# Livelihood, land use and environment interactions in the highlands of East Africa

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*Academic dissertation*

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- Soini E. 2006a. Livelihood capital, strategies and outcomes in the Taita hills of Kenya. Paper under review.

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## Abstract

This study aims at improving understanding of the interactions of livelihoods and the environment focusing on both socio-economic and biodiversity implications of land use change in the context of population pressure, global and local markets, climate change, cultural and regional historical factors in the highlands of East Africa. The study is based on three components (1) two extensive livelihood surveys, one on Mt. Kilimanjaro in Tanzania and the other in the Taita Hills of Kenya, (2) a land use change study of the southern slopes of Mt. Kilimanjaro focusing on land use trends between 1960s and 1980s and 1980s and 2000 and (3) a bird diversity study focusing on the potential impacts of the future land use change on birds in the main land use types on the slopes and the adjacent plains of Mt. Kilimanjaro. In addition, information on the highlands in Embu and the adjacent lowlands in Mbeere of Kenya are added to the discussion. Some general patterns of livelihood, land use and environment interactions can be found in the three sites. However, the linkages are very complex. Various external factors at different times in history have influenced most of the major turning points. Farmers continually make small adaptations to their farming practices, but the locally conceived alternatives are too few. Farmers lack specific information and knowledge on the most suitable crops, market opportunities and the quality requirements for growing the crops for markets. Population growth emerges as the most forceful driver of land use and environmental change. The higher altitudes have become extremely crowded with population densities in some areas higher than typical urban population densities. Natural vegetation has almost totally been replaced by farmland. Decreasing farm size due to population pressure is currently threatening the viability of whole farming systems. In addition, capital-poor intensification has lead to soil fertility depletion. Agricultural expansion to the agriculturally marginal lowlands has created a new and distinct group of farmers struggling constantly with climate variability causing frequent crop failures. Extensification to the fragile drylands is the major cause of fragmentation and loss of wildlife habitat. The linkages between livelihoods, land use and the environment generally point to degradation of the environment leading to reduced environmental services and ecosystem functions. There is no indication that the system is self-regulating in this respect. Positive interventions will be needed to maintain ecosystem integrity.

Keywords: Kilimanjaro, Taita Hills, land use change, landscape, sustainable livelihood framework, avian diversity

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## Abstract in Finnish / suomenkielinen tiivistelmä

Tutkimus pyrkii ymmärtämään elinkeinojen/elinolosuhteiden (livelihoods) ja ympäristön vuorovaikutusta Itä-Afrikan ylängöillä tarkastelemalla maankäytön sosio-ekonomisia ja biodiversiteettivaikutuksia väestönkasvun, globaalin ja paikallisten markkinoiden, ilmastonmuutoksen, kulttuurin ja aluehistorian viitekehyksessä. Tutkimuksen perustana on (1) kaksi laajaa haastattelututkimusta elinkeinoista/elinolosuhteista, yksi Kilimanjaron vuoren etelärinteiltä Tansaniasta ja toinen Kenian Taita-vuorilta, (2) maankäyttötutkimus Kilimanjarolta, jossa tarkastellaan maankäytön muuttumista vuosien 1960 ja 1980 sekä 1980 ja 2000 välillä, ja (3) lintudiversiteettitutkimus tulevaisuuden maankäytön muutoksen potentiaalisista vaikutuksista lintuihin eri maankäyttöluokissa Kilimanjarolla ja viereisillä tasangoilla. Lisäksi diskussiossa on käytetty informaatiota Kenian ylängöillä sijaitsevasta Embusta ja viereisiltä Mbeeren tasangoilta. Joitakin yleisiä suuntauksia elinkenojen/elinolosuhteiden, maankäytön ja ympäristön vuorovaikutuksessa on havaittavissa. Tosin vuorovaikutussuhteet ovat hyvin kompleksisia. Erilaiset ulkoiset vaikutteet historian eri aikoina ovat olleet suurimpien muutosten takana. Paikalliset viljelijät tekevät jatkuvasti mukautuksia viljelmillään, mutta paikalliset parannusvaihtoehdot ovat vähäisiä. Viljelijöiltä puuttuu tieto sopivimmista viljelykasveista, markkinointimahdollisuuksista ja laatuvaatimuksista. Väestönkasvu on suurin maankäytön ja ympäristön muutoksen liikkeellepaneva voima. Ylängöt ovat käyneet ahtaiksi ja väentiheys on paikoin suurempi kuin monilla urbaaneilla alueilla. Maatalous on lähes kokonaan syrjäyttänyt alkuperäisen kasvillisuuden. Väestönkasvun seurauksena tapahtuva tilojen jatkuva pilkkominen uhkaa kokonaisia viljelyjärjestelmiä. Lisäksi pääomaköyhä intensifikaatio on johtanut maaperän köyhtymiseen. Maatalouden laajeneminen marginaalisille alangoille on synnyttänyt uuden ja selkeän ryhmän viljelijöitä, jotka yhtenään kamppailevat ilmaston vaihtelevuuden aiheuttamien katojen kanssa. Maatalouden levittäytyminen hauraille kuiville maille myös pirstouttaa ja hävittää eläimille elintärkeitä habitaatteja. Linkit elinkeinojen/elinolosuteiden, maankäytön ja ympäristön välillä viittaavat yleisesti ympäristön rappioitumiseen johtaen väheneviin ympäristöpalveluihin ja heikkeneviin ekosysteemitoimintoihin. Systeemin tasapainottumisesta itsestään ei ole havaittavissa merkkejä. Siten positiiviset interventiot ovat tarpeen ekosysteemien eheyden säilyttämiseksi.

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the article on the livelihoods in the Taita Hills and the summary section of this dissertation. I am very grateful for these contributions.

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# Livelihood, land use and environment interactions in the highlands of East Africa

## Introduction

Livelihoods based on agriculture are closely linked with and dependent on the environment. But agricultural activities also powerfully shape the environment. Agriculture is, in fact, a human activity that affects the greatest proportion of the earth's surface, it is the single biggest user of fresh water (Pagiola & Holden 2001), and is still by far the largest single source of livelihoods and income (Ohlsson 2000). It is specifically through land use that the interaction of livelihoods and the environment is most clearly demonstrated. Land use acts as an interface between the two as it forms a unifying concept in which socio-economic and agro-ecologic variables coincide (Kruseman *et al*. 1996). However, some environmental changes are caused by natural processes and would happen without a human influence, and some changes are human induced but set in motion outside of the immediate realm and scope of the land user and his land. As the interaction usually happens in time with varying time lags of response and impact, it is not always easy to detect the underlying cause-effect relationships.

Livelihoods comprise of resources or assets or capital (human, natural, social, physical and financial capital and access to use these) that enable strategies to be employed in order to survive and attain desirable livelihood outcomes such as income, food security, well-being and sustainable use of natural resources (Carswell 1997; Carney 1998; DFID 2001). This process of transforming the resources into commodities or outcomes is influenced by a myriad of external factors such as laws, culture, policies, and institutions. In addition, livelihood dynamics are strongly influenced by personal characteristics and desires, and one's relation to others. A livelihood is considered to be sustainable if it meets three conditions: firstly, it should be adequate for the satisfaction of self-defined basic needs, secondly, it should be resilient to shocks and stresses (Chambers 1995), and thirdly, it should not undermine the natural resource base that forms the basis of the future options (Hyden 1998; Scoones 1998).

In classic French geography (Claval 1974 in de Haan 2000) a livelihood system (i.e. livelihoods of groups of actors) was an integrated set of livelihood strategies of a human group in a specific region, in which the interaction between society and natural environment played a major role. A livelihood system was characterised as having a clear spatial identity: the region. Nowadays livelihoods, even in the most remote corners of the world, are subject to a multitude of influences from the national, international and global context. However, locality continues to occupy an important position in sustainable livelihood thinking, because natural resources are place-specific. Perception of shocks and stresses are also dominated by a local and regional orientation (de Haan 2000).

Many land use practices are absolutely essential because they either directly provide critical natural resources and ecosystem services or through land use practices natural resources are converted into useful products. But some forms of land use degrade ecosystems and the services they provide (Foley *et al*. 2005). Malthus (1798, 1803) developed the first comprehensive theory of population-land use relationship. He

predicted that population growth would lead to famine and an eventual population crash, since, he noted, whereas human populations grow geometrically, food production tends to increase only arithmetically. Malthus also said that since the most productive land tends to be used first, as a population grows and the area used for agriculture expands with it, the average quality of new agricultural land brought into production declines, and thus mean land productivity also declines. In addition, where land area for cultivation is fixed, classical economists noted that increased applications of labour lead to a fall in mean output per worker through the law of variable proportions, more commonly referred to as the law of diminishing returns (e.g. Ricardo 1887).

In addition to being a local issue through extraction of resources in a specific locality, or regional through changing landscapes[1] and landscape functions, land use is increasingly becoming a global issue (Foley *et al*. 2005). Just as our collective land use practices are increasingly degrading ecological conditions across the globe, we have become dependent on an ever-increasing share of the biosphere (Vitousek *et al*. 1986). Global croplands, pastures, plantations and urban areas have expanded in recent decades, accompanied by large increases in energy, water and fertiliser consumption, along with considerable environmental degradation and losses of biodiversity[2]. Even though it has been recognised that biodiversity is important for the functioning of all ecosystems, and that excessive loss of biodiversity imposes real costs on resource users (Heywood 1995), short term benefits are realized at the expense of long term environmental services that we depend on. Extensive agricultural growth is considered to be a major contributor to loss of habitat and the reduced environmental resilience that buffers agro-ecosystems against environmental and market shocks (Cassells *et al*. 1987; Chomitz & Kumari 1996; Pagiola & Holden 2001).

Following more than a century of technological advances since Malthus (1803), including in agriculture, Boserup (1965) introduced the notion that technological change could mitigate the effect of population growth on food supply by facilitating increases in food production. As available arable land becomes scarce relative to labour, societies adopt more labour intensive techniques, which take advantage of increased labour-land factor ratios. Bilsborrrow (1987) groups theoretical views on responses to population pressures as economic (land intensification and extensification), demographic (fertility responses), and economic-demographic (out-migration). He hypotheses that households traditionally exhaust economic options first, beginning with land expansion. If that is insufficient, then available land intensification technologies are adopted. If such adjustments together still are inadequate, the next reaction is likely to be out-migration. Fertility reduction is claimed to occur in traditional societies only as a last resort.

In a highly capital-constrained continent, most African smallholders are intensifying land use in a financially or ecologically unsustainable fashion (Reardon *et al*. 2001).

[1] "Landscape" refers to "a mosaic of heterogeneous land forms, vegetation types, and land uses" (Urban et al. 1987).

[2] Biological diversity is "the variety and variability among living organisms and the ecological complexes in which they occur" (OTA 1987).

Capital-deficient intensification that does not meet either productivity or sustainability goals merely leads to soil mining and, if land is still available, a return back to extensification. Even where agricultural intensification has enjoyed widespread success, this has not occurred without environmental degradation e.g. waterlogging, salinisation, water pollution by pesticides, fertilisers and animal wastes, loss of habitats, loss of biodiversity. The empirical evidence does not support the argument that simple agricultural intensification and the economic growth associated with it are beneficial for the environment (Lee *et al*. 2001a; Lee *et al*. 2001 b).

Kuznets (1955), a macro-economist, originally theorized that there was a relationship between development and income inequality. Economists subsequently suggested that a similar theoretical relationship existed between wealth and environmental quality (Field 1997). The Environmental Kuznets Curve (EKC) hypothesis suggests that there is an inverted U-shape relationship between environmental degradation and per capita income. As economic development proceeds from very low-income levels, pollution, resource use and waste generation per capita increase rapidly. Then at higher levels of development structural change towards information intensive industries and services, together with increased environmental awareness, enforcement of environmental regulations, better technology and higher environmental expenditures, result in levelling off and gradual decline of environmental degradation. However, after a decade of debate the empirical evidence for EKC hypothesis is very mixed. The assertion that environmental quality is a luxury good has not been conclusively demonstrated. Many advanced economies have actually 'exported' their degrading production to developing countries, rather than using their resources to reduce overall degradation. This relationship exists with many types of natural resources such as land and forests, where the demand for products in wealthier countries is driving environmental degradation in poor countries (e.g. Redclift & Sage 1998; Wackernagel & Yount 1998). Ecological footprint analyses have illustrated this discontinuity between the consumption of natural resources by wealthier countries and their production in the poorer parts of the world.

The discussion on livelihood-environment interaction relates closely to the discussion on poverty-environment linkages. Since the 1970s it has been almost universally agreed that poverty and environmental degradation are inextricably linked. The links between poverty and environment have also been seen to be self-enforcing. The World Commission on Environment and Development (Brundtland Commission) wrote (1987):

> "Poverty is a major cause and effect of global environmental problems. It is therefore futile to attempt to deal with environmental problems without a broader perspective that encompasses the factors underlying world poverty and international inequality." … "Many parts of the world are caught in a vicious downwards spiral: poor people are forced to overuse environmental resources to survive from day to day, and their impoverishment of their environment further impoverishes them, making their survival ever more difficult and uncertain."

However, the natural environment becomes endowments and entitlements (i.e. natural capital) to actors through the complex working of both formal and informal institutions (Leach *et al*. 1997, 1999). Different people in the same area rely on

different institutions to claim natural capital in order to earn a livelihood. Often it is only the intertwining of different institutions (formal and/or informal rights and claims) that accounts for a successful livelihood. This 'environmental entitlements' approach which was adapted from Sen's work (e.g. Sen 1981) on entitlements in the context of famine, shifts the emphasis from questions of resource availability to those of access, control and management. Any relationship between poverty and environment is indirect. It is the diverse institutions that influence the course of ecological change (de Haan 2000). Local institutional arrangements are underpinned by power relations, and are shaped, in turn, by interactions with regional, national and global-level processes, both environmental and political-economic (Forsyth *et al*. 1998). The relationship between income/poverty and environment is not static but can be influenced by policies.

Livelihood, land use and environment interactions in a rural agricultural setting in the highlands of East Africa are the central theme of this paper. In a most simplified way interactions of the three components can be depicted as three circles partly coinciding each other (Figure 1a). However, the fact that these interactions happen in time suggests an interlocking tubes model around which the linkages spiral in time (Figure 1b). While various products are extracted from the environment by collecting natural products (fodder grass, firewood, medicinal plants) the majority of livelihood strategies in an agricultural setting involve reshaping the environment to accommodate production of commodities that the natural environment would not otherwise provide (cropping). The utilisation is controlled by different levels and forms of institutions (the right to collect natural products and cultivate land). Land use as a livelihood strategy belongs to the livelihood circle, but land use is also a manifestation of these strategies on landscapes, and landscapes are naturally part of the environment circle. The way the environment is treated in the utilisation process determines what livelihood strategies (e.g. what land use practices) are available for the future, whether the utilisation processes are sustainable or not. It is from this utilisation perspective that it is widely recognised that without environmental protection, there will be no sustainable development, and no successful poverty reduction. In the sustainable livelihoods thinking, environment is represented as natural capital.

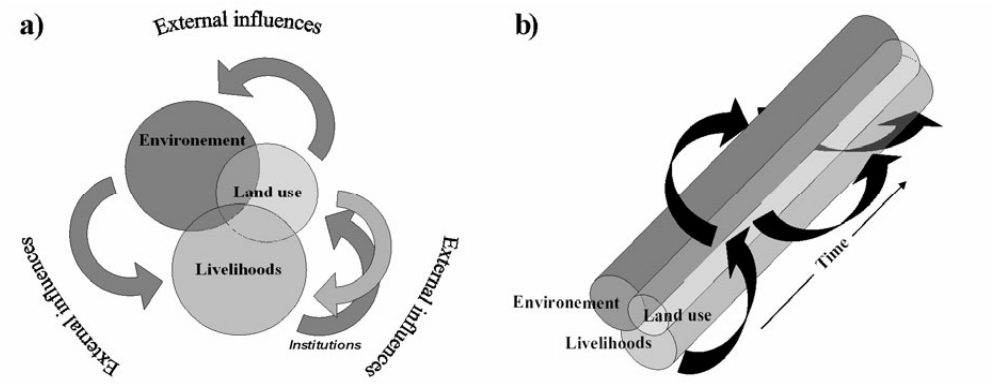


**Figure 1. Livelihood, land use and environment interactions in a rural agricultural setting in the highlands of East Africa.**

In this study, in addition to looking at livelihood, land use and environment interactions from the perspective of local farmers in the highlands of East Africa (a perspective of a rural poor farmer and his natural capital), a broader perspective of the environment as a habitat for other life forms is also taken. Environment with its diverse life forms has, of course, a value for its own sake, if all life is to be respected. However, with the current population numbers, the projected population growth, the number of poor people and the ever increasing expectations of the humans especially in the developed world, more collisions of the needs of the humans and the needs of most of the other life forms will be inevitable.

The highlands of East Africa have the highest potential for agricultural in the region. During the colonial era most of the white-owned farms were established in the highlands. These settlers and Christian missions introduced a variety of cash crops to the highlands. The need to pay taxes imposed by the colonial government forced local farmers to work on settlers' farms and to cultivate cash crops (in some areas this was, however, strictly regulated for decades). Later on, price changes of some of the crops in the world market have seriously affected the farming systems. Very rapid population growth has followed from improved health care brought about by the colonial governments. Highlands with their favourable climates for agriculture are today very crowded and an increasing number of people need to make their living by cultivating dryer lowlands, struggling constantly with climate variability causing frequent crop failures. However, environmental services provided by the highlands are one way or another significant to the whole population of the region. Highlands are particularly important for their water. Highland areas are also important for their forests and their biological diversity. Due to their vertical dimension, mountain and hillside areas can hold a particularly rich variety of ecological systems.

The main objective of this study is to improve understanding of the linkages between livelihoods and the environment in the highlands and adjacent lowlands in East Africa focusing on both socio-economic and biodiversity implications of land use change in the context of population pressure, global and local markets, climate change, cultural and regional historical factors.

Understanding livelihood, land use and environment interactions in the highlands of East Africa is highly relevant in any attempts to find solutions for sustainable agricultural development in the region. Agriculture is a livelihood practice that depends on continued productive capacity of the land and adequate water resources to sustain harvestable yields. Agricultural sustainability, sustainable livelihoods, sustainable land use, sustainable use of natural resources etc have over the past few decades become popular concepts in development thinking. "Waste of non-renewable resources, destruction of ecosystems and overexploitation of renewable resources have led to general feelings that the present human-nature relationship is untenable" (Kruseman *et al*. 1996). However, contrary to what can be expected due to the importance of the issue, sustainability is seldom quantifiably measured. Absence of adequate quantitative data on livelihoods and the state of the environment of a particular area over time is a major blockage to accurate analysis and search for solutions. Descriptive studies usually exist and relevant literature was, indeed, used as much as possible, to obtain historical perspective, and to make comparisons with the

current survey data. The current survey results will hopefully work as baselines in future assessments of agricultural sustainability in the two areas.

The study is based on two extensive livelihood surveys, one on Mt. Kilimanjaro in Tanzania and the other in the Taita Hills of Kenya; a land use change study of the southern slopes of Mt. Kilimanjaro focusing on land use trends between 1960s and 1980s and 1980s and 2000; and a bird diversity study focusing on the potential impacts of the future land use change on birds in the main land use types on the slopes and adjacent plains of Mt. Kilimanjaro. These separate studies naturally had their own objectives and justifications, and their contributions to socio-economic and ecological issues of development are presented in the separate papers written on the studies (Soini 2005a, 2005b, 2006a, 2006b).

## Study sites

This study is based on surveys conducted in the Taita Hills in southeastern Kenya and the southern slopes of Mt. Kilimanjaro in northern Tanzania (Figure 2). The study area on Mt. Kilimanjaro is a transect from lowlands to highlands (3° 20' S 37° 30' E). For the land use change analysis, the study covers approximately the administrative area of Kirua Vunjo division (Soini 2005a). For the interview survey and the bird diversity survey the study area was extended to the neighbouring Kilema and Marangu divisions (Soini 2002, 2005a, 2005b, 2006b). The lower boundary was drawn 5 km south of the main tarmac road at about 800 m altitude, the upper end of the transect was the forest boundary at about 1800 m altitude. The Taita Hills (3° 23' S, 38° 21' E), part of the Eastern Arc mountains, is an island of fertile mountain area surrounded by the dry bushlands of Tsavo East and Tsavo West National parks. The study area was a transect across the hills. It reached from Mwatate, a trading centre on the plains (800 m) on the southern side of the hills across one of the highest peaks of the hills, Yale (2104 m), to the northern plains (900m) at Kishushe (Soini 2005c, 2006a). The biggest population centre on the hills, and Taita-Taveta district headquarters, Wundanyi was included in the transect. Wundanyi town has a population of about 4000 persons (Kenya 1997).

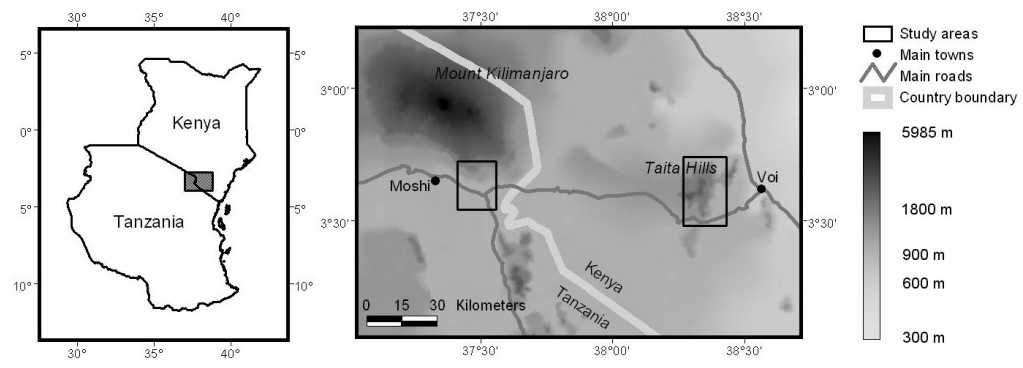


**Figure 2. The two main study sites, the southern slopes and the adjacent plains of Mt. Kilimanjaro in Tanzania and the Taita Hills in Kenya.**

The study transects in both sites span a number of altitudinal and agro-ecological zones. On Mt. Kilimanjaro three distinct altitudinal agro-ecological zones can be identified: (1) a lowlands zone of extensive livestock farming and open crop fields, with remnant bushland patches, (2) a midlands maize-bean belt which is a mosaic of homegardens and open fields, with few bushland patches interspersed between, and (3) a highland traditional Chagga homegarden area dominated by coffee and banana, with many large trees. The lowlands zone extends up to about 900 m, midlands up to 1200 m and the homegarden area to about 1800 m above sea level, up to the lower forest boundary. Annual rainfall received during two rainy seasons (March-May, September-October) varies according to the altitude, being 400-900 mm in the lowlands, 1000-1200 mm in the midlands and 1200-2000 mm in the homegarden area (Moshi Rural District Council, pers. comm.; Zongolo *et al*. 2000). In the Taita Hills five agro-ecological zones can be distinguished in the study transect: (1) midland livestock-millet zone (790-980m), (2) the marginal cotton zone (910-1220m), (3) the sunflower-maize zone (1220-1520m), (4) the marginal coffee zone (1370-1680m), and (5) the wheat/maize-pyrethrum zone (>1680m). Annual rainfall is received during two rainy seasons and varies from 480 to 700mm, 600 to 800mm, 700 to 900mm and 900 to 1200mm, and above 1200mm across the five zones respectively (Jaetzold & Schmidt 1983; Kenya 1989). Much less rain (250mm) is received on the surrounding plains. The two study sites cover approximately the same altitudinal zones, however, in the Taita Hills the transect reaches across the Hills and thus covers both the drier northern slopes and the more lush southern slopes.

## Methods

There are obviously many ways to study livelihood, land use and environment interactions. There are also very many ways to separately study the three components. Also, some methodological questions and challenges arise in planning the study. First, there is the practical need of studying dynamic processes – some of them long-term processes – in a short period of time. Second, understanding change both in the livelihoods and the environment without real baseline studies can be difficult. Third, as most of the processes are linked to a wider spatial and temporal setting, an appropriate spatial and temporal scale for the study can be hard to determine. Fourth, there is the challenge to decide how many sites are needed to find general patterns in East Africa. Fifth, there are a huge variety of foci and approaches that can be used, and the most appropriate ones that are also feasible, should be selected.

What is possible is often a compromise between availability of resources (time, skills, financial resources) and the optimal quantity and quality of information needed to draw credible conclusions. When a long-term study of change over decades cannot be planned due to constraints of resources, and no historical baseline data are available from other sources, an approach that relies partly on local observations and perceptions needs to be adopted. The studies on livelihoods, including questions on environmental change affecting livelihoods, represent this approach. In the case of biodiversity, looking at past and future changes can be done by a study of current biodiversity combined with a study capable of revealing trends in land use patterns. The temporal scale of the land use change study was simply determined by the availability of data. The oldest possible images (aerial photographs from 1961)

revealing land cover were used as the starting point. A shorter than forty year time period would hardly reveal land use trends. Critical earlier changes concerning land use were identified from the literature. The livelihood surveys had a historical perspective covering the scope of the interviewees' memory. Transects that catch the differing altitudinal zones were selected as study areas. On Kilimanjaro special attention was paid to select an area with only small-scale agriculture, as one of the objectives was to study the evolution of the traditional Chagga farming system with its strong interactions between the highlands and the lowlands. Having two sites only for the study was determined by time constraints. The two sites, Mt. Kilimanjaro in Tanzania and the Taita Hills in Kenya represent areas with similar ecological conditions and smallholder characteristics, but different sets of property rights and policy histories. In addition to the results from the two main study sites, information on a third site, Embu, on the slopes of Mt. Kenya was used in the paper where appropriate.

The sustainable livelihood (SL) framework (Carswell 1997; Carney 1998; DFID 2001) has been widely adopted as a useful analytical tool for structuring livelihoods related development research and especially as a framework guiding participatory planning of development interventions. As Ashley (2000) writes, it has an instinctive appeal, it is useful in generating insights and recommendations, it synthesises perspectives of different disciplines and provides an explicit focus on what matters to poor people. The SL framework was thus used to structure the livelihood studies. Livelihood surveys were conducted in both the Kilimajaro and the Taita Hills sites. Information was collected on the different livelihood capitals, strategies and the means that farmers use to adapt to long-term trends and short term shocks. Perceived problems with crops, livestock, trees, off-farm activities, and other spheres of life were documented. Temporal change was emphasized. To measure priorities and values related to livelihood objectives, farmers were asked questions on on-farm and off-farm activities or on-farm assets they would think most desirable in order to improve their livelihoods. To study interrelationships of livelihood capital and livelihood outcomes several variations of multivariate regression analysis were used. Farm revenue was used as a livelihood outcome in the Kilimanjaro study. In the Taita Hills an indicator representing livelihood outcomes was calculated as the mean of six components that were selected on the basis of desired livelihood objectives as perceived by the interviewed farmers. Individual household interviews – rather than group interviews – were considered the most feasible because a lot of quantitative household specific data was needed to study interrelationships of livelihood assets and outcomes.

There is potentially a myriad of ways to study environmental change. Some of the most relevant in the case of Mt. Kilimanjaro – in the light of the current knowledge of the area – include multi-temporal analysis of water quantity (and quality in terms of nutrient flow down the slope) in rivers and irrigation channels, studies on the linkages of exotic and indigenous vegetation and availability of water, land use or land cover change analysis over time, studies on biodiversity implications of land use change on overall biodiversity in the area, and assessment of soil nutrient balances in the homegardens. However, selection of topics is essential due to practical reasons. Only the land use change and the biodiversity questions were selected.

Land use change analysis at the landscape level using remote sensing data is a widely used approach to monitor changes in the environment. In addition to yielding information on how the landscape has changed over time – a big issue in itself on the slopes of Mt. Kilimanjaro – land use analysis and land use change analysis can effectively guide the selection of sites for further studies. Selection of data used in a land use change analysis spreading over several decades is often determined by what types of images are available for the time period. As the aim of the study was to look back as far as possible, black and white aerial photos were used for the whole change analysis. The three sets used were from 1961, 1982 and 2000. Landscape fragmentation analysis was done for the land use maps derived from the photo interpretation. Land use in the year 2000 was in addition analysed using a Landsat +ETM satellite image. Classification of the aerial photographs was done visually, the satellite image was auto-classified by the Fuzzy C Mean algorithm (Microimages Inc 2000).

A study of bird diversity in three important land use categories (lowland fields, bushland and highlands) on Mt. Kilimanjaro built on the land use and land use change studies. Birds have been widely used as indicators of overall biodiversity due to their sensitivity to respond to habitat change (e.g. Nohr & Jorgensen 1997; Canterbury *et al*. 2000; Chase *et al*. 2000; Naidoo 2004). As a full biodiversity survey was not possible due to resource constraints, a biodiversity survey focusing on birds was conducted. Within each land use category, timed walks were undertaken each morning (3 hours) and evening (2 hours) starting from a central point. All birds within about 30 m distance from a predefined route were recorded. The sample area in the highlands consisted of both traditional Chagga homegardens and a European type garden (highland garden). In the analysis these two were separated. Diversity of bird species and similarity between bird species in the different habitats were measured. Ordination was used to show bird species associations and their relationship with land use and season. The main aim of the bird study was to understand potential future impacts of the land use changes on birds.

## Results and discussion

### *Site characteristics: Similarities and differences*

The two study sites represent the typical mountainside setting in East Africa with linkages between the high potential highlands and the adjacent agriculturally marginal lowlands, with non-agricultural forest above the highland farms. The highlands represent the pre-colonial farming system with its diverse crop options. Lowlands were earlier used mainly for grazing and seasonal cropping. The marginal lowland farming system developed out of the necessity to accommodate the excess population from the highlands. Over the decades there has been a dynamic relationship between the highlands and the adjacent lowland areas. Since the cash crops were introduced, the highland people have depended on the lowlands for supplying part of their food production, mainly maize and beans, while the highlands provide the bulk of the fruits and vegetables for both the highland and the lowland populations. To sustain the intensive agricultural systems of the highlands, huge quantities of manure is transported from the lowlands to the highlands. The lowland areas also provide large quantities of fodder grass to feed the zero-grazing animals of the highlands. However,

to close the loop of the nutrient cycling between the highlands and the lowlands, the highlands constantly loose soil down the slope to the lowlands due to erosion.

Table 1 is a summary of farm and farmer characteristics of the two main study sites on the southern slopes of Mt. Kilimanjaro and the Taita Hills. A lot of similarities can be found. However, some significant differences (in bold font) emerge. One of the most significant differences relates to the issue of land scarcity or availability. Taita farmers have on average two and a half times more land per family than Kilimanjaro farmers. Even though in both places farmers usually have two plots and some even more, parcel size is much bigger in the Taita Hills than on Mt. Kilimanjaro. This is partly due to the land consolidation implemented in parts of the Taita Hills and simply due to more land per farmer being available in the Taita Hills. Far fewer Taita farmers have parcels in different agro-ecological zones than in the Kilimanjaro system. This is due to land policies involving land consolidation in the Taita Hills, contrasting with the Kilimanjaro system that has evolved without any major intervention from the state. Renting land is common amongst the Chagga of Kilimanjaro while it is almost nonexistent amongst the Taita. This is not necessarily related to the availability of land, but can be mainly due to traditions.

Several other differences can be observed from Table 1. The Chagga people are famous for their traditional irrigation system they have constructed on the southern slopes of the mountain. In the Taita Hills farmers do not typically use irrigation. Only two farmers amongst the 51 interviewed irrigated their farmland. Having a stone house is usually considered one of the main wealth status symbols in East Africa. On Mt. Kilimanjaro more than half of the farmers live in a stone house, while in the Taita Hills less than one third do so. Whether this is a major indicator of a wealth difference between the two sites is impossible to say without a full household economic survey. The number of livestock has also been traditionally considered as an indicator of wealth status, and Taita farmers have on average more animals than the Kilimanjaro farmers. Some significant differences can be seen in education levels. On the one hand there are considerably fewer women on Mt. Kilimanjaro who have not finished primary education, on the other hand, a higher percentage of men in the Taita Hills have studied for more than eight years. This means that the difference between the education level of women and men is greater in the Taita Hills than on Mt. Kilimanjaro. Significant differences are also seen in the level of collective action amongst farmers of the two sites. Many more farmers belong to farmer groups or women's groups in the Taita site compared to the situation on Mt. Kilimanjaro, where farmers are more household centred. According to Taita farmers, groups are an important source of support in times of crises. Money obtained from the village or women's merry-go-round groups is significant when school fees need to be paid or investments made on the farm (Soini 2005c).

Farmers of the two sites face very similar challenges with their farming systems and their livelihoods (Table 2). Most of the challenges mentioned in the two sites are the same (differences in bold font). Lack of capital to invest in farming was seen as the main challenge in both sites. Diseases are the main problem with livestock keeping. Lack of capital to start and to maintain a business is the main difficulty with off-farm activities. The two sites are, however, very different as regards to tree growing. The

Chagga system with its rich variety of multipurpose trees provides the area with the seedlings and knowledge needed for tree growing. Farmers claim that the droughts of the lowlands make tree planting difficult in Kilimanjaro. In the Taita Hills 82% of farmers complain that seedlings are not available. Some other differences can be observed from the problem table. Fodder availability seems a much more common problem in the Taita Hills than on Mt. Kilimanjaro. Also, animal destruction is a major challenge in the Taita Hills. The problem is present everywhere on the lower slopes and plains with monkeys and baboons looting the fields, but is most serious on the northern side of the Hills in areas adjacent to the Tsavo National Park, where elephants are said to be the main nuisance.

**Table 1. Some farmer and farm characteristics in Kirua Vunjo, Kilema and Marangu on Mt. Kilimanjaro in Tanzania, and the study transect in the Taita Hills of Kenya according to the interview surveys of 45 and 51 households respectively**

| **Socio-economic indicators** | **Quantity Kilimanjaro** | **Quantity Taita Hills** |
|---|---|---|
| Average number of years at school | 7.3 fathers<br>6.1 mothers | 6.8 fathers<br>5.5 mothers |
| Less than 7 years at school | 30% fathers<br>**34% mothers** | 34% fathers<br>**50% mothers** |
| More than 8 years at school | **19% fathers**<br>9% mothers | **32% fathers**<br>10% mothers |
| Vocational training | 56% fathers<br>14% mothers | 61% fathers<br>25% mothers |
| Off-farm job (both casual and permanent) | 55% fathers<br>15% mothers | 50% fathers<br>19% mothers |
| Average number of persons living in a household | 6.2 | 5.5 |
| Average family size | 6.5 | 6.5 |
| Farmers belonging to groups (collective action/social capital) | **23% fathers**<br>**18% mothers** | **39% fathers**<br>**54% mothers** |
| Farmers who have inherited/been allocated/given land | 91% | 98% |
| Farmers living in a stone house/mud house | **60 / 40%** | **29 / 71%** |
| Plots in different agro-ecological zones | **42%** | **20%** |
| Average number of plots per family | 2.5 | 2.1 |
| Average plot size | **0.6 ha** | **2.3 ha** |
| Farmers renting a plot | **51%** | **6%** |
| Farmers who have bought land | 29% | 27% |
| Farmers who have sold land | 7% | 8% |
| Average distance between the main farm and other plots | 5 km | 1 hour (about 5km) |
| Average total farm size | **1.74 ha**<br>(range 0.2–10.2 ha) | **4.6 ha**<br>(range 0.4–26 ha) |
| Farms covered by irrigation | **27%** | **4%** |
| Average number of improved/mixed cattle per farm | 0.8 | 1.5 |
| Average number of local cattle | 2.2 | ***0.3*** |
| Average number of goats/sheep per farm | 5.6 | 4.3 |

Source: Soini 2002, 2005a, 2005b, 2005c, 2006a.

**Table 2. Main challenges perceived by farmers on Mt. Kilimanjaro, Tanzania, and in the Taita Hills, Kenya (Problems mentioned by only one farmer not listed)**

| Challenge category | Challenge mentioned | % of farmers mentioning the challenge | |
|---|---|---|---|
| | | Kilimanjaro % | Taita Hills % |
| Crops | Lack of capital to buy pesticides, fertilisers, good seeds, land, or rent more land (at least one of these) | 60.0 | 64.7 |
| | Pests (In the Taita Hills Larger Grain Borer, *Protephanus trancutus*) | 55.6 | 72.5 (19.6) |
| | Decreasing rainfall or droughts | 37.8 | 56.9 |
| | Animal destruction (baboons, monkeys, but elephants in 11 cases in the lowlands) | | **45.1** |
| | Lack of labour | 20.0 | 19.6 |
| | Lack of preservatives or place for storage | 4.4 | |
| | Extension services not available[1] | 68.9 | 21.6 |
| Livestock | Diseases | 46.7 | 70.6 |
| | Medicines and treatment are expensive | 24.4 | 19.6 |
| | Not enough fodder | **17.8** | **39.3** |
| | No dipping facilities | | 11.8 |
| | Veterinary services not available[1] | 15.6 | 7.8 |
| Off-farm activities | Lack of capital to start or to expand or to maintain a business or an occupation | 17.8 | 13.7 |
| | Not enough customers to buy or give assignments | 11.1 | 11.8 |
| | Irregular prices and random taxation | 6.7 | |
| | Getting permits | | 3.9 |
| Tree growing | Drought kills seedlings | **20.0** | **9.8** |
| | Seedlings are not available (in the Taita Hills especially grafted) | **15.6** | **82.4 (45.1)** |
| | Termites and pests kill seedlings | 8.9 | 2 |
| | No time and labour to plant | 4.4 | |

Source: Soini2005a, 2006a.
[1] Availability of extension and veterinary services was not originally listed by the farmers amongst their problems, but came up when the farmers were asked about access to farm inputs and knowledge.

Similarities and differences are further studied in the following chapters on the linkages between livelihoods, land use and the environment which are looked at in the context of population pressure, socio-economic, cultural and regional historical factors. In addition to the two main sites of this study, information about the highlands in the Embu area and the adjacent lowlands in Mbeere, Kenya will be added to the discussions.

### *Livelihood, land use, and environment interactions*

An attempt to explain specific linkages between livelihoods, land use and the environment as depicted in the model (Figure 1) is not straightforward. First of all, the model, like all models, is a simplification of the reality. Linkages between livelihoods,

land use and the environment involve exceptionally complex interacting processes that are hard to capture by any model. Trying to describe a single linkage immediately leads to the realisation that the linkage is constantly modified by one or several feedback mechanisms. As all the linkages are active all the time, it is hard to freeze the processes and explain them one at a time. In addition, according to one of the main findings of the two livelihood surveys, livelihoods are very varied with a very large number of strategies, problems and outcomes, and combinations and interactions of these. An attempt to generalise these to represent 'livelihoods in the highlands of East Africa' and fitting that to the model can be difficult. Nonetheless, models with their attempt to simplify complex processes can reveal insights of complex systems that could otherwise escape notice.

*Livelihoods-land use linkages*

The first immigrants who moved to the southern slopes of Mt. Kilimanjaro area at least five or six hundred years ago, possibly much earlier (Odner 1971; Maro 1974), started to transform the original forest into an agroforestry system. Useful trees were kept while less useful species gradually disappeared (Fernandes *et al*. 1984). In Embu people moved together in small groups, shifting their crops and homes, within the relatively small area controlled by their clans (Olson *et al*. 2004). New crops were introduced by traders (Krapf 1860; Moore & Puritt, 1977; Koponen 1988). Regular market places developed to accommodate early trade (Nazzaro 1974). With the arrival of the colonialists and missionaries both Mt. Kilimanjaro and the Taita Hills were connected to the global market forces. Coffee on Mt. Kilimanjaro, and sisal in the lowlands of the Taita Hills and to some extent coffee in the highlands were the main cash crops introduced in the colonial period. Large areas of land were allocated for cash crops grown by the newcomers (Fleuret 1988; de la Masseliere 1999). Slightly later, large areas were allocated as National Parks and reserves. However, a major transformation of land use occurred, at least in case of Kilimanjaro, when the local farmers were allowed to grow the introduced cash crop, coffee (Maro 1974, 1975). With the increasing livelihood expectations created by the exposure to a higher standard of living, coffee was found an attractive cash crop that brought good income. The profitable cash crop favoured the Chagga and enabled them to develop faster than other areas in Tanzania. Income from coffee was used for improving farming practices

**Land use as a livelihood strategy**

- Migrations of populations leading to new land being opened up in high potential areas
- New crops for subsistence and cash introduced (traders, colonialists, farm extension)
- Control of access to land use (e.g. ownership, user rights)
- Population growth leading to encroachment to forests, expansion of agriculture to the marginal lowlands (extensification)
- Population growth leading to increased sub-division of farms; goes on until plots too small to function as farms
- Population growth and raising livelihood expectations leading to intensification and diversification
- Population growth leading to new settlements and migration to urban areas
- Connections to markets (local and global) lead to changes in land use

***Livelihoods changed by land use***

- Livelihoods are sustained and improved by new commodities from efficient land use
- Limited resources lead to differentiation of livelihoods due to unequal access to land and natural resources
- When the cultivation of land cannot support livelihoods, off-farm income becomes crucial

and water supply, establishing schools, dispensaries and courts, building roads and enhancing other public works and for investments in personal and household commodities (Moore 1986).

Population growth – enabled by improved health care introduced by the colonial government and the raised standard of living enabled by growing valuable cash crops - started to accelerate in the 1920s in both the Taita Hills and Mt. Kilimanjaro. In both sites population tripled between 1920s and the end of 1960s. Between the late 1960s and today population has tripled again (Kenya Land Commission 1930 and Census 1969 figures cited by Mkangi 1978; Swynnerton 1949; Maro 1974; Mlambiti 1985; Kenya 1997). Also, in the highest zone in Embu, population nearly tripled between 1969 and 1999 (Kenya 1970, 2001). The higher altitudes of East African highlands have become extremely crowded with population densities (500-700 persons/$km^2$) in some areas higher than typical urban population densities.

It is important to avoid oversimplification of the population growth-land use interactions. Access to land, access to grow a certain crop, markets and both individual and social responses following from the opportunities and constraints for new land uses are important in the process. Rapid land use change often coincides with the incorporation of a region into an expanding world economy. Also extreme biophysical events occasionally trigger changes. Olson *et al*. (2004) list the main driving forces of land use change as follows: political (e.g. land policies), economic (e.g. markets, labour and economic returns of crops/animals/non-farm activities), demographic (population growth, migration, birth rates, HIV-AIDS), social and cultural (e.g. changing gender roles, power from clans to families) and, locational (e.g. remoteness). Various human-environment conditions react to and reshape the impacts of drivers differently, leading to specific pathways of land use change (Lambin *et al*. 2001).

The cash crops introduced in the colonial times are in many highland areas still the main cash crops of the farming systems. However, due to changing markets, reliance on one cash crop is dangerous. Beginning in the 1960s, the market price for coffee started to decrease and has trended downward ever since. Land use impacts of this in the highlands of East Africa are many. Farmers have clearly neglected their coffee while other livelihood activities have taken a more important place (Olson *et al*. 2004; Soini 2005a, 2006a, 2005c). On Mt. Kilimanjaro more land is allocated to growing banana (Aminu-Kano *et al*. 1992). Other activities substituting coffee include dairy cows for milk sales and commercial vegetable growing (Soini 2005a). In the Taita Hills coffee growing is hard to find these days (Soini 2006a). In Embu, post-independence governmental programmes promoted coffee and tea growing through establishment of parastatals (Olson *et al*. 2004). The proximity of Embu to the national market of Nairobi has encouraged production of other commodities as well, such as milk and macadamia nuts. The Taita Hills and Embu both have better access to markets than Mt. Kilimanjaro. Mt. Kilimanjaro competes heavily with Mt. Meru in the markets of Arusha, about one hundred kilometres from Kilimanjaro and immediately next to Mt. Meru. It is also difficult for the Mt. Kilimanjaro area to compete with the Usambara Mountains in the Dar es Salaam markets.

Despite the close access to national markets, the decline of international coffee prices combined with the collapse of the coffee cooperative parastatal during the privatisation process associated with structural adjustment in the 1990s led to a crisis in Embu agriculture (Olson *et al.* 2004). At around the same time, the tea cooperative parastatal and tea prices also declined. The two cash crops were replaced with crops such as cabbages, potatoes or maize that have a low comparative regional advantage. The government's stricture against removing coffee bushes was relaxed during this time. In fact, smallholder coffee farmers in Kenya have uprooted an estimated 16 000 000 acres of coffee (Mathenge 2004). In Mbeere in the 1960's and 1970's, cotton was an important cash crop organized by a parastatal (Olson *et al*. 2004). Cotton growing ended when farmers were not receiving good prices for it. Today, because of its growing market, maize growing is increasing, despite the crop being vulnerable to drought. In some areas with easy access to transport *Catha edulis*, which is air freighted daily to Arabian and Somali markets, and horticultural crops are increasing (Olson *et al*. 2004).

Soil conservation structures, especially terracing (Figure 3), are another legacy left behind by the colonial government. In many places in the highlands of East Africa they are still clearly seen in the landscape – southwest Uganda with its terraced hillsides probably being the most conspicuous. The colonial administration started terracing programmes that the chiefs enforced. Following independence, the enforced terracing programme ended, and in Embu, for example, many people removed the terraces (Olson *et al*. 2004). However, the parastatals started to enforce soil conservation again. By the 1970's, most fields in Embu with tea and coffee crops received manure and fertilisers, and terracing coffee fields was mandatory though not necessarily well maintained (Berlekom & Larsson 1984). Currently on Mt. Kilimanjaro and in the Taita Hills, bylaws on terracing and riverbank conservation are not followed. Steep slopes are in places cultivated without any soil conservation methods. Riverbanks are often cultivated right up to the water's edge.

**Figure 3. Some of the farmland in the Taita Hills is well terraced: Terraced vegetable cultivations (left), and a new terraced farm on a very steep slope (right) in the Taita Hills.**

Expansion of agriculture to the more marginal lowlands adjacent to crowded highlands is a general trend in East Africa. On Mt. Kilimanjaro coffee growing and the

need of increased food production pushed part of the food production, and later, part of the population to the lowlands (Maro 1974; Fernandes *et al*. 1984). The largest land use change that occurred in the Mt. Kenya region since the 1960's was the expansion of cultivation from the higher elevation areas into the mid-elevation, then to the low-elevation and most recently to the semi-arid bushlands. Currently, however, in Mbeere, extensification of agriculture is slowing, as both in-migration and local population rates decline (Olson *et al*. 2004). In the Taita Hills, the lowland population is growing faster than the highland population as more and more un-demarcated land is put under cultivation (Kenya 1997; Soini 2006a).

Population pressure has not only resulted in expansion but also in agricultural intensification and diversification, following a typical Boserupian development (Boserup 1965). However, even though the Chagga system is one of the most intensive and diverse farming systems in East Africa, the fact is that currently a typical Chagga farm can no longer sustain a family. From Embu Olson *et al*. (2004) conclude that even though the farming system is not easily mechanized and requires high labour inputs hence high population densities, it does not support the increases in population that have occurred since independence. Livelihood-land use interaction seems to have taken the Malthusian pathway. While it has not lead to a population crash, it is clearly leading to less farm product per household due to smaller farm area and depleted soils. It has also lead to frequent famines in the more marginal land to which the excess population has been, and is being, pushed.

Access or the right to land is crucial in determining what role land plays in the livelihood of a household. Traditionally farms were held and used by individuals, but the user rights, especially transfer of land, was controlled by clans. At the death of the person holding a user right to his farm, this user right must pass to a male or males of the same lineage, preferably his legal sons (Moore 1969; Maro 1974; Mtei 1974; Moore & Puritt 1977). In Embu and the Taita Hills new land was allocated by clan elders. On Mt. Kilimanjaro, due to the strong tradition of chiefdoms, land was allocated by the chief of the area. Lowland farms were granted for a year by the chief or by an 'owner'. They were often re-granted to the same person year after year (Moore & Puritt 1977). In the homegarden area of Mt. Kilimanjaro the traditional system is still observed and clans still form neighbourhoods. However, the lowland fields are individually owned or rented, and they can be sold and bought without clan involvement.

For decades the farming systems on mountain slopes have made use of the different agro-ecological zones. In the Taita farming system, in the years of adequate rains many cultivators moved to the plains to plant and harvest crops in the lighter alluvial soils, during times of inadequate rainfall, these cultivators retreated to the more dependable moisture of the hills (Nazzaro 1974; Fleuret 1988). On Mt. Kilimanjaro there is a very clear pattern that if the inherited farm is in the highlands or midlands, the family has a field lower down (Soini 2002, 2005a). The majority of food (maize and beans) is produced in the lowlands (Soini 2002).

In 1954 the Swynnerton Plan (Swynnerton 1954) suggested that customary land tenure should be reformed from a presumed communal to an individual freehold basis. Land

consolidation was probably the most radical change suggested. Each landowner was to receive a single plot equivalent in size to the sum of his pre-existing multiple plots that were often scattered across different agro-ecological zones (Nazzaro 1974). However, as the livelihood survey in the Taita Hills showed (Soini 2005c) the Plan was never implemented in full in all areas of the Taita Hills. The process is still continuing in some areas, but some areas have refused to have it implemented. According to the present survey, half of the highland farmers still have access to a lowland plot. In Embu, according to Olson *et al*. (2004), implementation of the Swynnerton Plan was made possible by the forced abandonment of the land during the Mau Mau emergency when families were moved to emergency villages, and by the farmers' continued fear of the colonial government. Moving the population to the emergency villages was designed to stop further recruitment of the population by the Mau Mau fighters. When the emergency ended around 1959, Embu families were allowed to leave the emergency villages and return to their homes. However, in the absence of the land users, the colonial administration land tenure ordinance had been implemented. It completely altered where each family could live and what land they could crop and graze. By independence in 1963, the adjudication plan had been fully implemented and all families lived on and cultivated only their individual plots. No land was set aside for communal grazing or woodlands. The most serious implication of the tenure reform was that individuals lost their ability to make use of the different ecological zones that provided the variety and security of production due to varying climatic and agro-ecological conditions.

Lower down from Embu, in Mbeere, the Government of Kenya implemented a land adjudication programme similar to the Swynnerton Plan in the 1970s and 1980s. This led to radical changes in the Mbeere society. As the individual farms were not sufficiently large to support the former large goatherds, the formerly pastoralist Mbeere became primarily farmers (Olson *et al*. 2004).

Where the Plan has been implemented, a lot of young couples build houses on their husband's parents land. In the absence of the old clan based system, and due to the current official cumbersome and expensive administrative process of subdivision of land, neither customary nor legal subdivision of land now takes place. Depending on family dynamics, this can stop some young farmer families from making any considerable investments to develop their land (Pers.comm. A.M. Kiasi 2005). Olson *et al*. (2004) report from Embu that many parents are refusing to sub-divide their land even after their sons marry, so their sons control only small portions of the farm. Average land holdings per adult male (0.7 ha) are therefore lower than average total farm size of 1.3 ha.

The Plan had a particular effect in the Taita Hills where it changed the settlement patterns of the landscape. Traditionally houses that formed neighbourhoods of clans were clustered in groups of 15-20 houses on land with massive rock outcrops or on a ridge with shallow soils (Harris & Harris 1964; Mkangi 1978). After land consolidation, families built their houses on the consolidated plots, the old 'villages' disappeared and houses were scattered further apart in the entire cultivable landscape (Nazzaro 1974).

Access to land was very much modified in Tanzania during the time of Nyerere's socialism with its Ujamaa Villagization Programme, which peaked between 1973 and 1975. However, the strong resistance amongst the Chagga against the programme meant that it was not implemented in the area and did not have significant implications for land use and ownership (Mlambiti 1985).

Due to the very rapid population growth, and the need to sub-divide farms amongst the heirs of the family, farm size has decreased and continues to decrease significantly (Maro 1974; Fernandes *et al*. 1984; Soini 2002, 2005a, 2005b). The problem is naturally linked to the lack of other livelihood options in the region and in the country. Farming has continued to be the main livelihood activity in the absence of other alternatives. In the Chagga culture, the eldest son was traditionally the principal heir and successor, the youngest son the next favoured. When land was still abundant the middle sons were sent to the lineage-branch head and then to the chief to ask for land with which to start a homegarden. From the 1950s onwards, as no more land has been available for new farms, middle sons have needed to start inheriting from their father's land (Maro 1974) leading to further decreased plot sizes, now both in the highlands and the lowlands. Some plots are in fact becoming so small that they cannot function as farms any more (Soini 2005b).

Due to population pressure, the tradition of securing land to everyone by inheritance and user rights has not worked for a long time. As early as between 1948 and 1952 some of the farms previously owned by Germans on Mt. Kilimanjaro were returned and allocated to *landless* people by the chiefs, and by the 1970s landlessness had become a serious problem (Maro 1974). In the mid 1970's, 30% of the population in the Taita Hills were landless or residing on sub-economic units (Kenya 1976). Njeru (1978) found that landlessness in Embu increased soon after adjudication because of land sales. The current surveys showed great differences in access to land. Also, land pressure appears to be much more acute on Mt. Kilimanjaro and Embu than in the Taita hills. In the Taita Hills land size is approximately 4.6 ha (with a very large range from 0.4 to 26 ha), however, with no differences between the zones (Soini 2005c, 2006a). On Mt. Kilimanjaro farmers typically have 2 to 3 (2.5) separate plots with total farm area of about 1.74 ha (Soini 2002, 2005a, 2005b). In Embu, farm size is 1.3 ha (or 0.7 per adult male) and in Mbeere 3.2 ha (Olson *et al*. 2004). It is interesting to note that the Kenya Land Commission (1934) estimated that the average Taita household of 4.6 people would need a holding of 40 acre (16.5 ha) to meet its basic minimum requirements. In the 1940s experimentation led to the conclusion that 12 acres (5 ha) was the ideal economic size for a holding (in western Kenya), and 6 acres (2.5 ha) would suffice if the holding was cultivated intensively (Humphrey 1947).

Only one third (35%) of the plots in the Taita Hills had been divided when being acquired by the present owner (Soini 2005c). On Mt. Kilimanjaro 84% of the farms had been split on average into four new independent farms (Soini 2002, 2005b). Most of the people (c. 70%) in both sites live on inherited land, but the average size of an inherited plot differs greatly being 0.56 hectares on Mt. Kilimanjaro and 3.1 ha in the Taita Hills (Soini 2002, 2005b, 2005c). Nine percent of the interviewees on Mt. Kilimanjaro had not inherited or been allocated any land and half of them had not been able to buy land but were renting or borrowing it. Of those having inherited land,

47% had inherited less than 0.4 ha, and 21% inherited only about 0.1 ha, which can hardly be called a farm. Most of these extremely small 'farms' were found in the lowlands (Soini 2005a). In the Taita Hills only one farmer out of 51 had not inherited nor was allocated any land (Soini 2005c).

Economic differentiation is increasing due in part to the unequal chances of inheriting land and the very different ecological conditions land can be inherited in (Figure 4). Expansion to the agriculturally marginal lowlands has created a new and distinct group of farmers who have much fewer livelihood options than farmers in the highlands. In Embu, Olson *et al*. (2004) report that the poor in the lowlands (Mbeere) are poorer and a larger group than the poor in the highlands (Embu). The lowland areas are the poorest despite low population densities. Haugerud (1983) found that despite the initial somewhat egalitarian distribution of land, informal land rights, power differentials and non-farm opportunities eventually led to wealth differences. On Mt. Kilimanjaro the majority (87%) of the 'proper' jobs belong to highland or midland farmers while lowland and midland farmers hold the majority of casual jobs (Soini 2005a). Times of crisis drive differentiation. Land purchases by the more wealthy farmers are usually made during droughts when the more vulnerable farmers need to sell their land as a last resort. The losses of resources, especially land, are difficult to regain later, furthering the poverty of the poorest. Olson *et al*. (2004) found that the result of the land transactions was a solidification of wealth disparities that were later consolidated with differential investment in children's education.

Both highland and lowland farmers are looking for new diversification opportunities and are willing to engage in *ad hoc* activities depending on their livelihood capital. Farmers of the two sites reported a myriad of strategies they use to adapt to decreasing plot size, market changes and the need to cope with the unpredictable lowland climate. In the Taita Hills almost half (21/51) of the farmers and on Mt. Kilimanjaro more than half of the farmers (31/45) had introduced some new crops to their farms (Soini 2002, 2005a, 2005b, 2006a). In the Taita Hills the new crops include tomatoes, onions, groundnuts, beans, cowpeas, cotton, green grams, potatoes etc. It is impossible to pick typical choices. On Mt. Kilimanjaro farmers often mention the typical local crops such as banana, maize, coffee amongst the newly introduced crops. However, groundnuts and vegetables, and possibly sunflower are the only real new cash crops. Twenty-four percent of farmers have introduced these. Farmers are also looking for ways to increase the value of their tree produce (Soini 2005a, 2006a). The common popular species in both sites are *Grevillea, Persea americana* and *Mangifera indica.* In the Taita hills farmers have often planted *Cupressus* as well, and *Eucalyptus* is very common in the highland landscapes. On Mt. Kilimanjaro the selection of tree species is larger including *Albizia* ssp., *Citrus cinensis, Azadirachta indica, Cassia siamea, Cordia holstii, Prunus persica* and *Annona squamosa*. Other typical adaptation methods include spacing of maize and beans, building contours (which is, however, an old practice from the colonial times in both sites), and changing from local livestock breeds to improved ones. Still other adaptation strategies mentioned include using improved maize seeds, using fertilisers, manure and pesticides, taking better care of animals, growing fodder, applying deep tillage etc. However, what is conspicuous in the data is that a lot of introduced new technologies are also mentioned amongst the abandoned technologies. When one farmer introduces vegetables, another abandons

the same vegetable, when one starts using fertilisers and manure, another farmer abandons that practice. There is clearly plenty of local initiative to experiment (Soini 2005a, 2006a). Small adaptations are done constantly, but the decision-making lacks specific information and knowledge on the most suitable crops, where to market them, and how to grow the crops to meet the quality requirements.

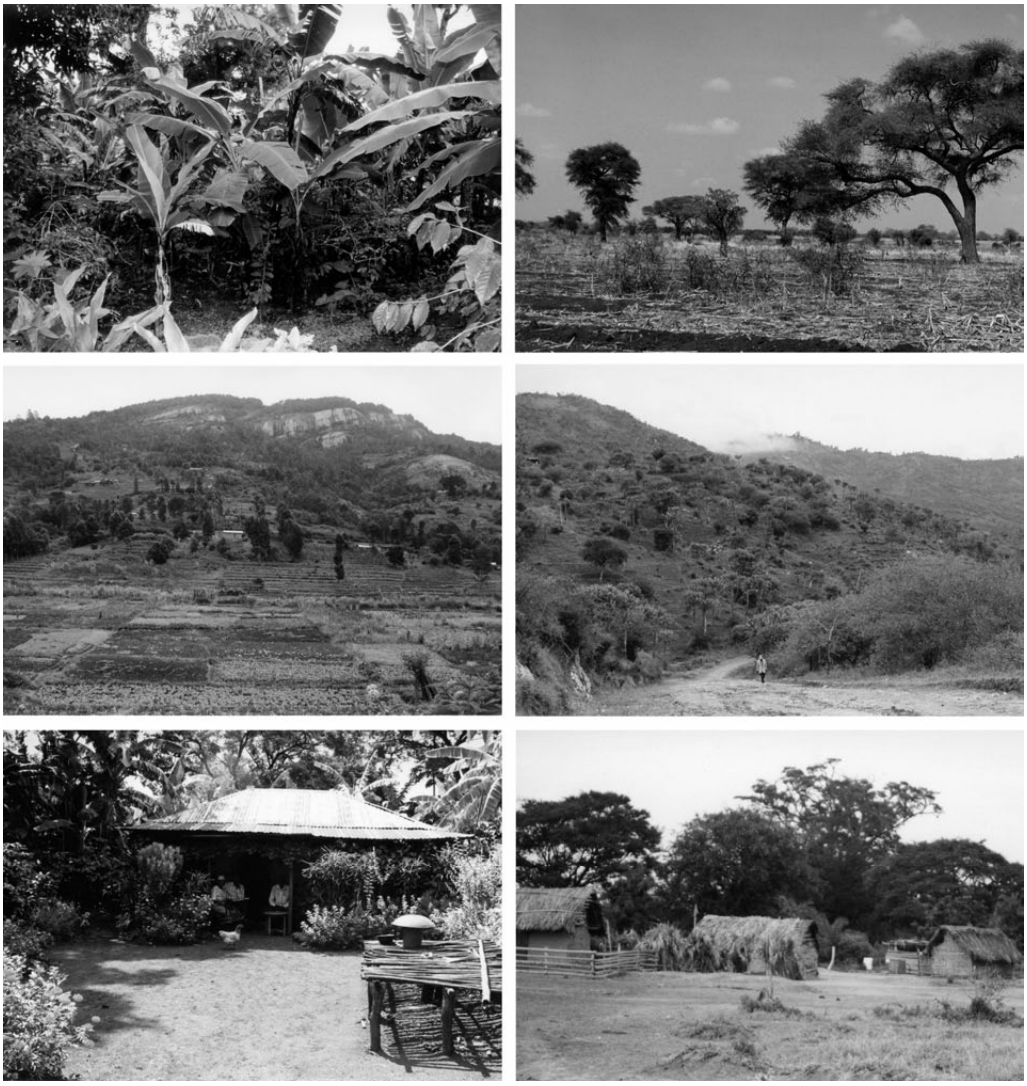

**Figure 4. Differing ecological conditions, differing agricultural opportunities, differing levels of well-being: A lush homegarden on Mt. Kilimanjaro (upper left), and lowland fields only ten kilometres away (upper right); Productive vegetable fields in a highland valley (middle left) and farmland on the northern slopes in the Taita hills (middle right); An attractive house on the upper slopes of Mt. Kilimanjaro (bottom left) and a poor lowland household next to a river on the adjacent plains (bottom right).**

Pressure on land, increased livelihood expectations, cultivation of marginal lands with marginal returns and limited agricultural options available to the farmers have lead to an acute need of non-agricultural livelihood options. This has resulted in the

mushrooming of new villages, especially along the main roads (Soini 2005a). According to Olson *et al*. (2004), in Mbeere, the departure of men to search for off-farm income, combined with the departure of especially immigrant families who left due to the harsh circumstances, has also had other important implications for land use. The labour required even for low value crop production is high, while the opportunity costs for that labour appear to be greater elsewhere, the result being that much of the land in the drier zones is not being cultivated. Some land have reverted to bush and is either not being used, is being used for grazing, or mango or other low maintenance trees have been planted on it. In addition to out-migration in search of work, many farmers are multi-occupational with a non-agricultural job based on the farm (Soini 2005a). This trend will gradually make the rural areas more urban with multiple services being made available in the previously purely agricultural countryside.

Olson *et al*. (2004) found an interesting relationship between poverty and out-migration in search of work. Men from households with few resources are more likely to be either working on off-farm activities nearby, or to have left the family on the farm in search of employment elsewhere. According to statistical analyses, those families tend to stay poor, with farm sizes not increasing as the family ages. An exception to this poverty-out-migration pattern is the richest group of farmers. This group also has a high percentage of husbands who are earning non-farm income, but more of them stay to live on their own farm and invest in it by buying additional land, labour, animals and other agricultural inputs. They often have a professional salaried job or a business. The majority of the households, those of medium wealth, tend to still rely on their own farm for most of their income. As couples grow older, they invest in buying additional land, animals, and in their soil. There is a significant increase in the percent of husbands and adult sons in the lower population density and lower elevation zones who have left. Embu has high population densities and extremely small farm sizes, so high rates of out-migration would be expected. Mbeere has lower population densities and larger farms, so lower rates of out-migration would be expected. Olson *et al*. (2004) conclude that the driving force of out-migration is poverty, not population pressure. However, one of the main causes of poverty is population growth that overrides the carrying capacity of the scarce natural resources of the fragile lowlands.

*Land use-environment linkages*

Decreasing soil fertility is a general trend detected by the farmers (Soini 2005a, 2006a). Land degradation is a direct effect of unsustainable intensification of land use, and agricultural extensification to the environmentally fragile areas. Degradation is also caused by cultivation of steep slopes and riverbanks especially in the highlands. Further, on Mt. Kilimanjaro, soil from the upper slopes is constantly lost along the inadequately managed

**Land use modifies the environment**

- Soil degradation (nutrition depletion, erosion, landslides) caused by capital poor intensification (insufficient soil nutrient inputs and soil conservation)
- Changed water courses and changed water balances along the slope due to land use by irrigating
- Species composition and overall vegetation cover change on farmland, forests, bushland and riverine woodlands (habitats change, may also lead to e.g. changes in water availability)
- Fragmentation of landscapes when new land for agriculture is cleared leading to decreased habitat viability and habitat loss

irrigation channels (Aminu-Kano 1992). In the lowlands of Kilimanjaro, volcanic brick cutting leaves enormous scars in the already fragmented bushlands (Figure 5). Contrary to expectations formed by the results from the Taita Hills and Mt. Kilimanjaro, Olson *et al.* (2004) write that in Embu, farmers report increased fertility of many fields. This trend is claimed to have started in the 1970s. It is impossible to say, based on the available information, whether fertility has been better retained in Embu than in the other two sites. A recent study groups the Central province of Kenya amongst the areas where the real income has decreased since 1980s (Young 2005). In Mbeere rapid declines in the soil fertility happened within a few years of adjudication. This is somewhat different from the neighbouring Machakos, an area that benefited from high capital and technological investments over a sustained period of time (Tiffin et al. 1994).

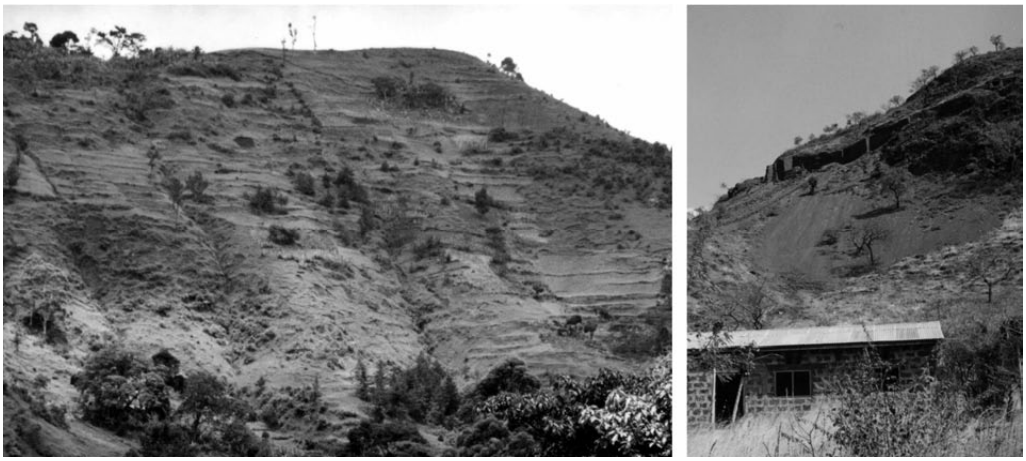

**Figure 5. Partly abandoned degraded farmland with eroded old terraces on a very steep slope along Nanga valley on Mt. Kilimanjaro (left). Volcanic brick cutting leaves enormous scars on the hill slopes but the bricks are important building material for houses (right).**

Kilimanjaro farmers, especially the lowland farmers, have noticed a gradual decrease of water in the rivers and irrigation channels since the 1960s (Soini 2005b). Some rivers have been reported to become seasonal and many irrigation channels that earlier brought water all the way to the lowlands are now dry most of the year. Decreasing water availability on the slopes of Kilimanjaro has, in fact, become a big issue. The simultaneous shrinking of the ice cap of the mountain has made it of major interest. Contrary to what might be assumed, observations of dry riverbeds are not, however, necessarily an indicator of long-term climatic changes or the impact of shrinking glaciers. Recent research reveals that the biggest cause of dried out rivers is the forest destruction at the *upper* edge of the forest zone. A satellite image interpretation revealed enormous changes in the upper vegetation zones, especially the *Erica* zone, of Mt. Kilimanjaro between 1976 and 2000, due to increased fires (Agrawala *et al*. 2003). 13 000 ha of forests, mostly of *Erica* forest, has been destroyed since 1976. Montane and subalpine mossy or cloud forests are of great importance for watersheds in East Africa. They protect the soils against erosion by controlling the damaging effects of torrential rainfall and regulating outflow patterns of watercourses. They

absorb, store and filter water, making the water percolate slowly to the ground water. In addition, they collect water by fog interception contributing typically far more than one third of the bulk precipitation in tropical montane forests (e.g. Cavelier & Goldstein 1989; Cavelier *et al*. 1996).

Another likely contributor to the decline of water in rivers and irrigation channels is the change of original vegetation of the homegarden zone into an agroforestry system with many exotic species. According to Kisanga (1989), during the 1970s the Government of Tanzania introduced tree planting campaigns along the riverbanks and natural spring water sources. It was found that this afforestation programme had negative impacts in some places contrary to farmers' expectations. Some previously swampy areas dried up. The most condemned species were Java palm (*Syzygium cuminii*), *Cupressus lusitanica*, *Acacia mearnsii*, *Pinus* ssp. and *Eucalyptus* sp. A further cause for the decreasing water supply is the increasing water demand by the rapidly growing population. Water diversion has in fact quadrupled in certain areas during the last 40 years (Sarmett & Faraji 1991). In addition, the traditional irrigation system utilising simple dug-out channels leads to a lot of seepage and leakages of water along the way, and less water reaches down to the lower slopes and the plains along rivers and irrigation channels. Also, cultivation of riverbanks and the eroded soil flushed down along the channels from the upper slopes lead to low water quality on the lower slopes and plains.

The ice cap on the Kilimanjaro has been in a general state of retreat since the end of the Little Ice Age around 1850 (Hastenrath & Greischar 1997; Thompson *et al*. 2002; Kaser *et al*. 2004). This retreat was driven by climatic shifts, but appears to have accelerated due to the warming observed in the second half of the 20$^{th}$ century. There is general consensus that the ice cap of Kilimanjaro will disappear by the year 2020. The impact of the disappearance of the ice cap on the natural and human systems would, however, be very limited. The present glaciers of Kibo cover an area equivalent to 0.2% of the area covered by the forest belt on Mount Kilimanjaro. The forest belt taps 90% of the precipitation. Only two rivers are directly linked by very small streams to the glaciers. Even if the glaciers have melted by 2020, there will still be precipitation on the main peak of the mountain, feeding springs and rivers.

Even if the *lower* forest edge on Mt. Kilimanjaro has stayed approximately in the same place, a recent aerial survey revealed illegal logging, burning of forest, charcoal production, establishment of villages, grazing and cultivation, landslides and quarries in the protected forest reserve (Lambrechts *et al*. 2002). In the Taita Hills, 98% of the original forests have disappeared. The only indigenous forests left are the few disconnected islands of gazetted forests covering only 6 km$^2$ in total (Newmark 2002). This percentage does not take into account the bushlands that, to some extent, are still found on most of the lower slopes. On the slopes of Kilimanjaro only small remnants of original vegetation can be seen below the national park forest edge (Soini 2005a). The homegarden zone from 1200 to 1800 metres a.m.s.l. has practically no original forest left. On the lower slopes and the adjacent plains small patches of bushlands, mainly on top of small volcanic hills, and the narrow riverine woodlands are the last remnants of natural lowland vegetation in the area (Soini 2005a). Riverine woodlands have decreased, forming now only a row or two of trees along the watercourse. Both

of these remnants are further under pressure due to firewood and timber collection, heavy grazing and volcanic brick cutting (Soini 2005a). The higher elevation Embu site had dramatic land cover conversions with the privatisation of farmland and clearance of remaining bush (Olson *et al*. 2004). This happened mainly in the 1950s and 1960s. A lot of degradation of natural areas has also happened, e.g. thinning of forest or woodlands, conversion from woodlands to bush, or bush to grassland. Within the bushland, disappearance of native tree, bush, grass and other plant species has been significant. The landscape of the semi-arid zones of Mbeere and Tharaka has changed from one dominated by bush savannah and woodland to one almost completely covered by farms, even if not all cropped (Olson *et al*. 2004). Much of the bush in the lowlands was cleared within the first years of adjudication, mostly in the 1980s and 1990s, creating a dramatic and exceptionally quick land use conversion. The only areas remaining of these natural vegetation types are in protected areas or on rocky, steep hills, but even there many of the woodlands have been cleared or thinned.

Land use change is known to be a key driver of biodiversity change (Sala *et al*. 2000). Over the decades land use change on Mt. Kilimanjaro has had significant impacts on both floral and faunal diversity (Misana *et al*. 2003). Changes from natural vegetation to cultivated land have led to a decrease in indigenous plant species diversity, and an increase in exotic plant species. The intense habitat alteration has also contributed to the complete disappearance of many species of birds (Moreau 1944) and mammals (Newmark *et al*. 1991; O'Kting'ati & Kessy 1991; Noe 2002). Land use changes have also negatively affected species richness through land degradation (Misana *et al*. 2003). Olson *et al*. (2004) conclude the same trends from Embu and Mbeere, i.e. loss and fragmentation of wildlife habitat, a decline in native plant species, and soil degradation. No useful land use change analysis exists from the Taita Hills. Due to lack of more comprehensive land use change data the focus there has been on natural forest fragments and their biodiversity, and the endemic forest bird species.

Land use, or more correctly land abuse, is considered by most observers to be the major threat to biological diversity. However, some agricultural systems can hold a lot of diversity. The Chagga homegarden system is a very diverse agricultural system even though the system is dominated by coffee and banana. Fifty-three tree species, 29 food crops, 21 other useful non-woody species and eight weed species have been identified in the Chagga homegardens (O'ktingati *et al*. 1984). Observation of the higher zones of the Taita Hills, and the lists of important tree species obtained from farmers by the interview,s reveal much less tree diversity on Taita farms than in the Chagga homegarden system (Soini 2005b, 2005c) (Figure 6). An extensive survey (Oginosako 2006) done on the slopes of Mt. Kenya may not be comparable with the results of O'ktingati *et al*. of the Chagga homegardens, but reveals rich diversity of trees on farmland in the Embu area. The survey team found a total of 261 tree and scrub species on farms in Embu district. One plot has on average 184.5 trees or shrubs representing on average 15.9 species. The zones with more intensive cultivation had more species per plot than the zones with less intensive cultivation. Conservation, enhancement and promotion of agrobiodiversity should be seen at least as important as conservation of protected areas or of remnants of natural habitats in areas of other land use (Kaihura & Stocking 2003).

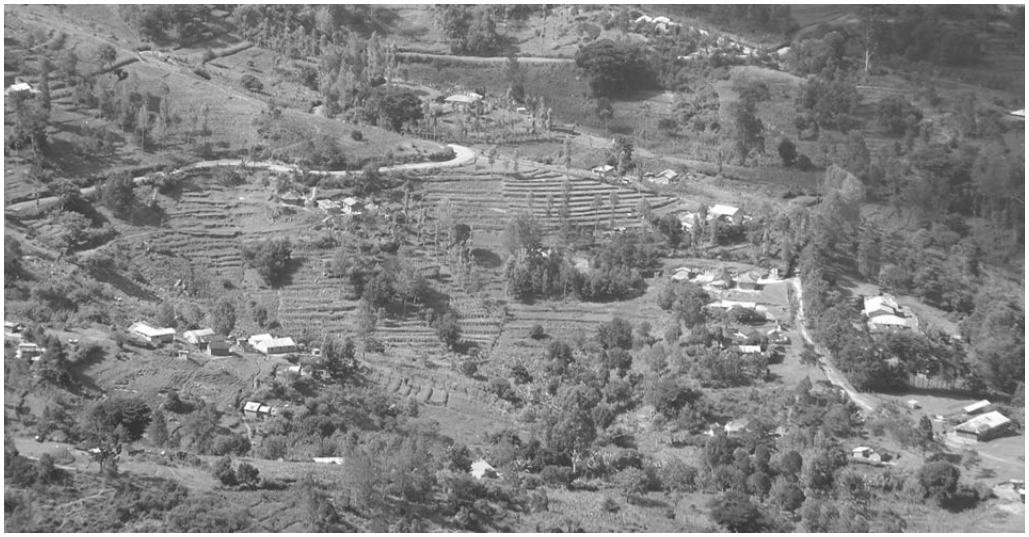

**Figure 6. Trees form an integral part of the Taita farming system. However, tree density and species diversity are much lower than in the Chagga homegarden system on the slopes of Mt. Kilimanjaro.**

In many cases baseline surveys of the past diversity do not exist. Informed guesses can, however, be made of the past and future changes in biodiversity by combining results of other studies, by using information derived from remote sensing based land use change analysis and by using indicators. Bird diversity in three land use categories based on a land use change analysis was studied on Mt. Kilimanjaro (Soini 2006b). The most significant areas of change are the bushlands due to their fragmentation and the homegarden area due to the sub-urbanisation of the area, and the miniaturisation of farms. Several studies conclude that while agroforestry systems or plantations may provide habitat for a large number of bird species that depend to some degree on forests, they cannot substitute for forest (Thiollay 1995; Perfecto *et al*. 1996; Reitsma *et al*. 2001; Perfecto & Vandermeer 2002). It is likely that homegarden bird communities are not the same as the forest communities before the establishment of homegardens. Now when homegardens are being subdivided into smaller and smaller plots which cannot any more function as farms, and more people depend on jobs elsewhere, an increasing number of homegardens are turning into highland gardens (Soini 2005a). This sub-urbanisation necessarily leads to decreasing tree cover as more land is taken for buildings, yards and small vegetable gardens. For this reason, and due to the fact that bird communities appeared distinct, the study looked at differences between the homegarden area and the highland garden. In the study, however, the highland garden was a very large and quiet European type garden with large open lawns, a rich variety of trees, lots of flowerbeds, a vegetable garden, and hedges. Interestingly, the highland garden had the highest Shannon index of bird diversity. It appears that it is not the density of trees (which is greater in the homegardens than in the highland garden), but rather the presence of trees together with a large variety of niches, and a quiet environment, which support a rich variety of birds. It is not clear, however, whether the impact of human disturbance in the much smaller highland gardens allows the area to support the highland garden type of a bird population in the future.

It is important to notice that the majority (87/119) of bird species seen in the three habitats of the study area were restricted to a single land use category. This is significant especially in the context of the general trend of fragmentation and overexploitation of the bushland areas in the lowlands (Figure 7). Out of 43 bird species detected in the bushlands in the survey, 15 were not found in the other two habitats. As the bushlands continue to fragment, these species are in danger of disappearing from the area. Fragmentation of habitats usually leads to species decrease or eventually species absence (e.g. Winter & Faaborg 1999; Cornelius *et al*. 2000; Zanette 2000; Zanette *et al*. 2000; Johnson & Igl 2001; Beier *et al*. 2002; Herkert *et al*. 2003; Kurosawa & Askins 2003). It is also interesting that Lyaruu (2002) found the undisturbed lowlands (bushlands) being the most plant diverse with a much higher number of grass and shrub species compared to anywhere else in the transects passing Mbokomu and Machame on the southern slopes of Mt. Kilimanjaro.

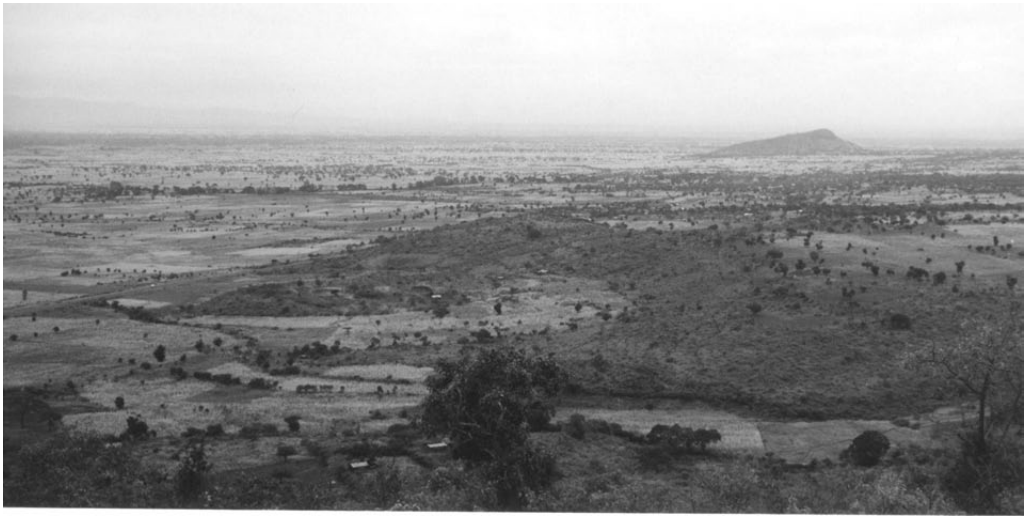

**Figure 7. The remaining bushlands are islands in the middle of the agricultural fields in the lowlands of Mt. Kilimanjaro.**

*Environment-livelihood linkages*

Despite technological advancement, climate and ecological conditions will always set some operational limits to agriculture. Studying livelihoods and land use along an altitudinal gradient captures the striking differences in the natural conditions in which farmers of East Africa operate. What is also remarkable in East Africa is the short geographical distances between the extremes of these agricultural gradients. In the Taita Hills and on Mt. Kilimanjaro, only ten kilometres separate the dry plains with their parched maize and beans fields from the lush and diverse agricultural systems of the highlands. The Taita Hills, Mt. Kilimanjaro and Embu-Mbeere all represent areas with two extremely different farming systems. Each have one based on export crops in the high potential upper zones and a second based on low-value, mostly subsistence production in the lowlands.

***Effects of the environment on livelihoods***

- Climatic and ecological conditions and variability setting the limits for agricultural choices
- Climate change(?)
- Decreased agricultural production (due to soil depletion, soil loss by erosion and landslides)
- Lower level of food security especially in marginal areas
- Decreasing water for domestic and agricultural use (declined quality?)
- Less natural resources available (firewood, timber, fodder)

***Livelihood strategies adjusted/changed due to the environment***

- Selection of suitable land use strategies
- Diversification for risk management
- Increased self-subsistence in wood and fodder production
- Decrease in population growth(?)
- When the cultivation of land cannot support livelihoods, off-farm income becomes crucial

Many farmers in the lowlands adjacent to highlands grew up in the highlands and absorbed their knowledge of the highland agriculture from their parents. From their parents they learned the art of growing coffee or tea, the differences between all the 15 varieties (Maro 1974) of banana, how to prune trees, how to plant trees, to know what trees are best on the boundaries of the farm and which can be planted as shade trees for coffee, how to repair irrigation channels and how to direct water to the different crops and trees of the farm, which plants repel pests, how to use banana mulch as a ground cover to fertilise and to protect the soil, and how to take care of a dairy cow. Instead of inheriting a homegarden of their own at their marriage, they were shown a piece of land in the dry lowlands where every few years the rains fail and ticks kill dairy cows. They had probably learned from their parents how to cultivate maize and beans and millet on a lowland plot. That was all they knew about dryland agriculture. And so most of the lowland farms still grow only maize and beans.

The farm extension service in both study sites is blamed for being inefficient. According to the farmers, extension workers previously travelled around the area giving advice. Now they are available only on request, and very few farmers do request (Soini 2005a, 2006a). In the lowlands of Mt. Kilimanjaro some farmers have discovered groundnuts and sunflower as cash crops. The few farmers with irrigation water available have started growing tomatoes, onions, green peppers and chillies. These crops seem promising, but lack of marketing channels often leads to extremely low prices during harvest times, and due to oversupply in the local markets, and no further processing, part of the harvest is spoiled (Soini 2005b).

It is a firm and widespread belief amongst the farmers in East Africa that the rainfall has decreased over the past decades. In the lowlands particularly, the unreliability of rain gives rise to regular complaints. This is locally attributed to global climate change and local vegetation change – especially decrease in tree cover on the upper slopes. Decreasing rainfall and droughts were perceived by farmers amongst the most pressing challenges in both study sites (Soini 2005a, Soini 2006a). In the lowlands of Mt. Kilimanjaro, reduction in water levels of the few rivers and irrigation channels that reach all the way to the plains, is rendering the lowland farming system increasingly limited. A recent study of the climate of Mt. Kilimanjaro (Agrawala *et al*. 2003) claims that there appears to be a decrease in precipitation since 1935 of about 11% or 177 mm at Lyamungo, equivalent to a decrease of 2.6 mm per year. However, the fact that 1936 and 1937 had significantly higher than average rainfall undermines the result – very different trends are estimated if the analysis is started at a slightly different time. However, increased variability of rainfall has been shown by a study in Arusha, just 100 km away from Mt. Kilimanjaro. The study looked at rainfall patterns between 1928 and 1998 (Kingamkono & Kaihura, 2003). It concludes that rainfall variability appears to have increased significantly in all rainfall zones in recent years. This has affected the start and finish dates of both the short and long rains, and in the lower rainfall areas it has even affected whether short rains are available at all.

Soil depletion is generally perceived as the most negative trend affecting cultivation, resulting in more work and demand of farm inputs (Soini 2005b, 2006a). Lack of capital for farm inputs such as fertilisers and manure is among the most pressing problems listed by farmers. The fertility of highland plots is maintained more effectively than that of the lowland plots. On Mt. Kilimanjaro 96% of the highland and midland plots receive either manure or fertiliser. However, fertiliser, and to a lesser extend manure, is applied to only 43% of the lowland plots (Soini 2002, 2005a, 2005b). In the Taita Hills 73% of the highland plots and 19% of the lowland plots receive either manure or fertiliser (Soini 2005c). However, the amount applied in either zone is usually not adequate. Olson *et al*. (2004) report that "the intensification of Embu agriculture appears successful in terms of high soil and commercial productivity and general well-being." The Chagga system has also often been referred to as a model sustainable farming system. However, the present livelihood survey reveals that the farming system is no longer functioning in a sustainable way. The location of Embu, like the Taita Hills, supports the production of higher value crops that enable better soil management. In addition, the Chagga irrigation system, causing soil loss and erosion leading to lower levels of production, has probably significantly contributed to the deteriorating of the Chagga farming system. In the lowlands of Mbeere, the lower value of lowland crop production and higher levels of poverty is associated with lower levels of input application, despite poorer soil fertility.

The differences between the higher and the lower areas of the study gradients are associated with parallel differences in economic returns to investment in the soil, and with differences in government involvement in soil maintenance. Highlands with their high population densities and high agricultural potential, have been the focus of government programmes to increase productivity since the colonial administration. In the early 1990s the structural adjustment programme introduced by the World Bank and International Monetary Fund (IMF) which, amongst others, involved the reduction

of subsidies on pesticides and fertilisers (Aminu-Kano 1992) had, according to farmers, a clear effect on the fertility of the farmlands. According to Olson *et al*. (2004) parastatals gave credit for Embu farmers to purchase chemical fertilisers, pesticides and fungicides for the coffee and tea. Farmers applied the fertilisers and the pesticides to their food crops as well. In the 1990's, before the coffee and tea prices collapsed, many of the wealthier Embu farmers were purchasing truckloads of manure brought in from Mbeere (Olson *et al*. 2004).

The deterioration of agro-ecosystems has had a direct effect on the livelihoods through diminishing production of food crops. The majority of the Taita farmers perceive a reduction of yields of most of their crops (maize, cowpeas, green grams, beans, millet and pigeon peas, cassava). Banana is the only crop with a perceived increase in yields. However, all who perceive an increase in their banana yields have also increased the area under cultivation (Soini 2005c). On Mt. Kilimanjaro, production trends are not so clearly observed. However, more farmers observe a reduction rather than an increase in the production of all of their crops, except banana. Thirty-six percent of the farmers observe an increase in banana production, 20% of the banana growers perceive a reduction. Not all farmers, however, perceive a change. Lack of record keeping makes it difficult to prove whether the perceptions are right or wrong.

The necessity of cultivating agriculturally marginal lowlands has created a new and distinct group of farmers who have settled in the dry lowlands previously considered as unsuitable for permanent settlement due to inadequate rains and malaria (Olson *et al*. 2004; Soini 2005a). Due to the marginality of their farming land limiting the number of livelihood options available, this group of lowland farmers is very vulnerable. In the lowlands of Mt. Kilimanjaro farmers reported some people having died of hunger during the drought in 2000 when both the short and the long rains failed (Soini 2005a). There is usually not enough knowledge of agricultural options and suitable practices for the dry conditions of the lowlands. Farmers continue to grow maize as their main crop even if the risk of losing the crop is high. Further, information of markets of possible cash crops is poor.

On the lower slopes and in the adjacent plains of Mt. Kilimanjaro and in Mbeere the overall decrease and fragmentation of bushlands and the reduction of riverine vegetation has significantly reduced the area earlier used for grazing, firewood and timber collection. On the one hand, this leads to more intensive and destructive use of the remaining bushlands and riverines, on the other hand farmers have realised the need for becoming more self-sufficient in firewood, timber and fodder production (Soini 2005a, 2005b). This has, however, not yet led to any large-scale diversification to trees in the lowlands, as could have been expected. In the Taita Hills, there is much more bushlands left and the issue of communal lands for the collection of firewood, small timber and grazing is not so pressing.

As the income derived from small-scale farming is often not sufficient due to small land size and poor yields, rural livelihoods have become increasingly multi-occupational. This follows patterns seen elsewhere in Africa where diversification happens in two ways: adding further agricultural enterprises or adding a non-farm activity to farming. Even though there are differences between regions, non-farm

earnings account for roughly 40% of farm household income in rural Africa, typically more so than in other world regions (Livingstone 1991; Haggblade *et al*. 1989; Reardon 1997; Reardon *et al*. 1998; Bryceson 1999). The livelihood survey results showed that on Mt. Kilimanjaro and in the Taita Hills 55 % and 50 % of the fathers and 15 % and 19 % of the mothers, respectively, earn off-farm income. For the poorest, diversification typically means highly diversified portfolios but low marginal returns, or desperation-led diversification (Barrett 1997; Reardon *et al*. 2000; Little *et al*. 2001). Reardon *et al*. (2000) have predicted that in the medium run, it is probable that the inequality in accessing off-farm opportunities will lead to an increasingly skewed distribution of land and other assets in rural Africa.

Some reduction in birth rates can be seen in both Kenya and Tanzania. In Kenya the total fertility rate declined from 7.8 in 1979, to 6.6 in 1989, and to 5.0 births per woman in 1999 (UNFPA 2003). In Tanzania the total fertility rate was 6.9 in 1978, declined to 6.3 in 1992, and to 5.8 in 1996, being currently at 5.11 children per woman (UNFPA 2000, 2006). However, five children per woman still means very high population growth.

## Conclusions

The main aim of this study was to understand the impacts of livelihood strategies on landscapes and the environment, and the feedback of environmental change to livelihoods. Some general patterns of livelihood, land use and environment interactions can be found in the three sites in the highlands and adjacent plains in East Africa. They are summarised in the text boxes of the Results and Discussion section. However, the linkages are complex. The complexity is due to

1. The simultaneous functioning of all the linkages
2. The cause-effect relations sometimes having considerable time lags
3. Complex and diverse evolutionary histories that lead to the current state
4. External influences dominating the results of locally directed development processes
5. The human-environment relationship being mediated by institutions
6. Land use choices being influenced by human perceptions and preferences that do not follow clear patterns

Population growth emerges as the most forceful driver of land use and environmental change. Migrations of populations to new areas, overexploitation of forest, expansion of agriculture to marginal lands, miniaturisation of farms, intensification and diversification of agriculture, establishment of new settlements, soil degradation (due to reduced fallowing and cultivation of fragile areas), reduction in water availability due to high usage rates and vegetation change, decreased habitat viability and loss of habitat due to fragmentation of landscapes are all processes that have been mainly driven by population growth. Raised livelihood expectations due to exposure to higher standards of living have further driven land use change. Various external influences at different times in history have to some extent influenced most of the major turning points. Ancestors of the current inhabitants were most likely pushed to look for new land by other populations, many crops were adopted from traders or colonialists, rules on access to land have been radically modified by policies implemented by external

powers (Taita Hills and Embu), population growth itself was made possible by external interventions, to mention a few. If internal (local) drivers are the ones that a local farmer has influence on, then few qualify. With this definition even the district farm extension service is probably an external driver of land use and environmental change. This raises questions about the validity of the often-promoted principles of locally driven development initiatives.

The high population growth has in many areas lead to overpopulation, defined as agricultural population in excess of the capacity of land to supply its food needs. Decreasing farm size due to population pressure and land scarcity is currently threatening the viability of whole farming systems. Farms have simply become too small to sustain a family. Further, an increasing number of young people in the future will not inherit any land at all. There are several responses to this. Many farmers strive to have a non-agricultural job based on the farm, some members of the family migrate to work in towns, and others commute daily to work in the nearby villages and towns. As the ability of formal manufacturing and service sectors to absorb excess labour from the rural areas is very limited in Kenya and Tanzania, much of the new employment is in the informal sector. There is, however, a large variation on the types of jobs and the remuneration they provide. Furthermore, not all those who need to are able to create an off-farm job for themselves. In the medium term it is probable that the inequality in accessing off-farm opportunities will lead to an increasingly skewed distribution of land and other assets in rural Africa.

Bilsborrrow (1987) hypothesised that human fertility reduction will occur in traditional societies only as a last resort. Also, it is widely believed that fertility reduction follows increased standards of living. This was the case in the developed world. However, raising the standard of living of the millions of poor without a simultaneous reduction in population growth is simply not feasible. In fact, every day the world population increases by 200 000, nearly all in developing countries (Young 2005). As Young (2005) argues, statements about agricultural development, increase in food security, poverty reduction and sustainability should recognize that population is not an external variable but an integral part of development. The world's scientific academies reached clear and unambiguous conclusions in a conference in New Delhi in 1993. In a statement issued from this meeting they say: "Family planning could bring more benefits to more people at less cost than any other single technology… Success in dealing with global social, economic and environmental problems cannot be achieved without a stable world population…" (World's Scientific Academies 1993). Political ecologists challenge both the optimistic Boserupian and pessimistic Malthusian views of population-land interactions, focusing instead on unequal access to resources as the relevant issue in population-environment interactions (Gray & Moseley 2005). Technological development, policies and market forces are believed to be the key answers in mitigating poverty and unsustainable human-environment relations. However, the potential for technology and policies to provide solutions within the current context of the East African Highlands is clearly limited.

The linkages between livelihoods, land use and the environment generally point to degradation of the environment leading to reduced environmental services and ecosystem functions. There is no indication that the system is self-regulating in this

respect. Positive interventions will be needed to maintain ecosystem integrity. This is not only to maintain rural livelihoods but also to support other life forms. It is not simply a question of providing protected areas. Policies and practices that enhance the environmental function and benefits of farmed landscapes need developing and promoting.

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