesand, Kiefer & Chipman 2008). The resultant classified image is essentially a thematic map of the original image (Gonçalves et al. 2008). Even though land use types can be adopted from known traditional classification schemes such as Anderson's or the FAO/UNEP schemes (Jansen & Di Gregorio 2002), the detailed land use classification applied is determined by the interest and aim of the study. Thus the scheme for this study (Table 3.2) was prepared after observation of land uses in the study area.

Table 3.2 Land use classification scheme

Use type	Code	Description
Bushland	Bd	Bushy natural vegetation dominated by trees and or shrubs. It includes dense, open and bushland with scattered cropland
Grassland	Gs	Dominated by grasses and other herbaceous plants used for grazing or pasture. It includes bush, open and grassland with scattered cropland
Mixed cropland with settlements	Cm	Crops are mixed or planted together (mainly maize, beans, potatoes) in a single plot mainly surrounding the homestead
Cultivation with bushy crops	Cb	Plots with tea
Tree crops	Tc	Continuous land/fields of tree crops (coffee, banana, tree mix, cocoa)
Woodland	Wo	Widely spaced trees with their crowns not touching. It includes open, closed and woodland with scattered cropland
Natural forest	Fn	Medium to high altitude forest with a tree canopy cover of more than 10 percent and area of more than 0.5 ha. It includes also lowland riverine forests
Plantation	Pt	Cultivated areas planted with timber (pines)
Water	Wt	Rivers, lakes and water reservoirs
Bare soils	Bs	Rocks, permanently degraded land, newly cleared land
Cultivation with herbaceous crops	Ch	Areas cultivated with annual crops such as rice
Settlements	St	Built-up areas, roads or any other infrastructure

The classification used here, however, largely followed the local classification scheme developed in 1995 by Hunting Technical Services of the United Kingdom in collaboration with the Institute of Resource Assessment and Ministry of Natural Resources and Tourism when the national land cover mapping for the whole of Tanzania was done (URT 1997c). Five broad land use classes were indentified: bushland, grassland, woodland, natural forest and cultivated land (several types of mixed cultivation were more finely distinguished). Additional classes for open land, water features and urban areas are allowed for and the full descriptions are provided in Appendix A of this dissertation.

3.3.3.2 Visual image interpretation

The visual interpretation process involves the human eyes and a prior knowledge of the study area to identify characteristic features in the images (Lillesand, Kiefer & Chipman 2008). Jansen & Di Gregorio (2003) asserted that there is no standard approach to the image interpretation process. The imagery and the interpretation equipment available influence how interpretation is undertaken, in addition to the specific goal that will determine the image interpretation process. Lillesand, Kiefer & Chipman (2008) stipulated that determination of land cover is based primarily on the spectral data content while land use information benefits from aspects of the data such as pattern, tone, texture and resolution. According to Ozesmi & Bauer (2002), early work with satellite imagery used visual interpretation to identify land use features, yet visual and digital analyses of remote sensing imagery are not mutually exclusive. Lillesand, Kiefer & Chipman (2008) further show that the mind is excellent at interpreting spatial attributes on an image and is capable of identifying obscure features. URT (1997c) asserts that the advantage of automatic classification systems is speed, but they are only reliably applicable in those cases where the relationship between spectral reflectance and ground truth is very consistent. This is very rare in the case of interpretation of vegetation or land cover, particularly when imagery may be acquired during different seasons of the year. In this case local knowledge, ground truthing and reference to secondary data become important inputs and manual interpretation becomes the only realistic method. Visual analysis seems to be more of a subjective process, unlike digital processes. However, the two analytical modes are not mutually exclusive and both methods have their merits (Hossain, Ahadi & Kamal 2003). In most cases a mix of both methods is usually employed when analysing satellite imagery.

For mapping purposes the class delimitation was originally done on paper printouts. Once accuracy checking and clarification of uncertainties had been achieved, the digital land use map was created through heads-up onscreen digitising, using the printouts as guides. Land use classes on the images were verified through field visits and use of existing land use map of the area to check accuracy of the interpretation. After ground truthing, corrections of the interpreted images were made, the hand drawn polygons were digitised and land use maps produced.

3.3.3.3 Colour appearance of land uses

Table 3.3 shows how each land use category was distinguished from others on the images. The land use categories were mainly recognised based on the visual elements of tone, texture and pattern, and polygons were hand drawn on the images to show different land use classes. Onscreen digitisation was done in ArcGIS 10.

Table 3.3 Colour appearance of different land uses

Land use class	Colour/pattern appearance of land uses on imagery				
	1973 imagery	1986 imagery	1991 imagery	2010 imagery	General comment
Bushland	Light red/dark brown	Dark brown	Dark brown	Dark brown	Where leaves are off it will appear brownish to dark grey
Grassland	Light red greyish	Green	Greenish to bluish	Light reddish	When it's dry season it appears grey to whitish
Mixed cropland with settlements	Mottled reddish/whitish	Mottled red	Reddish with mottled bluish	Mottled red	
Forests	Deep red	Deep red	Red to blackish red	Deep red to maroon	The colour depends on the season of the year.
Woodland	Red	Red	Red	Red	With leaves it appears red and without leaves it appears dark grey
Cultivation with bushy crops	Reddish with rectangular shape pattern	Light red	Reddish with regular pattern shapes	Reddish with regular pattern shapes	
Tree crops	Reddish	Red	Reddish to deep red	Red with regular shapes	
Settlements	Whitish	Bluish or violet	Bluish violet	Bluish violet	With iron roof it's bluish, with thatched it appears whitish
Water	Bluish to dark blue	Dark bluish to black	Bluish to dark to black	Blackish blue	Water depth determines the colour
Plantation	Large blocks in rectangular pattern	Reddish brown	Green and yellowish brown	Reddish brown	Depends on crop
Bare soils	White to blackish	Whitish or bluish black	Dark grey to black	Greenish to black	Depend on the wetness and colour of the soil.
Cultivation with herbaceous crops	Whitish to brownish red	Green with red mottles	Green with red patches	Greenish with reddish parcels	Depend on season; dry or wet

Basically the colour red usually indicates green vegetation. Therefore the natural vegetation such as forest, woodland and bushland were differentiated by the amount of reddish tone (densities), textures and patterns. Forest and woodlands have deep red tones and are irregular in shape. Tree crops showed up as red but with regular texture. Bare soils were grey to dark or black in colour due to the wet climate and type of crops grown in the area. Water appears in blue but this also depends on water depth and wavelength and hence it may appear dark blue (deep, clear water) or light blue (shallow, turbid water). Settlements appear bluish, but in the study area many houses are surrounded by banana or coffee fields at the homesteads that reduce reflection from the roofs, and thus this land use category was largely included in the mixed cropland except at the district level where there are open built-up areas. The mixed cropland category (crops are mixed or planted together in a single farm) was identified by regular patterns of plots with mottled red colours.

With these characteristics in mind the identification of different vegetation types was done. Generally, a combination of familiarity with the study area, and extensive field visits not only facilitated visual image interpretation and ability to delineate the land uses but also improved accuracy assessment.

3.3.4 Land use change detection

Digital change detection is a process that involves the application of multi-temporal datasets to quantitatively analyse the temporal effects of the phenomenon (Coppin et al. 2004; Lu et al. 2003; Shalaby & Tateishi 2007). Because of the advantages of repetitive data acquisition, its synoptic view, and digital format suitable for computer processing, remotely sensed data have become the major data sources for different change detection applications during the past decades (Chen & Stow 2002; Coppin et al. 2004; Jensen 2005; Lu et al. 2003;Wang, Cheng & Chen 2011; Weng 2002; 2012).

According to Lu et al. (2003) and Lu & Weng (2007) change detection methods are grouped into seven categories: algebra, transformations, classification, advanced models, GIS approaches, visual analysis and other approaches. Accordingly, the first six approaches are the most commonly used for change detection via imagery with relatively fine spatial resolutions such as Landsat MSS, TM, SPOT or Radar. To determine the changes in land use between different years, this study used the classification change detection category – in particular the post-classification comparison (PCC) strategy.

A post-classification comparison change (PCC) detection method was used to determine change in land use over four interval periods: 1973-1986, 1986-1991, 1991-2010 and 1973-2010. PCC is sometimes referred to as ‘delta classification’ (Coppin et al. 2004).

The PCC involves independent classification of multi-temporal images into thematic maps, and then implementing comparison of the classified images, pixel by pixel (Lu et al. 2003, Shalaby & Tateishi 2007; Wang, Cheng & Chen 2011). In addition, the PCC approach provides ‘‘from–to’’ change information, and the kind of land use transformations that have occurred can easily be calculated (Mundia & Aniya 2006; Wang, Cheng & Chen 2011). One of the advantages of the PCC is that it bypasses the difficulties associated with the analysis of images acquired at different times of the year and/or by different sensors (Coppin et al. 2004; Yuan et al. 2005). The inherent disadvantage of the PCC technique is that the accuracy of the change maps depends on the accuracy of individual classifications and is subject to error propagation (Yuan et al. 2005). Yet, the classification of each date of imagery builds a historical series that can be more easily updated and used for applications other than change detection.

PCC requires two digital thematic classified maps of two different time periods. Since image classification and the maps for the study villages were generated for all four target years, the same land use classes (listed in Table 3.2) were used in all four cases. The changes in various land use categories were detected by electronic GIS overlaying of the maps and performing land use change detection, through the cross-tabulation matrix method of Pontius, Shushas & McEachern (2004). These authors emphasise the importance of studying not only net changes but also systematic transitions between land-use types when trying to link patterns and processes in land use change studies. Short-term changes, swaps between locations and backwards transitions can be addressed by a study of each transition between one land-use type and another. Pontius, Shushas & McEachern (2004) contend that analysis of change via cross-tabulation is an efficient statistical method to identify signals of systematic processes within a land change pattern.

The method allows the examination of change in spatial relationships between features of the two images from different points in time (Wang, Cheng & Chen 2011). In the cross-tabulation matrix P_{ij} is the proportion of the land that experienced a transition from type i to type j. Entries on the diagonal (P_{jj}) indicate the proportion of the land that shows persistence of category j. Entries off the diagonal indicate the transition from category i to a different category j. P_{i+} is the proportion of the land category in time 1 that is equivalent to the sum of P_{ij} overall j. Similarly, P_{j+} is the proportion of the land in category j in time 2 that is equivalent to the sum of P_{ij} overall i. Therefore the loss or gain of a land use category between two times can be measured by comparing the marginal probabilities P_{j+} or P_{+j} with Pjj (Wang, Cheng & Chen 2011).

The same procedure was used to identify the rate of change that has occurred for the four periods i.e. 1973-1986, 1986-1991, 1991-2010 and 1973-2010. The change matrices were calculated in ERDAS 9.3 Imagine to indicate change and non-change land use classes for the four periods, the results of which are presented in Chapter 4 of this dissertation.

3.3.5 Population survey

Survey is one of the prominent techniques of data collection in geographic studies. Sheskin (1985) states that survey research fits within the realm of geographic field work and its inclusion in a field course is highly appropriate. Survey research provides a quantitative or numerical description of trends, attitudes or opinions of a population by studying a sample of that population. It includes cross-sectional and longitudinal studies using questionnaires or structured interviews for data collection (Babbie 1990). The purpose of the survey is to generalise from a sample to a population so that inferences can be made about some characteristics, attitude or behaviour of this population (Babbie 1990; Kothari 2004; Rubin & Babbie 2007). This purpose concurs with the purpose of this current study in the sense that it was not possible to study the entire population in MRE, hence a representative sample of the population was used and ultimately the research results could be extrapolated to the entire population subject to representativity constraints. The justification for the use of the survey method is outlined in the next subsections, followed by an explanation of the specific data collection techniques that were employed.

3.3.5.1 Advantages of the survey method

Firstly, the survey method was favoured due to the objectives of the study that focus on the analysis of land use and land use changes and their linkages to people’s livelihoods in the study area. It was shown in Chapter 2 that land use change is associated with negative ecological consequences, but the change may be associated with improved economic productivity and/ or livelihood needs being met. Through a socio-economic survey, the participants are in position to express their attitudes or opinions concerning change in land use and how it has been or is beneficial or detrimental to their own livelihoods.

Secondly, the survey method was chosen due to the fact that even though land use patterns can be observed, measured, characterised and monitored quite effectively with techniques of remote sensing and GIS, they are incomplete representations of human activities and systems (Olson et al. 2004). Land use patterns are also influenced by social systems such as land tenure, gender dynamics, power relations, people's decision making, health status, social networks and cultural values which may override economic or other expected drivers of change. These socio-economic systems are not visible on maps or images; they need to be studied with different methods but preferably with similar tools, so that information of the physical environment and socio-economic factors can be integrated effectively. Thus, conducting personal surveys remains an effective way to foster understanding of the relationship between the spatial patterns of change and the underlying causal processes. Olson et al (2004) and Ellis (2010) point out that linking spatial analysis with household[22] information, land managers and knowledge experts are required to avoid a common mistake in land use change analyses, namely to assume that spatial patterns provide causal explanations.

Thirdly, the survey method is a technique that can scan a wide field of issues by identifying attributes of a large population from a small group of individuals (Babbie 1990; Cohen, Manion & Morrison 2000). At a household level, survey research on land use and land use changes, for example, can yield information on such elements as changing soil properties, management practices, land use histories, household resources (livelihood assets), agricultural labour, household members and their economic activities, changing agricultural or herding practices and distances from farmers' homes to their fields. Identification of such information can provide answers to how, where and why land use change is taking place in the area.

Fourthly, survey research results can be statistically analysed. Cohen, Manion & Morrison (2000) describe a survey as a technique that can generate numerical data, provide descriptive, inferential and explanatory information, through the use of instruments and

[22]The term household in many cases describes a nuclear family – a man and woman with their children, if any. It sometimes includes the extended family and there may also be fragmented households such as an elderly, young or divorced person who lives alone, or friends sharing a house (Ünalan 2005). For the purpose of this study, a household is deemed to refer to 'people sharing one pot', which could vary from a nuclear family to an extended one. In this definition, people like parents, children and any other person who contributes to, participates in the daily economic and social life, and is dependent on the head of household, are considered members.

questions for all participants, and hence gather standardized and comparative information. In terms of statistical abilities the survey is useful in analysing multiple variables simultaneously and it can test their relationships (Rubin & Babbie 2007). With the survey method two techniques of data collection were used: interviews (semi-structured and in-depth) and direct observation.

3.3.5.2 Semi-structured interviews

In order to examine land use change and its relation to livelihoods, the study made use of semi-structured interviews with randomly selected representative household heads. Semi-structured interviews were done during face-to-face encounters at the respondents homes by use of a questionnaire (recorded as Appendix B). A total of 384 questionnaires was administered to heads of households including both men (47.7%) and women (52.3%). The questionnaire contained both closed and open-ended questions. Closed questions enabled the researcher to collect standardized information that was tabulated and from which frequencies were drawn. In order to maximize the advantages of a semi-structured technique and minimize its disadvantages, open-ended questions were included so as to allow the respondents to express their opinions fully. In these types of questions, answers from respondents were not restricted. The respondents had complete freedom to post their opinions on environmental issues, particularly change in land use, and how it has influenced their livelihoods.

According to Berg (2009), Rubin & Babbie (2007) and Sheskin (1985) a semi-structured interview technique involves asking each interviewee predetermined questions orally on special topics in a systematic and consistent order, but allows the interviewers sufficient freedom to probe far beyond the answers. The interviews conducted in this study aimed at particular topics relevant to the goal of the study (map changes and impact of such changes on household livelihoods) focusing mainly on the agricultural livelihoods and related land uses upon which most residents rely. At the household level the interviews involved broad themes such as demographic particulars, informant’s access to and specific use of land, livelihood activities, migration, land use change and drivers of change. Unfortunately, most respondents were unable to fill in the questionnaires on their own as they could neither read nor write. The researcher had to help them fill in the questionnaires in such circumstances. The rate of return was, however, high because there was questionnaire monitoring once it was completed.

3.3.5.3 In-depth interviews

In-depth qualitative interviews were held with key informants. In this study there were two target groups of key informants.

Target group one included 14 district and regional officials, namely ward executive officers (3), village executive officers (6), district natural resources officer (1), district agricultural and livestock officer (1), district water officer (1), district business and marketing officer (1) and Mt Rungwe nature reserve officer (1). These were purposively selected according to their positions as officials in the region, district, wards and villages as they have knowledge and vital information about environmental services and practices.

Target group two included the elderly group of long-term residents in the area. These excluded all heads of households captured in the previous survey. The age range considered in this category was 60 years and older. The assumption was that these people have knowledge of the different dimensions of land use and land use change in the study area. Four broad themes were considered: demographic particulars, informants' specific use of land, land based resources and composition of livelihoods. These elders provided additional information on the nature of land use and land use change over time (from the 1970s to the present), the drivers of such changes and opinions on whether land use change has been and/or is beneficial or detrimental to their livelihoods. Furthermore, with this group the in-depth interviews aimed at capturing the cultural perspective related to the observed changes by tapping their perceptions related to current land use change. A total of 12 elders (two from each village) were purposively selected for interviews.

With both target groups, there was a list of planned and structured open-ended questions (recorded as Appendix C and Appendix D) covering topics and issues that were discussed. According to Patton (1990) this is done to ensure that all respondents are asked the same questions, to maximize the compatibility of responses and to ensure that complete data are gathered from each person on all relevant questions; Moreover, structured open-ended questions aimed at helping the interviewer keep focused on the same predetermined topics and issues while remaining flexible to probe into unanticipated responses.

3.3.5.4 Advantages and disadvantages of the interviews

The study employed a survey interview method to both heads of households and target groups as the best way to extract information, perceptions, experiences, attitudes, opinions or beliefs and responses from the respondents verbally on the spot. The questions were with regard to land use and land use change and its implication to their livelihoods and the environment in general in the study area. However, the method has its inherent strengths and weakness. The next subsections explain how the strengths of the technique were maximized while overcoming its weaknesses.

In terms of its strengths, face to face interviews decreased the number of 'do not knows' and 'no answers' given since the interviewer could probe for answers and clarify matters in the case of incomplete or ambiguous responses, especially to open-ended question (Rubin & Babbie 2007; Sheskin 1985). Another advantage was that the interviewer could observe issues aside from/related to questions asked in the interview. Similarly, the technique was appropriate for illiterate respondents who could neither read nor write, as their views could also be recorded.

Despite the outlined strengths, a survey interview is a time-consuming method, poses ethical challenges, is highly labour intensive, quite expensive, might present some difficulties in accessing respondents' homes (Rubin & Babbie 2007; Sheskin 1985) and requires free consent of the respondents. During this study, for example, it took three months (1st April to June 30 2011) to complete the surveys in the six selected villages. Except for the in-depth interviews with key informants, at the household level interviews were conducted by both the main researcher and the research assistant.

3.3.5.5 Methods deployed to bolster survey outcomes

With regard to survey interviews this study adhered to the following logistics so as to reduce or eliminate the generic disadvantages of the chosen method. *First*, ethical consideration was taken to honour human rights, national policies and rules and regulations governing research and publications at the University of Dar es Salaam during the process of research in the field. For example, a clearance letter from the University was secured from the Vice-Chancellor (Appendix E), which allowed the researcher to go to the Mbeya Regional Administrative Secretary (RAS) and afterwards to the Rungwe District

Administrative Secretary (DAS). The letter enabled the researcher to access various offices in the region and the district (see Appendix F and Appendix G for a copy of the clearance letters) and later in study villages. *Second*, consent of respondents was obtained and confidentiality of information was closely observed. The consent of respondents was obtained through applying good communication skills to convince subjects to provide responses of their own free will. Respondents were assured beforehand that the information they provide would be treated confidentially.

Third, there was training of the personnel (one research assistant) who helped the principal researcher. The hired interviewer was a student at the University of Dar es Salaam doing his Master's degree in Geography and Environmental Management (MAGEM), and was targeted due to the fact that he was highly motivated and had a solid knowledge background in social sciences. It took three days to train this research assistant. One day was used to explain the background of the project. Time was also spent explaining aspects regarding his appearance, behaviour and responses to questions, observance of ethical survey behaviour, probing techniques during interview and on the recording of verbal and non-verbal responses. The second day was used to explain the questionnaire, question by question while on the final day the assistant was given four questionnaires to administer as a trial. The questionnaire used was identical to the one recorded in Appendix B and no alterations were found to be necessary.

Fourth, the principal researcher prepared specifications to accompany interview comments about how to handle difficult or confusing situations that may occur with specific questions. *Fifth*, the hired interviewer was sufficiently remunerated to attract better quality interviewers and to prevent attrition during survey. *Sixth*, the questionnaire was streamlined to contain only clear, relevant and short items and to avoid pitfalls like double negatives and biased items and terms (Rubin & Babbie 2007; Sheskin 1985). *Seventh*, the principal researcher checked incoming completed questionnaires daily to monitor the quality of the answers.

3.3.6 Population and sample

This subsection provides details of the target population, the sampling frame from which the data were gathered, the sample size and the statistical formula that was used to determine the number of respondents.

3.3.6.1 Target population

A target population is the researcher's population of interest to which she or he would like the results of the research to be generalized (Gay 1981). The target population for this study were all residents in MRE comprising of all farmers, pastoralist and agro-pastoralist households in the study villages and some officials at the district level who, according to their positions, were concerned with land and other natural resources management. The researcher selected a representative sample from the area where each stakeholder category was represented.

3.3.6.2 Sampling frame and subject selection procedures

The sampling frame for this study comprised three wards that were selected based on the agro-ecological zones (see Chapter 1). The selected wards were Isongole in the highland, Kyimo in the middleland and Ilima in the lowland. Since the entire population consists of groups or clusters of individuals living in areas with varied microclimatic characteristics, village names in each ward were recorded on separate pieces of papers, the papers were folded to obscure names and two papers representative of the two villages were then randomly drawn from containers with all names of villages for wards from each zone. The procedure yielded a total of six villages (two from each zone) in which a total of 384 households were selected and heads of households interviewed. To obtain sample households for the study, a simple random sampling technique was employed. The village executive officers (VEO) provided the total number of households in each village. Using lists of numbers that were made available by the village executive officers for each village, household heads to be interviewed were randomly sampled using tables of random numbers.

Healey (1993), defines tables of random numbers as lists of numbers that have no pattern to them, that is, they are random and have been programmatically computed. Sheskin (1985) provides a procedure for using tables of random numbers: first, each number should be treated as a multi-digital decimal number (e.g. if the first number is 8 4298, now .8 4298); second, determine the highest number on the sampling frame (e.g. 500); third, multiply .8 4298 by 500=421 then this element 421 should be included in the sample. This is of course a laborious technique; hence a systematic sampling technique was then employed to save time. At this stage, only the 1st case was randomly selected, thereafter, every k^{th} case was selected systematically after the random start (Kothari 2004; Sheskin 1985).

3.3.6.3 Sample size

A sample is defined as a small group of respondents drawn from a population in which the researcher is interested, for the sake of gaining information and drawing conclusion (Kothari 2004). Best & Kahn (2006) contend that a sample is a small proportion of a population selected for observation and analysis, the characteristics of which can enable the researcher to make certain inferences about the population from which the sample was drawn. They maintain that there is no sample size that is best; any sample can be accepted depending on the nature of the study. Therefore, a good sample should be one which reflects an actual profile of the population from which it is drawn. It should be economical and must be able to be gathered efficiently.

Sheskin (1985) identified five factors determining sample size: cost, time, geography, level of accuracy and subgroup analysis. He noted, for example, that a more geographically dispersed population will require larger sample size because of the differences in attitudes, beliefs and demographic characteristics. Regarding accuracy level he holds that the most common level is when one is 95% certain that no estimated percentage is off by more than +/- 5%. He concluded by adding that most surveys use the 95% and 5% confidence level and interval respectively.

Determined by the purpose of the study, the need for limiting cost and time, and geographical constraints of the dispersed population, preferred level of precision and accuracy criteria were used to determine the appropriate sample size. A 95% confidence level and 5% level of precision was used to select the sample size for survey purposes. Israel (1992), shows that a number of strategies can be used for determining the sample size. Among these are the uses of a census for small populations, imitating a sample size of similar studies, using published tables and applying formulas to calculate sample size. In order to minimize bias and errors and increase validity so that inferences can be made for the whole target population, a statistical formula was used to calculate the sample size for the study, and the results of the sample size for each village are shown in Table 3.4.

Sample size formula:

$$\boxed{\mathbf{n= \frac{N}{1 + N (e)^{2}}}}$$

Source: Israel (1992)

Where: n= the sample size

N= the total number of households (for all the six selected villages)

1= the desired confidence level (95%)

e= the desired level of precision/ sometimes called *sampling error* (the range in which the true value of the population is estimated to be; this range is often expressed in percentage points (e.g., ±5 percent)

Therefore:

$$n=\frac{4997}{1+4997(0.05)^2}$$

$$n=\frac{4997}{1+4997(0.0025)}$$

$$n=\frac{4997}{1+12.49}$$

n = 384

The total sample size was proportionally divided among the six sample villages as indicated in Table 3.4.

Table 3.4 Sample size by village

Wards	Villages	Zones	Total households	Sample size	% of Total
Isongole	Ndaga	Highlands	1900	146	38
	Unyamwanga		418	32	8
Kyimo	Kyimo	Middle lands	1012	78	20
	Syukula		984	76	20
Ilima	Ilima	Lowlands	350	27	7
	Katundulu		333	25	7
	Grand total		**4997**	**384**	100%

This also indicates that some villages, especially those of the lowland zone, were generally smaller, hence fewer households were selected there. Despite these disparities the selected sample size was considered sufficient and representative enough to capture variability of groups of households which may influence local land use and land management practices. Boyde, Westfall & Stasch (1981) contended that for a random sample to be representative of a population it should at least constitute 5% of the total population. The sample size in each of the selected villages constituted 7.5%, hence, it meets this criterion easily and should yield representative results.

3.3.6.4 Socio-economic characteristics of the surveyed respondents

A total number of 384 heads of households, ranging in age from 21 to 90 years, with a mean of 46.67 and a standard deviation of 15.59 were interviewed. Age wise more than 70%

of the surveyed respondents belonged to the working age group (21 to 59 years) and only 22% was elderly people 60 years and older. Of all the respondents 47.7% were males and 52.3% were females – a well-balanced gender sample. The married respondents were 68.8%, 23.7% were widows while 3.6% never married and the other 3.9% were separated or divorced. The education levels of the respondents ranged from non-attainment to attainment of certificates and a diploma. In fact, on average 30% were illiterate and 61% had progressed to primary school education only, while 9% had secondary education and college education. The relatively low educational level meant that great care had to be taken to help respondents to comprehend and fill out the survey questionnaires.

Average household size of the respondents consisted of a minimum of one and a maximum of 14 members in the family with a mean of 5.3 and a standard deviation of 2.1. This means that family size was not on average exceptionally high for a developing rural community. Agriculture was the main economic activity of most respondents with more than half (66.4%) depending on agriculture alone. Another 32.0% engaged in agriculture and some form of employment and only 1.6% engaged in agriculture and business as a combination.

3.3.7 Field observation

Whereas survey interviews allowed for a large sample, they suffered loss of details and accuracy. To minimize these effects, the advantages of interviews and direct observation were combined in this study. The observation technique was selected because it is relatively independent of the respondents and is less demanding of active co-operation on the part of the respondents. Also observation is useful because it takes place in a real life as well as in a controlled situation. Both observation and interviews were conducted after remote sensing data were interpreted and initial land use change analyses were available. This was done to help the researcher ask about specific nearby localities that have changed. Field observation was made on the evidence or features related to topography, land use, land degradation, vegetation, farming practices and status of the MRE. It was a non-participant physical observation on the activities taking place, and their implication to the environment. Data from field observation was recorded and is presented in the form of digital plates or photographs that were taken in the field. The purpose was to supplement the qualitative data with real-world evidence.

3.3.8 Documentary analysis

Policies and legal documents of Tanzania relevant to guiding or influencing rural development were reviewed. The aim of the review was to determine the extent to which various developmental policies in combination or singly have influenced or are influencing land use change and livelihoods of the communities studied. Such information was important in providing context and possible causative impetus to observed and measured developmental trends in the study area. According to Creswell (2009) documents include public and private documents that can be accessed as secondary information. Of particular concern for this study are policy and legal documents related to agriculture, forestry, energy, rural development, land and environmental management since before the 1970s to the present. The technique involved the review of existing reports (unpublished and published reports) from libraries and documentation centres at national and regional levels. Some policy reports were made available through the national government on-line document repository www.tzonline.org – a web repository that stores national Tanzanian policies. The major advantage of document analysis is that this resource represents stable written evidence that can be reviewed repeatedly (Creswell 2009). Section 2.5 of this dissertation explains in some detail the policies that were reviewed with regard to the objectives of this study.

3.4 CHAPTER SUMMARY

In this chapter the research methodology and methods employed by the study were discussed at length. Each of the data collection instruments and the justification for their use were elaborated. The inherent weaknesses and strengths for each instrument were also pinpointed. Likewise, a detailed research framework and the research design for achieving the set objectives were explained stepwise. The geographical characteristics of the study villages, total number of subjects and the way they were obtained were elaborated in some detail. The technicalities concerning Landsat imagery pre- and post-processing stages, image classification and change detection techniques were detailed as well. The methodological output of various processes and procedures explained in this chapter are presented in the next chapter.

CHAPTER 4 LAND USE OCCURENCE AND CHANGE IN THE MOUNT RUNGWE ECOSYSTEM

This chapter presents the results based on the first two objectives of this study. Since this was not a hypothesis testing study, the two objectives were captured and rephrased into a single research question: what is the extent and nature of land use change in the MRE. The chapter is structured into four main sections. The first section describes the mapped land uses of the whole study area whilst the second covers the analyses by sample village. The third section deals with change in land use types in the MRE during the study period, of which the trends are explained in the final section. All sections of this chapter present the results for the four years 1973, 1986, 1991 and 2010 or the interim periods, as justified in Chapter 1. The driving forces behind the observed change in land uses (in relation to policy change and zonation approach adopted by this study) are discussed later in Chapter 5.

4.1 SPATIAL LAND USE DISTRIBUTION IN THE MRE

In this section the land use occurrences at the district level are presented and then land use patterns are presented individually for the six selected villages representative of the three agro-ecological zones of the MRE. A similar approach is adopted for presenting spatial and temporal information on land use change of the study area.

4.1.1 Land use patterns at district level

As noted earlier in Chapter 3 land use classes were visually identified on the four images according to a classification scheme that involved broad land use categories (see Table 3.2 in Chapter 3). A pattern of 12 land use classes was identified on the four Landsat images mapped in Figure 4.1. The general observation is that natural vegetation (mainly bushland and woodland) are randomly distributed throughout the district area. The natural forests and plantations occur for a large part in particular locations, particularly in the highland zone (in the northern part of the district). These forests include the Rungwe Forest Reserve and other forest reserves in the district (see Figure 1.2 in Chapter 1). The water category is also randomly distributed indicating that the area is well drained. The cultivation categories are also randomly distributed in all zones, though with some clustered pattern of particular cultivation types, for example, cultivation with bushy crops, tree crops and cultivation with herbaceous crops categories are

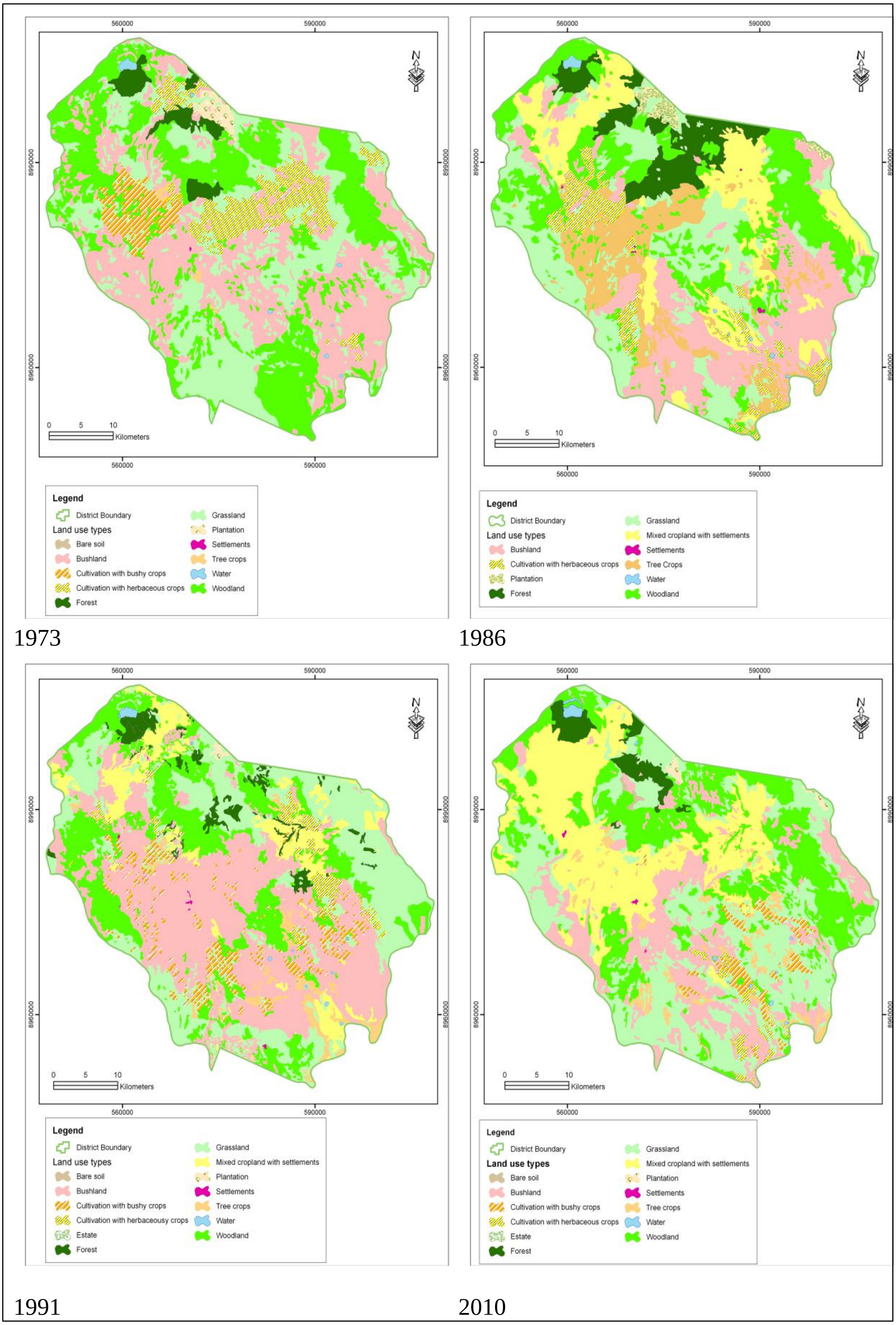


Figure 4.1 Patterns of land uses in Rungwe district

only concentrated in the middleland and lowland zones but mixed cropland is randomly distributed all over the three zones. The four years display a varied pattern of land uses across the district. In the 1973, 1986 and 1991 images natural vegetation is much more randomly distributed. On the 2010 image these categories are much more concentrated while cultivation classes, mainly mixed cropland with settlements and cultivation with bushy crops, are more randomly distributed.

4.1.2 Area coverage of the land uses at the district level

In all the four periods, the dominant land use classes were natural vegetation followed by cultivation. A statistical summary of the actual quantities of the different land uses in Rungwe district is provided in Table 4.1.

Table 4.1 Summary statistics of land uses in Rungwe district

Land use categories	Land use coverage (ha)							
	1973		1986		1991		2010	
	Ha	%	Ha	%	Ha	%	Ha	%
Bushland	70 248	33	41 748	19	72 883	34	35 849	17
Grassland	51 435	24	44 170	21	51 823	24	61 600	29
Woodland	60 516	28	41 926	20	41 859	20	46 790	22
Forests	5567	3	14 796	7	6373	3	5915	3
Plantation	2127	1	1998	1	373	0	844	1
Water	581	0	577	0	539	0	774	0
Bare soil	24	0	0	0	77	0	414	0
Cultivation with bushy crops	7083	3	0	0	9645	5	4587	2
Cultivation with herbaceous crops	15 845	8	11 621	5	5289	2	2501	1
Mixed cropland with settlements	501	0	31 666	15	19 051	9	48 053	22
Tree crops	568	0	25 894	12	6473	3	7085	3
*Settlements	16	0	115	0	125	0	98	0
Total	214 511	100	214 511	100	214 510	100	214 510	100

*As said already in Chapter 3, in the study area, many houses are surrounded by banana or coffee fields at the homesteads that reduce reflection from the roofs, and thus this land use category was largely included in the mixed cropland except at the district level where there are open built-up areas. Since the category was included in the mixed cropland, hence the settlement category is so low. Also probably, this reflects the situation before villagisation where settlements were so scattered.

In 1973, the most extensive land uses were bushland, followed by woodland and grassland. Natural forests did not cover an extensive area in the district. Cultivation covered a moderate land area compared to natural vegetation. However, cultivation with herbaceous crops and cultivation with bushy crops showed considerable coverage. The remaining cover, notably bare soils, settlements and water, covered a small portion of land. The trend of the various land uses in 1986 indicates that natural vegetation classes were still dominant at almost 70%. Natural forests in particular as well as cultivated land covered a larger portion of land as compared to 1973. Under cultivation classes, the dominant categories were mixed cropland with settlements, tree crops and cultivation with herbaceous crops. Plantations and water classes still covered a considerable portion of land though their extents were reduced while settlements (built-up areas) increased compared to 1973.

By 1991 natural vegetation (bushland, grassland and woodland) remained the dominant land uses with a notable decline in areas covered by forests and plantations. Other important land uses in this period included mixed cropland with settlements and cultivation with bushy crops, though with a declined coverage compared to 1986. In this period also there was a notable increase in areas with bare soils compared to the previous two sample years. This possibly indicated that although natural vegetation was increasing, some areas were degraded implying not being in use either for cultivation or settlements. In 2010, the surface covered by grassland and woodland was still relatively high, though not as high as in 1991; these were followed by mixed cropland with settlements. The coverage for tree crops and natural forest remained constant while that of cultivation with bushy crops and cultivation with herbaceous crops declined. Settlements (built-up areas), water bodies, and plantations occupied comparatively small areas during all four periods. Bare soils, possibly indicative of degradation, seemed to have covered significant land surface in 2010.

Table 4.1 indicates that Rungwe district is generally well endowed with natural vegetation including grassland, woodland, bushland and natural forests. For the four periods they were the prominent land uses, but with varying coverage signifying a fluctuating land use regime. The results of this study supports what McKone & Walzem (1994) and URT (2011a) have also pointed out that the district is endowed with natural vegetation, although in recent years much of the land has been transformed through agriculture, habitation and firewood provision. Table 4.1 also indicates increases in cultivated land, with cultivation classes (mixed cropland with settlements, cultivation with bushy crops, tree crops and cultivation with herbaceous crops) occupying a considerable amount of the total area.

4.2 EXTENT OF LAND USE TYPE PER VILLAGE

The land use patterns of the surveyed villages were not uniform although they reflected the patterns observed in Section 4.1.1. Land uses differed from zone to zone – in the sense that not all categories occurred in similar villages or that the extent of group coverage differed widely. The disparities though not much pronounced, are attributable to variation in microclimatic characteristics even inside specific zones of the MRE. The disparity in land use types was more pronounced in the villages of the middleland zone. The villages in other zones shared almost similar land use categories. In the highland and lowland zones for example, five broad land use classes occur, although with minor variation in intra-class types. In the middleland zone, five to seven land use types were present. This indicated that not all land use classes identified at the district level were found in specific village areas. The order of magnitude of spatial extent and the trend of coverage of land uses in the six villages on zonal basis are explained in the next section.

4.2.1 Land use patterns of the villages of the highland zone

Unyamwanga and Ndaga are villages representative of the highland zone of the MRE (see Figure 1.3 in Chapter 1). The spatial arrangement of the land use categories in Unyamwanga village expressed in Figure 4.2, displays a randomly distributed pattern of the cultivated land throughout the entire village land, except in 2010 where the category seems to be clustered in the southern part of the village. In 1973 and 1986, grassland, woodland, bushland and natural forests were mainly clustered in the south eastern and northern parts. In 1991 and 2010, grassland, woodland, bushland and natural forests are more randomly distributed.

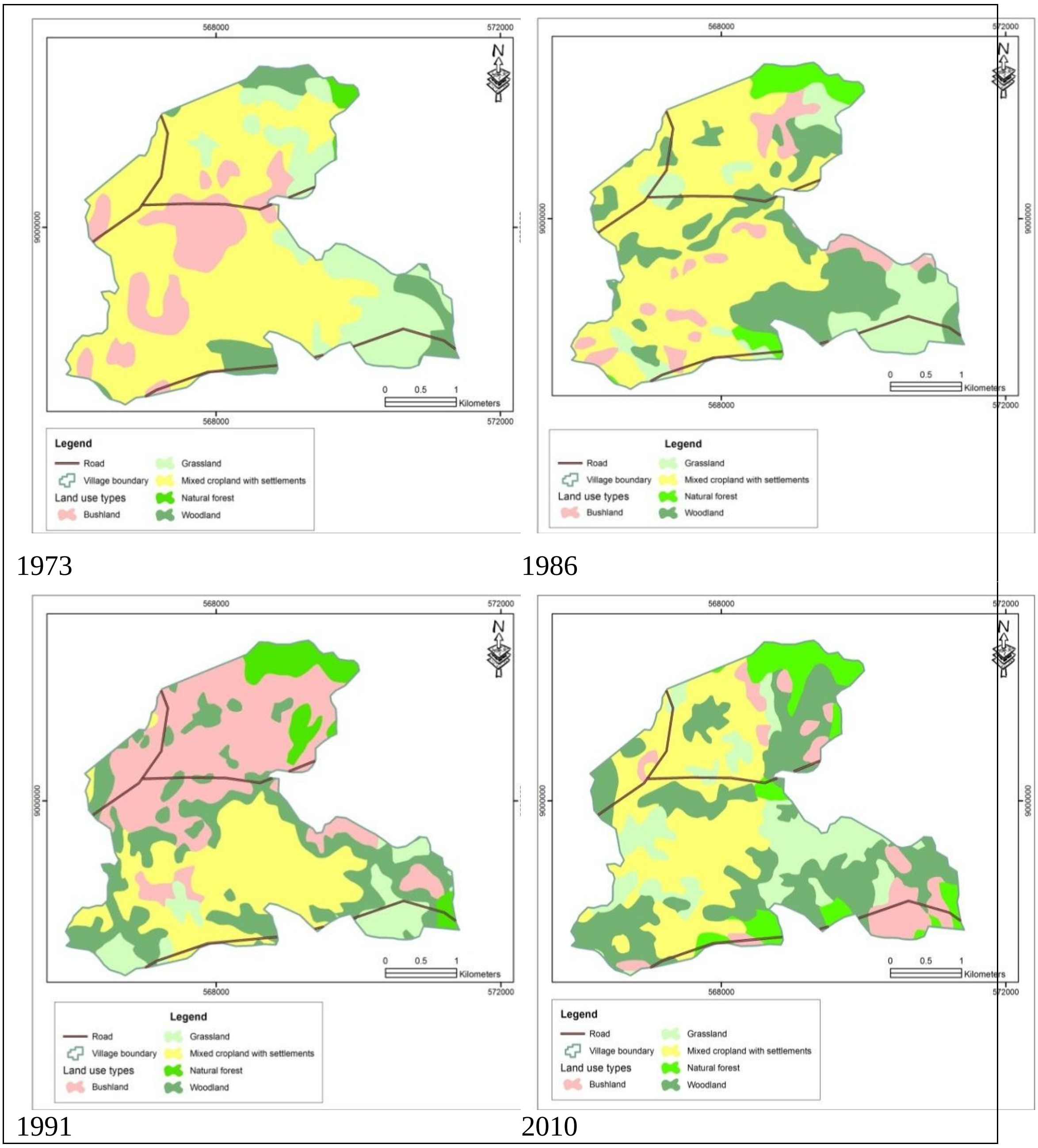


Figure 4.2 Land use types in Unyamwanga village

In Ndaga village as indicated in Figure 4.3, there is a somewhat even and random distribution pattern of most land uses except in 2010 where almost the entire village land is occupied by cultivated and settlement land while natural forests and woodland almost disappeared.

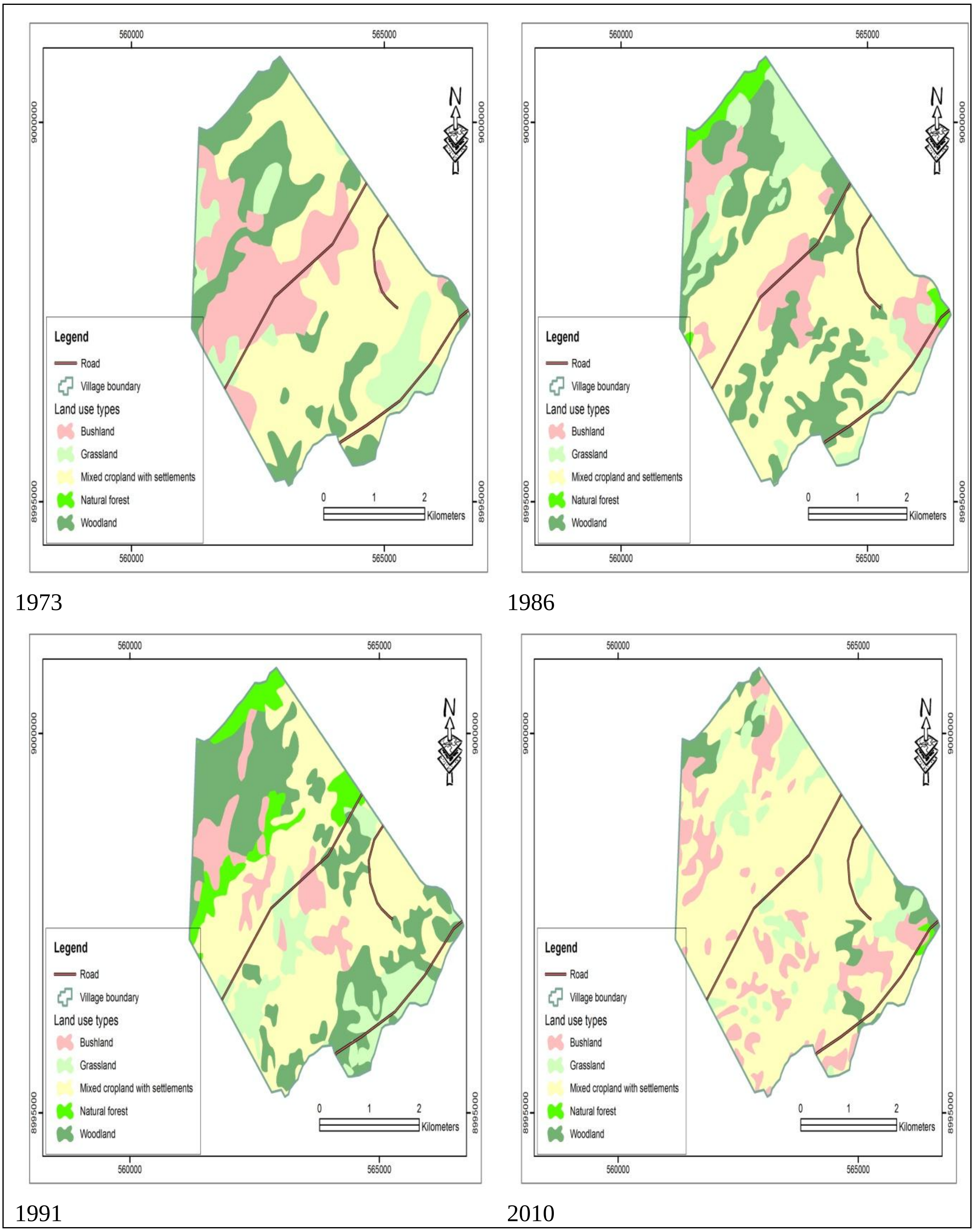


Figure 4.3 Land use types in Ndaga village

4.2.2 Area coverage of land uses in the villages of the highland zone

Table 4.2 clarifies the actual coverage area for each land use per village of the highland zone. In Unyamwanga village, mixed cropland with settlements covered more than

Table 4.2 Area coverage of land uses in Unyamwanga and Ndaga villages

	Unyamwanga village								Ndaga village							
Land uses*	1973		1986		1991		2010		1973		1986		1991		2010	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Bd	215	16	108	8	470	34	125	9	416	23	224	12	169	9	291	16
Gs	255	18	203	15	108	8	237	17	191	10	213	12	220	12	173	10
Cm	800	58	677	49	375	27	444	32	867	47	882	48	800	44	1265	69
Fn	12	1	68	5	96	7	135	10	0	0	54	3	137	7	9	0
Wo	103	7	329	23	336	24	444	32	363	20	464	25	511	28	99	5
Total	1385	100	1385	100	1385	100	1385	100	1837	100	1837	100	1837	100	1837	100

*Bd– Bushland; Gs– Grassland; Cm– Mixed cropland with settlements; Fn– Natural forests; Wo– Woodland

half of the total area in 1973. Although the trend in 1986 was different from that of 1991, mixed cropland with settlements was still a significant land use and this increased in 2010. In spatial extent, mixed cropland with settlement was followed by woodland, grassland and bushland. The prominence of woodland was fairly comparable to that of mixed cropland with settlements in almost all of the four periods except in 1973. By 2010 the land portion of bushland and grassland categories was less significant. Natural forests increased slightly since 1986 through to 1991 and 2010.

Table 4.2 shows that more than three-quarters of the total area in Ndaga village was covered by mixed cropland with settlements over the four periods with a remarkable prominence in 2010. This was followed by woodland and bushland categories especially in 1973 and 1986. By 1991 woodland area coverage increased compared to the previous years. The grassland covered almost a constant area over the four periods. Natural forest coverage was absent in 1973, which is a common phenomenon. In 1986 a small stand of natural forest was registered. In 1991 a big patch of natural forests appears in this village. The reappearance of natural forests in Ndaga village though was not sustained may be an outcome of the villagisation process: that 19 years after the villagisation, the natural forests that were less disturbed might have regenerated in some locations of the village and perhaps the management of the village forests was entrenched.

The general trend expressed in Table 4.2 indicates that mixed cropland with settlements was the prominent land use in all of the four periods in the two villages of the highland zone. There was an almost constant coverage of natural vegetation (woodland, grassland and forests) in Unyamwanga village. By contrast, natural vegetation declined unevenly in Ndaga village. This may be because their magnitudes of spatial extent differed significantly, especially in 2010. By 2010 natural forests for example, were almost non-existent in Ndaga village indicating transformation of the natural vegetation (woodland, bushland, grassland and natural forests) in favour of mixed cropland with settlements. This is indicative of pressure of agricultural land in Ndaga village that has necessitated the conversion of natural vegetation into cultivated land. Although there is correspondence in the trends of land use in these two villages, their magnitude differed considerably. Cultivation intensity occurs to a larger extent in Ndaga compared to Unyamwanga village, particularly in 2010. A number of factors, both human and natural, could explain such variations in these villages, as explored later in Chapter 5.

4.2.3 Land use patterns of the villages of the middleland zone

Kyimo and Syukula are villages representing the middleland zone of the MRE. In these villages, five to seven of the identified land use categories were present on the four Landsat images. Kyimo recorded five land use classes namely bushland, woodland, grassland, tree crops and mixed cropland with settlements. In 1973, the land use pattern is dominated by bushland that is randomly distributed almost in the entire village area. Woodlands are linearly distributed in the northern and southern part of the village. On the 1986 map, mixed cropland with settlements and tree cropland are randomly distributed over the village land while woodlands are clustered mainly in the southern and northern part of the village. On the 1991 and 2010 maps, cultivated land is still randomly distributed in the village with some concentration of tree crops in the southern part of the village. The spatial distribution of the land uses for Kyimo village is shown in Figure 4.4.

In Syukula village seven land use classes were recorded as the spatial distribution of the land uses in Figure 4.5 shows. These included bushland, woodland, grassland, natural forests, mixed cropland with settlements, cultivation with bushy crops and tree crops.

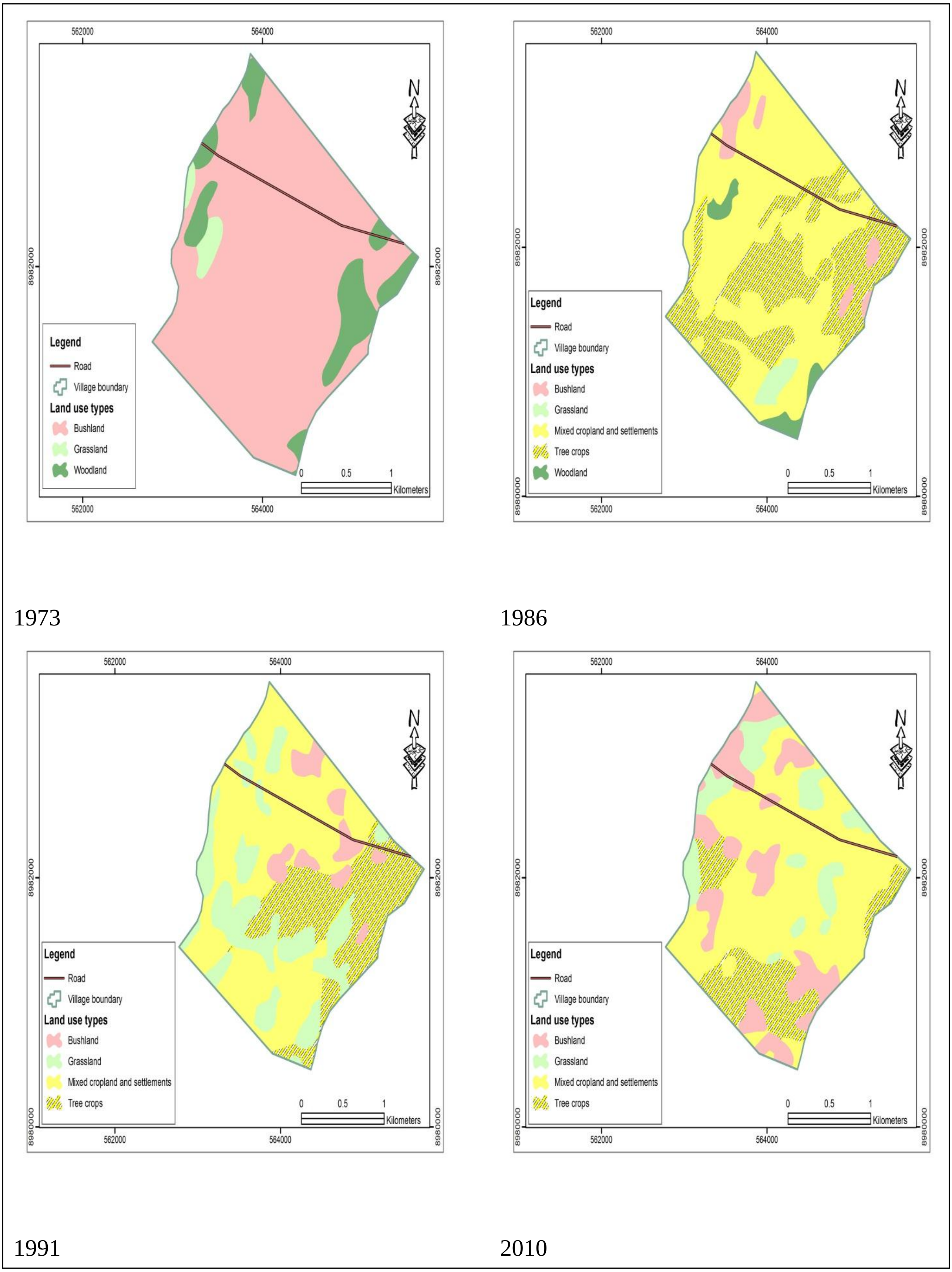


Figure 4.4 land use types in Kyimo village

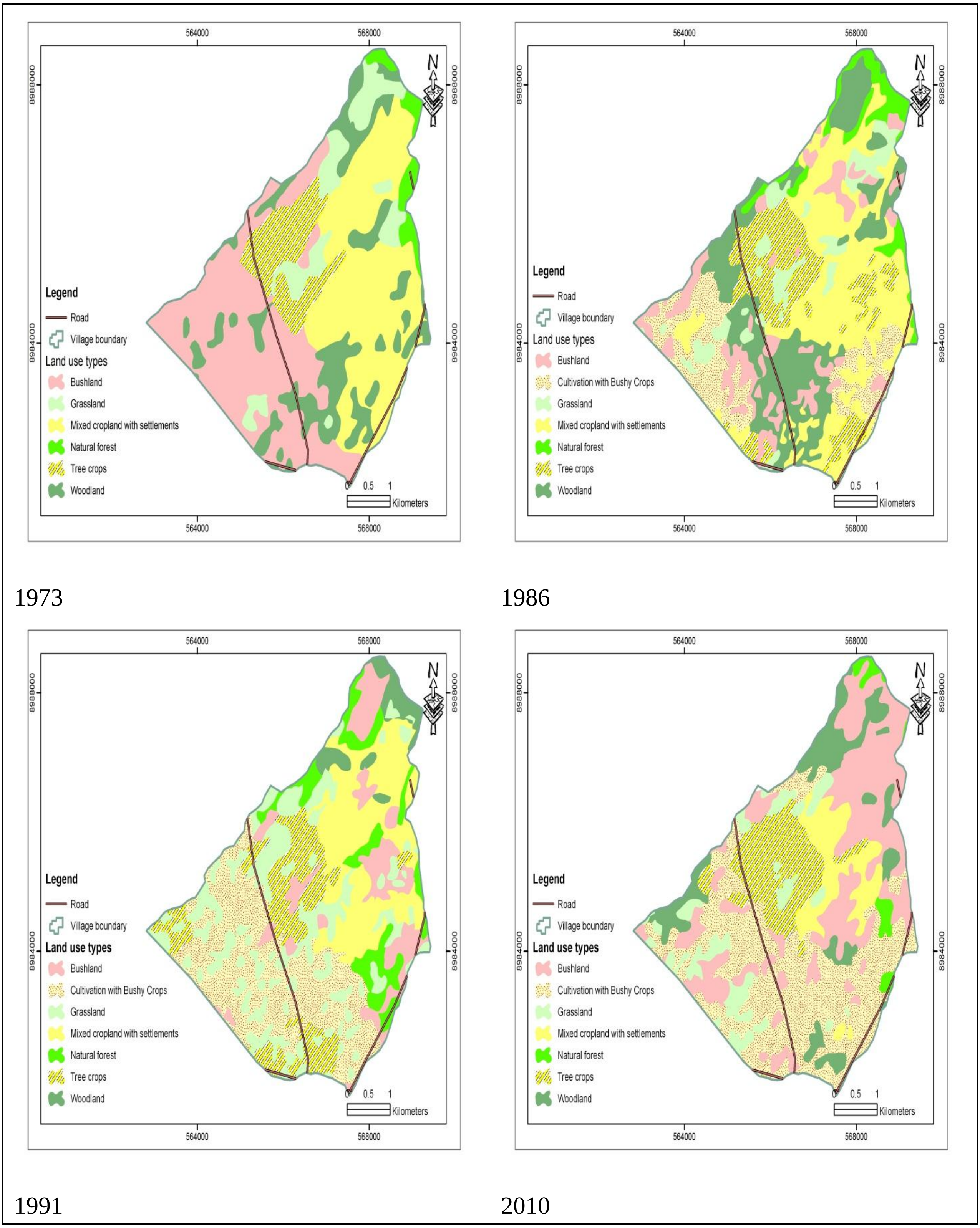


Figure 4.5 Land use types in Syukula village

In this village, on the 1973 map, bushland is the leading land use in terms of its spatial distribution in the land belonging to the village. Bushland is mostly randomly distributed in the south-west of the village. This is followed by mixed cropland with settlements which stretched from the northern to the south-eastern part of the village. Woodland is scattered while the tree crops category is concentrated in the central area of the village. In the remaining three maps (1986, 1991 and 2010) the most randomly distributed land uses are cultivation with bushy crops, tree crops, mixed cropland with settlements, and to a lesser extent woodland and bushland. Natural forests and grasslands are clustered in particular locations in the village lands.

4.2.4 Area coverage of land uses in the villages of the middleland zone

Table 4.3 presents the actual coverage in hectares and percentages of each of the recorded land uses in the two villages. The table basically shows a correspondence between the spatial patterns of the land uses shown in Figure 4.4 and Figure 4.5 and the actual coverage for each of the villages i.e. land uses which occupied a considerable land area were randomly distributed while those with smaller coverage were either clustered or linearly distributed.

Table 4.3 Area coverage of land uses in Kyimo and Syukula villages

	Kyimo village								**Syukula village**							
Land uses *	**1973**		**1986**		**1991**		**2010**		**1973**		**1986**		**1991**		**2010**	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Bd	419	86	20	4	34	7	92	18	752	32	273	12	267	11	646	27
Gs	11	2	11	2	106	22	58	12	211	9	179	7	450	19	140	6
Cm	0	0	276	57	234	48	263	54	728	31	705	28	494	21	220	9
Tc	0	0	167	34	115	23	76	16	226	9	331	14	340	14	326	14
Wo	58	12	14	3	0	0	0	0	392	16	465	21	54	2	203	9
Cb									0	0	306	13	592	25	793	33
Fn									72	3	122	5	184	8	53	2
Total	488	100	488	100	488	100	489	100	2381	100	2381	100	2381	100	2381	100

*Bd– Bushland; Gs– Grassland; Cm– Mixed cropland with settlements; Tc– Tree crop; Wo– Woodland
Cb– Cultivation with bushy crops; Fn– Natural forest

Table 4.3 shows that bushland was the most extensive land use in Kyimo village occupying more than three quarters of the total land in 1973. The trend changed in 1986, where more than half of the total land was covered by mixed cropland with settlements followed by the tree crop category. In 1991 the two categories remained prominent followed by grassland. In 2010, there was a remarkable increase in mixed cropland and this covered more than half of the total land as compared to 1991. The trend in this village indicated persistence of mixed cropland with settlements in 1986, 1991 and 2010. This could be an indication of the importance and need of agricultural land and settlement land over other land uses. Over the four periods, the natural vegetation (woodland in particular) consistently covered only a small portion of land. By 1991 and 2010 woodlands had been completely replaced by cultivation.

In Syukula village bushland was the leading land use in terms of its area coverage. This was followed by mixed cropland with settlements and woodlands. The trend was reversed in 1986, when the mixed cropland with settlements category was prominent followed by woodland, tree crops and cultivation with bushy crops. In 1991, the order was altered again where a large portion of land was occupied by cultivation of bushy crops and mixed cropland with settlements. These were followed by grassland, tree crops and bushland while woodland covered a small land area. In 2010, cultivation with bushy crops and bushland were dominant land uses. In this village, grassland and natural forest covered a very small land portion during this period.

The general spatial pattern of various land uses in the villages of the middleland zone is that of randomly distributed cultivated land and clustered natural vegetation. Such spatial pattern coincides with the coverage of these land uses as reflected in Table 4.3. However, there is little correspondence between the two villages, indicating variation even inside the same zone. The variation can possibly be attributed to microclimatic characteristics and other factors explained later in the next chapter. The maps also show that over the four periods much land was allocated to cultivation and settlements while natural vegetation covered only a small portion of land. Most notable from these figures are the remarkable decline in bushland and the concomitant rise in mixed cropland and settlements in Kyimo village. On the contrary, in Syukula a decline in mixed cropland and settlements and an increase in cultivated bushy crops were recorded. This may be explained by human impact and natural factors, as discussed later in Chapter 5.

4.2.5 Land use pattern of the villages of the lowland zone

Katundulu and Ilima are villages representative of the lowland zone of the MRE. These villages recorded five land use classes i.e. bushland, grassland, woodland, mixed cropland with settlements and tree crops. Although the total number of classes was the same as the villages in the highland zone, only four classes were similar. The spatial distribution of land uses for Katundulu village is expressed in Figure 4.6, where a random and mixed pattern of land uses is observed. In this village, natural vegetation, particularly bushland, is quite randomly distributed compared to cultivated land in almost all four periods, except in 1986.

Figure 4.6 Land uses in Katundulu village

Woodland is more confined in some locations especially in the 1973, 1986 and 2010 images. The grassland category also seems to be widespread except in 1973 where it is clustered in the southern part of the village. In 1991, mixed cropland is clustered in a few locations in the northern and southern part of the village, whereas in 2010 this category appears linearly in the north-western part of the village.

The spatial occurrences of land uses for Ilima village are displayed in Figure 4.7. There is some similarity to those of Katundulu village i.e. natural vegetation mainly bushland

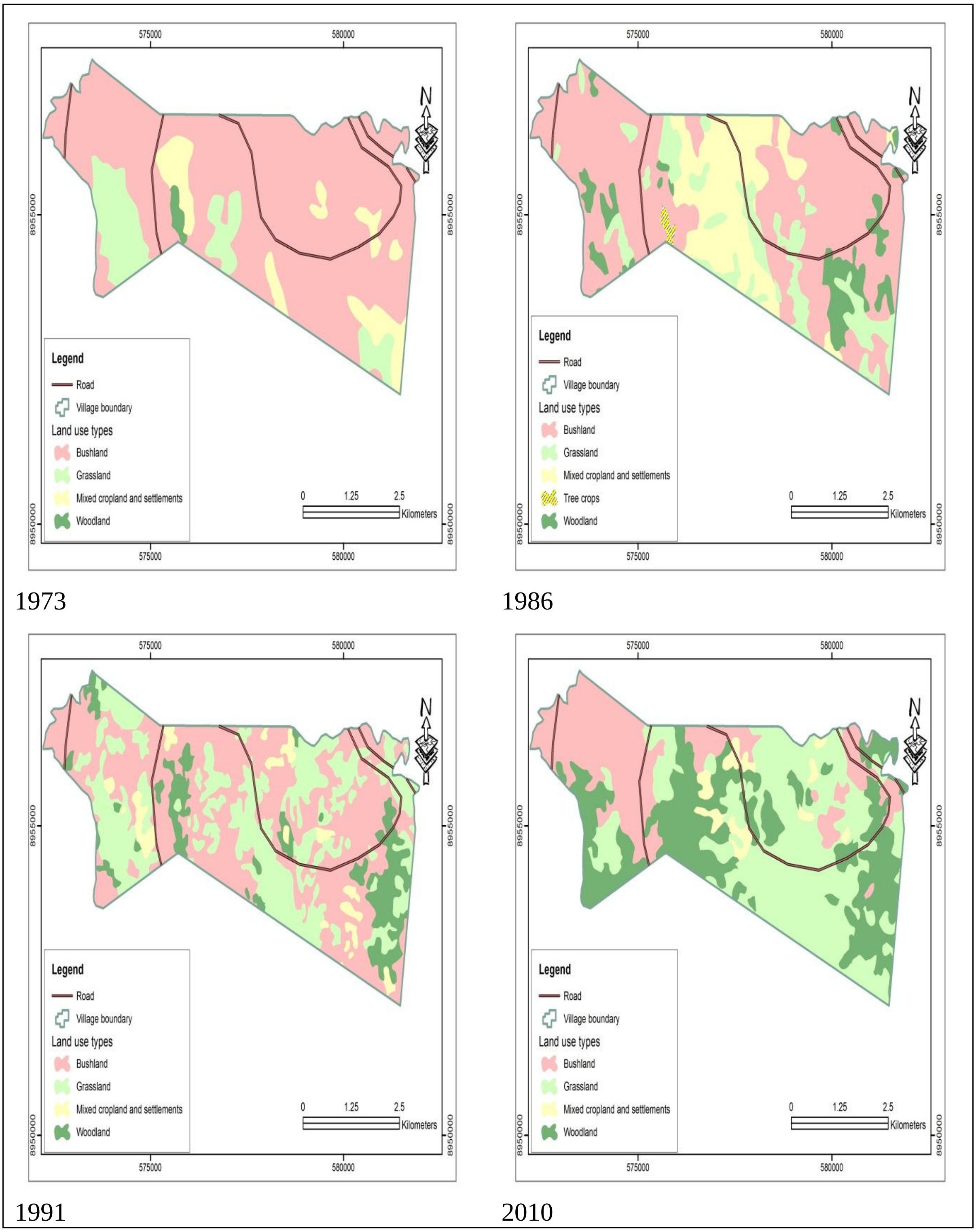


Figure 4.7 Land uses in Ilima village

and woodland are much more randomly distributed compared to cultivated land especially in 1973 and 1986. In these two periods, mixed cropland and tree crops categories are clustered in a few locations of the village land. The pattern in 1991 and 2010 is somewhat of a mixed nature, though natural vegetation is still dominating much of the village land. In 2010, for example, much of the area that had been covered by mixed cropland with settlements was extensively covered by woodland and grassland, indicating substitutions of the land uses.

4.2.6 Area coverage of land uses in the villages of the lowland zone

Like in the previous sample villages, a statistical analysis on the actual coverage of each land use for Katundulu and Ilima was done and the results are given in Table 4.4, which indicate that in Katundulu village bushland covered the largest part of the total land in 1973.

Table 4.4 Area coverage of land uses in Katundulu and Ilima villages

	Katundulu village								Ilima village							
Land uses*	1973		1986		1991		2010		1973		1986		1991		2010	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Bd	1078	58	333	18	919	50	769	42	2128	78	1606	59	1374	51	678	25
Gs	98	5	403	22	292	16	233	12	321	12	367	14	910	34	1098	40
Cm	309	17	694	38	38	2	278	15	238	9	506	19	119	4	96	4
Tc	271	15	266	14	253	13	382	21	0	0	12	0	1	0	1	0
Wo	95	5	155	8	349	19	189	10	26	1	222	8	309	11	840	31
Total	1851	100	1851	100	1851	100	1851	100	2713	100	2713	100	2713	100	2713	100

*Bd– Bushland; Gs– Grassland; Cm– Mixed cropland with settlements; Tc– Tree crops; Wo– Woodland

By 1986 the trend had changed and mixed cropland with settlement occupied a notable area, but this decreased to a small area only by 1991. In this same year, bushland, that had occupied more than half of the village land, occupied about a quarter of the land. For the two periods, i.e. 1991 and 2010, bushland remained a dominant land use followed by tree crops.

In Ilima village, for the four periods, bushland and grassland were the dominant land uses followed by woodland. In 1973 for example, bushland occupied more than three quarters of the village land whilst in 1986 and 1991 it occupied more than half of the total village land. Grassland and woodland coverage increased for all four periods especially towards the more recent 1991 and 2010 periods. Tree crops and mixed cropland with settlements occupied comparatively small areas. In summary, there was shrinkage of cultivated land in the villages of the lowland zone of the ecosystem. This could be indicative of a decline in and/or abandonment of agriculture in these villages. The spatial distribution of land use expressed in Figures 4.6 and 4.7 and a comparison of area coverage by each land use class for various years in Table 4.4 show that at different times natural vegetation was occupying a fairly substantial land portion in these villages of the lowland zone.

A general observation on the patterns and the trend of the various land uses in the six surveyed villages in the four periods is that some land uses were more dominant than others, hence an indication of their significance to land users. In 1973 mixed cropland with settlements was the common land use in the surveyed villages. From 1986 to 2010, mixed cropland with settlements covered the largest share in almost all villages particularly those in the highland zone, although the order of magnitude of spatial extent differed from year to year and from village to village. The land use dynamics, especially the increase of cultivated land is a typical indication of most rural areas that depend on agriculture as the main livelihood. Since crop cultivation, livestock grazing and settlements are the main land uses of the community their coverage have to respond to the needs. As the needs increase, some land has to be modified or converted into different uses to meet the needs and demands of the community.

In general, the results on actual area coverage of different land use categories showed shrinkage of areas covered by natural vegetation while cultivated land was increasing. This implies a change in land use where cultivated land expanded at the expense of natural vegetation. Expansion of cultivated land was especially apparent in the villages of the highland and middleland zones of the MRE. In the next section the precise quantification of changes in land use that have occurred in the study area for the four periods is presented.

4.3 LAND USE CHANGE IN THE MOUNT RUNGWE ECOSYSTEM

In Sections 4.1 and 4.2 the occurrence patterns and area coverage of the main land uses of Rungwe district and of the six surveyed villages representing the three agro-ecological zones of the MRE were presented. In this section the focus is on the detection of the actual change in land use at the district level and in the studied villages. The objective in this section was to assess the land use change in the area during the four periods from 1973 to 2010. The analysis of change in land use relied on the four land use maps derived from Landsat imagery and their GIS overlaying. Household survey information was also integrated to determine local people’s perception of land use change in their vicinity. The presentation starts once more with a general overview at the district level and then narrows the focus specifically to the zonally representative surveyed villages.

4.3.1 Nature and extent of land use change at district level

Post-classification comparison (PCC) through cross tabulation in ArcGIS showed that at one point in time each of the mapped land uses presented in Sections 4.1 and 4.2 were either modified or converted into other use types or remained unchanged for the entire study period. Coppin et al. (2004) indicated that at global level two main ecosystem changes can be distinguished: 1) land cover-conversion, i.e. the complete replacement of one cover type by another; and 2) land cover modification, i.e. more subtle changes that affect the character of the land cover without changing its overall classification. Similarly, in the spatial context, four types of changes can also be observed whereby spatial entities either (1) become a different category, (2) expand, shrink or alter shape, (3) shift position, or (4) fragment or coalesce (Khorram et al. 1999). In Rungwe district, a number of changes more or less similar to these two categorisations were detected. The change in land uses entailed both land cover conversion and modification. Due to conversion and modifications of the land use some expanded whilst others declined or shrank. The spatial distribution of land use change categories is illustrated in Figure 4.8. The figure shows change classification as the destination land use class only, and without indication of the original class (i.e. end use without origin indication). For the four time sequences, the conversion of natural vegetation to cultivation occurred mainly between 1973 and 1986, and between 1991 and 2010.

The processes of land use change that resulted in the patterns that were observed in Figure 4.8 are quantified in areal change in Table 4.5, covering the three interim study periods 1973-1986, 1986-1991, 1991-2010 and the overall period 1973-2010. The main processes involved conversion of one land use type to the other types and modification of the land use classes where their coverage was altered. Although change in land use was non-directional, almost all of the land use categories showed persistence to a certain degree, i.e. they were not completely replaced by a different use category.

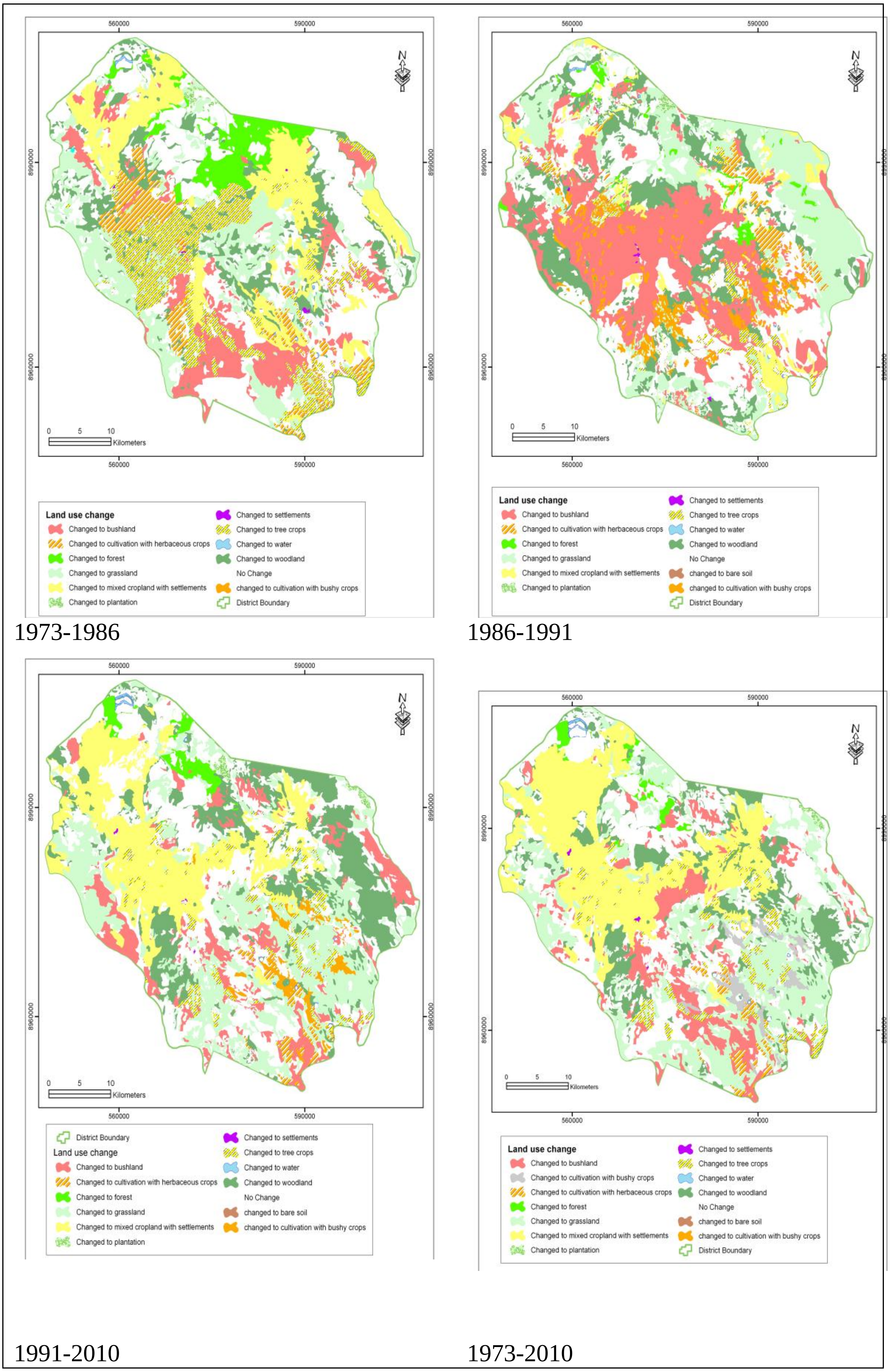


Figure 4.8 Trends of land use change in Rungwe district

Table 4.5 Cross-tabulation of land use change in Rungwe district

1973-1986	1973 Land use categories* (ha)												Total 1986
1986 LUC	**Wo**	**Ch**	**Gs**	**Cm**	**Tc**	**Bd**	**Wt**	**St**	**Fn**	**Bs**	**Cb**	**Pt**	
Wo	22 331	1023	9266	0	0	7638	35	0	753	0	838	42	41 926
Ch	2587	114	2351	0	22	2485	9	13	0	0	4040	0	11 621
Gs	9508	3019	14 304	0	68	16 344	12	0	263	23	238	391	44 170
Cm	5746	6329	6488	500	14	12 371	8	0	59	0	151	0	31 666
Tc	5592	3866	4939	0	401	9436	13	0	23	0	1624	0	25 894
Bd	7766	1230	12 312	0	63	20 129	63	0	24	0	161	0	41 748
Wt	124	0	21	0	0	55	376	0	1	0	0	0	577
St	0	11	0	0	0	88	0	3	0	0	13	0	115
Fn	6862	185	1524	1	0	1508	40	0	4428	0	18	230	14 796
Bs	0	0	0	0	0	0	0	0	0	0	0	0	0
Cb	0	0	0	0	0	0	0	0	0	0	0	0	0
Pt	0	68	230	0	0	194	25	0	16	1	0	1464	1998
Total 1973	60 516	15 845	51 435	501	568	70 248	581	16	5567	24	7083	2127	214 511

1986-1991	1986 Land use categories (ha)												
1991 LUC	**Wo**	**Ch**	**Gs**	**Cm**	**Tc**	**Bd**	**Wt**	**St**	**Fn**	**Bs**	**Cb**	**Pt**	**Total 1991**
Wo	13 415	643	13 277	2619	1642	4038	112	13	5811	0	0	289	41 859
Ch	928	337	401	2130	518	819	0	0	156	0	0	0	5289
Gs	13 300	1722	12 646	7032	2172	9045	32	50	4736	0	0	1088	51 823
Cm	1889	602	1573	9579	1694	3300	22	10	380	0	0	2	19 051
Tc	385	1059	854	528	2348	1124	5	1	169	0	0	0	6473
Bd	8834	5618	14 070	8456	14 026	21 443	42	35	239	0	0	120	72 883
Wt	42	12	10	5	10	29	351	0	66	0	0	14	539
St	15	18	26	10	39	11	0	6	0	0	0	0	125
Fn	1711	80	274	762	56	93	0	0	3239	0	0	156	6373
Bs	15	3	46	13	0	0	0	0	0	0	0	0	77
Cb	1392	1527	949	532	3389	1843	13	0	0	0	0	0	9645
Pt	0	0	44	0	0	0	0	0	0	0	0	329	373
Total 1986	41 926	11 621	44 170	31 666	25 894	41 748	577	115	14 796	0	0	1998	214 511

1991-2010	1991 Land use categories												
2010 LUC	**Wo**	**Ch**	**Gs**	**Cm**	**Tc**	**Bd**	**Wt**	**St**	**Fn**	**Bs**	**Cb**	**Pt**	**Total 2010**
Wo	14 791	1668	16 011	1391	647	8412	10	15	3035	16	794	0	46 790
Ch	601	0	490	208	374	738	1	0	0	0	89	0	2501
Gs	13 350	867	16 737	3756	1755	21 971	15	13	434	51	2280	371	61 600
Cm	4045	1985	6381	11 181	822	21 086	0	50	464	0	2039	0	48 053
Tc	727	507	631	610	1108	1560	5	2	72	1	1862	0	7085
Bd	4859	132	9679	1268	1302	16 604	9	4	294	2	1695	1	35 849
Wt	138	0	96	18	8	37	476	0	1	0	0	0	774
St	13	0	1	0	4	39	0	41	0	0	0	0	98
Fn	2718	0	940	126	0	37	21	0	2073	0	0	0	5915
Bs	23	0	369	0	0	22	0	0	0	0	0	0	414
Cb	427	130	87	355	453	2240	2	0	0	7	886	0	4587
Pt	167	0	401	138	0	137	0	0	0	0	0	1	844
Total 1991	41 859	5289	51 823	19 051	6473	72 883	539	125	6373	77	9645	373	214 510

1973-2010	1973 Land use categories												
2010 LUC	**Wo**	**Ch**	**Gs**	**Cm**	**Tc**	**Bd**	**Wt**	**St**	**Fn**	**Bs**	**Cb**	**Pt**	**Total 2010**
Wo	23 145	1169	10 245	6	12	10 178	17	0	1700	0	223	95	46 790
Ch	1213	0	200	0	20	1068	0	0	0	0	0	0	2501
Gs	13 395	2020	18 993	312	73	24 597	39	0	100	18	623	1430	61 600
Cm	9116	9032	9271	0	39	14 619	0	16	150	0	5810	0	48 053
Tc	2165	590	2248	0	356	1520	0	0	0	0	206	0	7085
Bd	8556	2894	8053	189	63	15 849	11	0	0	0	200	34	35 849
Wt	116	6	17	0	0	106	518	0	11	0	0	0	774
St	14	0	6	0	0	45	0	0	0	0	33	0	98
Fn	1491	17	462	0	5	239	0	0	3606	0	0	95	5915
Bs	28	0	345	0	0	41	0	0	0	0	0	0	414
Cb	1298	11	1391	0	0	1887	0	0	0	0	0	0	4587
Pt	0	150	250	0	0	21	0	0	0	6	0	417	844
Total 1973	60 537	15 889	51 481	507	568	70 170	585	16	5567	24	7095	2071	214 510

Values in cells along the diagonal of Table 4.5 indicate the area of all use categories that were not replaced by another, i.e. they retained their use status on original land areas. All land use classes above or below the diagonal indicate change in terms of either gains or losses to other uses. In 1973, for example, much of woodland was converted to grassland, bushland , natural forest, mixed cropland with settlements and cultivation with herbaceous crops and only 22 331 ha remained as woodland between 1973 and 1986. Mixed cropland that covered a fairly small land portion in 1973 increased significantly in 1986. The increase was at the expense of bushland, grassland, woodland and cultivation with herbaceous crops that were converted into mixed cropland with settlements during this period. Similarly, natural forests covered quite a significant land area in 1986, but declined greatly in 1991. A great part of the forests were converted to woodland, cultivation, grassland and bushland and the forests continued declining between 1991 and 2010.

Table 4.5 indicates an overall decrease of natural vegetation and expansion of cultivated land through conversions, whereas Table 4.6 provides areal figures for the absolute change of land use categories over three consecutive and for the full 37-year period. It shows

Table 4.6 Absolute change of land use classes in Rungwe district for the four periods

Land uses*	Net change							
	1973-1986		1986-1991		1991-2010		1973-2010	
	Ha	%	Ha	%	Ha	%	Ha	%
Wo	-18 590	-8	-67	0	4931	2	-13726	-6
Ch	-4224	-3	-6332	-3	-2788	-1	-13344	-7
Gs	-7265	-3	7653	3	9777	5	10165	5
Cm	31 165	15	-12 515	-6	29 002	13	47552	22
Tc	25 326	12	-19 421	-12	612	0	6517	3
Bd	-28 500	-14	31 135	15	-37034	-17	-34399	-16
Wt	-4	0	-38	0	235	0	193	0
St	99	0	10	0	-27	0	82	0
Fn	9229	4	-8553	-4	-458	0	348	0
Bs	-24	0	77	0	337	0	390	0
Cb	-7083	-3	9645	5	-5058	-2	-2496	-1
Pt	-129	0	-1625	-1	471	1	-1283	0

* Wo– Woodland; Ch–Cultivation with herbaceous crops; Gs– Grassland; Cm– Mixed cropland with settlements; Tc– Tree crops; Bd–Bushland; Wt–Water; St–Settlement; Fn–Natural forests; Bs–Bare soil; Cb– Cultivation with bushy crops; Pt–Plantation

that forest decreased between 1986 and 1991 while between 1991 and 2010 the coverage remained constant. Bushland declined between 1986 and 1991 as well as between 1991 and 2010. Woodland showed a decreasing trend between 1973 and 1986, but during the 1986 and 1991 periods it remained constant and from 1991 to 2010 the rate of decline was less intense compared with the two previous periods.

Cultivation increased in the periods from 1973 to 1986, and from 1991 to 2010, but it decreased slightly in the period between 1986 and 1991. From 1991 to 2010, mixed cropland with settlements increased over other land use categories. The increases of cultivated land in these two periods were at the expense of forest, bushland, woodland and grassland. For a period of 37 years, there was expansion of cultivated land – especially mixed cropland with settlements and tree crops. These two categories increased between 1973 and 1986 and between 1991 and 2010. The increase was at the expense of natural vegetation. Woodland, grassland and bushland decreased in the same period. It was only between 1986 and 1991 when bushland and grassland increased at the expense of cultivation. Table 4.6 also indicates that the area covered by forests only increased between 1973 and 1986, whereas during the remaining periods they were converted or cleared for cultivation and settlements. The trend and nature of change were identified through cross-tabulation techniques.

4.3.2 Nature and extent of land use change in the surveyed villages

In section 4.3.1 changes in land use on a broader scale were detailed. In this section a detailed analysis of change in land use in the six surveyed villages of MRE is provided. Similar cross-tabulatory techniques of identifying the transitions between and among land use classes were employed. In these sample villages there was a general trend of declining natural vegetation (i.e. bushland, woodland, grassland and forests) and expansion of cultivated land although the magnitude differed from village to village and zone to zone. The decline and expansion of these land uses were most apparent in the villages of highland and middleland zones of MRE as compared to villages of the lowland zone. The trend of change in land use is presented on zonal basis.

4.3.2.1 Patterns and trends of land use change in villages of the highland zone

Figure 4.9 indicates the pattern of land use change in Unyamwanga village from 1973-2010. The general pattern displayed here is that of a mixed nature where natural vegetation was converted to cultivated land and settlement lands and vice versa. Cross-tabulations for the villages are in the appendices.

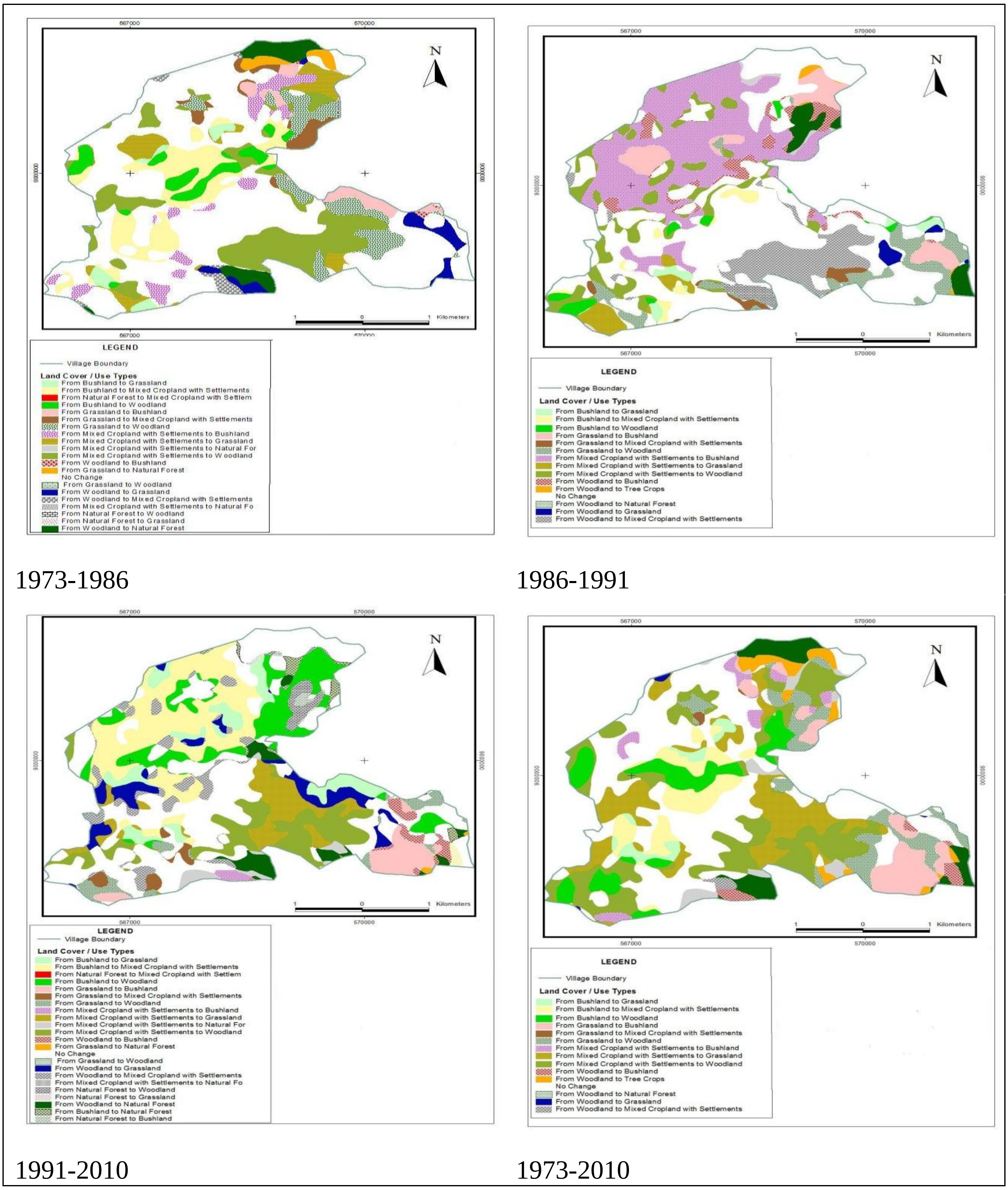


Figure 4.9 Land use change patterns in Unyamwanga village

Land conversion especially of natural vegetation to cultivated land was a phenomenon observed in Ndaga village as the maps on the spatial extent of land use change illustrates in Figure 4.10. The land use change maps indicate that each of the land uses were altered or modified in a way though the magnitude of change differed between and among land use categories.

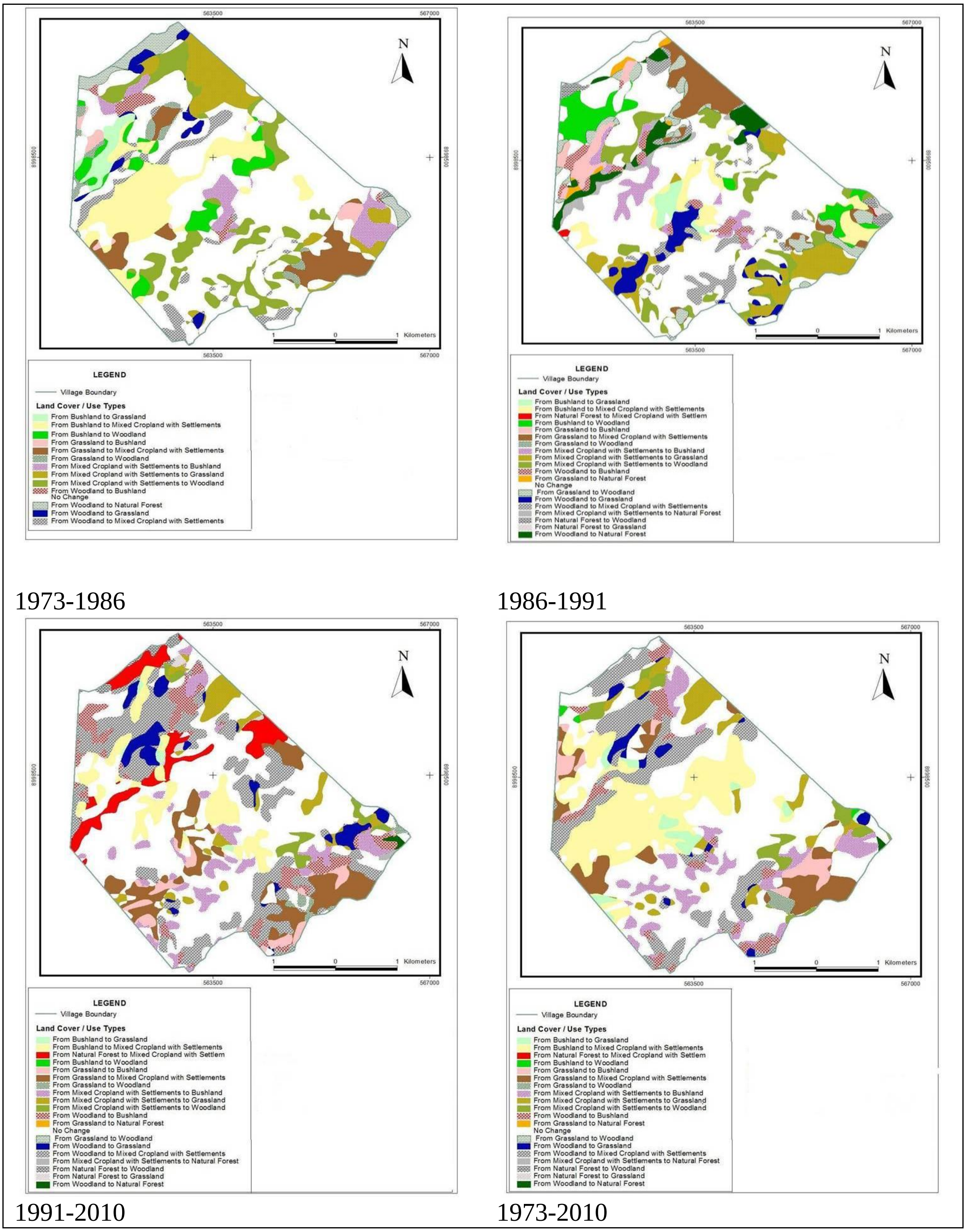


Figure 4.10 Land use change patterns in Ndaga village

Figure 4.9, used together with Table 4.7 for Unyamwanga village, shows that between 1973 and 1986 most land was converted from mixed cropland with settlements to woodland

and from bushland to mixed cropland with settlements, which led to declining coverage by mixed cropland with settlements and bushland.

Table 4.7 Absolute change in land use in villages of the highland zone

Land uses*	Unyamwanga								Ndaga							
	1973-1986		1986-1991		1991-2010		1973-2010		1973-1986		1986-1991		1991-2010		1973-2010	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Bd	-107	-8	362	26	-345	-5	-90	-7	-192	-11	-55	-3	122	7	-125	-7
Gs	-52	-3	-95	-7	129	9	-18	-1	22	2	7	0	-47	-2	-18	0
Cm	-123	-9	-302	-22	69	5	-356	-26	15	1	-82	-4	465	25	398	22
Fn	56	4	28	2	39	3	123	9	54	3	83	4	-128	-7	9	0
Wo	226	16	7	1	108	8	341	25	101	5	47	3	-412	-22	-264	-15

* Bd– Bushland; Gs– Grassland; Cm– Mixed cropland with settlements; Fn–Natural forests Wo– Woodland

Between 1986 and 1991 major conversions were from mixed cropland with settlements to bushland, followed by conversion from woodland to mixed cropland with settlements. Between 1991 and 2010 conversions were mostly from bushland to grassland, mixed cropland with settlements, natural forests and woodland. These four land uses increased especially grassland (9%) and woodland (8%). In fact, in this village the period between 1991 and 2010 was marked by an increase in grassland, woodland, mixed cropland with settlements and natural forests. Such expansion was at the expense of the bushland.

Between 1973 and 2010 the major conversion was from mixed cropland, bushland and grassland to either woodland and/or natural forests that increased by 25% and 9% in that order. Further details on cross-tabulation tables indicating the total coverage that each land use gained or lost at the expense of other land uses, and persistence of various land uses, in Unyamwanga village are provided in Appendix H of this dissertation.

With reference to Figure 4.10 and Table 4.7 it is evident that in Ndaga village much conversion was from bushland, grassland, woodland and natural forests to mixed cropland with settlements in almost all of the four periods. Significant expansion of mixed cropland with settlements in this village occurred between 1991 and 2010. Expansion of mixed cropland with settlements was at the expense of woodland, grassland and natural forests. A cross-tabulation of land use change transitions for Ndaga village from 1973-2010 is provided in Appendix I of this dissertation. In this cross-tabulation gain, losses and persistence of the various land use classes are indicated.

A general observation on the absolute changes in land use in the two villages representative of the highland zone given in Figures 4.9 and 4.10 and Table 4.7 is that of a considerable shrinkage of natural vegetation, mainly bushland, grassland and natural forests that decreased over time over the four periods and an increase of cultivated land. In short, the two villages in this zone displayed two trends in land use change. First, decline in natural vegetation and second, expansion of agricultural land that is much more dominant in Ndaga village. Over a period of 37 years, this land use increased by 22% in Ndaga village largely at the expense of other land uses. The driving forces behind such significant trends are explained later in Chapter 5.

4.3.2.2 Pattern and trends of land use change in villages of the middleland zone

The villages of the middleland zone displayed similar trends of change in the cultivated land to those of the highland zone. Kyimo's land use change maps presented in Figure 4.11 show that change was also non-directional. Each of the land uses were converted into other uses at certain points in time. From the land use change maps of this village it is clearly evident that three of the four periods (1973-1986, 1991-2010 and 1973-2010) entailed a considerable conversion of the natural vegetation as well as the cultivated land. The major land use change in these periods was the conversion from bushland to mixed cropland with settlements, from bushland to tree crops and from tree crops to mixed cropland with settlements.

The land use change pattern for Syukula village indicated in Figure 4.12 does not differ much from that of Kyimo village. The maps show a dominant conversion from natural vegetation to cultivated land particularly cultivation with bushy crops. There is also significant conversion of mixed cropland to either bushland or cultivation with bushy crops.

Table 4.8 summarises the absolute change in land uses in the two villages and it supports the patterns observed in Figures 4.11 and 4.12. Bushland, woodland and grassland were converted to other land uses particularly cultivated land and hence were reduced in terms of their coverage during almost the entire study period.

In Kyimo village for example, there was expansion of mixed cropland with settlements particularly between 1973 and 1986, and between 1991 and 2010. The expansion of mixed cropland with settlements in these periods was at the expense of not only bushland,

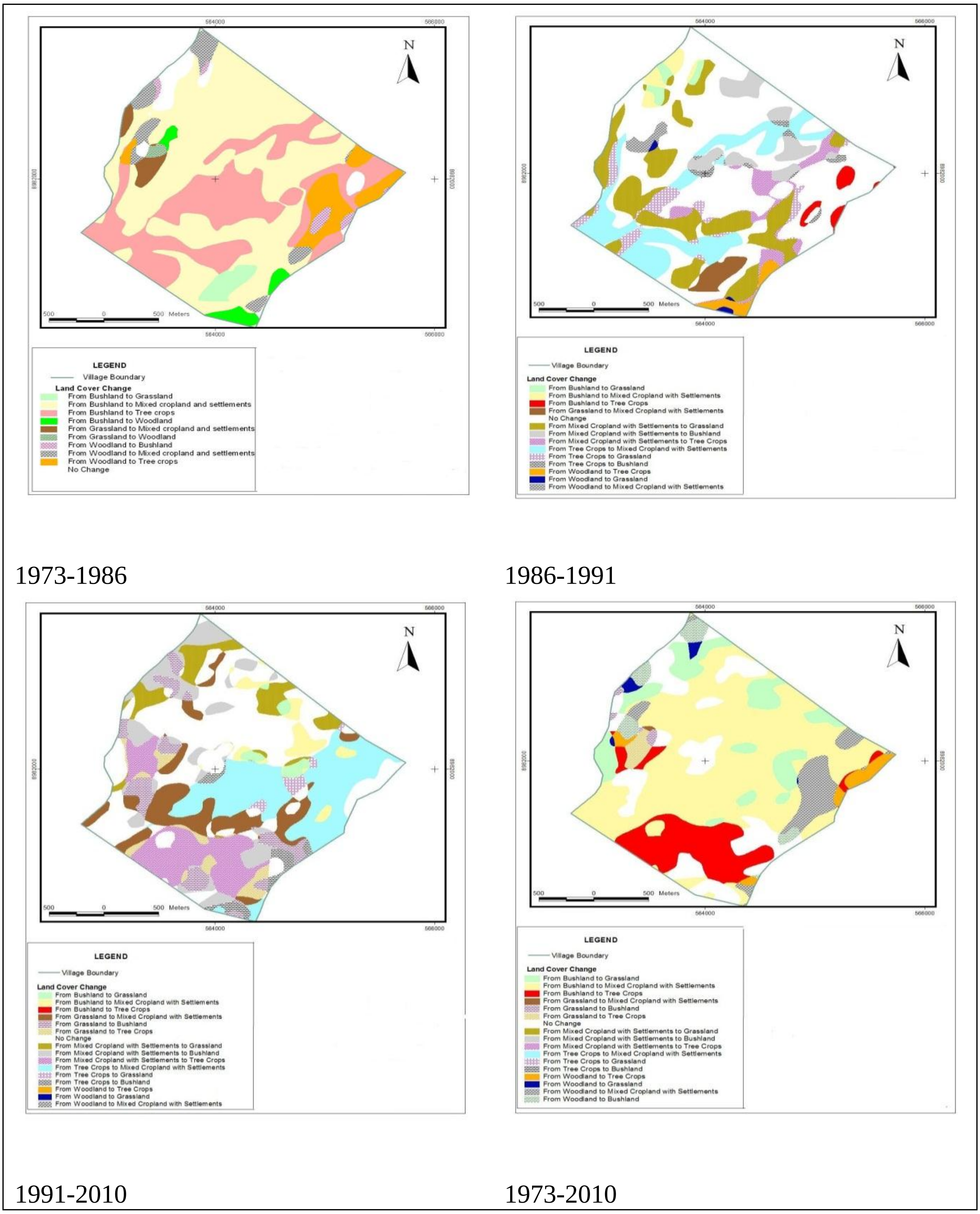


Figure 4.11 Land use change patterns in Kyimo village

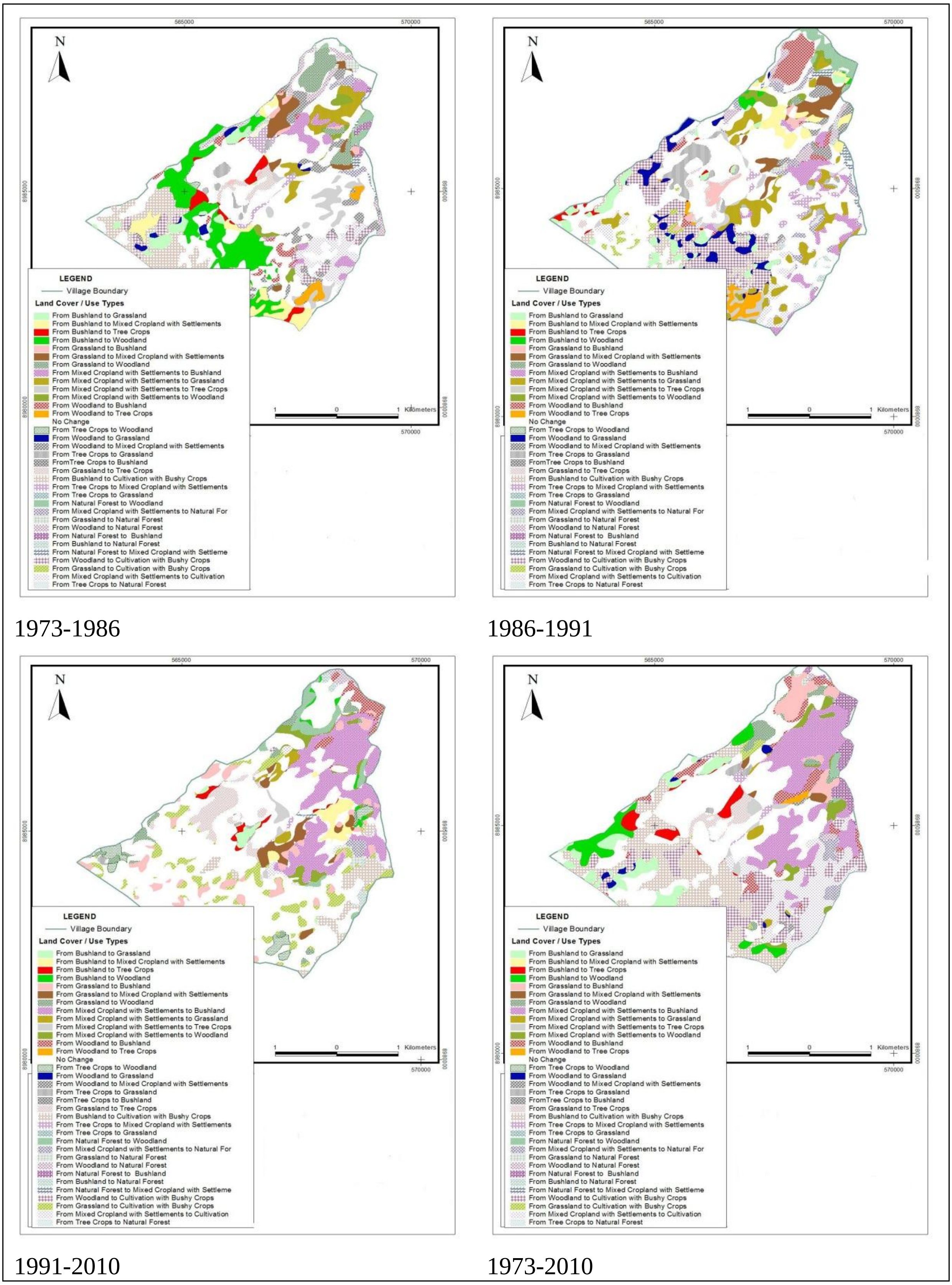


Figure 4.12 Land use change patterns in Syukula village

Table 4.8 Absolute change in land use in villages of the middleland zone

Land uses*	Kyimo								Syukula							
	1973-1986		1986-1991		1991-2010		1973-2010		1973-1986		1986-1991		1991-2010		1973-2010	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Bd	-399	-82	13	3	58	11	-327	-68	-479	-20	-6	-1	379	16	-106	-5
Gs	0	0	95	20	-48	-10	47	10	-32	-2	271	12	-310	-13	-71	-3
Cm	276	57	-42	-9	29	6	263	54	-23	-3	-211	-7	-274	-12	-508	-22
Tc	167	34	-52	-11	-39	-7	76	18	104	5	9	0	-14	0	100	5
Wo	-44	-9	14	3	0	0	58	12	73	5	-411	-19	149	7	-189	-7
Cb									306	13	286	12	201	8	793	33
Fn									50	2	62	3	-131	-6	-19	-1

*Bd– Bushland; Gs– Grassland; Cm– Mixed cropland with settlements; Tc–Tree crops; Wo– Woodland; Cb–Cultivation with bushy crops; Fn–Natural forests

grassland and woodland, but also the tree crops. From 1991 to 2010, grassland and tree crops declined in favour of mixed cropland and bushland while woodland was almost non-existent. For the 37-year periods, the statistics show that it is only bushland that declined significantly (-68%) in Kyimo village whereas other land uses increased especially, mixed cropland with settlements (by 54%) followed by the tree crops category (18%). A cross-tabulation indicating the transitions of the land use categories in Kyimo village over a period of 37 years is presented in Appendix J of this dissertation.

Unlike in Kyimo, there was a declining trend of mixed cropland with settlements in Syukula village over the four study periods. While the mixed cropland with settlements showed a declining trend, cultivation with bushy crops increased throughout the four periods. Cultivation with bushy crops expanded at the expense of a decline in mixed cropland with settlements, bushland, woodland and grassland. In this village, the transition between land use classes show that between 1973 and 1986 major conversions were from bushlands to cultivation with bushy crops and woodlands. In 1986 and 1991 conversion was from woodlands to cultivation with bushy crops and from mixed cropland with settlements to grassland. In 1991 and 2010 most conversions were from mixed cropland with settlements to bushland, from grassland to cultivation with bushy crops and from grassland to woodland. In between 1973 and 2010 the main conversions were from bushland and woodland to cultivation with bushy crops and from mixed cropland with settlements to bushland and cultivation of bushy crops.

Like in other villages a decline of bushland, woodland, grassland and natural forests was evident in Syukula village. Nevertheless, the highest decrease was observed in mixed cropland with settlements in all four periods. Comparatively, for a period of 37 years this category decreased by 22%, being the highest percentage followed by the woodland and bushland categories. Forests increased between 1973 and 1986, 1986 and 1991, but declined in the other two periods. All in all, over a period of 37 years, forests decreased by only one per cent. A cross-tabulation of the land use change in Syukula for the four periods of is presented in Appendix K of this dissertation.

4.3.2.3 Patterns and trends of land use change in villages of the lowland zone

While there were increases in land under agriculture in the villages of the highland and middleland zones, the situation was a bit different in the villages of the lowland zone. The analysis of the four satellite images showed that in these villages more of the agricultural land was being replaced by natural forests, woodland and grassland. In Katundulu village the analysis on land use change showed that mixed cropland, tree crops and bushland decreased significantly over the entire study period while grassland and woodland increased. The expansion of grassland and bushland was at the expense of the mixed cropland and tree crops especially between 1986 and 1991 and 1991 and 2010, as shown in Figure 4.13.

The land use change maps for Katundulu show that major changes occurred between 1973 and 1986 and 1986 and 1991. The conversion was mainly from bushland to grassland, mixed cropland with settlements and woodland, from mixed cropland with settlements to bushland and from grassland to bushland. The general and detailed cross-tabulation indicating gains, losses and persistence of the various land uses in Katundulu village are captured in Appendix L.

The land use change maps presented in Figure 4.14 show that grassland and bushland were expanding at the expense of other land uses in Ilima village. For the entire study period, major transitions in Ilima village were observed between 1973 and 2010 where, only 774 ha out of 2713 ha did not change to alternative usage. The transition was mainly from bushland to grassland and woodland, from grassland to woodland and from mixed cropland with settlements to grassland. A detailed cross-tabulation recorded as Appendix M in this dissertation shows gains, losses and persistence of the various land uses in Katundulu village.

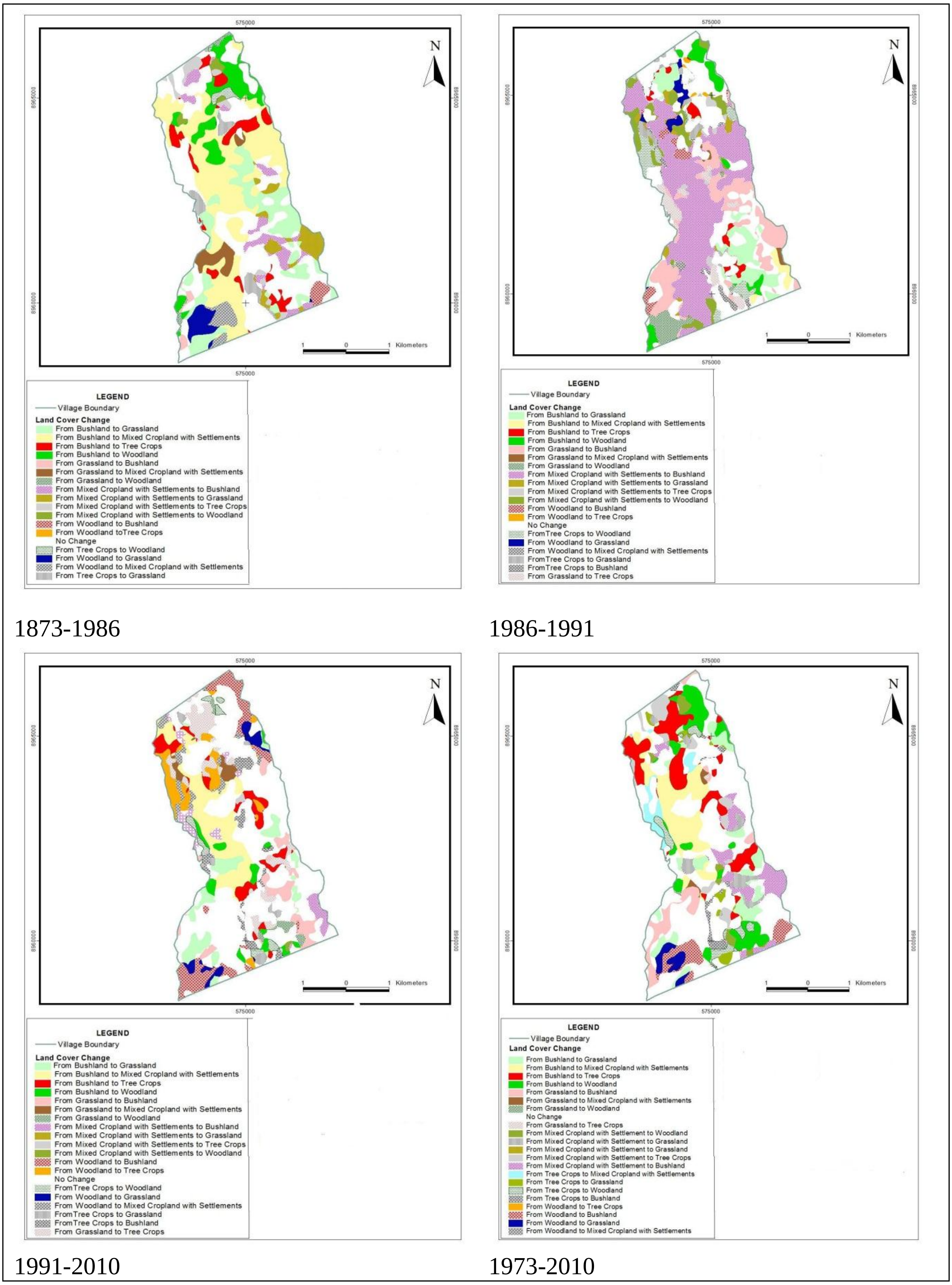


Figure 4.13 Land use change patterns in Katundulu village

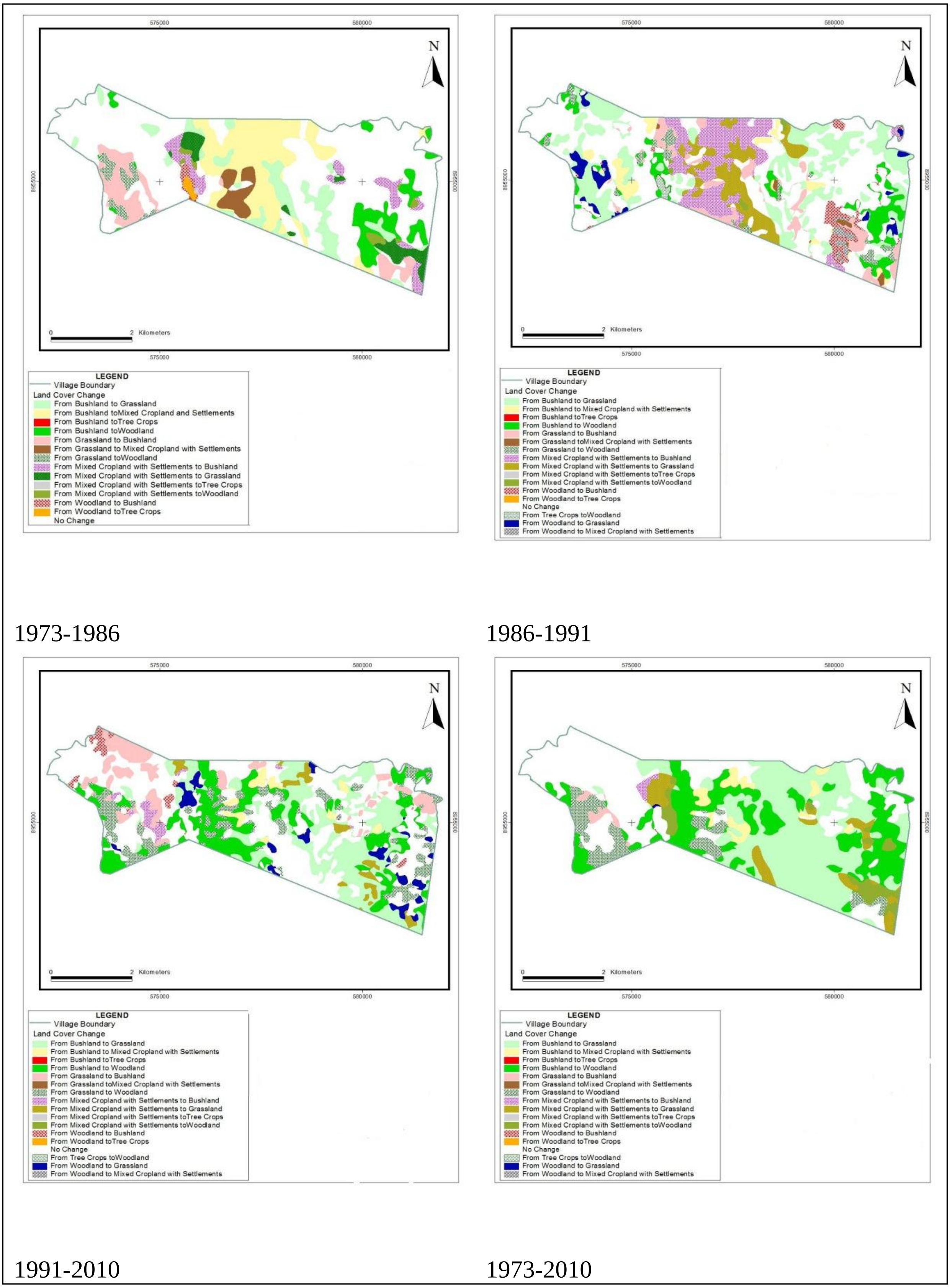


Figure 4.14 Land use change patterns in Ilima village

Table 4.9, which provides the net changes in land use for the four periods in the villages of the lowland zone, shows that, although natural vegetation seemed to decrease, much of it has almost remained constant or unchanged.

Table 4.9 Absolute change in land use in villages of the lowland zone

Land uses	Katundulu								Ilima							
	1973-1986		1986-1991		1991-2010		1973-2010		1973-1986		1986-1991		1991-2010		1973-2010	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Bd	-745	-40	586	32	-150	-8	-309	-16	-519	-19	-233	-9	-694	-26	-1446	-53
Gs	305	17	-111	-6	-59	-4	135	7	48	2	540	20	190	7	778	29
Cm	385	21	-656	-36	241	13	-31	-4	267	10	-383	-14	-26	-1	-142	-5
Tc	-5	-1	-13	-1	129	8	111	6	12	0	-12	0	0	0	0	0
Wo	60	3	194	11	-160	-9	94	5	192	7	88	3	531	20	811	30

*Bd– Bushland; Gs– Grassland; Cm– Mixed cropland with settlements; Tc– Tree crops; Wo– Woodland

In Katundulu village for example, the decrease in grassland is observed only in two periods. Grassland decreased between 1986 and 1991 and 1991 and 2010, respectively. Bushland decreased between 1973 and 1986, 1991 and 2010 and 1973 and 2010. Over a period of 37 years, it is only the bushland category that showed a decrease of 16%. In Ilima village, grassland and woodland constantly increased while bushland did not. Bushland on one hand, decreased in all four periods recording a total decrease of 53%. On the other hand the observed increases in the grassland and woodland categories in these villages were at the expense of bushlands and cultivated land (mixed cropland and tree crops) particularly in Ilima village.

The major change observed in the three zones of the MRE was expansion of agricultural land and replacement of natural vegetation by cultivated land in the highland and middleland zones. It was evident that over a period of 37 years mixed cropland with settlements increased by 22% and 54% in Ndaga and Kyimo respectively. Cultivation with bushy crops increased by 33% in Syukula whereas tree crops increased by 18% and 5% in Kyimo and Syukula respectively. This indicates that Mount Rungwe, like other mountain regions, is exposed to pressure from growing populations and expansion of agricultural land and settlements. Mbonile, Misana & Sokoni (2003) and Soini (2002) made similar observations of agricultural expansion in mountain areas on the slopes of Mt Kilimanjaro, indicating that this is a regional trend.

There was also a trend of decline in natural vegetation in the three zones although there were variations among villages. Bushland, for example, declined by 68%, 7% and 5% in Kyimo, Ndaga and Syukula villages in that order. In Ndaga village in particular, grassland and natural forests were completely replaced by agriculture and settlement land. Similar observation of the decline of bushland, grassland and woodland in mountain regions is recorded by Imbernon (1999), Misana, Sokoni & Mbonile (2012), Kangalawe (2010) and Soini (2002). This could indicate the shortages of land in mountainous regions and hence conversion of other land uses – especially natural vegetation.

Some villages in the study area underwent some degree of restoration of natural vegetation. In Kyimo, for instance, woodlands increased by 12% and grassland by 10% over a period of 37 years. In Unyamwanga, woodland increased by 25%, natural forests by 9% and bushland by 7% over the same period of time. However, such increases in natural vegetation were unexpectedly at the expense of cultivated land. In Unyamwanga village, mixed cropland with settlements decreased from 58% in 1973 to 32% in 2010 indicating a decrease of 26% over a period of 37 years. A similar trend in the decrease of the cultivated land was observed in Katundulu village and Ilima villages. The decreases were also in favour of bushland, grassland and woodland categories. In these three villages agriculture particularly the cultivation of tree crops and mixed cropland area declined. This could represent abandonment of agriculture or some rational decision on land use leading to restoration of nature. A similar result of declining arable land in mountainous areas is reported by Bakker et al. (2008) in four areas in the European mountains. In my study a number of factors could be behind such observed changes and these are explained later in Chapter 5.

4.4 EXPLANATION FOR LAND USE CHANGE

In addition to the analysis of the Landsat images of 1973, 1986, 1991 and 2010, a questionnaire was administered to respondents in order to understand the observed patterns and their change over the four periods. The aim was to gauge perception and understanding of local people regarding these land use changes in their area. According to Mbonile, Misana & Sokoni (2003) people's perceptions of land use is an important aspect in explaining land use change and their associated drivers as they afford the researcher a clear view of what the stakeholders perceive regarding the utilisation of natural resources. The interviews were led by observed onsite change in each village. Open and closed-ended questions regarding use and type of changes in land use (Questions 11, 36), status of forests (Question 38), parts of the mountain that are experiencing change (Question 39) and perceived livelihood function of forests (Question 31) were included in the main questionnaire (herein recorded as Appendix B). The results are presented in the next sections.

4.4.1 Perceived livelihood function of forests

Forests supply a variety of wood and non-wood forest products (NWFPs), offer employment, are a source of revenue through sale of wood and NWFPs and services, conserve soils, mitigate climate through sequestering carbon, are a source of water for domestic and industrial use, irrigation agriculture and power generation and have aesthetic, recreational, cultural, spiritual and scientific value (MNRT 2009). Forests contribute to agricultural stability by protecting the soil. Forests also contribute to poverty reduction. The majority of the rural communities depend heavily on forest products for their livelihoods. Miledge, Gelvas & Ahrends (2007), for example report that forests support the livelihoods of 87% of the rural poor in Eastern and Southern Africa although the continuing forest loss is a telling measure of the imbalance between human needs and wants and nature's capacity.

MRE is one of the areas in Tanzania endowed with forest resources (URT 2005). During this respondents confirmed that natural forest in the MRE plays an important role in their lives. As an ecosystem, the forest is an important resource because they believe it induces rainfall, protects watersheds and provides timber for house construction. Question 31 specifically required respondents to describe the goods and services they obtain from Mt Rungwe Forest Reserve. Of the questionnaire respondents 80% were able to state potential ecological, restoration, economic and sustenance values of the forests. Timber from wood, tourism attraction and firewood from wood featured most prominently as recorded in Table 4.10.

Table 4.10 Goods and services accrued from Mt Rungwe Forest Reserve

Forest resources	MRE villages (Number of responses)							
	Unyamwanga	Ndaga	Kyimo	Syukula	Katundulu	Ilima	Total	%
Timber from wood	2	30	21	25	0	0	78	20.3
Tourism attraction	12	35	4	8	0	1	60	15.6
Firewood from wood	2	27	6	9	10	3	57	14.8
Medicinal herbs	2	21	9	10	0	0	42	10.9
Inducing rainfall	0	16	3	6	0	3	28	7.3
Drinking water	1	9	7	4	0	0	21	5.5
Charcoal from wood	8	2	4	2	0	4	20	5.2
Wild products	2	1	0	0	0	0	3	0.8
Do not know	3	5	24	12	15	16	75	19.5
Total	32	146	78	76	25	27	384	100.0

These were followed by medicinal herbs, inducing rainfall, drinking water and charcoal from wood and wild products. Despite the potential goods and services accrued from Mt Rungwe Forest Reserve, as illustrated in Table 4.10 respondents' perceptions were that their ecosystem was under pressure, leading to declining forest areas as well as biodiversity. These perceptions were underscored through Question 38, which required respondents to describe the status of the forests in their vicinity. With regard to the time periods considered by this study i.e. 1970s, 1980s 1990s and 2010, respondents had varied perceptions about the status of the forests. As demonstrated in Table 4.11, the largest group of respondents (44.8%) thought that forests were declining; about one quarter perceived forest areas to have increased, and a similar contingent did not know whether forests were decreasing or increasing.

Table 4.11 Forest status in the MRE

Forest status	Enquiry target period					
	1970s-1980s	%	1980-1990s	%	1990-2010	%
Deteriorated	42	10.9	190	49.5	172	44.8
Improved	114	29.7	20	5.2	95	24.7
No change	25	6.5	26	6.8	19	4.9
Do not know	203	52.9	148	38.5	98	25.5
Total	384	100	384	100	384	100.0

In the three periods, the uncertain category was high, especially regarding the 1970s and 1980s. This was due to the fact that most respondents from the villages of the lowland zone lived far from the forests or were simply too young to remember what happened in those years. Nevertheless, the given responses are an indication that respondents were aware of land use change in their environment, especially the declining forest areas. The information provided by respondents also indicated the knowledge that local people have on different landscapes and land use changes over time, although they could not provide any sure measure of the actual amount of change in area coverage.

4.4.2 Changes in cultivated land area and type

Responses to Question 4 in the questionnaire (recorded as Appendix B) indicated that agriculture was the main occupation of the respondents. The majority (66.4%) relied solely on agriculture, 32.0% engaged in a combination of agriculture and government employment while the remaining 1.6% was involved in both agriculture and business. This indicates that, although some respondents were engaged in non-farm activities as well, agriculture remained the primary occupation. Respondents to Question 11 (in Appendix B) further indicated that they had acquired the land they are using now at different time periods in the past and through various means. Land acquisition of current occupants dates back to the 1940s and even before as reported in Table 4.12. However, the data in Table 4.12 reveals that most fields in use were acquired very recently – between 2000 and 2011, while a few of the fields were acquired between 1990 and 1999.

Table 4.12 Years of acquiring fields used by respondents

Periods	Responses				
	*Field1	Field 2	Field 3	Field 4	Field 5
1940-1949	2 (1%)	2 (0%)	2 (0%)	2 (0%)	0 (0%)
1950-1959	8 (2%)	6 (1%)	4 (1%)	3 (1%)	3 (1%)
1960-1969	15 (4%)	15(4%)	7 (2%)	5 (1%)	2 (1%)
1970-1979	44 (11%)	33 (9%)	25 (7%)	15 (4%)	5 (1%)
1980-1989	53 (14%)	38 (10%)	18 (5%)	10 (3%)	4 (1%)
1990-1999	93 (24%)	81(21%)	44 (12%)	22 (6%)	16 (4%)
2000-2010	113 (29%)	106 (28%)	77 (20%)	40 (10%)	25 (7%)
Do not know	56 (15%)	60 (16%)	53 (14%)	29 (8%)	13 (3%)
Not applicable	0	43 (11%)	148 (39%)	258 (67%)	316 (82%)
Total	384	384	384	384	384

*F1-5 indicates the total number of fields each respondent owned at a particular point of time.

Generally, the majority of the fields in use were acquired around the turn of the millennium. This spate of land acquisition is explained by the high rate of in-migration, commercialisation of land and the booming of potato production in the study villages. During this period and up to the present, land increasingly became a commodity and previous owners either sold or hired to in-migrants who were particularly commercial potato producers. With regard to land use, 43.7% of respondents confirmed that they had acquired land that was initially forest or bushland, while the remaining acquired cropped land, as indicated later in Table 4.13. Furthermore, respondents said that they have been changing the use of their land since they acquired it – an aspect explored further in the next sections.

4.4.2.1 Land uses at household level

Information on land use at household level was based on number of fields[23] accessed by households (Question 11 in Appendix B). In the surveyed villages, the number of fields for which the data were recorded during the surveys was limited to five for ease of analysis. In reality, only a fifth of households owned more than five fields. All the 384 respondents

[23] In this study the term fields is used to refer to a tract of land cultivated for the purpose of agricultural production. The reason behind the definition is related to the context of the study area where most respondents own several and very small tracts of land (of even less than an acre); and sometimes the field holdings are fragmented across different locations.

indicated having at least one field. Of these, 11% owned a single field, 27% owned two fields, 28% owned three fields, 16% owned four fields and 18% owned five or more fields. In all, a total of 1156 fields were reported on by the respondents, giving an average of three fields per respondent.

Having many fields, does not necessarily translate to large total land size holding as one would expect. In fact it may rather represent fragmentation of agricultural land. In the study area it was also observed that there are no large continuous fields of more than two or three hectares[24] that are owned by one farmer – but are invariably fragmented across locations. Having multiple fields may be seen not only as a strategy among farmers to cope with micro-ecological variation and exposure within the area, but also as an indication of land shortage, smallness of total land owned, inheritance practices and a vibrant property market operating efficiently. Multiple fields' ownership is, however, changing especially in Ndaga, where large scale[25] potato growers are consolidating small fields into single large production farms.

Table 4.13 shows various land uses by respondents since acquisition. In the three way categorisation of land use (i.e. before, after and current use of the land) food crop production

Table 4.13 Uses of land parcels since acquisition

Crops	Field 1			Field 2			Field 3			Field 4			Field 5		
	B_1	A_1	C_1	B_2	A_2	C_2	B_3	A_3	C_3	B_4	A_4	C_4	B_5	A_5	C_5
Banana	61	91	179	46	71	170	27	42	111	11	17	41	8	12	27
Maize	188	205	107	184	195	80	126	134	50	64	66	24	36	35	4
Forest/bush	60	0	0	49	0	0	35	0	0	19	0	0	5	0	0
Finger millet	5	4	2	5	1	0	3	0	0	2	3	0	1	0	0
Pyrethrum	11	7	0	7	4	0	11	9	0	10	4	0	5	2	0
Tea	7	7	6	7	7	5	8	8	7	2	3	3	4	4	3
Coffee	15	14	8	11	8	4	14	14	6	7	8	5	6	5	2
Pine trees	0	0	8	1	1	5	0	1	7	7	1	6	0	0	4
Potatoes	14	25	46	13	27	51	7	18	45	0	19	37	3	9	25
Rice	2	5	5	3	3	3	1	2	2	3	3	3	0	0	0
C/banana	21	23	11	14	15	5	4	7	5	1	2	2	0	1	2
Avocado	0	1	4	0	6	10	0	1	2	0	0	3	0	0	1
Cocoa	0	2	8	1	3	8	0	0	1	0	0	2	0	0	0
Total	**384**	**384**	**384**	**341**	**341**	**341**	**236**	**236**	**236**	**126**	**126**	**126**	**68**	**68**	**68**

Note: B– Land use before acquisition; A– Land use after acquisition; C– Current land use; 1– 5 Number of the field owned.

[24] In most cases (global and regional) the conventional measurement for a field or farm size is hectares, but in most rural areas in Tanzania (including in my study area) farmers measure their field sizes in acres. In this document the field sizes were recorded in acres, and where necessary conversion into hectares are made, for example (0.5 acres=0.20 ha; 1 acre=0.40 ha; 2 acres=0.80 ha) and so on.

[25] Large scale in this context refers to a situation where several small fields (owned by a single farmer or several farmers) at the same location are consolidated into a single farm, where it may range from 3 acres and above depending on the location of the fields. This practice is mainly in Ndaga and Unyamwanga villages where potatoes are now grown on commercial basis mainly by migrants. The large scale in this context therefore excludes tea plantations which are also grown on a large scale in the area.

was the main land use throughout, with some rotation of crop types. Apart from food crops, tree growing (mainly pines), emerged as an important current land use.

The first entry in column B_1 for example, indicates that, on their first field acquired, 61 respondents (16%) could confirm that bananas had been grown there before, that 91 (24%) declared they had subsequently used it for growing bananas and 179 (47%) were currently using it for that crop. This would point to an increasing trend of banana production. Maize production used to be even more prevalent (188 before, rising to 205), but seems to be losing (only 107 at present) to banana growing. These figures nevertheless confirm that most land has consistently been dedicated to banana and maize production than any other crops. For example, regarding the first field, the statistics in Table 4.13 indicate that the growing of crops such as pyrethrum, coffee and finger millet that was common before respondents acquired the fields, has either been discontinued or has declined after acquisition (A_1) or that the field is not currently in use at all (C_1).

The observed trend of the increases in cultivated land in these villages, representative of the three zones of MRE, concur with the URT (2010) report on the agricultural situation in Rungwe district from 2004 to 2010 (recorded in Table 1.2 in Chapter 1). The URT (2010) report for example, shows that production of the main crops such and maize, bananas and potatoes increased over the said years. On the one hand the increased production was due to increased acreage which means more land was converted to produce maize, bananas and potatoes, which are grown in these two zones. For example, the cultivated area for bananas increased from 24 000 ha to 24 710 ha between 2006 and 2007. Agricultural land under potatoes also increased from 5500 ha to 6750 ha, respectively. From 2007 to 2010 the production of these crops has doubled, which could mean more land is converted in order to produce these lucrative cash crops. On the other hand the use of improved seed varieties and chemical fertilisers has improved productivity per hectare. Despite the increased trend of land under agriculture in the villages of the highland and middleland zones of the MRE, there was a notable decrease in tree crops especially in the periods from 1973 to 1986 and 1991 to 2010.

At initial acquisition, also, none of the land had been planted with pines (except for field 4), avocados and cocoa trees. After acquiring the land, land use changed in a fair number of cases. For instance, no forest land remained as forest or even bushland, but all were converted to cropped lands. In fact, the trend on acquired fields in the study area shows a certain degree of crop replacement and conversion of forest land to crop production. A significant number of respondents started growing maize after acquiring fields. This is indicated by the number of responses regarding the use after acquisition. For example, a total of 205, 195, 134 and 66 respondents were growing maize in fields 1, 2, 3 and 4 in that order. At initial acquisition there was also an increase of respondents who were intercropping bananas with maize.

In the current use of various fields category it was indicated that none of the acquired land was still cropped with pyrethrum, finger millet or forested land. The majority of respondents were currently growing potatoes, maize and or bananas. For the five recorded fields, banana, maize and potatoes were the dominant crops followed by pine trees. Discussion with key informants revealed that pyrethrum farms have often been replaced by pine lots, and in some instances land used for food crop production (mainly maize) was no longer available for food production, as it had been converted into pine farms. Conversion of cropland to pine farms was, on the one hand, due to the shade that pines cast over the adjacent farmlands. As a result other farmers were also forced to convert their farms into tree lots as shade lowers productivity of maize or potato fields. Pensuk & Shrestha (2008) observe a similar situation in Southern Thailand where conversion of paddy to rubber was triggered by the same shading effect of the neighbouring rubber fields owned by fellow farmers.

On the other hand key informants noted that pine trees provide them not only with income from selling timber but also offer a source of firewood for their domestic use. To a large extent communal forests in the area are dwindling and firewood or timber cannot be gathered from reserved forests. Very often measures to conserve mountain and highland resources from further degradation have restricted population access to the ecosystem services and resources. Local communities have responded differently to the growing scarcity or limited access to forest products; these responses include the planting of their own trees for secure availability of firewood to meet day to day household needs. Sokoni (2001) and Mwanukuzi (2010) also observed a replacement of natural vegetation with eucalyptus and pines on the slopes of the Uporoto Mountains. According to these authors, contour bands, terraces and eucalyptus trees were replaced as they were perceived non-livelihood-based land management methods by local people as they were not satisfying their immediate livelihood needs.

The increase of woodlots offers an opportunity for better livelihoods. With limited access to firewood, this may alleviate energy shortages at the household level. Nevertheless, the planting of trees can compromise food security in the study area. There should be further investigation regarding this issue. Literature indicates that expanding on-farm tree cover could benefit agriculture by enhancing ecosystem services, including rainfall generation and soil conservation, thereby boosting productivity and livelihood ability. However, expanding on-farm tree growing can undermine the food security of subsistence farmers (Finighan 2011).

4.4.2.2 Change in cropping patterns and land management

Still with reference to Table 4.12, survey evidence points to the surveyed villages' experiencing changes in their cropping system as well. Practices change from intercropping to monocropping, and from perennial to annual crops. The number of respondents who indicated that they practised potato growing as monocrop (instead of intercropping), for example, increased from the period before acquisition to the current land use of the fields. A similar observation is made on bananas being intercropped with coffee. Such changes in the cropping patterns are a result of commercialisation of land that have resulted from the selling or hiring of land to different holders. With different holders the management and use of land changed, depending on the interest of the current owner or user of the particular land. A similar trend of change in the cropping patterns in some other villages in Rungwe District was also observed by Mwakalobo (1998).

The removal of contour bands on the sloping lands was noted during field observation in Unyamwanga and Ndaga villages. Before the replacement of pyrethrum and finger millet with potatoes, contour bands were the popular land management strategy in these villages. Currently, with commercialisation of potatoes, several small fields become consolidated into a single large field, thus contour bands are no longer used on the farms. Figure 4.15 provides graphic evidence of this trend.

Mwanukuzi (2010) reports a similar finding of the removal of contour bands on the slopes of the Uporoto Mountains indicating that abandonment of traditionally used land management startegies is becoming a general trend in the Southern Highlands of Tanzania, including Mount Rungwe. The abandonment of contour bands in the study villages was attributed to the replacement of some crops, mainly pyrethrum, with potatoes and adoption of tree crops such as avocado and cocoa.

Contour bands are still used in older fields where peas and pyrethrum are grown (a at left), while such practice has disappeared where potatoes (b and c at bottom) are cultivated.

Figure 4.15 Observed current altered cultivation practice of annual crops

Responding to Question 21 which required respondents to indicate various land management strategies they use on their farms, only 30.5% indicated that they use a variety of strategies. This is indicated in Table 4.14.

Table 4.14 Current land use management strategies used by respondents

Land management strategy	Number of responses	%
Burying grass	44	11.5
Use of lines and planting intervals	40	10.4
Mulching	24	6.2
Grass burning	6	1.6
Budding	3	0.8
None	267	69.5
Total	384	100.0

4.5 CHAPTER SUMMARY

This chapter presented the type of land uses in the study area as they manifested in 1973, 1986, 1991 and 2010 Landsat imagery. A total of 12 broad land use classes were identified and mapped at the district level while five to seven of these land use classes were mapped in the surveyed villages as they happened to occur on site. In all cases (at the district and in the surveyed villages), cultivated land was dominant, followed by bushland, grassland woodland and natural forests. The quantitative changes in the areas of various land use categories were presented in graphic and tabular formats. Areas of change for each year were compared for the four periods. The results indicated that natural vegetation was decreasing while cultivated land was increasing especially in the villages of the highland and middleland zones. There is however, a notable decline of agricultural land especially in the villages of the lowland zone. The reasons for the observed changes are further explained in the next chapter of this dissertation.

CHAPTER 5 DRIVING FORCES OF LAND USE CHANGE IN THE MOUNT RUNGWE ECOSYSTEM

In Chapter 4 land use and land use changes that have been observed in the MRE over a period of 37 years, were discussed. The general trend in land use changes depicted by Landsat images of 1973, 1986, 1991 and 2010 was the expansion of agricultural land at the expense of natural vegetation. Expansion of agriculture and decrease of natural vegetation was mainly observed in the villages of the highland and middleland zones as compared to the villages of the lowlands of MRE. These led to changes in the cropping patterns and intensification of fertilizer use, replacement of perennial crops with annuals, replacement of natural forest with cultivation and settlements and replacement of crops with pine trees. As shown in Figure 5.1 seven factors are isolated as having operated in the study area at different time periods to drive change. These derive from natural processes through a range of human dynamic and organisational origins.

Natural factors	Geographical endowment, pines invasion, fire incidences
Urbanisation	Urbanisation and market expansion
Technological	New crop varieties, fertiliser use, sawing machines
Government policies	Villagisation; Structural adjustments, sectoral policies, trade liberalisation
Economic	Trade and market liberalisation
Socio-cultural	Land fragmentation
Demographic	
	1960 1970 1980 1990 2000 2010

Source: Modified from Mbonile, Misana & Sokoni (2003)

Figure 5.1 Figure 5.1 Chronology of driving force influences on land use change in the MRE

In this chapter the driving forces listed schematically in Figure 5.1 and their variable influences leading to land use change in the MRE are assessed. The analysis follows the chronology and logic of Figure 5.1. The assessment of driving forces for land use changes can help with the explanation of past developments as well as speculative forecasting of future land use trends and patterns. The chapter is consequently structured into three main sections: the first section explains the direct and indirect drivers which are mainly attributable to the human impact on the natural environment; in the second section drivers related to natural phenomena are discussed; and the third section summarises the preceding discussions.

5.1 DIRECT AND INDIRECT DRIVING FORCES OF LAND USE CHANGE IN THE MRE

Changes in land use are direct and indirect consequences of human actions to secure essential resources. Direct drivers, also termed proximate or immediate drivers, as explained by Geist et al. (2006), Geist & Lambin (2002) and Lambin, Geist & Lepers (2003), originate from the intended use of the land by the people for their survival. Indirect drivers are the more contextual and developmental background factors that often underpin the direct driving forces. The drivers that could provide explanation for the observed patterns of land use and land use change in the MRE include variables or factors identifiable institutionally, in the area, and in its population. These are demographic, socio-cultural, economic, government-political, technological, locational and natural in nature. Each of these driving forces is discussed separately in the main sections of this chapter. However, this does not mean that each driving force works separately – instead they are interlinked, as various authors have pointed out (Antrop 2005; Rowcroft 2005; Bürgi, Hersperger & Schneeberger 2004).

5.1.1 Demographic factors as drivers of land use change

Natural population growth and in-migration are among the demographic factors that have caused land use changes in the study area. These two components of the demographic factor are considered to be the most important and hence their contributions to land use change in the study area are as explained forthwith.

5.1.1.1 Natural population growth

It is documented that between 1948 and 1967 the population of the Rungwe district grew at an annual rate of 2.2% (URT 1967). This figure, however, falls well below the average Tanzanian national population growth rate of 2.5% for the same period. Available data also show that the population of Rungwe increased from 235 314 in 1978 to 271 432 in 1988 and 307 270 in 2002 (URT 2010) at an average growth rate of 0.9% - a surprisingly low figure. This revealed lower growth rate compared to the 1960s is mostly explained by the high out-migration rate from the district reported since the 1950s – a trend that still continues today. Despite the low expected growth rate of Rungwe (0.9%) it is still one of the districts with the largest population in the Mbeya region after the Mbozi district with 513 600 people at the 2002 census. Other districts in the region have fairly moderate comparative population sizes: For example, Mbeya urban (265 586), Mbeya rural (254 069), Mbarali (234 101), Kyela (173 830) and Ileje (109 847) (URT 2003b). Thus, given the ongoing but fairly low trend of population growth in Rungwe district and the relatively limited available arable land of only 1668 km^2 for the whole district, pressure is mounting on natural resources such as land. The pressure manifests in small farm sizes, conversion of natural vegetation into cultivated land and settlements and land use intensification as Boserup's (1965) model postulates. In fact, land shortage compelled by population growth and the limited arable land in the district, has caused intensification of land and lack of fallow, a phenomenon Widgren & Sutton (2004) called “islands of intensification”. This means that, while the area in general may not be subject to high population densities, smaller areas appear as islands of population concentration. Census data for the individual study villages also reveal a similar varied increase and even decrease in the human population from 1978 to 2002 as indicated in Table 5.1. It is evident that for 1988 and 2002, Syukula, Ndaga and Kyimo villages have larger population sizes to other villages.

Table 5.1 Population of the study villages

Zones	Villages	Population per census year			Annual growth (%)
		1978	1988	2002	1988/2002
Highland	Unyamwanga	1749	1767	1436	-1.4
	Ndaga	1624	2018	3884	4.5
Middle	Kyimo	1173	1619	2448	2.9
	Syukula	3583	4162	4407	0.4
Lowland	Katundulu	1083	1155	952	-1.3
	Ilima	1990	2193	1913	-1

Source: (URT 1978; 1988; 2003a)

However, Ndaga and Kyimo have notably higher annual growth rates – well above the district growth rate of 0.9%. Satellite imagery analysis showed the expected matching increase in cultivated land in Ndaga, Kyimo and Syukula villages between 1991 and 2010. Cultivated land increased at the expense of decreasing grassland, woodland and natural forests. Such increases of cultivated land were certainly a result of increased population numbers.

Land shortage in the district is illustrated by the growing total number of fields on which households depend for both cash and food crop production as was explained in Chapter 4. With regard to the total land owned, my survey data showed that respondents own variably sized plots of land. At the individual level there was a notable variation in field sizes, an important feature of the agricultural land use system existing in the MRE. Spatial variance in field sizes reflects not only differences in land tenure and land availability, but also in the type of farming practised, variety and type of crops grown, and the extent/volume of inputs and outputs. In general, in terms of land holdings, well-off Tanzanians in village society are distinguished by having land holdings of more than four hectares, the middle class has less than four hectares while the poor have little or no land at all (Ellis & Mdoe 2003; Ellis & Freeman 2004). Approximating this classification in Table 5.2, some respondents must be classified as poor (land size smaller than 0.2 ha and thus approaching landlessness), about 40% own still less than 1 ha, and a similar contingent up to 2 ha. While less than 20% of the households own more than two hectares, very few can be considered above middle class in welfare status.

Table 5.2 Land size ownership per household

Total land owned/farmed (acres)	Total land owned (converted to ha)	Number of respondents	Percentage of Total
<0.5	0.2	3	1
0.5-1.0	0.2-0.4	56	15
1.1-2.0	0.4-0.8	90	23
2.1-3.0	0.8-1.2	84	22
3.1-5.0	1.2-2.0	86	23
>5.0	>2.0	65	16
Total		384	100

The statistics in Table 5.2 are based on Question 11 (in Appendix B). As noted earlier, 384 respondents reported owning a total of 1156 fields, or on average 3 fields per respondent. The 1156 fields represent a total land size of 530.8 ha. Therefore, on average each respondent owned 1.37 ha of land, indicating that although there are some households owning more, most respondents have land significantly less than the national average of 2.5-3.5 ha (URT 2007). A small land size is not a problem peculiar to the study area, since it is the state of affairs in most Sub- Saharan countries. Ellis & Freeman (2005) for example, studying rural livelihoods and poverty reduction strategies in four African countries (Tanzania, Kenya, Uganda and Malawi), noted a similar state of land holding sizes. These authors surveyed 1345 households in 37 villages in 9 districts across the four countries and their results show that in all countries, except Kenya, about three quarters of the sampled households owned less than 2 ha of land. A study in Ethiopia also indicates that the average farm size in that country is about 0.75 ha and has been declining for decades (Cross 2005). According to Cross (2005), farm size in most Sub-Saharan countries is a reflection of inheritance norms under customary and state land tenure, exhaustion of land, and a failure of rising populations to urbanise fast enough to stabilise available farmland per rural household. A similar case of customary influence on landholdings is apparent in the study area.

During my household survey, respondents were asked (Question 11) to identify the various modes used to acquire the fields they are cultivating. The modes included inheriting, purchasing, renting, village allocation, allocation by chief and land being given by relatives or friends. Table 5.3 lists the frequencies of inheritance by the number of fields owned. It shows that about 65% of all households inherited their land.

Table 5.3 Inheritance status of respondents' fields

Owned field number*	Frequency	% of Total	% of Inherited
0	137	35.7	
1	75	19.5	30.4
2	74	19.3	30.0
3	52	13.5	21.1
4	23	6.0	9.3
5	23	6.0	9.3
Total	384	100.0	100.0

*0- Fields obtained through other means; 1-5 Fields that were obtained through inheritance

This is especially the case for their first and second fields and the proportion for subsequent additions becoming less prevalent. This might mean that individual acumen and industriousness account for relatively few acquisitions (less than 40% of fields 3-5 were inherited).

5.1.1.2 Regional human migration

Population pressure does not only accelerate land shortages in the area but also triggers short and long distance out-migration that started in the 1950s and continues today. Odgaard (1986) and Mwamfupe (1998a) both showed that most young landless men chose labour migration over the alternative cash crop production as a way of making a living. Many of them migrated to Chunya (work on the Lupa gold fields) before its gold deposits declined in the 1930s. In the 1950s they migrated to South Africa (work in the gold mines), Zimbabwe (work in the coal mines), and Zambia (work in the copper mines). In 1963, after independence, the Tanzanian government prohibited labour migration to Zimbabwe and South Africa. Also, the labour demand in the Zambian copper belt had stabilised. The miner migrants were suddenly without cash earning opportunities. At the same time coffee production became much less lucrative due to the drop in world coffee prices and coffee plants in Rungwe became plagued by diseases (Wilson 1977). These compounding factors forced some Nyakyusa to migrate to neighbouring districts, particularly to Mbarali (in Usangu Plains) to become rice cultivators (Charnley 1997). According to the latter source, 20 to 30 ethnic groups migrate to the Usangu plains regularly and the most numerous immigrant rice cultivators in the plains are the Nyakyusa of Rungwe District. The Usangu plains with their fertile soils and many rivers were favoured by Nyakyusa as the plains are well-suited to rice irrigation.

Currently, the major population movements are directed to major urban centres within the region, such as Mbeya, Tukuyu, Kyela, Vwawa, Tunduma and Rujewa where migrants engage in both formal and informal sector occupations (Kayunze, Mwageni & Novaty 2006). There is also migration to other regions in the country, especially to metropolitan Dar es Salaam and regions with large scale plantations such as Morogoro and Kilimanjaro or mining regions such as Shinyanga (Mbonile 2005). In fact, it was the onset of these migratory systems that slightly alleviated the problem of population pressure by creating outlets for a young population, which was gradually becoming landless. The fact that out-migration is still practised in the study area, could explain the decline in agricultural land that was observed on the images especially in the lowland zone.

Although out-migration is high in the district, in-migration is also high, approximating dynamic equilibrium. As Table 5.4 (based on Question 8 in Appendix B) indicates, at village level, of the 384 respondents interviewed, one-third were born outside the surveyed villages, indicating that there has been pronounced in-movement of people from neighbouring villages, districts and regions in the study area.

Table 5.4 Place of birth of respondents

Respondents place of birth	Number of respondents per village							
	Unyamwanga	Ndaga	Kyimo	Syukula	Katundulu	Ilima	Total	%
Within the village	28	80	46	58	20	22	254	66.1
Within the ward	0	0	3	1	0	1	5	1.3
Within the district	1	24	25	11	2	2	65	16.9
Within the region	2	13	1	5	1	2	24	6.2
Outside the region	1	29	3	1	2	0	36	9.4
Total	32	146	78	76	25	27	384	100

The table further indicates that the main sources of in-migration into the surveyed villages are from within Rungwe district, followed by those outside the Mbeya region. Mbeya region also contributes a certain percentage of the in-migrants. Villagewise, Ndaga, Kyimo and Syukula have the highest number of in-migrants – to be expected since they are also the largest centres. In-migration has largely been driven by the search for agricultural, grazing and residential land, employment opportunities, and the desire to join relatives and families. The most notable reason was the practice of inter-marriage and people joining their relatives and families (i.e. social motivation). This category constituted 50% of all in-migration motivations. Access to agricultural, grazing and residential land constituted a significant 36% while availability of employment constituted 11%. Included in this category are civil servants and hired labourers. Only three per cent of the respondents migrated into the study villages due to availability of social services. Aside from local pull (attraction) factors that encourage in-migration, there are push factors in the areas of origin, mostly lack of agricultural land and employment opportunities.

Respondents were further asked (Question 10 in Appendix B) to indicate the year of migration into their current villages. Table 5.5 shows that migrants have moved to the study villages since the 1950s. During subsequent decades the number of in-migrants to the study villages increased steadily – indicating a clearly accelerating trickle of in-migrants over time. A notable feature in the in-migration statistics is that two-thirds of migrants arrived during the last two decades alone.

Table 5.5 Migration periods of migrants to the study area

Migration period	Villages of destination							
	Unyamwanga	Ndaga	Kyimo	Syukula	Katundulu	Ilima	Total number of in-migrants	%
1950-1959	0	4	2	1	0	0	7	5.4
1960-1969	0	7	5	1	0	2	15	11.5
1970-1979	1	6	1	5	0	2	15	11.5
1980-1989	0	5	7	3	3	0	18	13.8
1990-1999	1	18	7	4	1	0	31	23.8
2000-2010	2	26	10	4	1	1	44	33.8
Total	4	66	32	18	5	5	130	100.0

Interviews with village leaders and elders revealed that Ndaga village is experiencing an influx of people due to the recently booming growth of potato cultivation. Most of the previously uncultivated land has been converted to farms for potato production. The booming potato cultivation started in the early 1980s and gained significant impetus towards the 2000s. The village chairperson declares that the village's population growth has accelerated since 2000. For example, the 2002 national census recorded 3884 people, but in 2009 the village population had grown to 4500 people (Said 2011, pers com) indicating an annual growth rate of 2% for the last 7 years.

In terms of population increase and the need for land and settlements, the village chairperson added that Ibungu and Mwashatela hamlets (part of Ndaga village) were previously wetlands but that they have been drained artificially through cultivation and have been transformed into farms and settlement areas. This correlates with observations on the 2010 image regarding the expansion of mixed cropland with settlements in Ndaga village. Similarly, in Kyimo, the village executive officer indicated that in the last 10 years Nkuka and Ikata hamlets, that were grazing lands previously, have been converted into cultivated and settlement lands (Mwaijala 2011, pers com). These two cases are indicative of other lands (wetlands and grazing lands) being converted to agriculture and settlements to meet the needs and demands of the communities.

5.1.2 Socio-cultural factors leading to land fragmentation

This section is premised on the assumption that socio-cultural factors such as the reigning local system of land inheritance have caused land fragmentation and re-distribution between generations in the study area. Kadigi & Mbiha (2000) defined land fragmentation as the process whereby a larger holding is divided among several heirs leading to smaller remaining units per household. King & Burton (1982) defined land fragmentation as the state or extent of subdivision of holdings into discrete separate parcels that are dispersed over a wide area and are usually farmed as single units. Land fragmentation leads to reduction in the size of individual holdings or plots. Reasons for land fragmentation differ from society to society.

Culturally, the Nyakyusa had chieftainship organised in age-villages in which men of approximately the same age gathered irrespective of their lineage, and formed a village with their wives and children (Kurita 1993). One chiefdom contained 6-12 age-villages, with about 30 households each headed by a man. In these age-villages of the elderly, boys of ages between 10 and 12 from several villages in one chiefdom constructed their own huts and established a new boys' village on land that was not in use, but cultivated their fathers' fields. Married young men (culturally boys married in their twenties) would obtain their own allotted arable land not in use in the villages. In these age-villages, married young men could cultivate as much land as was needed to support their households, if there was no land, the age-villages of the elderly men and their households moved to less fertile or less convenient places to provide better places for new age-villages.

With the spread of perennial crops such as coffee and tea plantations in the 1960s, land became scarce in the district and it became difficult to find new areas to establish age-villages as a means to access land for the young men. This changed the Nyakyusa inheritance system, so that men began to inherit land from their fathers (Kurita 1993). Since the land holdings were too small to divide, often younger brothers could not access land for subsistence or cash crops, hence they were forced to migrate elsewhere as labourers in the mines or as cultivators. Small landholdings had necessitated intensification of agriculture.

In the Nyakyusa culture two types of fields exist: a homestead and an adjacent farmland called the *kaaja*[26] (my dwelling) and a distant farmland called *ngunda*[27] or *kyalo* Thus in inheritance culture it is the *kaaja* that is transferred from a father to sons and the land is divided equally among the sons (Kurita 1993). In the *ngunda* or *kyalo,* sons can cultivate the father's fields by borrowing them while the father is alive. After the death of the father, the first born son inherits the fields and then in many cases distributes them equally among his brothers. The culture of inheritance started in the 1960s and it is still practised among the Nyakyusa. As indicated in Table 5.3 two-thirds of the respondents reported inheritance as the means by which land is acquired in the study area, affirming the prominence of this practice. Just more than one-third bought their land, but these figures show that more than half of land is customary owned rather than bought or rented.

The Nyakyusa culture of inheritance has resulted in land fragmentation such that individual households own small pieces of land (see Table 5.2) that may perhaps not meet their food production and income needs. Respondents indicated having insufficient land for their agricultural activity requirements as recorded in Table 5.6. Here it is shown that more than one-third of the respondents reported having insufficient land for both food crops and for cash crops.

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[26] Kaaja is a basic unit of land-holding by the Nyakyusa of Rungwe. It is a space where each household settles and cultivates a home garden mainly of bananas, coffee and bamboo forests (*Arundinaria alpina*).The bamboo forests were used for constructing houses (Kurita 1993; Maruo 2007).

[27]Ngunda or kyalo is a field or plot within or outside the villages where the people cultivate annual or biennial crops such as maize, tea, rice, potatoes, beans and cassava (Maruo 2007).

Table 5.6 Land sufficiency expressed by respondents

Land sufficiency status	Land for food crops		Land for cash crops	
	Number of respondents	% of total	Number of respondents	% of total
Sufficient	247	64.3	243	63.3
Not sufficient	137	35.7	141	36.7
Total responses	384	100.0	384	100.0

In answers to Question 14 respondents reported a number of factors leading to the perceived insufficient land. Small land sizes accounted for 42% of the reported land insufficiency. Other factors such as large numbers of heirs in the household, soil infertility, lack of fertilisers and increased rate of urbanisation in some villages accounted for the remaining 58%. A correlation analysis was performed to test the strength of the relationship between land size and household size. Product moment correlation indicated that there is a strong positive relationship of 0.943 between household size and landholding size. This indicates that there is need and demand for land in this community.

Land shortage in the study area has resulted in intensification of agriculture and lack of fallow. Of the 384 respondents, 31% indicated that their farms do not lie fallow hence resulting in a decline in land productivity due to deterioration of soil fertility. Lack of fallow implies that agricultural practices on individual plots have been intensified for so long that productivity margins might have been reached as postulated by Boserup (1965).

Although declining land productivity was pointed out by the respondents 16.7 % of the respondents used none of the available land management strategies. Some respondents have been responding to decline in land productivity in a number of ways. It was observed that a single household sometimes employs one or more adjustment strategies. These strategies included intercropping, use of chemical fertilizers, manuring, taking off-farm employments, putting land to other uses and fallowing the land. Application of chemical fertilizer is their first and major strategy to increase soil fertility (52.9%), followed by manuring (26.3%) and intercropping practices (2.1%). Other strategies include mulching (0.8%), putting land to other uses (0.5%) and fallowing (0.5%). Agro-forestry (0.3%) is almost absent – on-farm trees are solely grown. Other respondents indicated taking off-farm employment as an alternative to increase income. With regard to intercropping, all the main crops are intercropped in combination: maize and potatoes, maize and beans, bananas and maize and bananas and coffee. Tea is the only perennial and bushy crop that is grown in pure monoculture stands. However, with increasing commercial production of potatoes, intercropping is a fading practice – symptomatic of a systemic change in the cropping and thus land use patterns in the MRE.

5.1.3 Economic factors

As pointed out in Chapter 2, Tanzania started implementing economic reforms through change of policies in the mid-1980s. The 1980s was a period which spawned various structural adjustment programmes (SAPs) under the instigation of the IMF and World Bank. SAPs commenced in the 1980s and are characterised by free-market economic prescriptions aimed at economic liberalisation and the privatisation of the major means of production, removal of subsidies on farm inputs, price reforms and institutional reforms (Kikula 1996; Shivji 2009) in all countries wishing to benefit from international development support programmes. In this section there is an analysis of how the structural and liberalisation aspects of the economic reforms have affected and are influencing land use change in the study area. The discussion adopts a chronological framework.

5.1.3.1 Structural adjustments

Coffee and tea were introduced as cash crops in Rungwe in the early 1930s. Between the 1940s and 1950s up to the early 1960s, coffee and tea production had become well established. During this period much land that had been used for subsistence cultivation was converted to coffee and tea production (Wilson 1977). Apart from rapid population growth, the spread and expansion of coffee production therefore became a major cause of land shortage in Rungwe (Odgaard 1986) and it slowly displaced the age-village system. With the spread and expansion of coffee and tea farms, areas to establish age-villages became scarce and family elders became unwilling to transfer their land to juniors. Coffee as product had increased in value and had became a substantial source of income.

The onset of structural adjustment programmes, particularly market liberalisation, removal of subsidies and price reforms resulted in changes in smallholder farming systems and cropping patterns in the area. Already prior to market reforms, substantial chemical fertilizer input and application to soils had become established in the district – mainly in the coffee, tea and maize fields. This was partly a result of the government fertilizer subsidy policy (Turuka 1995) which benefited the southern highlands including Rungwe district due to its climate that favoured such practices (Bryceson 1990). Before the structural adjustment programmes of the mid-1980s, over 65% of government subsidized fertilizer and insecticides was allocated to farmers in the southern highlands, mainly for coffee and maize production. Such government subsidised fertilizer was no longer available following the implementation of SAP policies.

The removal of government subsidies for fertilizers and insecticides therefore affected coffee producers as the coffee trees fell prone to berry diseases in the absence of insecticide use (URT 2010). This compelled farmers to uproot the coffee trees and some switched to crops that required fewer farm inputs, because coffee farming had become unprofitable (Anderson 1996; Mwakalobo 1998). A report by the Tanzania Tea Authority (TTA) (1997), showed that coffee production in Rungwe declined from 248 950 tonnes in 1992 to 219 700 and 185 614 tonnes in 1994 and 1995, respectively. The report also showed that tea production declined by 50% from 11629.8 tonnes in 1991/92 to 5757 tonnes in 1995/96. Decline in production was related to increased cost of production resulting from the removal of government subsidies, delay in payments for the crops sold and a drop in the price for tea and coffee crops.

In the study area, satellite imagery shows that between 1986 and 1991 the tree crops (mainly coffee) decreased in the four village areas of the middleland and lowland zones, which were mainly coffee belt zones. Kyimo village, for example, used to be prominent in coffee production but this is no longer the case. According to a weekly market sale it has now become the main banana trading centre in the district. Ndaga and Unyamwanga villages, that used to be centres for pyrethrum production, are now centres for potato production. Potatoes as crops are comparable to coffee in the sense that their production also demands extensive capital inputs; they are disease prone and are subject to tuber degeneration (Anderson 1996). However, potatoes have advantages in that they can be used for home consumption, profit levels are higher and they are grown on a seasonal basis – unlike coffee. As a result potatoes have become a profitable cash crop for the people in the highland zones, leading to the replacement of earlier crop production types.

5.1.3.2 Trade and market liberalisation

Apart from removal of government subsidies on inputs, conditions for coffee production were exacerbated by the lower prices of coffee on the world market in the early 1990s. This forced most farmers in the middleland and lowland zones of the MRE to convert their coffee farms (Anderson 1996; Mwakalobo 1998) into banana farms. Before the 1970s pyrethrum and finger millet were also major cash crops in Ndaga and Unyamwanga villages of the highland zone of the MRE. In the 1970s, however, pyrethrum production in Tanzania also collapsed because of falling world market prices (Anderson 1996). The lower prices that coffee and pyrethrum fetched on the world market resulted in a decrease in acreage under these crops and farmers even refraining from their production altogether. Household surveys in my study in Ndaga and Unyamwanga villages show that from the 1990s farmers have shifted from growing pyrethrum and finger millet to potatoes and pine trees for reasons of economic yield. Market failure of traditional crops such as coffee, tea and pyrethrum, constrained farmers to such an extent that they could no longer continue to depend on these crops as sources of income.

As a result of the foregoing, farmers in the highland and middleland zones of the MRE have turned their attention to crops such as potatoes, bananas and timber. The economic benefits, ready availability of markets and good prices for these crops have motivated change from production for domestic consumption to production for market sales. During the1980s, changing consumption patterns in Dar es Salaam, on the one hand, stimulated demand for potatoes production due to the elevated consumption of processed potato chips (Anderson 1996). Economic liberalisation in the 1990s on the other hand, opened more domestic and international markets for agricultural crops. Bananas as a crop, for example, have an expanded market inside and outside the region. They are sold in large cities such as Dar es Salaam and are exported to South Africa, Zambia, Malawi, Dubai and Zaire (Samwel 2007). My surveys in the lowland zone, particularly in Ilima village, proved that the price and availability of improved varieties of cocoa have encouraged farmers to grow cocoa instead of coffee. The Ilima village chairperson confirms this observation with reference to cocoa production in his village:

> *"[28]In this village agriculture employs about 95% of the residents. Mostly we cultivate maize, cassava, rice, groundnuts and beans. However, rice needs a lot of fertilizer. Most farmers have been failing to cultivate because of lack of fertilizers. Before the year 2000 a few farmers had cocoa trees. This was because it was not preferred like coffee as a cash crop in our area. Cocoa thrived much in a nearby district (Kyela*

[28]This and other personal communication extracts/quotation from respondents are my own translations based on original Swahili texts.

district). After the collapse of coffee, today about 50% of the residents here have cocoa farms. The main reasons are that cocoa has good price (3500 Tsh per kilogram) and it does not need pesticides and fertilizers. Again there is a cocoa farmer organisation (group) of 10 people (I am the chairperson of the group) that sells cocoa seedlings to villagers at a cheap price. Each seedling is sold at 150 Tsh. The district council provides pesticides when the seedlings are still in the yards. The villagers are provided with education on how to plant and take care of the seedlings until they mature. For this year (2011) we have sold 5000 seedlings to the villagers. Most villagers here have realised that having a cocoa farm is a sign of being rich/wealthier unlike the one who owns a shop" (Magila 2011, pers com).

As already pointed out, liberalisation of the economy promoted the participation of the private sector in agricultural production in the study area. Following the removal of government subsidies, private traders on the one hand started to supply agricultural inputs and thus facilitated intensification of agriculture through the general use of chemical fertilizers. On the other hand, the private sector was encouraged to invest in land for production on a fairly large scale. In Ndaga village, there has been a significant involvement of absentee farmers on whose ground potatoes are cultivated on a comparatively large-scale mainly for commercial purposes. This has translated to conversion of grassland, woodland and natural forests into cultivated land. Consequently, the freedom of the private sector to participate in agricultural production and distribution as well as the efficient marketing of agricultural produce has contributed significantly to land use changes in the MRE.

Generally, the availability of markets and the demand for agricultural products, mainly by the urban population within the district, the region, nationally in cities such as Dar es Salaam, Arusha and Mbeya and linkages with the international world, have expanded market opportunities. This in turn stimulates intensive cultivation of potatoes and bananas in the area resulting in profound changes to the farming systems in the study area. This finding is supported by Ponte (1998), who noted that economic reforms under structural adjustment programmes in Tanzania since 1984 have brought about a wave of changes in farming practice and rural livelihoods. The finding is also in line with that of Pensuk & Shrestha (2008) who indicate that before the 1990s, rice was the main crop cultivated in the Phatthalung watershed of Thailand, but that in the last 30 years rubber production, which formerly occupied 44% of the total land area, had increased to 61%. The motivation for land use conversion and modification was derived from the expected gain in income from cultivating rubber crops and the higher price of rubber compared to that of other crops. Braimoh (2009) also shows that the domestic cropland expansion rate of rice cultivation in Ghana and the preparation of new plots were driven by the high price of rice.

Jayasuriya (2001) and De Jong (2001) also noted that higher prices for agro-forestry products have often stimulated conversion of natural forests (and sometimes even reforestation of agricultural or bare land) in southern Thailand, Malaysia, the Philippines and Indonesia. Similarly, Mbonile (1999) reported that farmers in Pangani River basin changed their farming systems from cultivation of food crops and traditional cash crops to flowers for which a large demand exists in Western Europe. This shows that farmers respond to economic opportunities as argued by Bockstael & Irwin (2000) from the market theory perspective. Thus, it is clear that market changes in terms of price incentives, accessibility to markets and level of technology available to farmers, strongly influence the ways in which farmers change land usage.

5.1.4 Government policies

Official government policies tend to influence human behaviour in particular sectors of the economy in order to achieve desired national or regional development goals and objectives (Ostrom 2009). Some of such government policies may have adverse impacts on land use and the management of land resources in general (Bray et al 2004; Jepson et al. 2001). In this section there is a discussion on the ways in which past and present Tanzanian national policies have influenced changes in land use in the study area. The discussion is specifically based on government policies regulating the use and access to forest, agriculture, energy and the famous villagisation programme. The analysis of these policies and their perceived effect on land use change are mostly dependent on the review of relevant policy documents and information gathered from key informants.

5.1.4.1 Villagisation programme

As noted earlier in Chapter 2, the post independent government of Tanzania adopted a socialistic, self-reliance policy, under which the villagisation programmes in the mid-1970s forced rural populations to move into what were called Ujamaa villages (Kikula 1996). Ndaga and Unyamwanga villages were formed during this resettlement scheme of the 1970s (URT 2011), while the other four sample villages involved in this study were not. According to Kurita (1993), Ujamaa was not so forcibly instituted in the Rungwe District because of its relatively large population, and consequently the villagisation process did not affect the study area as much as it did elsewhere in Tanzania. However, during my surveys in Ndaga and Unyamwanga villages, discussions with village leaders and elders show that the villagisation process affected them in terms of land use as agricultural farms were either converted into settlements or were abandoned because occupants had to move.

In Ndaga specifically, key informants said that in 1967 the Mbeya-Kyela tarmac road was built and that in 1974, following this construction, the village was relocated from its former location on steep slopes to a location near the road. Among other things the relocation aimed to bring the village and its occupants closer to the road, the primary school (established in 1970) and the village dispensary. This reorganisation may have encouraged an influx of other neighbouring villagers and migrants into this and similar villages and hence it had an effect on land use pattern due to the pressure that the larger population numbers exerted on the prevalent land resources. The satellite image analysis of the Ndaga area between 1973 and 1986 found a decrease in area covered by bushland and an increase in mixed cropland with settlements. This indicated that bushland was cleared for field cultivation and settlement construction during this period. Similarly, between 1973 and 1986 the analysis showed a decrease of mixed cropland and bushland in Unyamwanga village while woodland increased. This is an indication that some farms were left uncultivated and the land reverted to natural woodland coverage.

5.1.4.2 Forest protection policy and the Forest Act

Colonial and post-independence forest policies and Acts have been influential in shaping the past and current resource use patterns and the concomitant land use change in the MRE. From the 1930s to the 1950s, for example, six forest reserves were demarcated in the district. Sawago (907 ha) was declared in 1937, Livingstone (26 366 ha) in 1940, Rungwe (13 652 ha) in 1949, Kitweli (234 ha) in 1952, Kyejo (693 ha) in 1956 and Masukulu (589 ha) in 1958 (McKone & Walzem 1994). In 1959 the Kiwira plantation (1243 ha) was also established from two blocks, one from Rungwe Forest Reserve and the other one from Livingstone Reserve (URT 2011a). In 2009, Mt Rungwe Forest Reserve was declared a Nature Reserve (URT 2011a). All these declarations are in relation to the then colonial forest policy and the post-independence national forest policy (1998) and The Forest Act (2002) which emphasise the protection of forests.

The establishment of these reserves and plantations in the MRE reduced land available to local communities for grazing and farming by a total of 42 441 ha of the whole district. In a way they accelerated the onset of land shortages in the area and encouraged out-migration of affected populations (Odgaard 1986). This could explain the recorded change in land use and resource use patterns, which manifested as the conversion of woodlands and bushlands to cultivated land and settlements, and also the growth of natural woodland.

According to the GIS analysis (see Chapter 4) for the entire period of 37 years, conversion of woodlands and bushlands to cultivated land was apparent not only at the district level but also in the sample villages, particularly those of the highland and middleland zones of MRE. The GIS analysis further reveals that natural forests and plantations were also converted to cultivated land leading to their decline especially between 1986 and 1991 and 1991 and 2010. This could indicate the community's and government's laxity regarding the stewardship of natural resources including forests. Despite the fact that most forests in the MRE are reserved, and the fact that the country adopted a forest policy in 1998 and enacted legislature in 2002, both encouraging sustainable use of forest resources and prohibiting illegal activities particularly in the reserved forests, forests continue to degrade.

During this study an interview was conducted with the District Natural Resources Officer to underscore the status of the forests and the challenges facing their management in the district. The District Natural Resources Officer confirmed among other factors, the laxity of the central government in managing forests, with particular emphasis on the Mt Rungwe Forest reserve:

> *"Apart from the natural factors (fires and pine invasions) human activities are also causing damage in the forest reserve especially farm encroachment, hunting and charcoal making. Animal species such as aboti dyka (digidigi) has been overhunted. Again people are living very close to the reserve boundary. There is no buffer zone like in Kilimanjaro Forest Reserve where there is a half mile strip inside the National Park. The forest (Mt Rungwe Forest Reserve) has been declared a reserve since 1941, but for the last 20 years the government has not played its role in the management of the reserve. There has been no clearance or trenches put in place on the existing boundary. This has led to farm encroachment in the forest boundary and other illegal activities like hunting and logging as the forest was unmanned. Today*

about 20 metres from the buffer zone have been encroached by establishing farms regardless of the steepness" (Chibwaye 2011, pers com).

This interview confirms the view that forest reserves in the district are heavily encroached upon because they are accessible by surrounding communities. Also they are not frequently patrolled by government officials. This might also indicate that, despite the biodiversity and catchment value of the MRE, it is threatened by unsustainable use of natural resources and a general lack of awareness of the quality and importance of dwindling natural resources (such as forests) in the area.

5.1.4.3 Agricultural development policy

Since 1930 colonial agricultural policies introduced industrial crops such as coffee, tea and pyrethrum in the Rungwe District (Wilson 1977) and land was converted from subsistence cultivation and used for the production of cash products. By the 1960s, coffee and tea production had spread to most parts of the Rungwe district, particularly in the middleland and lowland zones. Post-independence agricultural policy continued to put much emphasis on these industrial crops. The government subsidised the production means of these crops and cooperatives were formed – in this case the Rungwe Cooperative Union (RUCU) – to help farmers purchase fertilizers and pesticides and market their produce (Mwakaje 1999). Research has shown that in the 1970s and early 1980s over 66% of land in the MRE under cash crop was allocated for coffee production (Mwakaje 1999).

In my study, however, satellite image analysis at the district level and in the sample villages – particularly those of the middleland and lowland zones – recorded a decline in stands of tree crops (coffee) and the cultivation of bushy crops (tea). The main decline in this category was observed between 1986 and 1991, and in the 1991 to 2010 time series. For a period of 37 years the tree crops category showed an increase of 18% in Kyimo, only 3% in Syukula, 6% in Katundulu and almost totally disappeared in Ilima village. The decline in tree crops could be attributable to the removal of government subsidised fertiliser for these traditional cash crops.

The 1997 revised agricultural policy encouraged private investment in the sector. This has necessitated smallholder farmers and larger-scale producers to revert to food crops that have become commercialised since the mid-1990s after the failure of traditional cash crops.

The agricultural policy, in conjunction with liberalisation of agricultural markets have improved efficiency in marketing food crops though at the expense of other cash crops such as coffee, tea and pyrethrum. The increase in mixed cropland with settlements in the highland and middleland zones is an indication of expansion of cultivation of food crops – especially potatoes and bananas – which have become profitable due to the decline of coffee and tea as cash crops.

5.1.4.4 Energy policy

In the energy sector, Tanzania adopted a national energy policy (2003) and rural electrification policy (2003) relevant to Agenda 21 (URT 2003c; 2003d). The objective of the energy policy is to establish an efficient energy production, procurement, transportation, distribution and end-use system in an environmentally sound manner, whereas the rural electrification policy targets electricity provision to rural areas. These objectives are to be achieved through different strategies such as the development and utilisation of natural gas and coal resources, exploitation of hydroelectricity generation potential, and arresting fuelwood depletion by developing more appropriate land management practices and more efficient fuelwood use technologies. Neither policies have, however, been adequately implemented. Although the energy policy favours promotion of energy efficient technologies such as biogas, it has mainly focused on developing hydroelectric power and petroleum, ignoring more efficient fuelwood use technologies – the main energy source used by people. Due to the high cost of electricity, petrol and kerosene (Ghanadan 2004), most people in both urban and rural areas have continued to rely on fuelwood as their main domestic energy source. This has resulted in continued land use change, especially in the form of deforestation due to over-dependence on fuelwood by the majority of rural and urban dwellers.

At a national level for example, fuelwood accounts for more than 90% of the total Tanzanian energy consumption (URT 2008), with a per capita consumption of fuelwood estimated at 1 m^3 per year. In urban centres like Dar es Salaam, households consume 69% of all fuelwood requirements (Malimbwi 2008). In Rungwe district, like other rural areas in Tanzania, fuelwood is the main source of energy (URT 2005) despite the fact that some villages have access to grid electricity. On average fuelwood energy requirement in the district is about 600 000 m^3 while the supply capacity is only 400 000 m^3– creating a deficit of 200 000 m^3 (URT 2005).

The demand for fuel and energy among respondents in the study area is high. Findings of this study show that more than three quarters of the respondents indicated they use fuelwood as their main source of energy, mostly for cooking; of these, 53% bought their fuelwood and the remaining 47% sourced their firewood from either government forests, woodlands or own planted woodlots. The dependency on fuelwood on the one hand, could explain the recorded decline in forests on the Landsat images in both periods analysed between 1973 and 2010 at the district level and in the sampled villages, though there were a few cases (in some years) where forests and woodlands increased. On the other hand, the decline in communal forests could explain the increase of on-farm woodlots and the decrease in formerly agricultural land being converted to woodlots. Forest decline in the district is also reported by research (McKone & Walzem 1994; URT 2005) asserting that most of the forests in the district had been cleared for fuelwood, agriculture and settlement requirements.

Mwakaje (2008) and URT (2005) showed that the Rungwe district has a high biogas potential due to the presence of a large number of indoor-fed dairies – keeping 26 137 improved dairy and 52 036 indigenous cows. The district, however, has limited active or developed biogas projects. Promotion of biogas harnessing in the district started in 1993, but by 1996 only 12 households out of 74 450 had adopted the technology and since then the adoption has been low and more or less constant (URT 2005). According to Mwakaje (2008), up to now there are about 100 biogas plants in the district used by only 0.13% (about 5727) of the total number of households. Unaffordability of the technology and water scarcity are among the factors leading to slower adoption. This may explain the continued reliance on fuelwood – mainly obtained from the available natural forests and woodlands for the majority of local communities. The changes in land use such as deforestation observed in the spatial analysis, might be attributed to failure to implement environmentally friendly renewable energy such as biogas as stipulated in the energy policy. An effective implementation of renewable energy such as biogas in the district could provide a substitute fuel for fuelwood supplying energy for cooking and lighting. In turn, this would not only secure forests that are subject to depletion but also would encourage dairy farming and production facilities thereby increasing livelihood opportunities of the local communities.

5.1.5 Technological factors

Hasselmann et al. (2010) define technological driving forces as those factors that can be ascribed to technology adoption and application in a broad sense, including organisational and social, as well as material aspects of technology. The term encompasses, for example, agricultural production methods, infrastructure systems, artefacts such as building materials, as well as embedded knowledge systems. Technology as a driving factor of land use change can lead to rise in agricultural productivity (Semwal et al. 2004), conversion or modification of land use (Hansen 2005; Braimoh & Onishi 2007) or fragmentation of landscapes. Technological factors being considered in this study are mainly agricultural innovations.[29] These innovations have led to change in cropping patterns, and intensification and expansion of cultivation in the highlands and the middlelands, respectively. The use of sawing machines in the lumbering industry has also led to decrease in natural forest. These factors are explained in the subsequent sections.

5.1.5.1 Adoption and spread of coffee cultivation

In the Mt Rungwe ecosystem, population increase and limited geographic expansion of cultivated land due to the mountainous nature of the area and the reserved forestry areas, has made land the scarce factor. To increase land productivity in such a scenario, technological change can include the introduction of high-value crops and the use of chemical fertilizers. In the case of the MRE there is technical agronomic change (Anderson 1996) in terms of the selection and adoption of new crop and livestock varieties, cultivation practices and change in the use of agricultural inputs. The agronomic changes have resulted in change to the cropping and grazing patterns and intensity of cultivation of crop varieties in the area.

Coffee cultivation was introduced in Rungwe in the early 1930s with encouragement from a British agricultural officer (Odgaard 1986). The introduction and spread of coffee fields brought changes in the farming system of the Nyakyusa as land formerly used for subsistence farming, was converted to coffee plantations. By the 1940s coffee had spread in the Rungwe District. It is during this time that the colonial government alienated parts of community land to white settlers for large scale coffee production. It is documented that about 10 500 ha were given to white settlers for large scale coffee production (Wilson 1977). This means that 4.6% of the district area and (presuming the lands were fully suitable for agriculture) potentially 6.3% of the area deemed suitable for agricultural production was

[29] The agricultural innovations referred to herein are various type of agronomic changes but mainly those associated with the selection and adoption of new crop and livestock varieties and the use of chemical fertilizers and those related to timber harvesting techniques.

transferred to commercial producers. This could have contributed to the land shortages already experienced in the area and may have precipitated the change in the inheritance system where men started to inherit land from their fathers while women could only obtain land through their husbands (Kurita 1993). Land alienation triggered agricultural intensification in the area. The spread and adoption of coffee production also resulted in the conversion of woodlands into cultivated land and/or forced out-migration as people became landless.

5.1.5.2 Adoption of new cash crop varieties

The increasing adoption of the new varieties of potatoes has precipitated changes in cropping patterns, and hence land use change. While the former potato varieties were intercropped with maize, the new varieties require solitary cropping. Potatoes were introduced in the southern highlands in the early 1920s and records show that by the 1950s the southern highlands (including the Rungwe district) had become a major potato producing area in Tanzania (Anderson 1996). However, there had been changes concerning the varieties of potatoes grown since 1980s up to the present. During my interviews, it was established that potato varieties that used to be grown in the past are no longer cultivated. The major reason was a lack of market demand for these potato varieties. Currently the much improved varieties include *Arika, Kagiri, Kidingh'a, Tigo* and *CAP*. These improved varieties are believed to have higher commercial value and can more readily be marketed. Each of these potato varieties has particular beneficial qualities on which farmers' preferences are based, as one of the respondents explained:

> *"Currently we have so many potato varieties but the most notable include* ***Arika, Kagiri, Kidingh'a, Tigo*** *and* ***CAP****. Of these the mostly preferred varieties are Arika, Kagiri and Kidingh'a. Arika is a fast growing variety followed by Kagiri hence guarantees quick turn over. A sack of harvested Arika or Kagiri is sold between 27 000-28 000*[30] *Tsh while that of Kidingh'a is between 35 000-38 000Tsh depending on the harvesting season which is a reasonable good price. Apart from that these two*

[30] The prices mentioned by the respondent may be correct but should perhaps not be generalised to all farmers. An attempt was made to get the real value of a bag of round potato at the district business and marketing officer, but it proved impossible as he confessed that there is no clear channel for marketing this crop at the district level. Key informant reported that the prices are negotiated between farmers and buyers and in most cases through middlemen between the producers and the wholesalers. The failure to get the actual value of potatoes at the district level affirms the findings of Anderson (1996) who contended that the potato trade in the southern highlands and in Tanzania in general is not organised through official marketing channels, but is largely unofficial and local in nature.

varieties have a wider market in Dar es Salaam, Mbeya, Dodoma and Morogoro mainly for chips. CAP is not widely traded and not preferred by most farmers as it has an expansive root system, so it brings difficulties during harvesting as you can uproot the maize intercropped in. ***Tigo*** *is the very recent variety and is believed to originate from Kenya. It is not so preferred by farmers because it takes much longer to mature (6-8 months) and hence intercropping it with maize is difficult as it delays the next planting season"*(Yuda 2011, pers com).

Other respondents further revealed that the majority of the round potato varieties, particularly *Kagiri*, are from Magoma and Kikondo villages in the Uporoto Mountains[31] to the south of Mt Rungwe. According to Anderson (1996) there are approximately 15 different potato varieties grown in the Uporoto Mountains and it is said to be the regional source of potatoes. The reason behind having a large number of potato varieties is that, due to land scarcity and need of income, most people from Uporoto highlands migrated (mainly from the 1940s to the 1960s) to Tanga (to the sisal estates) or Arusha (to the sugarcane plantations) and there encountered potato varieties unknown to them. On their return to Uporoto they brought back these varieties and planted them in their local fields. Through in-migration of young men from Uporoto to other parts of the region including the Rungwe District most of these varieties from Uporoto became widespread in the MRE. Apart from *Kagiri*, other varieties including *Tigo* are suspected to have come from Kenya. This might be true or not, because the respondents were not quite certain. Anderson (1996), however, pointed out that in Kenya there is a long-standing tradition of Irish potato production and research reaching back to the 1930s.

The adoption and commercialisation of potatoes (particularly in the sampled villages of the highland zone of the MRE) has led to the replacement of the bamboo forests and pyrethrum at the homesteads and adjacent farms (*kaaja*). The *kaaja* in these villages are increasingly used for farming potatoes and a few pines or indigenous trees as indicated in Figure 5.2. Clearly, land is at a premium and no cultivable space goes wasted – cultivation reaching right up to the walls of houses.

The middleland zone villages experienced a change from indigenous to improved varieties of bananas and maize. Currently, banana varieties that are grown include *Uganda*,

[31] The Uporoto Mountains are mainly situated in the Mbeya region, but they also stretch into the Iringa region.

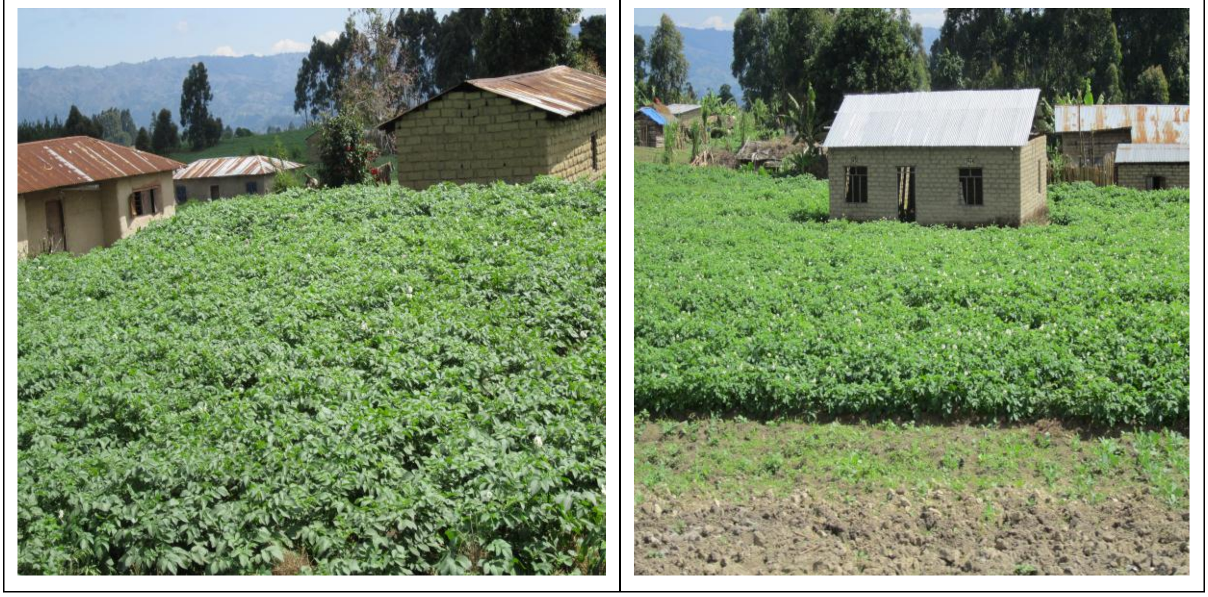

Figure 5.2 Potato fields surrounding homesteads

Malindi, Mshale, Matoke, Fia 23 and Bukoba. Indigenous varieties have been abandoned mainly due to their susceptibility to diseases and the long time they take to mature, which delays income realisation. Maize productivity has also increased due to a shift away from indigenous varieties to hybrids. Hybrid maize seed varieties are obtained from Uyole Agricultural Centre that has the mandate for conducting research and training agricultural and livestock farmers in the mountain ecosystem. In the lowlands other maize hybrid varieties are believed to have come from Malawi, Zambia and South Africa.

In terms of zonation, in villages in the highland and middleland zones of the MRE, agriculture is now practiced in a variety of ways, undergoing a clear trend of production away from permanent crops to annuals with preference for potatoes, bananas and maize cultivation. Food crops such as bananas, maize and potatoes are fully commercialised. Such transitions from staple food and subsistence production to cash crops production are also supported by the World Bank (2007) as a way of enhancing smallholders' market integration. The World Bank (2007) stresses that increased incomes derived from agricultural development will only be substantial if smallholders also make the transition from growing low-value staple crops to producing high-value agricultural products.

It must be emphasised here that crop production and expansion of food crops such as potatoes and bananas on a commercial basis in the study area are driven primarily by socio-economic change from a subsistence- to a market economy, and that macro-economic conditions foster these changes. The changes in selecting crop and animal varieties and intensive cultivation, however, are made as a result of agents' (land users) ambitions, motivations and opportunities in their local environment. Through in-migration people learned different technologies in the farming system and this has helped them improve their livelihoods through adoption of income-generating crop varieties. Nelson et al. (2006) contend that development and diffusion of scientific knowledge and technologies that exploit knowledge have profound implications for ecological systems and human well-being. In this context improved potato and banana varieties have become lucrative to local communities and much land is converted to the production of these crops at the expense of other cash crops.

5.1.5.3 Fertiliser application

In the study area agronomic change was also observed in the use of agricultural inputs. Pyrethrum is a perennial crop requiring infrequent tillage and no chemical fertilizer application. Following its market failure, pyrethrum was replaced by new annual crops, mainly potatoes and maize. These crops require annual tillage and most potato and maize farms apply chemical fertilizers. The widespread use of fertilizers is linked with commercialisation and increased agricultural productivity. During my survey, key informants reported that, with the use of chemical fertilizers, harvest yield from one hectare can reach between 120 and 150 sacks[32] of potatoes, depending on the extent of fertilizers and pesticides usage, the type of fertilizer applied and the location of the field. In the MRE, lowland fields were reported to be more productive than highland fields due to soil erosion problems experienced in the highlands.

Since potato productivity is linked to fertilizer usage, farmers who cannot afford chemical fertilizers either use manure or homemade compost from cut and buried grasses and crop remains. However, buried materials are often not given sufficient time to decay before the ground is tilled. This is because potatoes are grown and harvested twice or three times per year with no fallow season allowed. Fallow is largely not practised due to land scarcity and rented land for commercial production of potatoes having to be squeezed hard for as much annual production as possible. The latter practice obviously puts undue pressure on soil

[32] A sack is a large bag used as container for potatoes and hence is the main weight and volume measurement unit in the potato business, particularly for wholesale trade. In most cases, a sack weighs 100 kg. Other measurements include a bucket of either 20 kg or 10 kg. This practice contrasts with the use of 7 kg or 10 kg 'pockets' in South Africa and elsewhere for containing potatoes.

quality and endangers long-term sustainability of agricultural cultivation in the region. This observation is in line with Mwanukuzi (2010) who also reports the intensive use of fertilizers in the maize and potatoes in the Uporoto Mountains.

5.1.5.4 Adoption of improved cattle breeds

Rungwe is one of the districts in the Mbeya region with a large number of indoor-fed cattle and where dairy keeping is practised (URT 2005). The spread and adoption of coffee growing, alienation of land to white settlers (10 500 ha) and for forest reserves (42 441 ha) significantly reduced the available land by more than 23% and made land scarce – not only for crops, but also for livestock production. One outcome was that the commencement of stall feeding of cattle and adoption of improved breeds were necessitated. This development resulted in changes to the grazing system practised by the traditional Nyakyusa people. Unlike in crop production the shift from local breeds to improved breeds was a result of land scarcity aided by a government initiative to help farmers adopt new breeds not only for improved commercial production purposes but also to elevate food production and reduce the high level of malnutrition recorded in the villages (URT 2005).

Since the 1970s, different international organizations have introduced and supported dairy projects in the Mbeya region. These included the Heifer International Project (HIP), DANIDA and Swiss Agencies (Mwakaje 2008). These programmes provided dairy cattle to smallholder farmers via a scheme called ‘‘Heifer-in-Trust’’ under which a farmer was loaned an in-calf heifer, upon agreement to give the first two female calves to other farmers on the same condition. Upon final payment the loaned heifer would be owned by the farmer. This scheme helped most people in the Rungwe district to start keeping dairy cows. The Uyole Agricultural Centre has also been promoting dairy development in the area by distributing dairy animals to small-scale producers since the mid-1970s (Maganga & Matumla 1992). The centre has continued to carry out problem oriented research programmes geared towards solving problems hindering increased production in the dairy sector (Kifaro, Mbwile & Mchau 1986).

An interview with the district agricultural officer showed that the Small-Scale Dairy Development Project (SSDDP) also assisted farmers to raise hybrid livestock on credit and assisted farmers with extension services. In total the district has 52 036 indigenous cattle and 26 137 head of improved breed (Mwakaje 2008). Other important livestock being kept are pigs, of which the district has 44 334, making it second only to the Mbinga district in the southern highland zone (URT 2010). The district clearly accords great importance to livestock development at the household level. In particular dairy cattle and pigs are kept due to shortage of grazing land. It not only represents a means of diversifying incomes, but animal husbandry is also relatively profitable in the growing market provided by an increasing population in the district.

My household survey showed that 57% of the respondents kept livestock. On average each household had up to five cows depending on the breed type being kept. In terms of stock feeding, 90% of the respondents had no recourse to grazing land (had to feedlot their own animals), 8% grazed fallow land (other people’s land not in use) and a mere 2% grazed unreserved public land. Unlike in other livestock keeping communities in Tanzania (mainly Mwanza and Shinyanga regions), where free public or communal grazing land is still available, the absence of grazing space and opportunity in the study villages is an indication of how limited land is to entertain a free grazing system. However, the indoor feedlot approach adopted by necessity is also a strategy for obtaining milk and meat, as well as manure that is spread on their fields to improve soil fertility.

Field observation showed that traditional breeds were prevalent in Ilima and Katundulu villages of the lowland zone of the MRE. In Ndaga, Unyamwanga, Kyimo and Syukula villages only improved breeds are kept. Villagers in the highland and middleland zones made use of the district projects to acquire hybrid cows while their counterparts in the lowland zone were laggards and, except for a few villagers, still keep local breeds. The change from local breeds to the domestication of hybrid livestock in the villages of the highland and middleland zones is also explained by the general scarcity of grazing land already referred to. The district authority, though, encourages farmers to keep improved breeds. The livestock component of individual farmers does not show major changes in productivity and is not as clearly commercially oriented as compared to crops. This might be due to, among other factors, shortage of land for both crop and animal production. URT (2010) shows that in addition to shortage of grazing land, inadequate marketing, poor storage facilities and inadequate processing industries are other factors hindering livestock development in the district.

5.1.5.5 Introduction of timber sawing machines

In the study area respondents commonly engage in illegal[33] logging for timber, poles, firewood and charcoal as part of their non-farm activities. Illegal logging activity was admitted to by 44% of the respondents as a factor responsible for forest decrease in the area. An interview with the district natural resources officer revealed that:

> *"Human activities including illegal logging are also causing damage in the forest reserve, though from 2007 such activities do not take place at an alarming rate. However, some valuable plant species such as* olea-capensis *(mloliondo) and* entandrophragma *(mkalikali) have been completely lost due to illegal logging as they provided valuable timber products"*(Chibwaye 2011, pers com).

Another interview with the Unyamwanga head teacher indicated that lumbering activities started booming in their village in the early 2000s with the technological development and adoption of hand-held chainsaws driven by petrol motors. The head teacher said:

> *"The introduction of hand-held chainsaws driven by petrol motors in 2001 made lumbering activities easier. By 2005/2006 there were so many of these motor driven chainsaws in this village. People from different places came for the timber business. The timber activities were done in the forest reserve as by that time there were no personal trees grown on farms. The lumbering activities though changed our livelihoods they have caused a lot of forest decrease in the reserve as people were felling trees without replacement"* (Mwanjwango 2011, pers com).

From the extract it is clear that illegal logging is one of the contributing factors to forest decline in the MRE. The views of these local observers are supported by satellite imagery analysis which showed that between 1991 and 2010 the natural forest decreased by three percent. The decrease observed can be attributed to illegal logging activities that were taking place in the forest reserve. Yanda & Shishira (2001) made a similar observation as they noted that illegal logging, charcoal making and cutting of firewood and poles for sale had predominantly degraded the forest on Mt Kilimanjaro.

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[33]There is no universal definition of illegal logging. Nevertheless, for the research purpose here illegal logging is defined as taking place when timber is harvested in violation of national laws, including ratified international treaties and conventions (European Commission 2005).

It is emphasised here that illegal logging continues in reserved forests despite the fact that the country adopted the Forest Act in 2002 that prohibits logging, particularly in the reserved forests (URT 2002; 2004; 2011a). The country has also adopted the National Environmental Management Act (EMA) No. 20 of 2004 which realises the importance of mountain ecosystems. The EMA of 2004, in Section 58, mandates protection of mountains, hills and landscapes that are perceived to be at risk from environmental degradation (URT 2004). This indicates that the surrounding community has been taking advantage of the non-enforcement of government rules and regulations for managing the forest reserves. The World Bank acknowledges the fact that illegal logging and the lack of appropriate forest governance are major obstacles to developing natural resources and protecting environmental values and services (World Bank 2008).

5.1.6 Urbanisation

Urbanisation, simply defined, is the shift from a rural to an urban society and involves an increase in the number of people living in urban areas as gauged in a particular year (Muzzini & Lindeboom 2008; Otiso & Owusu 2008). It also refers to the agglomeration of formerly rural populations into cities, with increasing numbers of cities and increasing populations in the individual cities (Boadi et al. 2005; Henderson & Wang 2005). The Tanzanian urban population increased from a low base of 5.7% in 1967 to 22% of the total in 2002 based on census data (URT 2006c). Countrywide the lead regions in urban growth are Dar es Salaam (94%), Arusha (31%) and Morogoro (27%). Similarly, according to the 2002 census data, the southern highlands of Tanzania had a population of more than 2.5 million, feeding the growth of cities like Mbeya with an urban population of 20.3% of total Tanzanian urban dwellers and medium-sized towns like Tukuyu in the Rungwe district (Muzzini & Lindeboom 2008; URT 2003a).

Agricultural produce in the MRE is not only in demand from the population within the ecosystem itself, but also from the population in distant urban areas. The exponential growth of cities such as Mbeya, Dar es Salaam, Arusha, Morogoro and Mwanza with their daily large, medium and small-scale markets creates a higher demand for agricultural products from the MRE. Most of the agricultural products such as potatoes, bananas, and forestry resources such as timber are sold at these urban markets. Urban residents all over Tanzania provide a stable market for the agricultural products from the MRE. The high demand for agricultural products has in turn led to intensification and expansion of agriculture in the study area at the expense of local grasslands and forests, which are being cleared for intensive commercial agriculture. Antrop (2005) asserts that cities form extended networks affecting large areas that fulfil a multitude of functions such as trade and industrial production.

Apart from urbanisation that is taking place at a district level, social changes are also taking place within the villages. Among the surveyed villages, Ndaga and Kyimo are transforming into small towns (Mwamfupe 1998a) a situation prompted by the booming banana and potatoes trade. As indicated in Table 5.1 the two villages have been experiencing rapid population growth. The 1991 and 2010 images showed vegetative cover, particularly woodlands, natural forests and grasslands being converted into cultivated and settlement lands. The foregoing political, economic, technological, demographic and socio-cultural factors are inherently human related drivers of land use change that have been identified and discussed in this study.

5.2 NATURAL FACTORS

Apart from human related drivers, natural spatial factors such as soil types, variation in rainfall amount, forest fire incidence and alien vegetation infestation (like pine invasions) are also driving change in land use of the study area. These drivers are explored in the sections following below.

5.2.1 Geographic features

It is worth noting here that local variation in natural geographical endowment plays a significant role in explaining the agronomic change in the study area. According to World Bank rating criteria, the Rungwe district can be characterised as a favoured area, i.e. it belongs to a group of areas classified according to their agricultural potential based on: good access to irrigation; high to medium levels of humidity; and medium to good access to markets (World Bank 2007).

Most sample villages for this study have good transport facilities, access to the district headquarters of the Mbeya region and locations along the main Tanzania-Malawi road. However, a diversified agriculture and the transition from staple food to commercial market production developed only in villages where advantages from niche climatic conditions and favourable soil types accrue. As noted earlier in Chapter 1 the three agro-ecological zones of

MRE differ in amount of rainfall and temperature experienced per year. The highland and middleland agro-ecological zones are more advantaged in rainfall amounts than the lowland zone. Although the three agro-ecological zones have good volcanic soils, replacement of traditional cash crops such as finger millet, pyrethrum, and coffee-banana fields by potatoes and maize in the highland and middleland zones of the MRE is partly due to cool weather conditions and high rainfall throughout the year. These conditions are more favourable for potatoes, maize, bananas and vegetables.

Intensification and expansion of agricultural land are more apparent in the highland zone (see Chapter 4) where annual crops are mostly grown twice per year. Currently, there is also a southward extension of potato growing area in the MRE which is facilitated by high rainfall amounts. Villages such as Ntokela have also become potato production centres where potato fields are now replacing the traditional coffee-banana fields. In the lowland zone where the weather is generally hot and there is shortage of irrigation facilities (traditional irrigation) there is less diversified agriculture and fewer non-farm activities. While more land is converted to agricultural use in the highland and middleland zones, more agricultural land is allowed to revert to natural vegetation in the lowland zone. The recorded decline in the cultivated land (see Chapter 4) in the sample villages of the lowland zone, among other factors, can be partially attributed to climate conditions that limit agricultural activities or the climate facilitates changes caused by other drivers.

5.2.2 Incidence of forest fires

There are two schools of thought regarding fire occurrences in tropical forests. The first school of thought argues that fire is part of the ecosystem and is an unavoidable ecological process: fire regulates vegetation competition, supplies nutrients to the soil, controls pests in forests, and in general sustains the forest ecosystem (Shlisky et al. 2009; Sugihara et al. 2006). The other school of thought argues that fire threatens biodiversity, particularly when these fires are human-induced, occur at too short and regular incidences and are intensified by the presence of dense alien invasive vegetation (Burgess et al. 2007). Both arguments are valid in particular contexts, but in an area undergoing drastic change in land cover, including the introduction of foreign species like monoculture plantations, the latter approach should weigh more heavily in landscape management.

Fires in plantations and montane catchment areas have become a serious problem in Tanzanian forestry (URT 2006b) causing losses to timber and biodiversity. Like any other natural forest reserve, the Mt Rungwe Forest Reserve has experienced fire incidences that have profoundly impacted its biodiversity and the survival of montane grassland and the natural forest cover. According to URT (2011), in 1984 and 1989 severe fires broke out in the Mt Rungwe Forest Reserve and destroyed 400 ha and 1500 ha, respectively, of natural forest cover. According to the District Natural Resources Officer and key informants, in recent years two fire incidents are recalled to have occurred in the Mt Rungwe Forest Reserve: in 2000 and 2009. The 2009 fire incident occurred in September and was only suppressed after a couple of days of burning. The lack of a proper scientific and managerially efficient official response to the threat held by this hazard is evident in the district natural resources officer's verbatim explanation of the two fire incidents:

> *"Forest degradation in the Mt Rungwe is to a large extent due to natural factors such as fire incidents in the forest reserve. Two notable fire incidents of 2000 and 2009 had tremendous effects in the reserve. Although it was not possible to quantify the loss but a large part of the forest was destroyed especially with the 2009 fire incident. The 2009 fire was intense because of the grassland at the upper part of the mountain. Until now we do not know exactly what caused the fires although there are different explanations. To me I perceived the fire incidents as accident caused by natural factors rather than human induced phenomenon"* (Chibwaye 2011, pers com).

A different view on these events surfaces from interviewed village leaders and elders. They claim that the 2009 fire incident was human induced as a result of a lack of perceived benefits among the local communities. These key informants asserted that, apart from the good weather and the water for domestic use they were enjoying from the mountain, there were no direct income related benefits derived from the mountain land. They added that people from outside the region were given permits for lumbering but the local communities surrounding the mountain ecosystem were denied such permits – claims that could not be substantiated. The informants further pointed out that the local communities surrounding the reserve were not involved in the management of the forests, so they lacked that sense of ownership of the forests. As a consequence, at the outbreak of the 2009 fire incident, the communities refused to help to fight the fire destroying their resource base – simply because they perceived that they receive no benefits from the forest or forest products in the reserve.

These views from key informants and elders in the sampled villages concur with a fire report that was made available by the Wildlife Conservation Society (WCS) authority. Among other things the report shows that the fire incident started on the 12th September and ended on the 30th September (18 days) (Machaga et al. 2009). The report also indicates that the main cause of the fire is yet to be proven and that it is estimated that about 2150 ha of forest were burnt (Machaga et al. 2009). The report further reveals that during the effort to extinguish the fire, a number of challenges were encountered, which were significant distractions from the fire fighting effort. These included, among others, financial and limited initial response of some communities caused by their concerns about forest management and benefits from the forest. The communities pointed out that they weren't ready to participate because, first, the Mbeya regional forest office had been illegally giving permits to people from outside the Rungwe area to harvest timber inside Rungwe Forest Reserve, whereas villagers are only involved when problems arise or when their help is needed. Harvesting timber is not only illegal as no harvesting is allowed in the reserve; but also, it undermines local communities who are the key stakeholders in the conservation of Rungwe (Machaga et al. 2009). Secondly, their relatives who were employed as cheap labours during harvesting were arrested (in lockup to date) while the harvest permit owners who order the harvesting are free (Machaga et al. 2009).

The State and the Law hold a different view of community responsibility in this regard. With reference to the 2009 fire incident, the District Forest Officer believed that local communities had an obligation to help extinguish fires. The Forest Act No.7 (2002) actually requires local people to extinguish fires burning in any forest in their proximity (URT 2002). However, with no perceived benefits accruing, local communities are reluctant, disinterested and do not execute their legal obligation. My surveyed respondents displayed a low awareness that forest fires were devastating events leading to a decrease in forest cover in the MRE, since only 14% raised it as a serious concern in 2010. With regard to the preceding decades, responses about fire incidences did not feature as a cause of forest degradation in the ecosystem.

The fires reported by the informants did have the reported effect on land use change in the Mt Rungwe forest reserve. Change analysis showed that natural forest decreased in both the periods between 1986 and 1991, and from 1991 to 2010. The decrease in area covered by natural forests between 1991 and 2010 coincided with the two fire incidents reported. Similar observations on forest fire incidence and its effects in tropical forest reserves is reported by William (2010) in the Uluguru Nature Reserve in the Morogoro region (shown in Figure 1.1), where frequent fire outbreaks have resulted in conflicts between local communities and forest authorities. Nash et al. (2006) also support the view that change in vegetation cover is related to anthropogenic activity and/or natural events such as fires and floods, and that in the absence of fires and floods, changes in forest cover would only be related to rainfall availability.

Before the 2009 fire incident there were no organised efforts to forestall or suppress fires in the forest reserve. Since the 2009 fire incident, two measures have been instituted by the government in collaboration with the WCS. Firstly, the local community was involved in monitoring illegal activities including illegal logging, hunting and honey collection in the forest reserve. In each of the surrounding villages two people have been selected by the village for patrolling the reserve. The WCS provides garments, equipment and compensation: gumboots, rain jackets and machetes, and it pays a subsistence allowance. These measures have helped to combat illegal hunting and lumbering activities in the forest reserve over recent years. During the 2011 survey, respondents reported an improvement in the status of the reserved forest compared to the situation in preceding decades. Among the factors contributing to the improved status were effective law enforcement through forest patrols and fines imposed on culprits apprehended in the forest reserve while committing illegal practices.

Secondly, Mt Rungwe Forest Reserve was declared a nature reserve. Mt Rungwe Forest Reserve used to be classified as a Territorial Forest Reserve, but since 2009 it had its status changed to a Nature Reserve – Mount Rungwe Nature Reserve (MRNR). With this higher status, MRNR is an important area for conservation in Tanzania and is classified as protected area whereby timber and Non Timber Forest Products harvesting and other human activities are prohibited. This nature conservation perspective adopts the view that fires are a threat to species in the reserve and that biodiversity (fauna and flora) cannot be sustained if fire outbreaks are not curbed (Burgess, Lovett & Muhagama 2001). The declaration is also in line with the conservation priority of a nature reserve based on endemism and the magnitude of threat, as articulated by Weeks & Mehta (2004). The local people, however, will perceive forests as beneficial only if they are allowed to obtain access to forest resources like dead wood, medicine and fruits, regardless of the forest's status. During my survey, respondents showed that they had derived various forms of livelihood from the forest resources in times prior to preservation and have benefited from the forest as well as from non-forest products and ecosystem services. Their exclusion may consequently generate management conflicts and lead to more and damaging fire occurrences. It is therefore clear that in these traditional settings a utilitarian valuation system of natural resources prevails, rather than the loftier ideals of existence or bequest valuation systems prevalent among modernised societies elsewhere (Bateman 1995).

5.2.3 The invasive spread of pines

Biological invasion is a global phenomenon affecting ecosystems in most biomes (Mack et al. 2000). Human-driven actions, deliberate or accidental, may cause massive alteration of species ranges in ecosystems. Ecosystem changes brought about by invasions can have both short-term or ecological and long-term or evolutionary consequences. In some ecosystems, invasions by alien organisms and diseases result in the extinction of native species or catastrophic loss of ecosystem services (Nelson et al. 2006). In the MRE there has been a problem of invasion by pine trees (photographic evidence appears in Figure 1.5). However, in contradiction of the visual evidence, a mere four per cent of the respondents indicated that they considered pine invasion caused forest degradation in the Mt Rungwe Forest Reserve. The responses were low because most people do not know much about what is happening in the upper part of the mountain and rarely go there. A compounding factor is also the utilitarian value system prevalent among the people, and referred to in the previous section. The district natural resources officer did indicate an official awareness that invasive pines from the Kiwira forest plantation have affected the grassland in the upper parts of the reserve.

Concerning this particular problem, Davenport (2004) indicated that the upper grasslands of the Rungwe Mountain have been colonised by the exotic pine species *Pinus patula*, although the exact extent of the invaded area varies among sources. Davenport contends (perhaps most accurately) that 64 ha of the reserve are completely covered by pine trees, while URT (2011a) claims that more than 100 ha have been invaded by *Pinus patula*.

Since the latter source reports seven years later, it might rather point to the fast pace of invasive spread. Davenport cautions that methodological problems due to the altitude at which satellite images are taken from and coarse image resolution, imply that single pines are ‘invisible’ and can only be ‘seen’ when they are clumped together in sufficient numbers. Single or small groups of trees are poorly detected by this method and consequently the figures can under-represent the threat. Determining the extent of pine infestation in the reserve was of course not an objective of this study, and so no further analysis was done to measure the actual coverage. Further research should be directed at establishing the exact extent of the threat posed by pine invasion in the reserve. Nevertheless, the infestation is posing a threat to the existence of the montane grassland habitat, which could result in ecological disaster for the ecosystem. Despite the observed and recorded impact of the pine invasion originating from the Kiwira forest plantation in the MRE, the government is expecting to extend that plantation by a further 300 ha (URT 2003e). If this plan is implemented, the ecological integrity of the MRE may be compromised.

Pine infestation has also been widespread in the villages surrounding the mountain. Villagers very early on realised the usefulness and importance of pines as source of fuelwood and timber for sale. The Kiwira forest plantation has been a source of pine seedlings that are distributed to villagers wishing to propagate trees. Apart from Kiwira pine seedlings, the WCS has since 2005 established indigenous tree nurseries in schools and villages around Mt Rungwe for seedling distribution to local communities. Thanks to this effort, over half a million indigenous tree seedlings have been planted from these nurseries with a survival rate of 85% (URT 2011). The MRNR authority, in cooperation with WCS, has set as its target the distribution of 50,000 seedlings per village surrounding the mountain. Generally, the availability of seedlings has encouraged farmers to establish their own woodlots on their farms. The main preferred exotic tree species include *Eucalyptus maidenii* (mlingoti), *Pinus patula* (mipaina) and *Curpressus lusitanica* (mkombakomba) while some of the indigenous are the *Catha edulis* (msoroti), *Podocarpus usambarensis* (mpodo) and *Arundinarica alpine* (mwanzi).

Through the support from WCS, communities are encouraged to grow their own trees, thus there are numerous on-farm woodlots (field sizes ranging from 0.5 ha-2.0 ha depending on the land available to individual farmers) in the study area, especially in Unyamwanga, Ndaga, Syukula and Kyimo villages. The growth of timber production results in change from cropland to woodland. This was evident from image analysis where increased conversion of cultivated land into woodland and natural forests was revealed. The spatial analysis in Unyamwanga for example, showed that 117 ha were converted from cropland to woodland between 1991 and 2010 alone, while 235 ha in total were converted in the same category during the whole survey period between 1973 and 2010. Similarly, in Ndaga 121 ha and 51 ha were converted from cropland to woodland between 1986 and 1991 and between 1973 and 2010, respectively. The increase of woodland and decrease of cultivated land within these villages of the highland zone is evidence of such a development.

5.3 CHAPTER SUMMARY

In this chapter the driving forces for land use change in the MRE, were discussed. It has been shown that a number of interacting drivers, both natural and human-induced were responsible for the observed changes. It was also noted that these drivers behaved differently within the same ecosystem. In the highland zone for example, the villagisation process had a significant impact on land use patterns between 1973 and 1986, while in the middleland and lowland zones it did not have any impact. Similarly, technological and natural factors had more profound impacts on land use patterns in the highland and middleland zones compared to the lowland zone. Nevertheless, it is emphasised here that these drivers operate together and neither of them work independently. The observed land use changes were a result of cumulative interacting factors. The next chapter discusses the linkages between land use change and communities' livelihoods.

CHAPTER 6 LINKAGES BETWEEN LAND USE CHANGE AND LIVELIHOODS

In Chapter 4 the focus was on the main land use changes that have occurred in the MRE from 1973 to 2010. The main land use changes observed in the study area include expansion of agricultural land and intensification of agriculture, changing grazing systems, increased reforestation and expansion of forest reserves and plantations. In this chapter the linkages between land use change and livelihoods of the population in the study area are investigated. The key question is to what extent does land use change influence people's livelihoods?

Land use change is a diverse phenomenon that offers opportunities and constraints to people's livelihoods. Researchers such as Foley et al (2005), Lambin, Geist & Lepers (2003) and Ringler (2008) point out that land use change can be detrimental or beneficial to communities' livelihoods. This is because peoples' livelihoods are realised through a system of interactions between society and the environment. As noted earlier in Chapter 1 the concept of livelihoods is also diverse. It includes a number of approaches to assess livelihoods change and or sustainability. It is a concept that centres on links between individual or household assets, activities in which, households engage with a given asset profile, and the mediating processes (institutions and regulations) that govern access to assets and to alternative activities. Livelihoods relate to how people earn a living and therefore to people's well-being. This study focuses on a rural context where the major means of earning a living is agriculture and other supplementary non-agriculture activities. In order to assess the implication of land use change on people's livelihoods, activity modes that indicate variations in livelihoods, namely agricultural practices and forestry developments are considered and projected against change in peoples' well-being. The chapter concludes by linking the changes in land use with social changes that the local communities and society have broadly undergone.

6.1 AGRICULTURAL PRODUCTION AND LIVELIHOODS

In Chapter 4 it was observed that cultivated land (especially mixed cropland) increased over the entire study period both at the district level and in sample villages representative of the three agro-ecological zones of the MRE. The spatial analysis in all of the study area showed an increase in the cultivated land – particularly between 1991 and 2010. The observed expansion of agricultural land corresponds with the main occupations of the respondents. Results of the household surveys indicated that 66% of the respondents (Question 4 in Appendix B) rely on agriculture as their primary means of earning a living. Agricultural expansion revealed on the images of the four time sequences provides an indication that more land was brought into cultivation as crops are diversified and associated with significant change in agricultural practices. The increase in the cultivated land could as well as mean more volume of production and income accrued from agricultural activity. Agricultural expansion and increases in production are also proffered by the district economic report (URT 2010) on crop production trends of the district in recent years. Fundamental change in the way agriculture is practiced in the MRE were accompanied by diversification in the modes of livelihood generation outside of agriculture by the population; they adopted new modes of animal husbandry and improved incomes by introducing new crop varieties as explored in the next sub-sections.

6.1.1 Income from non-agricultural sources

The increased usage of agro-chemicals in cultivating potatoes is now a common practice. Intensification of agriculture has provided greater employment opportunities. Business volumes particularly related to selling of farm inputs and other non-farm activities have increased as Figure 6.1 evidences visually. Running small business (shops, kiosk, tea rooms, carpentry, food) and clothing retail (second hand clothes) selling are some of the non-farm occupations observed in these photographs.

Figure 6.1 Evidence of non-farm occupations

A number of retail outlets for farm inputs (agro-chemical) have also been established particularly in Ndaga (five agro-chemical shops) and Kyimo villages (four agro-chemical shops). This has resulted in the creation of permanent non-farm employment to some residents. Other villages like Unyamwanga that have no agro-chemical retailers buy their fertilizers from nearby villages of Ndaga or Isongole – hence providing a stable market for farm input business.

Where respondents were asked to give the number of members of their households engaged in non-farm activities (Question 24 in Appendix B) only 22.7% had up to three members engaged in non-farm activities (mainly timber related), while 77.3% did not have such members in their households. Despite such low participation by respondents, field observations revealed that non-farm activities such as harvesting and selling of timber, charcoal production and firewood selling at the roadside (as shown in later sections) have become established additional to agricultural activities.

Respondents to the household questionnaire were also asked (Question 33 in Appendix B) to relate changes in agricultural land use to their well-being, i.e. whether they perceived having improving or deteriorating livelihoods or quality of life over the last 10 years. Although the study covers a 37-year period, a 10-year view was opted for since it was anticipated that respondents would recall such a shorter and more recent period of their lives most vividly and reliably. The responses on the perceived quality of life are indicated in Table 6.1, where half (189) of the respondents perceived their lives to have improved, and the other half (195) to have registered worse-off conditions over the last 10 years (the first decade of the new millennium). Table 6.1 indicates that changes in the quality of life associated with

Table 6.1 Perceived well-being of respondents

Why life is better?	Responses	%	Why life is worse	Responses	%
Enough food to feed the family	151	80	Lack of land to cultivate on	63	32
Good health	14	7	High living cost	33	17
Higher income from agriculture	11	6	Old age/senility	29	15
Constructed a house	4	2	Low yield of agricultural crops	26	13
Able to keep livestock	4	2	Widowhood (personal circumstances	23	12
Received remittance	3	2	Inability to purchase farm inputs	15	13
Started a business	2	1	Disease prevalence	6	3
Total	189	100	Total	195	100

agricultural land expansion and intensification have differently affected communities. It is also noted that some of the factors are not directly linked to land use change but are mediated by other social factors such as remittances received from elsewhere and personal circumstances. To a rural community where agriculture is the main means of livelihood, other social variables influencing change in livelihoods include household size, gender, marital status and education level. The extent to which such factors might have contributed to the quality of life of the community in relation to the ongoing agricultural expansion and intensification practices, is explored below.

6.1.2 Income from agricultural produce

Another important factor that was considered by respondents as contributing to their perceived better-off life included income mainly from agriculture. The increased income from agriculture has been possible due to significant changes in the agricultural production system. Increase in cropland was carried out alongside replacement of traditional cash crops (tea, coffee and pyrethrum) by annuals (mainly potatoes, maize and bananas) that are intensively cultivated and are used as food and cash crops. The traditional cash crops were replaced as they were deemed to have no stable market outlets or did not receive good prices. The adopted annuals which also are of improved varieties are lucrative for the communities. The structural and liberalisation aspects of the economic reforms, particularly trade and market liberalisation, have enhanced the commercialisation of food crops like potatoes, maize and bananas. That is, respondents in the study villages are producing not only for subsistence but also for commercial purposes and they have therefore been able to improve their income and concomitant level of well-being.

This study did not record income figures from agricultural produce because respondents were reluctant to disclose their incomes. Secondly, unlike formally paid workers who have a fixed and reliable monthly income, rural incomes that depend on agriculture are not consistent, reliable and are unrecorded. This is because sometimes agricultural produce is sold in instalments and as needs arises. Thirdly, the focus in the study was not on specific livelihood strategies that later on would be compared and draw conclusion based on the similarities or differences among the various groups undertaking similar livelihood activities.

6.1.3 Changing grazing systems

The Nyakyusa of Rungwe District are livestock keepers although in small numbers compared to other livestock communities in the country (such as Mwanza and Shinyanga regions). The cows kept are mainly traditional breeds mainly for paying dowries and are grazed on free public or communal lands. The demarcation of the natural forests and plantations not only restricted access but also affected livelihoods through limitation of communal grazing areas. In turn, this has encouraged a more intensive system of livestock keeping through zero grazing. As pointed out in Chapter 5 Rungwe is one of the districts in the Mbeya region with a large number of indoor-fed cattle and dairy cattle (URT 2005). My household survey (Question 27 in Appendix B) showed that 218 (56.8%) of the 384 respondents kept livestock. Of these, 42.7% kept cows and the remaining 14.1% kept pigs, goats and/or chickens. Figure 6.2 shows improved breeds of indoor-fed cows and pigs kept by respondents.

Figure 6.2 Indoor-fed livestock kept by respondents

In terms of stock feeding (Question 28 in Appendix B), of the 56.8% who kept livestock, 50.8% of them had to feedlot their own animals, 4.7% grazed fallow land (other people's land not in use) and a mere 1.3% grazed unreserved public land. Table 6.2 tracks the grazing practices in the various sample villages. Majority of the respondents practise zero-grazing (indoor-fed system) and that cattle owning is more prevalent in the highland and middleland zones (Syukula, Kyimo, Ndaga).

Table 6.2 Grazing place per village

Village	Grazing place			
	Public land (not reserved)	Fallow land (others' land not in use)	Indoor-fed	Total
Unyamwanga	1 (7.7%)	3 (23.1%)	9 (69.2%)	13 (100.0%)
Ndaga	0 (0.0%)	0 (0.0%)	45 (100%)	45 (100.0%)
Kyimo	0 (0.0%)	2 (3.1%)	62 (96.9%)	64 (100.0%)
Syukula	0 (0.0%)	0 (0.0%)	66 (100%)	66 (100.0%)
Katundulu	2 (15.4%)	4 (30.8%)	7 (53.8%)	13 (100.0%)
Ilima	2 (11.8%)	9 (52.9%)	6 (35.3%)	17 (100.0%)
Total	5 (2.3%)	18 (8.3%)	195 (89.4%)	218 (100.0%)

Such an intensive system of livestock raising increases not only the supply of milk, meat and manure but also offers a means of diversifying livelihoods. It is therefore not surprising that in Table 6.1 (reported in Section 6.1.1), the ability to keep livestock was associated with experiencing a better life.

6.2 FORESTRY DEVELOPMENT AND LIVELIHOODS

As noted earlier in Chapter 1 and Chapter 5, Rungwe District has six gazetted catchment forest reserves, and plantations that cover 2% of the total district area (URT 2010). The introduction of these forest reserves and plantations limited not only cropland and grazing area for livestock in the study area but also access to fuelwood, the chief energy source of local communities. Expansion of agricultural land results in decline of unreserved natural forests in the area. Most of the remaining natural forests are found in government forest reserves and in locally protected areas. Since communal forests are dwindling and firewood or timber cannot be gathered from reserved forests, local communities have developed strategies to ensure availability of energy resources needed for their daily lives. One such strategy has been planting of own trees individually or woodlots for secure availability of firewood to meet household energy demands. An expanding forestry industry and private entry into forestry production allowed access to new building materials, which has led to improved housing construction and elevated the fuel stocks available from woodlots, as elucidated below.

6.2.1 **Forestry development**

In Chapter 4 it was observed that natural forest is declining at the expense of agricultural land. The remaining forests have restricted access. It was also observed that some cropland is being replaced by on-farm woodlots, which indicates that some afforestation practices are being undertaken. The increase of woodlots as illustrated in Figure 6.3, (especially in the highland and middleland zones) of the MRE provides an opportunity for improved livelihoods.

Figure 6.3 Pine woodlots in the study area

The increase of woodlots has opened up opportunities for timber industry and trade in timber products. Figure 6.4 shows how various types of timber and firewood products are being sold at the roadside.

Figure 6.4 Timber and firewood for sale at the roadside

Timber, mainly from pines, is harvested by chainsaw and afterwards crafted into a range of products. As the photographs in Figure 6.4 show, some logs with a diameter of around 20 cm or less are sold as poles, while larger logs are split into thick rafters or even thinner construction planking. Also note that processed timber is not only sold to the outside world, bringing much needed currency to the local community, but that construction material for improved buildings become available locally. Key informants reported that selling of timber is currently a prominent income generating activity which attracts many people. As such, increasingly some of the inhabitants in the study villages are engaged in on-farm tree planting as an employment and an alternative livelihood activity.

6.2.2 Improved rural housing

The increase of woodlots had not only opened up opportunities for the timber industry and trade but also a means to improve housing. The Nyakyusa people of Rungwe district were famous for their bamboo usage as building material especially in the villages of the highland zone. The bamboo (*Arundinaria alpina*) was used for constructing houses, as examples (a) and (b) in Figure 6.5 show. According to Kurita (1993) bamboo houses attracted foreign travellers because of their beauty and neatness. Bamboo was also used for wine making, where liquid extracted from the bamboo (example (c) in Figure 6.5) is processed to make a local alcoholic beverage called ‘*ulanzi*’.

The two upper photos (a & b) show the traditional bamboo-thatched houses while photo (c) shows the bamboo woodlots near homesteads and how liquid from bamboo is extracted for making local wine

Figure 6.5 Traditional bamboo roofed houses and extraction of liquid from bamboo used for making bamboo wine

Deforestation and the replacement of bamboo woodlots with potato fields at the homestead led to the disappearance of these trees that were used for house construction. Perhaps this explains why in Table 6.1, of the 189 respondents perceiving to have a better-off life, a mere 2% indicated that having a good house (with corrugated iron roof) contributed to their well-being. Nevertheless, despite this low response from the respondents, field observation and interviews with key informants showed that there is a transformation of the rural housing styles in the study villages. During an interview the Unyamwanga head teacher, discussing the quality of life of the villagers, acknowledged the fact that his community's well-being had changed due to improved income levels. This observation translates in his narrative as follows:

> *"Life has changed in Unyamwanga. The village has made remarkable development in terms of life styles. I was transferred to Unyamwanga primary school in 2001. By that time there was no corrugated iron roofed house except school buildings. Today there are numerous corrugated iron roofed houses. The change is attributable to growing of potatoes and planting and harvesting of pines. In this village it is now a common practice that after every harvest of potatoes one buys a mattress and a bundle of iron sheets"* (Mwanjwango 2011, pers com).

During discussions the Unyamwanga village chairperson also supported the view that housing status has changed greatly in his village. He revealed that in 2000 there were no corrugated iron roofed houses in his village, but by 2010 there were 769 corrugated iron roofed houses out of 900 houses (i.e. 85.4%). A similar situation was observed in other surveyed villages where very few traditional grass-thatched houses remain and of these none was built of or thatched with bamboos as used to be the tradition for Nyakyusa housing. The absence of bamboo-thatched houses was common in all of the surveyed villages; most houses are built with bricks and have corrugated iron roofs. The change in farming system has resulted in loss of the bamboo forests as they are increasingly replaced by potato fields (as seen in Figure 5.2 in Chapter 5) and maize. This has also promoted the building of the modern houses (Figure 6.6) with brick walls and corrugated iron roofs.

Figure 6.6 Modern corrugated iron roofed houses in the surveyed villages

Indeed, a change from pyrethrum and millet production to potatoes and the afforestation practices (especially of pines and other tree species) have changed the livelihoods of the local communities. This is especially the case in the highland and middleland zones of the MRE. Higher incomes are being generated and invested in the construction of modern houses.

6.2.3 Improved availability of fuelwood

Increased woodlot planting is not only seen as a way of diversifying the means of deriving livelihoods among the local communities but also a way of securing household energy supplies. With limited access to firewood, this may alleviate energy problems at the household level and hence ensure better livelihoods. Emtage & Suh (2004) observed that on-farm tree planting, besides generating income, is related to livelihoods through meeting subsistence requirement of household fuelwood.

My household survey revealed that on-farm tree planting helps respondents' source firewood from their own trees as there are restrictions on harvesting in the forest reserves. In Chapter 5 it was observed that all of the 384 surveyed respondents depend on fuelwood as their main source of energy for cooking. It was also indicated that of these 53% bought their fuelwood while the remaining 47% sourced it from government forests (illegally) or from their own on-farm trees. The increased conversion of cropland to woodlots that was observed in Chapter 4, particularly, in the highland and middleland zone of the MRE is attributable to the high dependence on fuelwood and the fact that reserved forests are restricted and most of the communal forests have been cleared for agriculture and settlements.

The ongoing increased on-farm tree planting in the study villages on the one hand may reduce pressure on the remaining forest reserves for timber, charcoal and firewood. The involvement of people in tree planting, on the other hand, may make a positive contribution to the environment as it is a mitigation measure which increases carbon sinks and the sequestration of carbon. In future such on farm tree growing could be a livelihood asset in the carbon trade and thus benefit respondents by increasing their incomes from different sources so that they do not have to depend on agriculture only. According to URT (2003e) smallholder or village tree growing for multi purposes has the potential to limit or offset the production of greenhouse gases or at least to act as a mitigation measure. However, the extent to which this is realised in the study area needs further investigation.

The combined effect of potential production of fuelwood and construction timber for generating income in an era of growing urban demand bodes well for increased future involvement in planting on-farm woodlots in the study villages particularly in the highland and middleland zones. Growing urbanisation drives the high demand for timber for house construction and the fact that locals in the study area are no longer using bamboos for houses construction (especially the roofing material), timber is in high demand. The declaration of the Rungwe Forest Reserve as a Nature Reserve has also compelled people to rather cultivate their own on-farm tree stands. From an environmental point of view, tree planting could improve soil fertility, regulate climate and hence enhance agricultural productivity. Thus increased on-farm tree planting is a change in land use that promises positive outcomes for the livelihoods of the people of the study area. However, woodlots are competing with agricultural land use, a phenomenon that requires further investigation in relation to food security.

6.3 LAND USE CHANGE AND POPULATION DEVELOPMENT

The changing land use regime in the MRE found expression in improved well-being in the developing population exposed to that change. Well-being as expressed in improved food security, health status, education levels, and as determined by household size and the dependency ratio are analysed in these subsections. As a point of departure, Table 6.1

(reported in Section 6.1.1), introduces the perceived levels of well-being reported by respondents, so subsequent discussions can continually probe explanations for the status of well-being in a range of explanatory variable characteristic of the population.

6.3.1 Improved household food security

Respondents associated access to sufficient food directly with a better quality of life. In Table 6.1, 80% of the 189 respondents who perceived to have better quality of life relate food availability to their improved livelihood. This is not surprising because for the rural communities whose agricultural production is mainly for subsistence, food security is a main concern. This is in line with Todaro (1992) who contended that the basic reason for the concentration of people and production in agricultural and other primary production activities in developing countries is the simple fact that at low incomes, the first priorities of any person are food, clothing and shelter. In relation to food availability the FAO (2005) holds this a basic human right, mandated in international law and recognized by all countries.

Increase in cropland and intensification of agriculture in the study area particularly in the highland zone, has provided opportunities for the communities to produce not only for food but also for sale. Elsewhere at the global level, Foley et al. (2005) and Geist & Lambin (2002) contended that many forms of land use change enhance increase in food production. The image analysis in highland and middleland zones showed an increased conversion of grassland, natural forest and woodland to cultivated land mainly for food crop production.

6.3.2 Enhanced household health status

Good health was, second to food availability only, in the respondents' perception, essential for good quality of life. From a livelihood point of view good health is one of the human capital in production (De Sherbinin et al. 2008). With good health a person can engage in a number of economic activities including on- and off-farm activities. The communities' health status in the study area has increased not only because of the availability of dispensaries and health centres but also because of adequate supplies of food and the fact that there is food that they can sell. Agricultural intensification such as ability to adopt zero grazing of livestock provides in their immediate livelihood needs. As noted earlier, dairy livestock keeping was introduced to increase the supply of milk, meat and manure and to diversify livelihoods of the communities as a response to loss of grazing land, as land use for crop farming expanded.

6.3.3 Education level linkages

Education is a very important developmental characteristic of a person. It determines the level of understanding and interaction with the surrounding environment. In terms of human assets, education is one of the key determining elements considered in livelihood frameworks (Ellis 2000; Pensuk & Shrestha 2008). The cross-tabulation shown in Table 6.3 to test the relationship between education and quality of life was performed to underscore its influence on the quality of life. The analysis indicates a trend where a larger contingent of respondents with higher levels of education registered higher quality of life enjoyment.

Table 6.3 Relationship between quality of life and education level

Life status of respondents	Education level* (Frequency and % of row total)						
	0	5	7	9	11	14	Total
Better-off	24 (12.7%)	11 (5.8%)	125 (66.1%)	9 (4.5%)	16 (8.5%)	4 (2.1%)	189 (100.0%)
Worse-off	55 (28.2%)	23 (11.8)	98 (50.3)	4 (2.1%)	15 (7.7)	0 (0.0%)	195 (100.0%)
Total	79 (20.6%)	34(8.9%)	223(58.1)	13 (3.4%)	31 (8.1%)	4 (1.0%)	384 (100.0%)

*0 – none; 5 – did not complete primary education; 7 – completed primary education; 9 – did not complete secondary education; 11 – completed secondary education; 14 – others

The worse-off category registered a consistently lower level of education. Most of those who completed secondary education and those who have obtained other qualifications perceive their lives to be better. In fact, for the respondents who had other qualification none of them reported to have worse-off quality of life. These included a group of respondents who undertake agricultural activities alongside other businesses or who are civil servants. Furthermore, correlation analysis to probe the relationship between total land size owned by individual respondents and their education level recorded a positive but weak relationship of 0.539. The reason behind this fairly low figure, disproving the expected relationship somewhat, could be that inheritance has more influence on land ownership than education. Respondents may inherit large or small fields from their parents or kinsmen regardless of their education levels. This is explicitly supported by data in Chapter 5 which indicated that of all the total fields recorded, 64.3% were inherited.

6.3.4 Household size determinants

Household size is an important factor in determining the characteristics of labour supply in economic activities, production patterns and consumption levels within the household. Also, household size has implications for the dependency ratio (number of people relying on household income), resource usage and environmental conservation since most people in a rural setting depend on natural ecosystems (mainly land based) for their livelihoods. In the study area household sizes were highly varied. Responding to Question 6 (questionnaire in Appendix B), my survey data shows that the majority (58.4%) of the respondents had less than 6 family members while 38.7% had between 6 and 10 family members. A small (2.9%) high-dependency group had more than 10 family members in their households. According to Mwamfupe (1998a), in the Nyakyusa society households had as many as 8-10 members living together. Such large households were considered to be an asset, particularly in the provision of labour, on which the local economy heavily depended. Today, it is not surprising to find smaller households of four to six members comprising husband and wife together with their own children. My household survey indicates that more than half of the respondents have less than six family members. This is an indication that rural households in the study area are transforming from having many family members to medium and few family members. The transformation may be attributed to out-migration especially of the youths in search of alternative economic activities in other parts of the country.

A cross tabulation of the relationship between land size and household size was executed to probe its effect on the quality of life, as lack of land to cultivate on was reported by respondents (reported in Table 6.1) as one of the factors for their worse-off life. The results in Table 6.4 indicate that household size has limited influences on the quality of life of respondents. In fact, and contrary to normal expectations, smaller households tend to

Table 6.4 Relationship between household size and life status of respondents

Total household size (members of household)	Quality of life status of respondent			
	Better-off	Worse-off	Total of respondents	% of total
<2	6 (1.6%)	13 (3.4%)	19	5.0%
3-4	63 (16.4%)	67 (17.4%)	130	33.8%
5-6	74 (19.2%)	64 (16.7%)	138	35.9%
7-8	30 (7.8%)	35 (9.1%)	65	16.9%
>8	16 (4.2%)	16 (4.2%)	32	8.4%
Total	189 (49.2%)	195 (50.8%)	384	100.0%

experience worse-off living conditions than middle-sized larger families. The largest households are equally divided between positive and negative life experiences.

The reported worse-off quality of life in this case translates to lack of land to cultivate (as the available land has to be subdivided among the members/heirs of households). With large family size other factors such as small land to cultivate on, low production, inability to purchase inputs, diseases and personal circumstances may lead to worse-off quality of life as reported earlier. Additionally, as recorded already in Chapter 5, there is a strong positive relationship between household size and total land sizes in the study. This means that as household size increases land size also increases and so does income. Inability of respondents to increase landholding to meet the needs and demands of the household means that the small land units owned have to be subdivided among the household members. This in turn, may explain the lack of land to cultivate and the little productivity reported by respondents which, was related directly with the perceived worse-off life status.

6.3.5 Gender and access to land

Gender composition of the respondents was considered in assessing the quality of life of the surveyed community. The analysis of the composition of gender is very important in this study because land use changes interplay with social systems such as land tenure systems, gender dynamics, power relations, people's decision making, health, social networks and cultural values. The impact of land use change on livelihoods may vary by gender of the affected respondent. A cross-tabulation of gender and quality of life indicated in Table 6.5 does not, however support any gender based variability assumption.

Table 6.5 Relationship between gender and respondent's quality of life

Gender of respondents	Respondent's quality of life		
	Better-off	Worse-off	Total
Male	96 (52.5%)	87 (47.5)	183 (100.0%)
Female	93 (46.3%)	108 (53.7%)	201 (100.0%)
Total	189 (49.2%)	195 (50.8%)	384 (100.0%)

This could be an indication that females compared to their male counterparts have no better access to land on which their livelihoods depend. Inequitable access to and control over land other key resources that is attributed to statutory and customary practices are not unique to rural communities in Tanzania, but in most of the Eastern and Southern Africa countries. UNECA (2003) shows that in Southern Africa, with the exception of Zambia and Malawi, although women make up more than 60% of smallholder farmers, they do not enjoy rights to own land except through their husbands. In Botswana for example, every male head of household is entitled to three pieces of land: one each for his homestead, cultivation and grazing (Kalabamu 1998). Women regardless of their marital status or age could not acquire land or landed property of their own without their husbands' written consent. In South Africa, women do not usually qualify to hold land independently from men; rules of access and inheritance generally tend to favour men over women and women with children over those without (UNECA 2003). Similarly, in Uganda, access to land has gender connotations that favour the male gender; for most women, effective rights in land remain elusive, even as their marital and kin support erodes and female headed households multiply (Mugagga, Kakumbo & Buyinza 2012).

Table 6.6 shows a cross-tabulation of marital status and quality of life. The results seem to indicate that married respondents are clearly better-off than the unmarried. Especially disconcerting is the observation that divorced and widowed status seems to contribute significantly to lower quality of life – an indictment of the social system governing community life, and especially the lack of access to resources like land.

Table 6.6 Relationship between marital status and quality of life

Marital status of respondent	Quality of life of respondents		
	Better-off	Worse-off	Total
Never married	7 (50.0%)	7 (50.0%)	14 (100.0%)
Married	147 (55.7%)	117 (44.3%)	264 (100.0%)
Divorced	3 (20.0%)	12 (80.0%)	15 (100.0%)
Widow	32 (35.2%)	59 (64.8%)	91 (100.0%)
Total	189 (49.2%)	195 (50.8%)	384 (100.0%)

While Table 6.6 aimed at exploring the relation between marital status and quality of life, Table 6.7 shows the relationship between marital status and modes of land acquisition by respondents. The aspect of marital status and land acquisition was important

Table 6.7 Relationship between marital status and modes of land acquisition

Marital status	Mode of land acquisition		
	Inherited	Other modes	Total
Never married	8 (57.1)	6 (42.9%)	14 (100.0%)
Married	163 (61.7%)	101 (38.3%)	264 (100.0%)
Divorced/separated	10 (66.7%)	5 (33.3%)	15 (100.0%)
Widow	66 (72.5%)	25 (27.5%)	91 (100.0%)
All	247 (64.3%)	137 (35.7%)	384 (100.0%)

due to the fact that land (ownership) is one of the most fundamental resources to women's living conditions and economic empowerment. But also the fact that in the study area inheritance is still a dominant mode of land acquisition and it mainly favours males and to a lesser extent, married women. Carpano (2010) shows that although married women (with registered marriage) have the right to acquire, hold and dispose of property, customary norms in rural areas are still biased against women, thereby limiting their ownership and control of land resources. The results in Table 6.7 indicate that while inheritance is the dominant mode of land acquisition of married respondents, other modes of land acquisition are even more dominant (approaching the only means) in the unmarried categories.

Table 6.6 and Table 6.7 indicate the dynamics of resource access (especially land) in the study area. In the Nyakyusa culture the issues of access to and use of land are still favoured by the traditional rules of inheritance that favour male offspring in inheriting property, especially land, though not all males inherit land as it is usually the oldest male in the family who receives more land. Table 6.7 further indicates that the traditional land access, though still dominant, is changing. As illustrated by my household surveys, respondents are using different means to acquire land. These changes related to resource access are gradually changing due to globalisation and other local forces such as the national land policy and Land Act. Both the national land policy and Land Act stipulate equal and equitable access to land for all citizens. The national land policy in particular, acknowledged the fact that under customary laws, female access to land was insecure and indirect and therefore it provides women with the right to acquire land in their own right through purchase and allocation.

6.4 LAND USE AND SOCIETAL LINKAGES

In the previous sections of this chapter the extent to which land use change has provided opportunities and constraints to people's livelihood, was discussed. It has been also observed that some livelihood changes are related to multiple land use changes. This section focuses on observed land use change and societal linkages in the surveyed community. The consequences or outcomes of land use change manifested in such observables as change in living conditions, change in gender roles and relations and the commercialisation of land. Fundamental changes that have emerged in the MRE related to land use change are explained in the next subsections.

6.4.1 Change in gender roles and relations

The shift away from production of coffee, tea and pyrethrum to potatoes and the commercialisation of food crops has resulted in a change in gender roles. Traditionally before the 1990s, banana trade as a business was run by the women only, but with the decline in productivity of the traditional or industrial crops (tea, coffee and pyrethrum), which were solely owned by men, both men and women are currently trading bananas (Figure 6.7a, b, c) and potatoes (Figure 6.7d). The selling of products is often done by women – offering new opportunities to women to earn income and escape from the drudgery of home work.

In fact commercialisation of food crops such as bananas and potatoes has given women access to financial resources and therefore empowered them – commercialisation of food crops provides more opportunities for women now than before. Previously the agricultural policy was biased to support industrial crops in terms of farm inputs and credits. The involvement of women in the trading activities has shifted family roles where women become the breadwinner in the family. This means that to support women, the government should also encourage food crop production that is now commercialised.

Figure 6.7 Banana and potato trade

With commercialisation of potatoes, field cultivation is done by both men and women as a family, and or by hired labourers. According to Kurita (1993) in the 1970s few women cultivated fields. This author contends that in the 1980s cultivation was still done by men except in the case of some women that were mainly widowed. Today both men and women grow potatoes and bananas for sale. Nindi (2007), studying changing livelihoods of the people living along the shores of Lake Nyasa in Tanzania, observed a similar trend of change in gender relations as a result of land use change. It was found in his study that, with the decline in fish catches and ever-smaller trading volumes, women no longer waited for fish at home but interacted with men by buying fish along the shore. Previously, traditional culture dictated that female fish traders had to wait for fish at home. In my study area, both men and women are involved in the trading of agricultural produce in the outside world.

6.4.2 Change in social relations

The replacement of pyrethrum and finger millet with potatoes in Ndaga in particular has led to the commercialisation of manual farm labour. In the late 1980s labour was still free (Kurita 1993) and there was labour cooperation and reciprocal obligation on a social basis, where young men would gather and perform farmwork and be rewarded with boiled rice, ugali made of maize flour, cooked beans, beer and prepared chicken. Key informants asserted that during those days when coffee, tea and pyrethrum production was lucrative, women were obliged to work on their husbands' farms to harvest cash crops like coffee, tea and pyrethrum. They had no control over the produce except where food crops were produced. Kurita (1993) showed that in the latter half of the 1980s hired labour replaced the traditional cooperative and reciprocal labour system. From this time up to the present labour needed for farmland preparation, digging, planting and harvesting mainly of the potatoes is mostly hired. Large-scale potato production has accelerated and intensified the commercialisation of labour.

My household survey showed that about half of the respondents who farm used hired labour and the remaining 49% depended on family labour only. The change from traditional subsistence food crops to commercialised food crops, and the change from free social labour to commercial or hired labour meant that women's obligation to work on their husband's farms is likely to decline. This implies a transformation of the cultural norms governing gender involvement in the agricultural production and marketing system. Currently, obtaining hired labour is unavoidable due to the fact that the amount of farm work has increased, especially since potato production has changed from small to large scale, but while most farm work is still done by means of hand hoes. That is, the transformation from small scale to large scale production is yet to be mechanised. In all of the six surveyed villages for example, none had a tractor or power tillers. Lack of mechanisation is partly attributable to steep slopes preventing larger machinery from operating there and the light nature of soils of the study area.

This corresponds with the findings of Nindi (2007) who notes that change in land use led to a decline in the volume of fish catches, which then altered the dancing traditions among the Nyasa people, along the shores of Lake Nyasa in Tanzania. The Nyasa had their traditional dances, *kioda* for women and *mganda* for men that fostered social cohesions among communities. These dances were performed after crop harvest and when fish from the lake were available. Dance groups from nearby or distant villages would be invited and dancers would stay in host houses for two to three days eating, dancing and drinking together. At present, though, due to declining fish catches, the traditional dances involve mostly nearby groups only whose members dance and return home on the same day – no longer requiring the host to prepare special food, drinks and accommodation for the guest friends.

6.4.3 Commercialisation of land

Both formal and informal modes of access to land exist in the study area. The formal mode involves getting the land by applying to the government and following the required purchase procedure. The informal land access mode often involves land transactions which are entered into between buyers and sellers outside government regulations and procedures. In this case the local leaders play an active role in the process. The majority of urban dwellers acquire land through the informal procedures (purchasing, renting and hiring) whilst rural communities mostly use the customary land tenure procedures. Under the customary system, the main means of land acquisition and ownership is through inheritance.

In Chapter 5 of this dissertation it was noted that inheritance was the significant mode of land acquisition among the surveyed respondents. This was attributable to cultural practices where pieces of land have to be allocated to children. With the liberalisation of the economy and accompanying change in land use, informal land transactions, through purchasing and renting in the study area increased. Thus, land transaction through the market was observed to be the popular emerging mode of land acquisition. This research noted that

35.7% of the total fields were reported by respondents to have been obtained through other means such as purchase and renting. Kurita (1993) showed that purchase of cultivated land in the study area had already been observed since the 1970s. However, the rate of land purchasing has clearly increased over time.

My survey indicated that 50% of the fields were purchased between 1990 and 2010 and 20% were bought during the 1980s (Question 11 in Appendix B). This trend is attributable to population increase through in-migration and the value attached to land by both the locals and urban residents who are investing in commercial potato production. This latter group of urban residents, here referred to as "absentee farmers"[34] is seen as a source of capital for agricultural development. Their investment in potato production has facilitated a shift from small-scale to fairly large-scale farming. This is actually also supported by the World Bank (2007) in its insistence that smallholders should transform into large-scale producers. The process has been encouraged by the liberal economic policies of the 1990s that have enhanced commercialisation of resources for agricultural production (Sokoni 2008). Changes in land use for agriculture (from small- to large-scale production) are associated with a process of land redistribution through the land market where a danger of some members of the community, especially the poor, loosing land is apparent. Selling of land may have disadvantaged women, as family land for food production is likely to have been lost. In the future, this may contribute to food insecurity, especially if land sales continue uncontrolled.

6.5 CHAPTER SUMMARY

In this chapter the implications of changes in land use on communities' livelihoods, were discussed. To a large extent, the change in land use has enhanced improvement of the local communities' livelihoods. The household surveys, observation and interviews with key informants show that most local communities' livelihoods in the surveyed villages are

[34] Absentee farmers refer to land owners who live so far away from their land that they rarely visit their property in person. Their motives for owning land (inherited, bought or rented) are related to either family connections or investment of capital. In most cases, they are not occupied with daily management of the land and very often relatives or hired labour are in charge of the property (Bakker & Van Doorn 2009; Mbonile 2005). In this study the total number of absentee farmers in the study villages was not established. However from interviews it was revealed that there are a number of them and they occupy large land parcels (of more than two hectares) consolidated into single fields, unlike the local communities who have small fields scattered in different locations. The trend has resulted not only in the commercialisation of land, but also caused land conflicts and land scarcity among locals as land is rented out to these absentee farmers (Mwakapola 2011, pers com).

changing in terms of their housing type, life styles, purchasing power and consumption patterns. Although the majority of the respondents engage fully in agriculture, their livelihoods are transforming. A change in communities' livelihoods is noted as there is increasing reliance on monetary incomes. This is possible due to the fact that there is a remarkable shift away from only consuming self-produced food to purchasing marketed food. It was observed, for example, that bananas and potato production have become commercialised. The changes in the agricultural system supported by the availability of commercial markets have positively benefited the local communities. Their livelihoods in terms of land access, finance and other social assets have improved due to the ongoing changes in land use. However, it has also been shown that among the communities, land use change has impacted the members of the community differently – the least advantaged losing opportunities for realising their livelihoods. Some socio-demographic variables such as gender, education, household size and the total land size owned by individual households were shown to account for some of the variations in the impacts of land use change on livelihoods experienced by households.

CHAPTER 7 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

In this study the focus was on land use and livelihood changes in MRE, Tanzania. The objectives of the study were (i) to identify and map land uses of the study area for four periods (1973, 1986, 1991 and 2010), (ii) to analyse land use change that has occurred in the four periods (i.e.1973-1986, 1986-1991, 1991- 2010 and 1973-2010; (iii) to identify and evaluate the factors responsible for the observed land use change and (iv) to establish the linkage between land use change and livelihoods of the affected local communities. In order to adequately explore, explain and describe the nature and extent of land use change and its associated drivers a triangulation methodological approach was followed. Specifically the research methods used in this study included the analysis of satellite imagery and the use of a geographical information system (GIS), socioeconomic surveys, in-depth interviews, field observation and document analysis. This chapter firstly summarises the main findings based on the objectives of the study. Secondly, conclusions are drawn and recommendations are made especially for future research.

7.1 SUMMARY OF RESULTS

In this subsection a summary of the finding of the study based on the four set objectives, is provided. With regard to the discussion in this dissertation; the first and second objectives were joined and largely formed the material for Chapter 4. The third objective was separately covered in Chapter 5, whilst the fourth objective was covered in Chapter 6. The summary of the results based on these objectives is offered in a systematic order below.

7.1.1 Observed land use and land use change in the MRE

Mapping land uses and analysing change in land use in the MRE were the first two objectives of the study. It was important to first understand the land uses of the study area in terms of coverage. Four Landsat images (1973, 1986, 1991 and 2010) were manually classified and polygons representing different land uses were digitised onscreen. At the district level twelve land use categories were identified. In the study villages, which were subsets of the broader analysis, five to seven main land uses were present and mapped. The classification showed that villages of the same zone shared similar land uses, with the exception of villages of the middleland zone. In this zone Syukula village has one more land use category compared to Kyimo (i.e. the cultivation of bushy crops that appears only in

Syukula village). This is largely attributable to variation in microclimatic characteristics within the zone.

During the pre-forced villagisation period, the general pattern and trend in spatial extent showed that mixed cropland with settlements was the most extensive land use in Unyamwanga, Ndaga and Syukula villages. During the same period bushland was the prominent land use in Ilima, Katundulu and Kyimo. Although all the surveyed villages were settled by 1973, mixed cropland was dominant only in Unyamwanga, Ndaga and Syukula while bushland dominated in the rest of the villages of the ecosystem. This indicates that intensification of agriculture started longer ago in the highland zones as compared to the middleland and lowland zones.

During the forced villagisation and post-villagisation periods, mixed cropland with settlements still covered a large proportion of land area both at the district and in the surveyed villages particularly in Unyamwanga, Ndaga, Kyimo, Syukula and Katundulu. In these villages mixed cropland with settlements land use was followed by woodland in Unyamwanga, Ndaga and Syukula and tree crops in Kyimo and grassland in Katundulu village. In the same period, bushland remained the dominant land use in Ilima village followed by mixed cropland with settlements. This indicates that the villagisation policy had an impact in the area. During this time, as the villages were settled, more land was converted to agricultural and settlement land at the expense of natural vegetation.

During the structural and post-structural adjustment period up to the present, land use coverage showed two dominant trends: intensification of use and abandonment of agricultural fields in some villages. In 1991, for example, the mixed cropland was still prominent in almost all of the surveyed villages, though there were substitutions in certain land uses. In Unyamwanga village for example, bushland replaced the mixed cropland with settlements as a dominant land use in 1991. In Ndaga and Kyimo villages the mixed cropland with settlements was still prominent though on reduced acreage as compared to 1986. In Syukula, the cultivation with bushy crops dominated in 1991, followed by grassland and mixed cropland with settlements categories. In Ilima and Katundulu villages, grassland and bushland were dominant land uses.

In 2010, there was still no progressive change in the cultivated land in Ilima and Katundulu villages whereas in the other villages the cultivated land increased as compared to the year 1991. In Unyamwanga village for example, mixed cropland with settlements occupied 32% of the total land whereas in Ndaga and Kyimo villages, mixed cropland with settlements occupied three quarters of the total land. In Syukula village, cultivation with bushy crops was dominant in 2010 occupying 33% of the total land. In 2010, it was also observed that natural forest, grassland and woodland were important land uses in Unyamwanga village; while in Ndaga, Kyimo and Syukula villages the natural forest category no longer existed. The dominance of mixed cropland with settlements was also observed in 2010 in almost all villages except in Ilima and Katundulu villages. The area acreage for cultivated land increased in 2010 as compared to 1991. The results also showed that, apart from the increases in cultivated land, other land uses such as woodlands were increasing especially in the villages of the highland zone. This showed that the local communities were increasingly establishing woodlots on their farms. With regard to the three agro-ecological zones, the results indicate that the highland and the lowland zones are more advantageous in terms of agricultural production that is market oriented. The liberalisation of markets and enabling environment of private production and marketing of agricultural produce have had a significant impact on land use change in the study area. Smallholders are diversifying their agricultural produce including on-farm trees.

In addition to mapping land uses, the changes in land use for the four year-snapshots were evaluated. In assessing the changes in land use, four different time sequences 1973-1986, 1986-1991, 1991-2010 and 1973-2010 were assessed using the PCC procedure in ArcGIS. The results revealed that major changes, mainly land conversions, had taken place. The PCC method further revealed that at least each of the mapped land uses in the MRE had undergone some changes from one class to another from 1973 to 2010. There was a general trend of declining natural vegetation and that of increasing cultivated land particularly in the villages of the highland zone. Woodland, bushland, grassland and natural forests were overtaken by cropland with settlements. For the study period of 37 years, results indicated that more than three quarters of the natural vegetation had been replaced by mixed cropland with settlements. With regard to the four periods considered, much conversion to mixed cropland with settlements was observed between 1991 and 2010 and 1973 and 2010 – particularly in the highland and middleland zones of the MRE. This was evidenced by the spatial analysis using the four Landsat images. Land use conversions were either from bushland, woodland, grassland or natural forest to mixed cropland with settlements.

Between 1991 and 2010 for instance, mixed cropland with settlements increased by 5% in Unyamwanga village; 25% in Ndaga; 6% in Kyimo and 13% in Katundulu villages. In the same period, cultivation with bushy crops increased by 8% in Syukula village. For the 37 years, mixed cropland with settlements, increased by 22% in Ndaga village, and 54% in Kyimo village. The tree crops coverage also increased by 16% in Kyimo village while the bushy crop cultivation increased by 33% in Syukula village. The increases of cultivated land in these villages were at the expense of bushland, grassland, woodland and natural forests.

The periods between 1986 and 1991, and between 1991 and 2010, were both marked by an increase in natural forests and woodlands particularly in Unyamwanga and Ndaga villages of the highland zone. The increases of these land use categories were at the expense of cultivated land. Generally, following the preceding discussion on these two objectives of the study, it has been demonstrated that rural communities' livelihood activities such as land use are important and therefore need to be recognised through a variety of scientific methodologies.

7.2 Instrumental drivers of land use change in the MRE

The third objective focused on the driving forces of change in the MRE. A number of generic direct, indirect and natural drivers of change were identified and their impact on land use change elaborated. The identification of these drivers of change in the MRE, however, was mirrored against the common findings of a number of studies around the world. The findings of the study showed that the area was endowed with forests, grassland and woodland resources, which provided a range of opportunities to communities for their livelihoods; increasing human activities nevertheless, were a major source of their conversions into agricultural and settlement lands. A combination of direct, indirect and natural factors was responsible for the changes in land use in the MRE. Population growth, in particular that resulted in land shortages was among the factors behind the conversion of natural vegetation into cultivated land. Other factors such as political and economic policies, technological development and local urbanisation played a significant role in current land use changes.

In the study area the *villagisation policy* had a less significant impact on land use change than it had elsewhere. This was attributed to high population numbers that had already resulted in land shortages and outmigration of the locals. Of particular importance were government policies on use and access to agricultural land, forest and energy resources. The forest policy for example, influenced land use change in the study area by emphasising the establishment of private and government plantations and natural forest reserves. In the district, six forest reserves (Rungwe, Livingstone, Sawago, Masukulu, Kyejo and Kitweli) are demarcated and the local communities are excluded from this land, which could be suitable for cultivation. In addition, the Kiwira forest plantation was also established during the same period. The establishment of these forest reserves and plantations decreased agricultural land available for local communities by 2% of the total district area, and hence encouraged the conversion of woodlands and natural forests to cultivated lands.

Comparisons among the three agro-ecological zones, however, showed that *natural factors* such as rainfall availability in conjunction with market outlets for agricultural products are the strongest drivers influencing change in land use in the highland and middleland zones as compared to the lowland zone. The availability of *markets* that offer competitive prices and access to farm inputs, especially fertilizers, are influencing current land use change in the highland and middleland zones. The *macro economic reforms,* especially the removal of subsidies on traditional industrial crops such as coffee, tea and pyrethrum, have made significant contributions to the mapped land use changes in the highland zones. These factors in turn have led to a change in the cropping pattern of the local communities in the MRE. For instance, perennial crops such as tea, coffee and pyrethrum have been replaced by annuals such as potatoes and bananas. Such a change has led to intensification of agricultural land use and changes in cropping patterns. Intercropping which is considered ecologically healthy is fading. Traditional cropping patterns have changed, for example previously potatoes were intercropped with maize, but currently potatoes require sole cultivation. This indicates that smallholders have been sensitive to the market opportunities created by increasing demand for potatoes, maize and timber products as well as to the lucrative prices. The political and social reforms to orient production have resulted in intensification of agriculture and expansion of agricultural land in the study area.

The commercialisation of potatoes has also resulted in change in land management practices. Formerly, when pyrethrum was grown, contour bands was the dominant land management practice. Today, with potato production and especially where individual small fields are consolidated into single continuous fields, contour bands are no longer in use. In the study area the wave of changes from perennials to annuals is driven not only by *economic* and *urbanisation* factors, but also the *natural* factors in the specific zones.

Apart from the changes from perennials to annuals there is also a wave of change from food crops to on-farm trees production particularly in the villages of the highland zone. The *spread of pines* and certain other indigenous tree species and the socioeconomic values attached to them by local communities has resulted in the replacement of food crop land with pine woodlots. In Unyamwanga village, for instance, cultivated land showed a decline between 1973 and 1986 and 1986 and 1991. From the discussion it is acknowledged that land use change taking place in the MRE is an outcome of complex interactions between biophysical and societal processes. Generally, government policies, economic, technological, demographic, cultural and natural factors singly or cumulatively have contributed to the conversion of natural vegetation to cultivated land and intensification in the available land in the MRE. This indicates that the socio-economic changes to orient production as well as changes in consumer consumption patterns have resulted in agricultural land use and cropping patterns tending towards higher value crops.

7.3 Land use and livelihoods change interrelationships

The fourth objective of the study aimed at investigating a linkage between the observed changes in land use to communities' livelihoods, the outcome of which was explored in Chapter 6 of the dissertation. It was demonstrated that land use change and livelihoods are intertwined. The discussion on this objective in essence has shown that land use change is not necessarily only a negative phenomenon. The commercialisation of food crops such as potatoes and bananas has given resource and income access to women who previously did not have cash crops of their own. The loss of bamboo forests had resulted not only in income generation but also in building of houses with brick walls and corrugated iron roofs instead of thatched ones. Additionally, the on-farm planting of exotic and certain indigenous species is a positive change as tree planting is known for its role as measure of land management and conservation and may support income and livelihoods of the local communities. In the future this may positively benefit the community by satisfying their energy requirements and may reduce distances travelled in search of firewood.

7.4 CONCLUSIONS

Based on the research findings it is concluded that the MRE has various potential generating attributes, including fertile land and natural vegetation. Changes, however, are taking place in MRE due to population growth and the need to meet people's enhanced livelihood needs. Demographic, technological, economic, socio-cultural, political and natural factors such as the spread of pines are among the drivers of land use change in the MRE. For example, demand and supply of potatoes are high in growing cities, thus the commercialisation of potatoes and pines is likely to continue, and that may lead to further changes in land use. This calls not only for proper land use planning but also addressing the observed land use changes to ensure the ecological integrity of the ecosystem.

It is further concluded that remote sensing data in conjunction with GIS techniques are effective tools in measuring change in land use. The tools facilitated spatial identification and assessment of land use change through which the overall changes were determined. The inclusion of socioeconomic aspects improved and confirmed remote sensing and GIS results. The results of this study have not only built a database on the nature and extent of land use change occurring in the MRE, but also has contributed to knowledge about the current debate on global land use change and its impact on ecosystems and people's livelihoods, especially in Sub-Saharan Africa. Furthermore, the results of the study are relevant for informed decision making, particularly for sustainable use and management of mountain resources. Since the study has provided site-specific land use change information, it can assist planning authorities and decision makers in land use planning, and can feed into future scenario modelling and effect policy changes.

7.5 GENERAL RECOMMENDATIONS

Land use change is taking place in the MRE due to anthropogenic and natural factors. Both positive and negative land use changes were observed in the ecosystem. In respect to livelihood options the positive outweigh the negative changes. The ongoing negative land use changes however threaten MRE and its ecological integrity. This calls for proper planning, policy initiatives and management of the ecosystem to ensure sustainable use of available resources by the communities and other biodiversity dependents in this ecosystem. The study therefore recommends the adoption of sustainability management principle that can ensure the establishment of an enabling institutional and legal framework for enhanced environmental management. The adoption of the sustainability scenario may also reduce the negative environmental, socio-economic and socio-political implications in the future.

Since agriculture is contributing to clearance of forest and bushland, priority should be given to working with communities and the government to improve agricultural land productivity. This will reduce unnecessary farm expansion into natural vegetation available. However, the choice and emphasis on certain crops could be an important attribute as a way to address local food security. The intercropping practices that aimed at satisfying both cash and food crop requirements need to be re-emphasised. This is because increasing replacement of farmland crops such as maize by more commercial non-food crops like trees may seem to be a step away from addressing local food security.

Many of the agricultural extension programmes that were implemented in the 1970s and 1980s focused on the traditional cash crops, though most of them have failed for lack of funding. With the changes in the cropping pattern, where now food crops are commercialised, there is a need of extension services targeting growing of food crops such as potatoes and bananas. Furthermore, service investment is needed to help farmers make use of the new developments in crop and livestock production. Agricultural transformation as well as enhancing its sustainability economically and environmentally would be an important option for smallholder farmers. Transformation of agriculture through the use of high-yielding varieties of seeds and animals, mechanisation, irrigation, and use of manure and fertilisers will make the small farms produce enough for food and for cash, thus avoiding the need to clear more land for agricultural expansion. If this process of intensification of agriculture continues sustainably, most likely human well-being and livelihoods would be improved and the environment conserved. In addition, for sustained economic growth there is a need to address the link between production, processing and marketing of agricultural commodities.

Since the Mount Rungwe Forest Reserve has gained nature reserve status, conservation efforts should aim at developing and promoting nature tourism and leisure in the area. This will provide employment to the youth and function as a way of diversifying livelihoods. The local communities should also be allowed to have beehives in the nature reserve. This will help not only in conserving the forests and water catchment, but also monitoring of fire incidents and diversifying communities' livelihoods. It is an important aspect in economic terms as the local communities will not conserve the forests without tangible benefits. In this case local communities can organise themselves into village committees.

It was reported that local communities surrounding the mountain reserve are inadequately involved in the planning and management of the forests in the ecosystem. Lack of involvement hinders local people from managing the environment effectively. Thus broad networking and consultation are recommended to build awareness, understanding, acceptance and ownership of various policies, strategies and plans. This can be achieved through training, village meetings and information sharing.

It was found that more than three quarters of the respondents rely on fuelwood as an energy source, and it is the force behind diminishing woodlands and natural forests. The Ministry of Energy and Minerals, in collaboration with TaTEDO, could finance and enhance the use of more efficient charcoal stoves that could reduce charcoal use. This could protect not only the forest but also could be a carbon offset project and help poor households to save money, as such stoves use much less charcoal. Awareness raising and sensitisation programmes on the impacts of ongoing land use change should be undertaken. This can go hand in hand with financial and technical support on the ongoing tree planting efforts by local communities. The environmental knowledge owned by local communities should also be utilised and/or integrated into any adopted rehabilitation project.

Remote sensing data in conjunction with GIS has proven to be effective tools for monitoring land use change. Policy makers are advised to create an affordable and appropriate GIS that analyses, stores and displays geographical data to help with planning and management for mountain areas, particularly in the realm of climate change, to which mountain areas are so vulnerable.

The exotic *Pinus patula* pines are posing a threat to the sustainable provision of ecosystem goods and services, both to man-made and natural ecosystems. It is suggested that remote sensing data be used to map the actual distribution of areas at risk of invasion and that the GIS be used as a tool for interventions aimed at avoiding or eradicating or controlling established invaders in the MRE.

In the potato business it was reported that smallholder farmers use middlemen to sell their produce. This strategy might be advantageous because it saves time as well as costs of transport and market place fees. Through this mechanism however, the smallholder farmers are not empowered to have control over their activities in the value chain and to gain direct access to markets, and remain competitive. It is recommended that smallholder farmers should form common interest groups (i.e. cooperative societies) to help them in stabilizing prices and save them from middlemen who take advantages of a bumper harvest to exploit them. When belonging to such groups, farmers agree on the lowest price and no one could sell below that margin. The government should fulfil its enabling role by involving or attracting the private sector to contribute to the development of the market and to reduce marketing constraints.

Although statutory and customary tenure systems in Tanzania recognise women's access to land, discrimination against women access to land is still persistent in the study area. It is recommended that more deliberate effort including legal reforms accompanied by awareness raising, capacity building and improved access to legal services, which are key for women and other frequently marginalise groups such as pastoralists should be taken to improve and promote gender equality. This will strengthen not only the links between land tenure security and land use but also to sustainable management of the natural resources such as land.

It was also reported that there is no clearance or trenches put in place on the existing boundary between village land and the reserve. Therefore it is recommended that a clear buffer zone covering the entire reserve should be created and be protected as an officially reserved area. This should go hand in hand with policy commitment on a number of initiatives and actions with the aim of addressing environmental sustainability at national and regional levels.

The formulation of a national management strategy specifically addressing the use and management of land in mountain regions in the country is recommended. This is important due to the fact that these are fragile environments. Currently, there is just one clause under the Environmental Management Act (EMA) that insists on the management of these environments.

7.6 SUGGESTIONS FOR FUTURE RESEARCH

Among the notable changes is the decline in farming areas and increase in areas planted with trees. More detailed research would need to be undertaken to establish the implications of the replacement of farmland with woodlots on food security status in the area.

In the future the ongoing on-farm tree planting can satisfy household and regional fuelwood demand, while reducing harvesting pressure on local forests and the associated carbon emission. There is a need to assess the efficacy of planted on-farm trees to reduce deforestation and possibly avoid carbon emission. Carbon sequestration and credit marketing systems should be established in the area to encourage more on-farm tree planting.

There is a lack of real valuation of the resources in the ecosystem, hence a study is required on real valuation of goods and services provided by the ecosystem to establish a pay for ecosystem services (PES) scheme of the different attributes of the mountain's surrounding ecosystem and its economic and environment linkages. A detailed study on optimal species in the reserve and the effect of change on social fabric and ecological functions is also recommended.

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APPENDICES

Appendix A: Mapping classes for Hunting Technical service, MNRT and IRA

	Level 1	Level 2
1	Forest	Humid montane
		Lowland
		Mangrove
		Plantation
2	Woodland	Closed woodland
		Open woodland
		Woodland with scattered cultivation
		Thicket
3	Bushland	Dense bushland
		Bushland with scattered cultivation
		Open bushland
4	Grassland	Wooded grassland
		Bushed grassland
		Grassland with scattered cropland
		Open grassland
5	Cultivated land	Agro-forestry system
		Wooded crops
		Herbaceous crops
		Grain crops
6	Open land	Bare soil
		Coastal bare land
		Bare rock
		Ice-cap/snow
7	Water features	Inland water
		Ocean
		Wetlands
8	Built up areas	Built up areas

Source URT (1997a)

Appendix B: Household questionnaire on land use and livelihood changes in the Mount Rungwe ecosystem

To be filled by head of household
Name of the village...

A: Demographic information of household head
1. Age of respondent (years) …….
2. Gender of respondent i) Male……..ii) Female
3. Marital status of respondent:
(i) Single (ii) married (iii) separated /divorced …………
(iv) Widow/widower (v) Living together…………
4. Occupation of respondent:
i) Main occupation……….. ii) Others (specify)……..
5. Educational level of respondent:
i) None……….. ii) Did not complete primary education…….
iii) Completed primary education….. iv) Did not complete secondary education…………
v) Completed secondary education……
vi) University degree………vii) others (specify)……………….
6. Household composition

Type	No. of household members
Children under 18 years	
Adults (18-65)	
Aged (65+)	

7. Indicate the place where you were born

1	Within the village	
2	Within the ward (different current village)	
3	Within district (different current ward)	
4	Within region (different current village)	
5	Outside the region	

8. If you were born outside the current village specify your area of origin
....

10. Indicate the reasons for migrating to this village (tick all that are applicable to you)

Employment (specify type of employment	1	
Access to agriculture (specify crops you grow)	2	
Lumbering	3	
Joining family	4	
Access to residential land	5	
Access to grazing	6	
Business opportunities (specify the type of business)	7	
Others(specify)	8	

10. Indicate when (year) you migrated to this village...

B: Land availability and use

11. If agriculture is your main occupation give details of the number of plots, size, distance, means of acquiring and the uses of each plot owned

Number of fields owned	Size of each field (ha)	Distance to the plot (km)	Year acquired	Means of acquisition	Use before acquisition	Use after acquisition	Current use
1							
2							
3							
4							
5							
6							
7							

12. Indicate which crops you grow for sale and which for food

Cash crops	Land size for cash crops	Food crops	Land size for food crops

13. Do you perceive to have enough land for food and cash crop production?

Land sufficient status	Land for food crops	Land for cash crop
sufficient		
Not sufficient		

14. If the land you own is insufficient provide reasons for inadequacy

Reasons for inadequate land for cash crops	Reasons for inadequate land for food crops

15. Indicate whether you have adopted any new crop varieties and reasons for adoption

Adopted crop varieties	Year of adoption	Reasons for adopting

16. Concerning different types of land use, who makes the decisions on how the land is and how it will be used in a year's time?

Land uses	**Decision maker**

17. Indicate who does the farm works in your household

Family hand labour only	1	Community groups	5
Hired hand labour only	2	Labour cooperation	6
Hired tractor	3	Others (specify	7
Owned tractor	4		

18. Describe the status of your land productivity, and if deteriorating provide reasons

Land productivity		Reasons for deterioration
Deteriorating	1	
Constant	2	
Increasing	3	
Do not know	4	

19. Indicate fields with deteriorating productivity

Fields (crop types)	

20. How do you address the problem of decreasing land productivity (tick more than one)

Agroforestry	1	Farm abandonment	7
Manuring	2	Off-farm activities	8
Chemical fertilisers	3	Opening a new farm	9
Fallow	4	Intercropping	10
Put land to other use	5	None	11
Mulching	6	Others (specify)	

21. Indicate whether you have adopted new land management strategies and the crops grown under the new land management strategies

New land management strategies	Crops grown under the new land management

22. Indicate whether you have ever given land to other people

Size of farm given away	Mode of giving away the land	Reasons for giving land away

23. Have you ever had conflict regarding the use of land?

Type of conflict	Parties involved	Description of the conflict	Date of conflict	How was it resolved

24. How many members of your household do wage employment during the agricultural on and off-season in order to raise cash to supplement agricultural income?

No. of house hold members	Type of employment during agricultural on and off-seasons		For how long has he/she been involved	Time spent on the activities (days/ months)
	Agricultural on-farm seasons	Agricultural off-farm seasons		

25. Indicate the value of off-farm activities in your household

Income value	Amount earned (Tsh)
Valuable	
Less valuable	
Least valuable	
Not valuable	

26. Indicate how the non-form income is used at the household

Use of non-farm income

27. Indicate type, number and years of the livestock kept in your household

Type of livestock kept	Number/total	Since when

28. Where do you graze your livestock?

Grazing places		Reasons for grazing in the mentioned place
Public grazing land	1	
In the forest reserve	2	
On own fallow land	3	
Zero grazing	4	
Others land not in use	5	

29. Have you ever abandoned livestock keeping? If so why?

Livestock abandoned	When abandoned	Reasons for abandonment

30. Indicate the type of energy used in your household

Type of energy	Use of the energy	Where obtained

31. What services and or goods do you obtain from Mt Rungwe (tick more than one)

Services/goods		Uses (domestic or commercial)
Source of firewood	1	
Source of timber	2	
Medicinal plants	3	
Building poles	4	
Food (meat, honey)	5	
Source of charcoal	6	
Water source	7	
Rainfall attraction	8	
Tourism attraction	9	

32. Are there any similar services indicated in question 31 that are obtained in the village? If yes list them out
i)..
ii)..
iii)...
33. Do you perceive your quality of life generally getting better or worse in the last 10 years?
(i) Better (ii) Worse
34. Reasons for better life
....
....
....
35. Reasons for worse life
....
....
....

C. Land use change

36. Indicate the type of change in land use on your plots in these years: 1970s. 1980s, 1990 and 2010 (i.e. 30. 20, 10 or 2 years ago)

periodisation	Change in land use	Reasons for change
1970s (before villagisation		
1980s(structural adjustments)		
1990s (liberalisation)		
2010 (liberal and neo-liberal)		

37. Indicate whether the changes mentioned in question 36 impact positively or negatively on your livelihood strategies

Periodisation	Change in land use	Impact on livelihood strategies	
		Positive impact	Negative impact
1970s			
1980s			
1990s			
2010			

38. What was the status of the Mt Rungwe forest reserve in these years: 1970s, 1980s, 1990s and 2010?

periodisation	Forest status		Reasons for the status
1970s	1	Improved	
	2	Deteriorated	
	3	No change	
	4	Do not know	
1980-1990s	1	Improved	
	2	Deteriorated	
	3	No change	
	4	Do not know	
2010	1	Improved	
	2	Deteriorated	
	3	No change	
	4	Do not know	

39. Which parts of the Mountain reserve is experiencing pronounced changes in land use?

Parts experiencing change	Changes that have occurred	Reasons for changes

Thank you for your time and cooperation

Verdiana Tilumanywa

Appendix C: Checklist for interview with elders

1. What has been the history of the major land use and land use changes in this area since 1970s to the present?
2. Where have these major changes occurred?
3. What are the policies, institutions, and processes that have influenced and currently influence land use in favour or against certain land uses and management practices?
4. To what extent policy changes (from 1970s to the present) have affected people's livelihoods in terms of land use management practices?
5. How has the commercialisation of forests affect communities? How the district and regional policy and plans implement community based forests?
6. Is land use change affecting your livelihood strategies? How are you coping to sustain your livelihood strategies?
7. What potential conflicts exist between households' livelihood activities and sustainable land use?
8. Do the local communities have access to the forest reserve? How is the forest managed?
10. What comments do you have about the sustainability of current land use trends in you village?

Thank you for your time and cooperation.

Verdiana Tilumanywa

Appendix D: **Checklist for interview with officials**

1. Incidences of encroachment
   - Incidences of encroachment on the mountain forests
   - Measures in place to abate the situation
   - Prevailing laws and regulations governing the use and management of the forest resources
   - Which areas of the mountain experience more encroachment
   - If possible provide acreage of the areas that were under forests but have been taken up for use by the local community
   - Any fire incidents
2. Status of the forest and plant and animal species diversity
   - Species that are disappearing or have already disappeared (plants and animals)
   - Activities that adversely impact the status of the forest, plant and animal diversity
   - The status of the forest in the 1970s, 1980s, 1990s as compared to 2010
   - Major land uses of the areas surrounding the mountain and whether these have been changing overtime (specify periods for particular land use change)
3. Local people participation in the management of the forests
   - How the local community are involved/participate in the management of the forests
   - What is the level of participation of the local community
   - The input of the local community
   - How do the local communities benefit from the management process
4. Issues on diversification of the local population’s activities not to rely heavily on use of forest resources
5. Issues on the role of the government in the management of the forest and biodiversity in Mt Rungwe
   - Changing roles of the government overtime in the management of forest resources(1970s)
   - Current attempt to manage the forest
   - The forest boundary(increased, decreased, remained the same)
   - How they do avoid overlapping mandates by c0-operating with institutions in the district (if there are such attempts)
   - Any organisation, NGO, CBO involved in the conservation of the reserve
6. What are your comments on the conservation of forests and sustainability of the communities ‘livelihoods?

Appendix E Clearance letter from the University of Dar es Salaam

UNIVERSITY OF DAR-ES-SALAAM
OFFICE OF THE VICE-CHANCELLOR
P.O. BOX 35091 ♦ DAR ES SALAAM ♦ TANZANIA

Ref. No: AB3/12(B)
Date: 20th December, 2010
To: The Regional Administrative Secretary,
Mbeya Region.

UNIVERSITY STAFF AND STUDENTS RESEARCH CLEARANCE

The purpose of this letter is to introduce to you **Ms Verdiana Tindichebwa Tilumanywa** who is a bonafide staff member of the University of Dar es Salaam and who is at the moment conducting research. Our staff members and students undertake research activities every year especially during the long vacation.

In accordance with a government circular letter Ref.No.MPEC/R/10/1 dated 4th July, 1980 the Vice-Chancellor was empowered to issue research clearances to the staff and students of the University of Dar es Salaam on behalf of the government and the Tanzania Commission for Science and Technology, a successor organization to UTAFITI.

I therefore request you to grant the above-mentioned member of our University community any help that may facilitate her to achieve research objectives. What is required is your permission for her to see and talk to the leaders and members of your institutions in connection with her research.

The title of the research in question is **"Land Use and Livelihood Changes in the Mount Rungwe Ecosystem, Tanzania".**

The period for which this permission has been granted is **December, 2010** to **June, 2011** and will cover the following areas/offices: **Rungwe District.**

Should some of these areas/offices be restricted, you are requested to kindly advise her as to which alternative areas/offices could be visited. In case you may require further information, please contact the Directorate of Research, Tel. 2410500-8 Ext. 2087 or 2410743.

Prof. Rwekaza S. Mukandala
VICE-CHANCELLOR

VICE CHANCELLOR
UNIVERSITY OF DAR-ES-SALAAM
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Telegraphic Address: UNIVERSITY OF DAR ES SALAAM
E-mail: vc@admin.udsm.ac.tz
Website address: www.udsm.ac.tz

Appendix F **Clearance letter from the Mbeya region**

THE UNITED REPUBLIC OF TANZANIA
PRIME MINISTER'S OFFICE
REGIONAL ADMINISTRATION AND LOCAL GOVERNMENT

MBEYA REGION
TELEGRAM: "REGCOM"
Telephone No: 025-2504045
Fax No.025-2504243
Email: *ktm-mby@iwayafrica.com*
rasmbeya@pmoralg.go.tz
In reply please quote:

REGIONAL COMMISSIONER'S OFFICE
P.O. Box 754,
MBEYA.

Ref. No. **DA.191/228/01/67**

22nd March, 2011

District Administrative Secretary,
P.O. Box 34,
RUNGWE - TUKUYU.

Ref: RESEARCH PERMIT

The reference is made on the above subject.

May I introduce to you Ms Verdiana Tindichebwa Tilumanywa from University of Dar es Salaam. By the moment is conducting research on **"Land Use and Livelihood Changes in the Mount Rungwe Ecosystem, Tanzania".**

Please assist her accordingly.

Mbeyela
Mbeyela Q. G (Ms)
For: REGIONAL ADMINISTRATIVE SECRETARY.
MBEYA

C.C. Ms Verdiana Tindichebwa Tilumanywa

Appendix G Clearance letter from Rungwe district council

JAMHURI YA MUUNGANO WA TANZANIA

OFISI YA WAZIRI MKUU

TAWALA ZA MIKOA NA SERIKALI ZA MITAA

Anwani ya Simu: "ADMIN"
Simu ya Mdomo: 025 2552036

Unapojibu Tafadhali taja:

Ofisi ya Mkuu wa Wilaya
RUNGWE.
S. L. P. 34,
TUKUYU.

Kumb.AB.365/374/01/71. **24/03/2011.**

Afisa Maliasili(w), Afisa Maji (w), Afisa Mazingira (w),
Afisa Kilimo/Mifugo(w), Vikundi/Wanaharakati wilayani,
Afisa Mtendaji Kata ya Isongole, Afisa Mtendaji Kata ya
Kyimo na Afisa Mtendaji Kata ya Ilima.
WILAYA YA RUNGWE.

YAH; KIBALI CHA KUFANYA UTAFITI.

Somo la hapo juu lahusika.

Ndugu Verdiana Tindichebwa Tilumanywa ni mwanachuo wa Chuo Kikuu cha Dar es Salaam ambaye hivi sasa anafanya utafiti. Utafiti anaokusudia kufanya unahusu **"Land Use and Livelihood Changes in the Mount Rungwe Ecosystem, Tanzania".**

Kibali kimetolewa kwake afanye utafiti huo katika maeneo atakayohitaji. Tafadhali mpatie msaada atakaohitaji.

Kazi njema.

M.A. Mwidete
KATIBU TAWALA WILAYA
RUNGWE.

Nakala; Verdiana Tindichebwa Tilumanywa.

Appendix H: Cross-tabulated statistics of land use change in Unyamwanga village (in ha)

1973-1986

	1973					
1986	Bd	Gs	Cm	Fn	Wo	Total
Bd	22	33	51	0	2	108
Gs	19	98	57	0	29	203
Cm	128	26	511	0	12	677
Fn	0	15	1	11	41	68
Wo	46	83	180	1	19	329
Total	215	255	800	12	103	1385

1986-1991

	1986					
1991	Bd	Gs	Cm	Fn	Wo	Total
Bd	55	66	304	0	45	470
Gs	16	51	30	1	10	108
Cm	16	14	241	1	103	375
Fn	2	4	6	52	32	96
Wo	19	68	96	14	139	336
Total	108	203	677	68	329	1385

1991-2010

	1991					
2010	Bd	Gs	Cm	Fn	Wo	Total
Bd	43	46	6	10	20	125
Gs	78	15	81	1	62	237
Cm	216	14	154	0	60	444
Fn	15	2	17	66	35	135
Wo	118	31	117	19	159	444
Total	470	108	375	96	336	1385

1973-2010

	1973					
2010	Bd	Gs	Cm	Fn	Wo	Total
Bd	1	79	30	0	16	126
Gs	27	49	160	0	2	238
Cm	89	2	345	0	6	442
Fn	4	34	30	12	54	134
Wo	94	91	235	0	25	445
Total	215	255	800	12	103	1385

Appendix I: Cross-tabulated statistics of land use change in Ndaga village (in ha)

1973-1986

	1973					
1986	Bd	Gs	Cm	Fn	Wo	Total
Bd	106	21	74	0	23	224
Gs	33	34	117	0	29	213
Cm	207	107	494	0	74	882
Fn	3	0	3	0	48	54
Wo	67	29	179	0	189	464
Total	416	191	867	0	363	1387

1986-1991

	1986					
1991	Bd	Gs	Cm	Fn	Wo	Total
Bd	45	37	51	0	36	169
Gs	25	5	127	3	60	220
Cm	75	89	556	2	78	800
Fn	4	12	27	33	61	137
Wo	75	70	121	16	229	511
Total	224	213	882	54	464	1837

1991-2010

	1991					
2010	Bd	Gs	Cm	Fn	Wo	Total
Bd	40	41	95	16	99	291
Gs	7	24	70	7	65	173
Cm	122	145	604	100	294	1265
Fn	0	0	3	3	3	9
Wo	0	10	28	11	50	99
Total	169	220	800	137	511	1837

1973-2010

	1973					
2010	Bd	Gs	Cm	Fn	Wo	Total
Bd	65	45	119	0	63	291
Gs	36	24	84	0	31	175
Cm	311	112	609	0	234	1266
Fn	0	0	4	0	2	6
Wo	4	10	51	0	34	99
Total	416	191	867	0	363	1837

Appendix J: Cross-tabulated statistics of land use change in Kyimo village (in ha)

1973-1986

	1973					
1986	Bd	Gs	Cm	Tc	Wo	Total
Bd	14	0	0	0	6	20
Gs	10	1	0	0	0	11
Cm	248	8	0	0	20	276
Tc	137	0	0	0	30	167
Wo	10	2	0	0	2	14
Total	419	11	0	0	58	488

1986-1991

	1986					
1991	Bd	Gs	Cm	Tc	Wo	Total
Bd	1	0	27	6	0	34
Gs	5	1	80	19	1	106
Cm	8	10	150	61	5	234
Tc	7	0	19	81	8	115
Wo	0	0	0	0	0	0
Total	21	11	276	167	14	488

1991-2010

	1991					
2010	Bd	Gs	Cm	Tc	Wo	Total
Bd	11	28	43	10	0	92
Gs	7	18	28	5	0	58
Cm	16	47	111	89	0	263
Tc	0	13	52	11	0	76
Wo	0	0	0	0	0	0
Total	34	106	234	115	0	489

1973-2010

	1973					
2010	Bd	Gs	Cm	Tc	Wo	Total
Bd	75	2	0	0	14	91
Gs	53	3	0	0	4	60
Cm	232	0	0	0	30	262
Tc	59	6	0	0	10	75
Wo	0	0	0	0	0	0
Total	419	11	0	0	58	488

Appendix K: Cross-tabulated statistics of land use change in Syukula village (in ha)

1973-1986

	1973							
1986	Bd	Gs	Cm	Tc	Wo	Cb	Fn	Total
Bd	143	21	64	2	33	0	10	273
Gs	171	13	72	0	50	0	0	179
Cm	51	18	70	24	16	0	0	705
Tc	90	50	442	28	88	0	7	331
Wo	11	12	20	4	38	0	37	465
Cb	43	27	60	164	37	0	0	306
Fn	243	70	0	4	130	0	18	122
Total	752	211	728	226	392	0	72	2381

1986-1991

	1986							
1991	Bd	Gs	Cm	Tc	Wo	Cb	Fn	Total
Bd	16	26	82	30	71	34	8	267
Gs	89	57	148	19	79	41	17	450
Cm	52	51	333	22	20	0	16	494
Tc	15	18	38	206	41	22	0	340
Wo	10	4	0	0	0	0	40	54
Cb	80	18	61	51	219	163	0	592
Fn	11	5	43	3	35	46	41	184
Total	273	179	705	331	465	306	122	2381

1991-2010

	1991							
2010	Bd	Gs	Cm	Tc	Wo	Cb	Fn	Total
Bd	96	102	271	14	37	94	32	646
Gs	15	45	19	8	0	49	4	140
Cm	40	45	125	3	0	4	3	220
Tc	13	69	15	194	0	24	11	326
Wo	9	40	37	35	4	28	50	203
Cb	81	143	16	86	1	393	73	793
Fn	13	6	11	0	12	0	11	53
Total	267	450	494	340	54	592	184	2381

1973-2010

	1973							
2010	Bd	Gs	Cm	Tc	Wo	Cb	Fn	Total
Bd	157	70	292	3	76	0	49	647
Gs	111	34	12	12	17	0	0	186
Cm	0	10	186	11	6	0	0	213
Tc	37	34	19	189	7	0	0	286
Wo	72	40	44	0	69	0	10	235
Cb	375	20	175	11	209	0	1	791
Fn	0	3	0	0	8	0	12	23
Total	752	211	728	226	392	0	72	2381

Appendix L: Cross-tabulated statistics of land use change in Katundulu village (in ha)

1973-1986

	1973					
1986	Bd	Gs	Cm	Tc	Wo	Total
Bd	188	11	79	37	18	333
Gs	222	32	67	42	40	403
Cm	464	43	109	41	37	694
Tc	86	3	39	138	0	266
Wo	118	9	15	13	0	155
Total	1078	98	309	271	95	1851

1986-1991

	1986					
1991	Bd	Gs	Cm	Tc	Wo	Total
Bd	107	207	547	27	31	919
Gs	122	86	26	32	26	292
Cm	19	7	11	1	0	38
Tc	27	49	24	148	5	253
Wo	58	54	86	58	93	349
Total	333	403	694	266	155	1851

1991-2010

	1991					
2010	Bd	Gs	Cm	Tc	Wo	Total
Bd	514	71	23	51	110	769
Gs	98	82	0	19	34	233
Cm	186	20	9	31	32	278
Tc	80	99	3	124	76	382
Wo	41	20	3	28	97	189
Total	919	292	38	253	349	1851

1973-2010

	1973					
2010	Bd	Gs	Cm	Tc	Wo	Total
Bd	508	67	100	30	63	768
Gs	110	22	48	21	32	233
Cm	172	7	64	36	0	279
Tc	169	1	68	145	0	383
Wo	119	1	29	39	0	188
Total	1078	98	309	271	95	1851

Appendix M: Cross-tabulated statistics of land use change in Ilima village (in ha)

1973-1986

	1973					
1986	Bd	Gs	Cm	Tc	Wo	Total
Bd	1338	154	101	0	13	1606
Gs	231	51	85	0	0	367
Cm	412	67	27	0	0	506
Tc	1	0	1	0	10	12
Wo	146	49	24	0	3	222
Total	2128	321	238	0	26	2713

1986-1991

	1986					
1991	Bd	Gs	Cm	Tc	Wo	Total
Bd	883	139	285	0	67	1374
Gs	500	150	197	0	63	910
Cm	76	12	10	0	21	119
Tc	0	0	0	1	0	1
Wo	147	66	14	11	71	309
Total	1606	367	506	12	222	2713

1991-2010

	1991					
2010	Bd	Gs	Cm	Tc	Wo	Total
Bd	416	192	34	0	36	678
Gs	522	417	69	0	90	1098
Cm	50	44	0	0	2	96
Tc	0	0	0	0	0	1
Wo	386	257	16	0	181	840
Total	1374	910	119	1	309	2713

1973-2010

	1973					
2010	Bd	Gs	Cm	Tc	Wo	Total
Bd	643	23	14	0	0	680
Gs	870	104	122	0	1	1097
Cm	83	9	3	0	0	95
Tc	0	0	0	0	0	0
Wo	532	185	99	0	25	841
Total	2128	321	238	0	26	2713