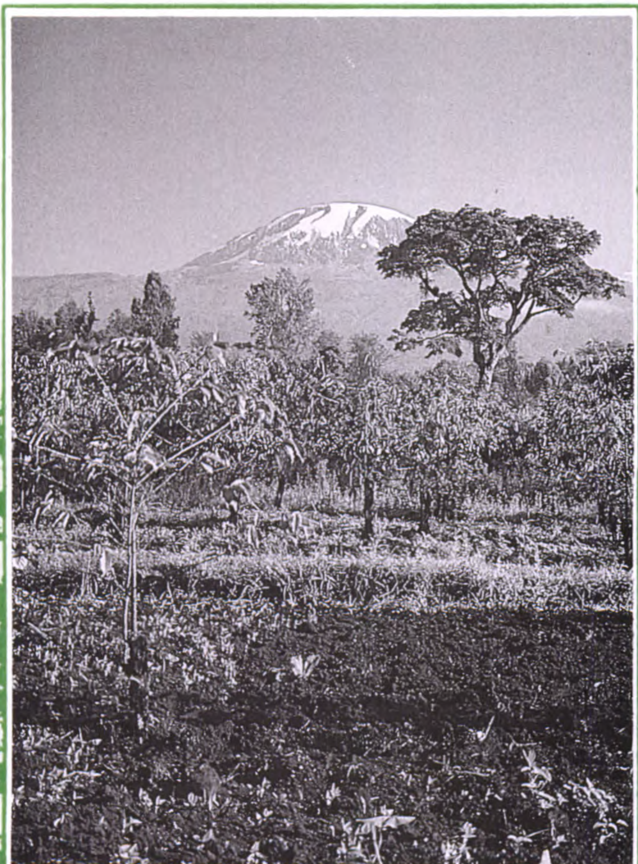
The IUCN Tropical Forest Programme

The IUCN Tropical Forest Programme

The Conservation of Mount Kilimanjaro

Edited by

WILLIAM D. NEWMARK



The Conservation of Mount Kilimanjaro

IUCN – The World Conservation Union

Founded in 1948, IUCN – The World Conservation Union – is a membership organisation comprising governments, non-governmental organisations (NGOs), research institutions, and conservation agencies in 120 countries. The Union's objective is to promote and encourage the protection and sustainable utilisation of living resources.

Several thousand scientists and experts from all continents form part of a network supporting the work of its six Commissions: threatened species, protected areas, ecology, strategy and planning, environmental law, and education and communication. Its thematic programmes include forest conservation, wetlands, marine ecosystems, plants, the Sahel, Antarctica, and population and sustainable development. These activities enable IUCN and its members to develop sound policies and programmes for the conservation of biological diversity and sustainable development of natural resources.

The IUCN Tropical Forest Programme

The IUCN Tropical Forest Programme coordinates and reinforces activities of the IUCN members and Secretariat which deal with tropical moist forests. The Programme focuses on the conservation of species and ecological processes, and on investigating and promoting sustainable use of the resources of these forests.

The Programme includes international and national policy initiatives and strategies as well as field projects addressing selected problems in managing the world's most biologically significant tropical forests. These selected projects put the World Conservation Strategy into action by reconciling the requirements of conservation with national development and the needs of people living in forest areas. Special emphasis is given to the development of compatible uses for buffer zones around national parks and reserves.

IUCN develops its positions and policies on the basis of the concerns and information communicated by members, trends identified by monitoring activities, and the feedback from numerous field projects. Data on species of plants and animals, and on tropical forest sites which are important for biological and ecosystem conservation, are held by the World Conservation Monitoring Centre in Cambridge, UK.

This series of publications from the Tropical Forest Programme, in conjunction with regular meetings, enables IUCN to communicate policies and technical guidance to governments, major international institutions, development planners, and conservation professionals. The Programme works closely with development assistance agencies, governments and NGOs, to ensure that conservation priorities are adequately addressed in their activities.

The Tropical Forest Programme receives generous financial support from the Government of Sweden. It is coordinated by Jeffrey Sayer at IUCN Headquarters in Gland, Switzerland. Mark Collins is responsible for tropical forest monitoring at the World Conservation Monitoring Centre.

The IUCN Tropical Forest Programme

The Conservation of Mount Kilimanjaro

Edited by
William D. Newmark

IUCN – The World Conservation Union
1991

Published by: IUCN, Gland Switzerland and Cambridge, UK, and funded by the World Wide Fund for Nature (WWF)

WWF

Citation: Newmark, William D. (ed) (1991) The Conservation of Mount Kilimanjaro. IUCN, Gland, Switzerland and Cambridge, UK. 136 pp.

ISBN: 2-8317-0070-1

Design and Layout by: Liz Jarvis and Gordon Otieno – Communications Unit, IUCN Regional Office for Eastern Africa, Nairobi, Kenya

Printed by: The Regal Press Ltd, Nairobi, Kenya

Cover design by: James Butler

Cover photo: Coffee estate, Mweka, 1400 m. William D. Newmark

Available from: IUCN Publications Service Unit,
219c Huntingdon Road, Cambridge, CB3 ODL, UK. or
IUCN Regional Office for Eastern Africa, Nairobi, Kenya

Contents

Preface

Few natural features worldwide are as well known as Mount Kilimanjaro. Its dramatic snow-clad slopes predominate the landscape of northcentral Tanzania.

For people living outside of Africa, Mount Kilimanjaro has served as the backdrop for much of the art, literature, and movies that have been produced outside of Africa about East Africa. Similarly for the people of northern Tanzania, Mount Kilimanjaro is central to much of their own oral traditions, religion and art. In recognition of its beauty, cultural significance, and size – being the highest mountain in Africa – Mount Kilimanjaro was declared in 1989 a World Heritage Site.

In addition to its important cultural and spiritual significance, Mount Kilimanjaro is the primary source of much of the water, food, fuel, and building material for the people of northcentral Tanzania. Unfortunately the capacity of Mount Kilimanjaro to continue to provide these vital products and services is being threatened by inappropriate and some cases over-exploitative use of many of its natural resources.

This book is a result of a symposium held in October 1989 in Moshi, Tanzania. This symposium was organized by the College of African Wildlife Management, Mweka and was one of a series of activities to celebrate the 100 year centenary of the first successful ascent of Mount Kilimanjaro by Hans Meyer. Much has changed on Mount Kilimanjaro since Hans Meyer climbed Kibo peak 100 years ago. However, few places in the world have not changed in the last 100 years and thus what is most instructive at this centenary date is not to compare the environmental conditions of Mount Kilimanjaro 100 years ago with today but to consider what may be the environmental conditions on Mount Kilimanjaro in the next 10, 20, or 50 years if current trends in population growth and resource use continue.

Much of the current stress upon the natural resources of Mount Kilimanjaro is a result of the dramatic increase in human population on the slopes of Mount Kilimanjaro during the last 100 years. In Chapter 1, Deo-Gratias Gamassa reviews the change in human population since 1913. Human population on the slopes of Mount Kilimanjaro has more than tripled during the last forty years. As of 1978, Moshi Rural District which covers all of the southern slopes of Mount Kilimanjaro has the highest rural density of any administrative district in Tanzania.

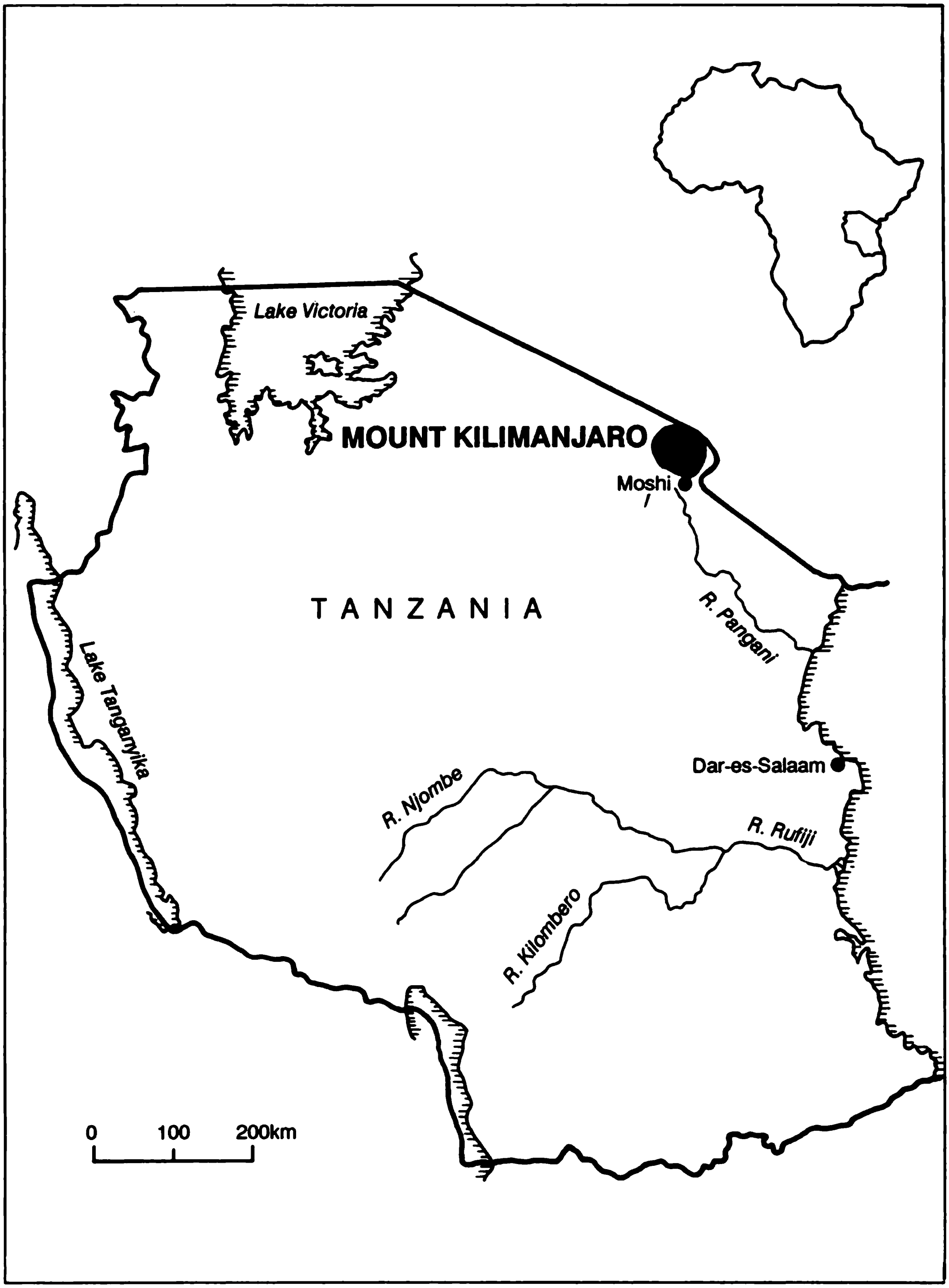


Figure 1. Location of Mount Kilimanjaro.

Richard and Hugh Lamprey and Frances Michelmore report in chapter 2 that approximately 6% of the montane forest has been lost since 1958 as a result primarily of its conversion to softwood plantations. They show based upon remote sensing analysis that the montane forest on Mount Kilimanjaro is effectively bisected into two parts: a small northern block and a larger southern block.

In addition to the quantitative loss of montane forest cover, there has been a qualitative change over time within the montane forest as a result of logging and fires. In chapter 3, Balekebajobege C. Mwasaga discusses the qualitative changes that have occurred to the montane forest in several selected areas as a result of past logging and fires.

Tamás Pócs, in Chapter 4 reports on the high level of diversity and endemism of bryophytes on Mount Kilimanjaro and the critical role that particularly the mosses and lichens play in intercepting rain. The loss of the bryophytes on Mount Kilimanjaro would have a severe impact upon the regional hydrology of northern Tanzania.

In chapter 5, I along with Charles Foley, John Grimshaw, O. R. Chambegga, and A.G. Rutazaa report on the local extinction of two large mammals within Kilimanjaro National Park and Forest Reserve. We also document the presence of seven large mammal species that have not been previously included on the checklists of the large mammals of Kilimanjaro National Park and Forest Reserve. We suggest that the increasing isolation of Mount Kilimanjaro has been an important determinant in the local extinctions.

Tourism has also had a direct impact upon the mountain. In Chapter 6, I and Pascal Nguye discuss the problems of trail erosion and firewood collecting along the Marangu Route.

Water is probably the most valuable natural resource of Mount Kilimanjaro. Virtually all of the population in northcentral and northeastern Tanzania is dependent either partially or wholly on the water from Mount Kilimanjaro for household use, agricultural production, and energy generation. In Chapter 7, J.D. Sarmett and S.A. Faraji provide evidence of a decrease in the dry season discharge of water from several non-spring fed rivers on Mount Kilimanjaro. The most likely cause of the decrease has been the increased use of water and land use changes.

There has been a significant change during the last 30 years in the agricultural systems particularly at the lower elevations on Mount Kilimanjaro. A. O'Kting'ati and S.A. Kessy in Chapter 8 discuss these changes as well as the environmental impacts that have occurred as a result of these changes. They also review the trends in the per capita production of coffee, maize, millet and beans on Mount Kilimanjaro between 1964 and 1988.

The Chagga have a long history of managing the forest resources on Mount Kilimanjaro. In Chapter 9, C.O. Kivumbi and I report on the very successful management of the half-mile forestry strip, one of the first social forests in East Africa, by the Chagga Council prior to independence as well as its post-independence management. The local people living on the slopes of Mount Kilimanjaro also recognize the importance of Kilimanjaro National Park and Forest Reserve in terms of watershed protection and the generation of foreign exchange. In Chapter 10, I and Nancy Leonard present results of a questionnaire examining the attitudes of local people to Kilimanjaro National Park and Forest Reserve and discuss how these attitudes are influenced by resource use and dependency. Local people living adjacent to Kilimanjaro National Park and Forest Reserve are strongly opposed to the abolishment of the reserve and do not condone poaching.

Integrated research and management is vital in designing future programs to promote the conservation of Mount Kilimanjaro. Jørn Bjørndalen, in Chapter 11, presents a detailed outline for the inventory and monitoring of catchment forests in Tanzania and argues that such a program is needed for the catchments forests of Mount Kilimanjaro. In Chapter 12, S.B. Misana proposes a broad strategy for integrated research and management of Mount Kilimanjaro.

Finally, the major recommendations of each chapter to promote the conservation of Mount Kilimanjaro are brought together in Chapter 13 and priorities for the conservation of Mount Kilimanjaro are presented.

William D. Newmark

June 1991

Acknowledgements

I would like to thank the World Wide Fund for Nature (WWF) for providing support for the symposium on the conservation of Mount Kilimanjaro and the publication of this book. Special thanks are given to John Boshe for his initial support of the idea for a symposium and a book. I also thank Jon Lovett, Paul Nyiti, Chief Tom Marealle, B.O. Zaaten, Kim Howell, D.V.N. Kihwele, and M.I.L. Katigula for their substantive comments and recommendations as well as Joachim Chuwa for his typing. I am very grateful to the College of African Wildlife Management, Mweka and the Danish International Development Agency (DANIDA) for granting me the time to complete the editing of this book and the Save Mount Kilimanjaro Committee for proposing the symposium on the conservation of Mount Kilimanjaro. Finally I would like to thank my colleagues and friends for their encouragement especially D. Manyanza, W. Foya, H. Sariko, D. Gamassa, M. Mangubuli, G. Makumbule, J. Machange, D. Bayona, T. Boshe, O. Chambegga, A. Rutazaa, P. Nguye, O. Ndosi, Rebecca Watts, Mary Bakken, Peter and Marija Ozolins, Lawrence, Antje, Amani, Brent, and Jo McIntyre, Karl, Marianne, Melanie, and Benjamin Kiefer, Rebecca Kohler, Sitsu Tapaninen, and Karla Van Eynde.

Chapter 1

Historical change in human population on Mount Kilimanjaro and its implications

D.M. Gamassa

Abstract

According to the 1988 national census, the population on Mount Kilimanjaro is 840,386. It has tripled since 1948. Of the four districts in the Kilimanjaro Region immediately adjacent to Mount Kilimanjaro – Moshi Rural, Moshi Urban, Rombo, and Hai – Moshi Rural has the highest population of 342,553 followed by Rombo with 200,859.

The mean annual rate of increase between 1978 and 1988 for the four adjacent districts to Mount Kilimanjaro as a whole is 2.1%. For this same period the mean annual growth rate for Moshi Rural, Moshi Urban, Rombo, and Hai districts is 1.0%, 8.6%, 2.7%, and 1.6%, respectively. The present growth is increasing at a decreasing rate for the rural districts. Assuming growth rates remain constant, the population on Mount Kilimanjaro will double in 39 years while the population of the town of Moshi will double in 8 years.

The overall population density for the four districts immediately adjacent to Mount Kilimanjaro is 158.3 people per km^2. In the 1978 census, Moshi Rural had a density of 200.3 people per km^2, which was the highest rural density of any district in all of Tanzania. If rural density is based upon actual land availability, the rural density for the area immediately adjacent to Mount Kilimanjaro is approximately 264 people per km^2 but localised densities varying from 650 to 1000 people per km^2 have been recorded.

Introduction

Humans have continuously occupied the slopes of Mount Kilimanjaro for the last 2000 years (Schmidt, 1989). The relatively abundant precipitation and fertile soils have been very important in attracting various agricultural peoples. The dramatic increase in the human population, however, is a phenomenon of the last 60 to 90 years.

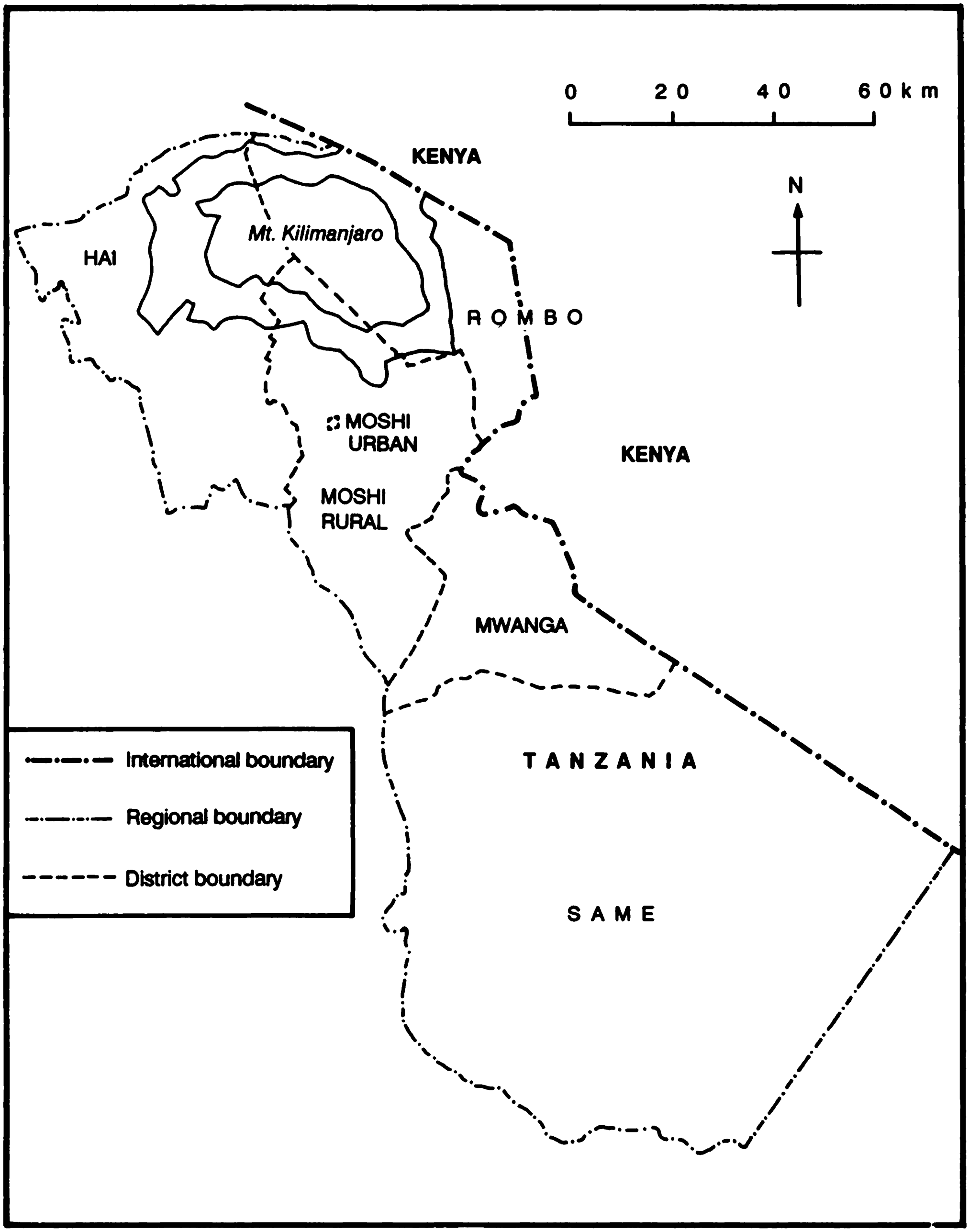


Figure 1.1 Administrative districts of the Kilimanjaro Region.

This chapter reviews the change in human population in the administrative districts immediately adjacent to Mount Kilimanjaro since 1948. The Kilimanjaro Region consists of six districts: Moshi Rural, Moshi Urban, Hai, Rombo, Same and Mwanga (figure 1.1). I shall examine the change in population in the four former districts immediately adjacent to Mount Kilimanjaro. In order to place the recent population increase in perspective, estimates of population between the turn of the century and 1948 are made.

Methods

Population estimates from 1948–1988 are obtained from national census results (Central Statistical Bureau 1968a, 1968b; Bureau of Statistics 1982, 1989). Most of the results in this chapter are based upon the 1967 and 1978 national census because much of the data from the 1988 national census have not yet been analysed.

Statistics for the period 1913–1948 are scant. Population estimates for this period are derived using national annual growth rates based on mainland population estimates by Koponen (1986). Using the average national growth rate for the time periods 1913–1921, 1921–1931, and 1931–1948, estimates of the population on Mount Kilimanjaro are calculated by projecting backwards from the 1948 national census results. It was assumed that the population growth prior to 1948 followed a logarithmic growth pattern (Isard *et al.*, 1960) within intercencal periods. The logarithmic growth model is:

$$P_{t-i} = P_t e^{-ri}$$

where,
- P_t = population at base year t
- P_{t-i} = population at any year within an intercensal period
- i = years before the base year
- r = average annual growth rate in the intercensal period
- e = 2.71828 (the base of the Naperian logarithm system)

Results

Change in population 1948-1988

According to the 1988 census, the population in the four administrative districts immediately adjacent to Mount Kilimanjaro is 840,386 (table 1.1). In 1948, the population on the slopes of Mount Kilimanjaro was 267,700 (table 1.1). Thus the population has more than tripled in the last 40 years (figure 1.2).

The change in population in the town of Moshi has been even more dramatic. According to the 1988 census, the town of Moshi has a population of 96,838. In 1967, the population of Moshi was 29,423 and thus the population in Moshi has tripled in 21 years.

Population growth rate

The population growth rate varies considerably between rural and urban areas on Mount Kilimanjaro. For the censal period 1978–1988, the rural districts of Moshi Rural, Hai, and

Table 1.1 Estimates of district and total population on Mount Kilimanjaro, 1948–1988. The 1948 and 1957 estimates of the total population are based upon the former Kilimanjaro District which included the current districts of Moshi Rural, Moshi Urban, Hai, and Rombo.

Year	Moshi Rural	Moshi Urban	Hai	Rombo	Total
1948					267700
1957					365000
1967	242075	29423	116974	114615	503087
1978	312041	52046	172444	157715	694246
1988	342553	96838	200136	200859	840386

Source: Central Bureau of Statistics, 1968a, 1968b; Bureau of Statistics, 1978, 1988.

Rombo had annual growth rates of 1.0%, 1.6%, and 2.7%, respectively. The overall doubling time for the three rural districts is 39 years (table 1.2). All rural districts show a decrease in population growth rate between censal periods of 1967–1978 and 1978–1988 (table 1.2). Although data on the birth and death rates and in- and out-migration based upon the 1988 national census are not yet available for the Kilimanjaro region, the decrease in the annual growth rate between the censal periods 1967–1978 and 1978–1988 is most likely due to an increase in the out-migration rather than a decrease in either the birth rate or an increase in the death rate. In the 1978 census, the Kilimanjaro Region had an annual net out-migration of -0.6% (Mbaruku, 1982). Between 1967–1978, the Kilimanjaro Region had the second highest regional natural growth rate (3.5%) after the Dar es Salaam Region in Tanzania.

Table 1.2 Administrative districts, population annual growth rates, and doubling time on Mount Kilimanjaro, 1967–1988.

District	1967 – 1978 (%)	1978 – 1988 (%)	Doubling time (years)
Moshi Rural	2.6	1.0	70
Moshi Urban	7.0	8.6	8
Hai	4.3	1.6	44
Rombo	3.4	2.7	26

Source: Bureau of Statistics, 1978, 1988.

In contrast to the decreasing rate of growth in the rural areas, Moshi Urban has experienced an increase in growth rate between the censal periods of 1967–1978 and 1978–1988. The net out-migration from rural areas has most likely contributed to the rapid population growth in Moshi Urban. Assuming the current growth rate remains constant the population of Moshi Urban will double to 193,676 in eight years (table 1.2).

According to the 1978 national census, the age ratio between children and adults is 1:1.2. The high proportion of children within the population constitutes a significant momentum to the population when the children enter the reproductive age class. Since 1948, the birth rate nationwide has been increasing while the mortality rate have been steadily declining (Koponen, 1986). In addition, approximately 40% of the nationwide population is within the reproductively most active age class (Yeager, 1989). Assuming that the current age class structure on Mount Kilimanjaro mirrors the age class structure of the nation, the population on Mount Kilimanjaro will continue to have a high rate of population increase well into the 21st century.

Population density

Of the three rural districts immediately adjacent to Mount Kilimanjaro, Moshi Rural has the highest population density. Based upon the 1988 census, the current density for Moshi Rural is 219.9 people per km^2 (table 1.3). In 1978, Moshi Rural had the highest population density (200.3 people per km^2) of any rural district in Tanzania.

Table 1.3 Rural district population densities on Mount Kilimanjaro, 1967–1988.

District	Area	1967	1978	1988
	(km^2)		(people/km^2)	
Moshi Rural	1558	155.4	200.3	219.9
Hai	1482	77.3	106.4	135.5
Rombo	2269	51.6	76.0	88.2

Source: Central Bureau of Statistics 1968a; Bureau of Statistics, 1978, 1988.

Although Moshi Rural has the highest density of any rural district on Mount Kilimanjaro, the density of the other rural districts on Mount Kilimanjaro is increasing at a more rapid rate. Between the 1978–1988 intercensal period, Rombo and Hai had a percentage increase of 27% and 16% respectively in comparison to 9.8% for Moshi Rural.

Estimates of population density based upon the total area of each district are, however, misleading because much of the land use within the districts on Mount Kilimanjaro is allocated to activities other than small-scale farming (table 1.4). The total area of the four administrative districts immediately adjacent to Mount Kilimanjaro is 5310 km^2, however, only 3184 km^2 are available for small-scale farming. Much of the land within the four

Table 1.4 The area and date of establishment of the major non-small scale farming land use types in Moshi Urban, Moshi Rural, Hai, and Rombo districts.

Land use type	Area (km^2)	Date of Establishment
Kilimanjaro Forest Reserve	1078.8	1921
Kilimanjaro National Park	756.0	1973
KNCU coffee estates	26.6	1910-1945
KNCU maize, beans, arable land, pasture	110.6	–
NAFCO farms (wheat, barley, pasture)	121.5	1910 – 1950's
TPC sugar cane plantation	32.4	1950's
Total	2125.9	

administrative districts on Mount Kilimanjaro is reserved as national coffee and wheat estates, sugar cane plantations, national park, and forest reserve (table 1.4). Thus, the actual rural density on the slopes of Mount Kilimanjaro is approximately 264 people per km^2.

The population on Mount Kilimanjaro is not evenly distributed. Most of the population is concentrated at an altitude between 900 m and 1800 m with the highest densities occurring between 1100 m and 1800 m. Densities between 650–1000 people per km^2 have been recorded in certain places between 1100 m and 1800 m on Mount Kilimanjaro (FAO, 1986). Below 900 m, population density is approximately 50 people per km^2 (FAO, 1986).

Pre-1948 population estimates

In order to place the current population growth rate on Mount Kilimanjaro in perspective, it is useful to examine the estimated population on the slopes of Mount Kilimanjaro for the period of 1913 to 1948. If one assumes that the population on the slopes of Mount Kilimanjaro between 1913 and 1948 mirrored the change in population for the rest of Tanzania then the population for the slopes of Mount Kilimanjaro was approximately 122,300 in 1913, 133,400 in 1921, and 166,300 in 1931 (figure 1.2).

The estimate of the 1931 population on Mount Kilimanjaro is very similar, though slightly higher than the estimate by Bock (1942) of 155,900 in 1934 for Mount Kilimanjaro.

Implication of population growth on Mount Kilimanjaro.

In most environments without adequate controls, a rapid increase in population will contribute to the deterioration and depletion of natural resources resulting often in deforestation, overgrazing, soil erosion, siltation, flooding, and species extinction (Rees,1985).

However, population growth alone is not the only factor responsible for environmental deterioration. It is influenced by and acts in conjuction with non-demographic factors (Repetto

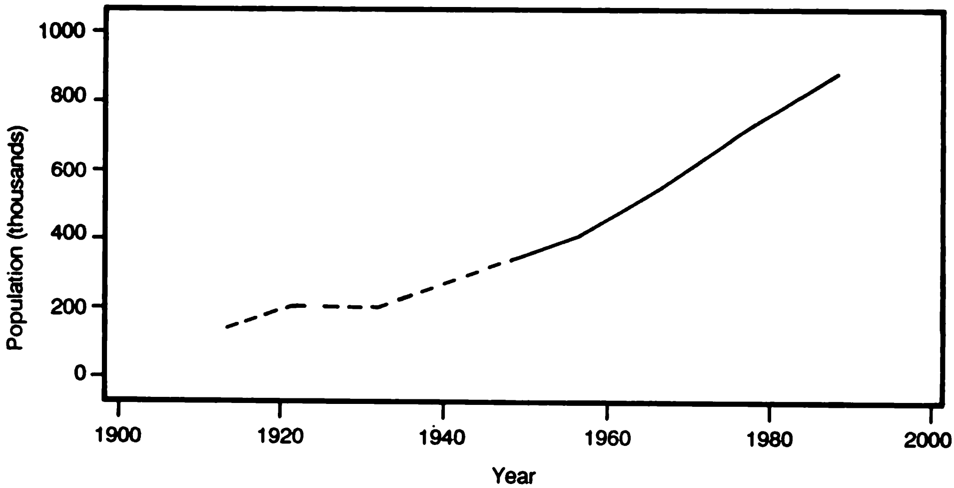


Figure 1.2 The change in population on Mount Kilimanjaro between 1913 and 1988. The solid line is based upon the national census results. The dotted line is an estimate of the pre-1948 population.

and Holmes, 1983). These factors include inequality in access to natural resources particularly land, commercialization of natural resources, a breakdown of traditional resource management systems, and geographic, and climatic factors.

Mount Kilimanjaro is experiencing serious environmental stress in part because of inequality in access to particularly land. Much of the land on Mount Kilimanjaro was transferred either to European colonists or the central government between the turn of the century and the 1950's. The establishment of the forest reserve and the large coffee estates restricted the local people particularly on the southern slopes of Mount Kilimanjaro between the two. This resulted in a compression of the traditional resource base. After independence, there was no major land reform undertaken to favour the compressed and marginalized small-holder farmers.

Closely related to the inequality in access to natural resources is the commercialization of natural resources which has also contributed to environmental deterioration. The introduction of cash crops such as coffee, sugar cane, and cattle ranching, along with commercial logging has placed greater pressures on the natural resource base by increasing the demand for these resources. Additionally, in many places on Mount Kilimanjaro, traditional mixed cropping practices (e.g., coffee, bananas, taro) which conserve the soil and nutrients were displaced by monocultures (e.g., maize) which are poor in soil conservation and need external nutrients in forms of inorganic fertilizers.

A third factor that has contributed to the environmental deterioration on Mount Kilimanjaro has been the breakdown of traditional resource management systems. Following independence, restricted lands such as forested areas adjacent to rivers and streams and upland grazing areas were placed under heavier grazing pressure and cultivation (see O'Kting'ati and Kessy, chapter 8) without a coherent management strategy being simultaneously developed (Gamassa, 1989). More recently there has been a laxity in the management of the Kilimanjaro Forest Reserve which has resulted in the over-exploitation of the forest. Due to excessive cutting of hardwoods on Mount Kilimanjaro during the last 50 years, all harvesting was formally banned as of 1984 by a Presidential order. Nonetheless, the forest reserve still remains an important source of fuelwood and building materials for the local people.

The above factors also work in conjuction with land use practices and geographic and climatic factors such as soil types, slope, temperature, and intensity and duration of rainfall. Much of the environmental stress on Mount Kilimanjaro is centred within the lowland zone. In large part this is due to the greater fragility of the soils and the sparser vegetative cover because of the more arid conditions. In addition, the lowland zone is affected by the externalities such as water pollution and flooding generated by human activities within the upland zone.

Chapter 2

Changes in the boundary of the montane rainforest on Mount Kilimanjaro between 1958 and 1987

R.H. Lamprey, F. Michelmore, and H.F. Lamprey

Abstract

A study was conducted to examine changes in the indigenous forest boundary of Mount Kilimanjaro in Tanzania over the period 1958–1987. The extent of the forest in 1958/59 was determined from aerial photography acquired over this period by the Royal Air Force and from 1:50,000 topographic maps produced from this photography. On behalf of the Tanzania Forestry Department, the Swedish International Development Agency mapped the forest boundary from aerial photography acquired in 1987. Additional data on forest distribution were obtained from LANDSAT satellite images from 1976 and 1988. All spatial data were digitised using the Geographical Information System (GIS) software ARC/INFO for comparison of the forest boundaries.

Of the original 96,700 ha of indigenous forest in 1958, 90,500 ha are remaining. Of the 6200 ha reduction in forest area, 6125 ha has been excised by the Tanzania Forestry Department for conifer plantations. These plantations have been established in two areas, in West Kilimanjaro (3775 ha) and in Rongai (2350 ha). In both areas plantations now extend from the lower forest boundary to the 7800 feet (2377 m) contour, with a one km strip of indigenous forest remaining between the upper plantation boundary and the heathline. The indigenous forest of Mount Kilimanjaro has therefore become divided into a northern and a southern section.

It was not possible to assess the considerable impact of illegal felling within the forest, using the methods employed in this study.

Introduction

The needs of a growing human population are putting increasing pressure on natural forests in the tropics. In Tanzania, it is estimated that 300,000 to 400,000 ha are deforested annually as a result of agricultural expansion, charcoal, firewood, and timber production, and fire (Ministry of Lands, Natural Resources and Tourism, 1989).

The indigenous forest of Mount Kilimanjaro, one of the major watersheds of northern Tanzania, is under great threat from the extraction of timber, the encroachment of agriculture resulting from an increasing human population, the establishment of softwood plantations, and from fires started by honey gathers.

This study was conducted to measure changes in the natural forest boundary on Mount Kilimanjaro from 1958–1987 and to examine the implications of these changes from the perspective of maintaining the integrity and diversity of the Mount Kilimanjaro indigenous forest.

Natural forest vegetation

The climax vegetation of the Kilimanjaro Forest Reserve between 5000 – 9000 feet (1524 – 2743 m) on the eastern and southeastern sides and between 6000 – 9000 feet (1829 – 2743 m) on the northern and western sides is montane rainforest that varies in composition and structure along altitudinal and rainfall gradients. The upper eastern slopes are dominated by *Ocotea usambarensis*, *Hagenia abyssinica*, *Ilex mitis*, and *Podocarpus usambarensis* sometimes grading into *Cassiipourea malosana* and *Myrica salicifolia* downslope and to the drier north.

At lower altitudes, *Newtonia buchananii*, *Macaranga kilimandscharica* and *Parinari excelsa* are common, while at the 3,050 feet (1200 m) level woody species are characterised by *Albizia spp.*, *Bombax schumanianum*, *Chlorophora excelsa*, *Diospyros mespiliformis*, *Khaya nyasica*, *Newtonia puacijuga*, and *Terminalia kilimandscharica*. The drier northwestern slopes are dominated by *Juniperus procera*, *Olea africana*, and *Olea welwitschii* at all levels (Greenway, 1965; Fernandes *et al.*, 1984).

Softwood plantations

In West Kilimanjaro and in Rongai, portions of the Mount Kilimanjaro forest have been converted to softwood plantations by the Tanzania Forestry Department. The primary plantation species are *Cupressus lusitanica* and *Pinus patula*. The impact of these plantations on the ecology of Mount Kilimanjaro will be discussed later.

Methods

In 1958 and 1959 the Royal Air Force acquired complete aerial photography coverage of Mount Kilimanjaro. This photography of approximate scale 1:48,000 was used by the Directorate of Overseas Surveys (DOS) to compile the first accurate topographic maps of the mountain. These maps, produced in 1968 as the Y742 Series (Tanzania sheet numbers 42/3, 42/4, 56/1, 52/2, 56/4, 57/1 and Kenya sheet 182/3), accurately portray the rainforest boundary of Mount Kilimanjaro. However, differences in forest density are not defined and thus there is only one category, 'natural forest'. For the purpose of checking the validity of the interpretation of forest from the original source photography (stored at the Ordinance Survey in Southampton, England), the forest boundaries on both maps and photography were carefully compared and found to be consistent.

Aerial photography of Mount Kilimanjaro (scale 1:50,000) was acquired again in 1987 by the Swedish International Development Agency for the Tanzania Forestry Department. The 1:50,000 maps produced from this photography, covering the northern, eastern and western forests of Mount Kilimanjaro, were used as the second main source of data for this study. These maps show seven different categories of natural forest, ranging from 'forests greater than 25 metres high with high density' to 'forest less than 15 metres high with low density'. The maps also show the distribution of the Forestry Department softwood plantations on Mount Kilimanjaro. As with the earlier maps, the forest interpretation was compared from the source photography, which was located at the Forestry Department offices in Arusha, Tanzania.

It was realized that differences in the forest boundary between the 1958 and 1987 maps might simply reflect the classification system used by the different photo-interpreters. From a comparison of the photography and maps it was found that the least dense category of forest on the 1987 maps, 'forest less than 15 metres high with low density', would not have been classified as forest under the classification system of the 1958 photography. This 1987 category was therefore excluded from subsequent analyses of forest boundary change.

Since the 1987 photography did not cover the southern side of Mount Kilimanjaro, information on the southern boundary of the forest was obtained by visual interpretation of a LANDSAT Thematic Mapper (TM) simulated true-colour composite satellite image of the mountain from August 1988 (image number 42285-07143-890703). Although the precise limits to the forest were not very clearly defined, it was possible to use this image in the analysis.

Finally, to supplement these sources of data, the forest boundary was mapped from the red band 5 of a cloud-free LANDSAT 2 multi-spectral scanner (MSS) satellite image of the mountain from January 1976. It was found that the red band clearly defined the limits of the forest, particularly on the eastern sunlit side of the mountain; LANDSAT overpasses take place at 9.30 a.m. local time.

All forest boundary data derived from the maps were digitised using the Geographical Information System software ARC/INFO on a micro-VAX computer at Global Environment Monitoring System (GEMS) of the United Nations Environment Programme in Nairobi, Kenya. The data were transformed to a Miller Oblated stereographic projection for comparison of the forest boundaries.

Results

The distribution of indigenous forest on Mount Kilimanjaro in 1958 and 1987 is shown in figure 2.1, which indicates that most forest reduction over the last 30 years has occurred in West Kilimanjaro and in Rongai to the northeast.

Much of the indigenous forest boundary reduction between 1958 and 1987 has resulted from the excision of indigenous forest for softwood plantations by the Tanzania Forestry

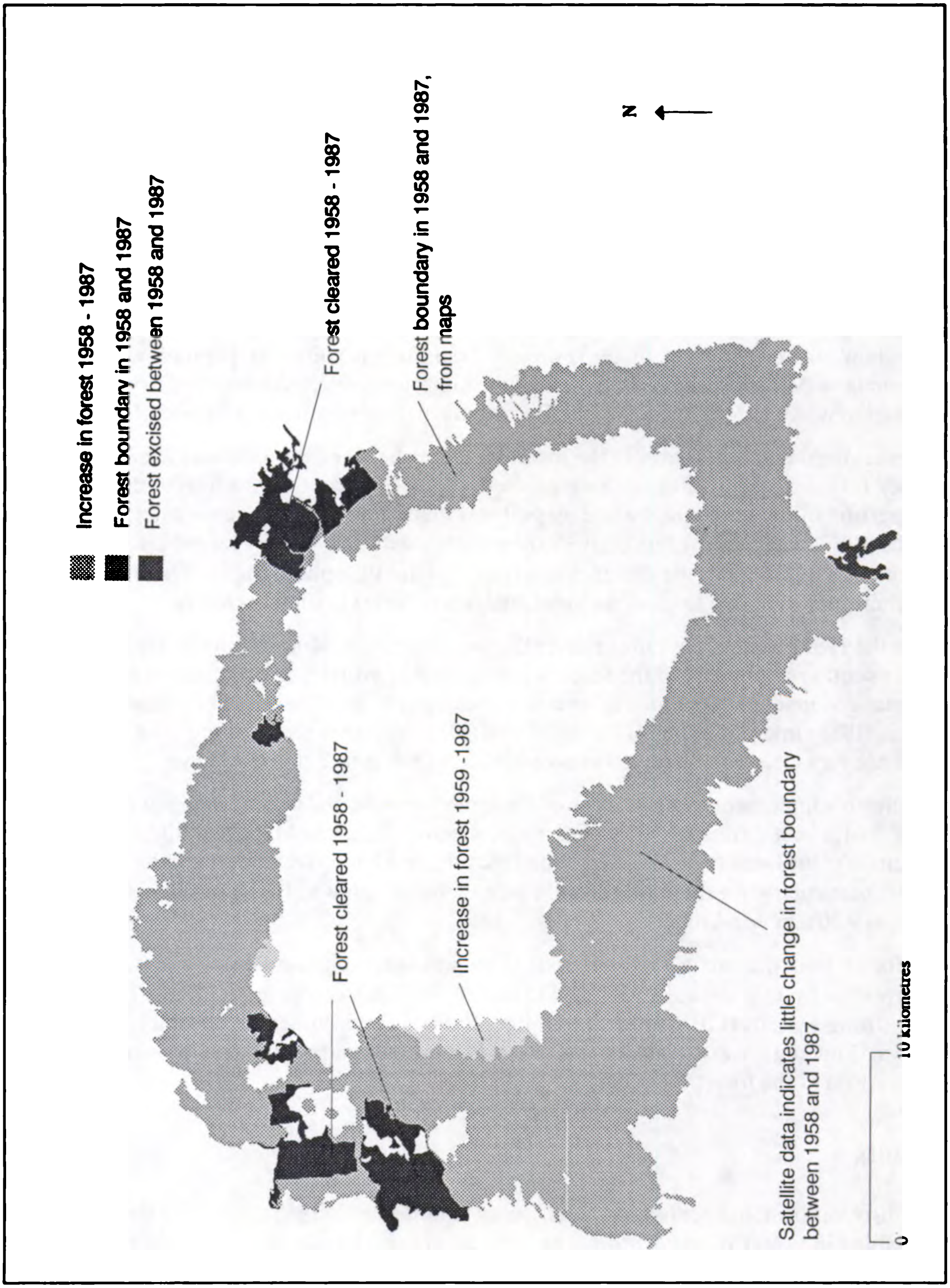


Figure 2.1 Indigenous forest boundaries on Kilimanjaro in 1958 and 1987.

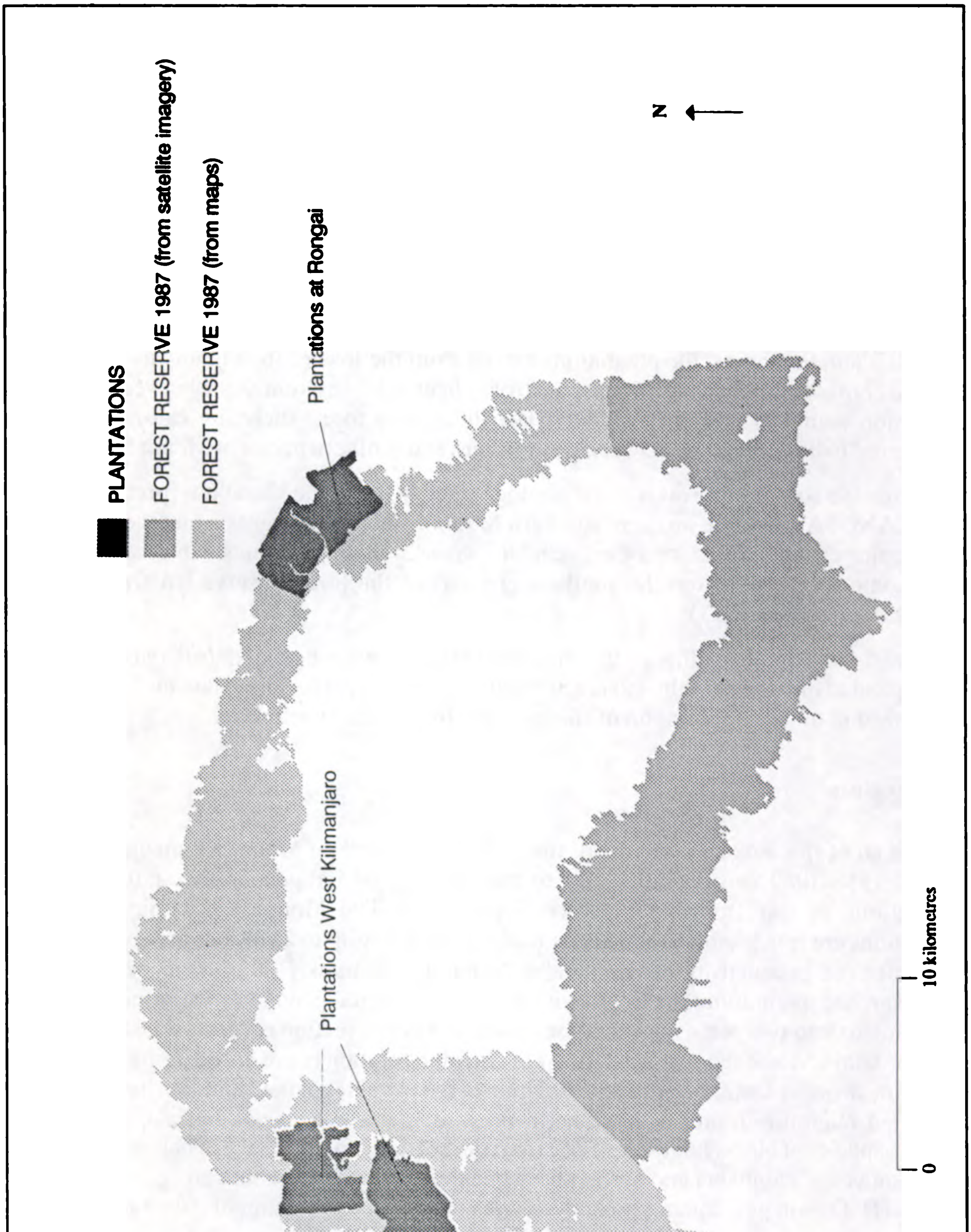


Figure 2.2 Distribution of indigenous forest and softwood plantations in 1987.

Department (figure 2.2). Of the original 96,700 ha of indigenous forest in 1958, 90,500 ha now remain. 6125 ha, or 6.3% has been cleared for *Cupressus* and *Pinus* plantations and the cleared buffer zones separating these plantations from the indigenous forest. In West Kilimanjaro, 3775 ha of indigenous forest has been cleared for plantations and in Rongai to the northeast approximately 2350 ha has been converted. In West Kilimanjaro the 'glades', openings in the forest originally maintained by fires lit by Maasai pastoralists (Wood, 1965a), have now been turned over to plantation, although another untouched glade to the northwest of the Shira plateau has expanded in size. Wood (1965b) indicated that until 1964 'owing to the expense the clearing of natural forest [for plantation] is not undertaken'. As indicated by sources in the Tanzania Forestry Department, much of this clearing and planting occurred in the late 1960's and 1970's.

In both plantation areas, the plantations extend from the lower forest boundary to the 7800 feet (2377 m) contour leaving a one km strip of indigenous forest remaining between the upper plantation boundary and the heathline. The indigenous forest therefore can no longer be considered to be continuous between the northern and southern halves of Mount Kilimanjaro.

Although the southern forest was not photographed in 1987, the visual interpretation of the 1988 LANDSAT satellite image of southern Mount Kilimanjaro suggests that there has been little major change in this southern boundary between these two dates. However, there has been some forest loss from the southeastern part of the forest reserve from encroaching agriculture (see figure 2.1).

Figure 2.1 indicates that although the outer forest boundary has been reduced, the upper forest has expanded into the heathline to the north and southwest of the Shira plateau. This is almost certainly due to the proliferation of *Hagenia* into the *Erica arborea* zone.

Discussion

Almost all of the reduction in area of the indigenous forest on Mount Kilimanjaro over the period 1958–1987 can be attributed to the clearing of indigenous forest for softwood plantations by the Tanzania Forestry Department. The Mount Kilimanjaro softwood plantations are remarkably productive, producing annually up to 25 m^3 per ha, approximately ten times the productivity of comparable Scandinavian forests (H. Olsson pers. comm.). However, the plantations have effectively divided the indigenous forest zone of Mount Kilimanjaro into two parts, a northern section and a larger section covering the southern and eastern flanks. Although two small one km corridors of indigenous forest remain along the heathline in both plantation areas, the isolation of the two sides of the mountain has most likely disrupted migratory routes of large herbivores, such as elephant and buffalo, and altitude specific species of birds (Lamprey, 1965) from the northern to the southern half of the reserve. In recent years, elephants and buffalo have been causing considerable damage to plantation forests (H. Olsson per. comm.) possibly as a result of the compression of their ranges.

It is recommended that the Tanzania Forestry Department should not undertake any further excision of indigenous forest for plantations. If further expansion of conifer plantations is planned, natural forest corridors should be maintained through these plantations to allow the movement of wildlife. In addition, future planning should take into consideration the annual migration of elephant from the Mount Kilimanjaro forest to the Amboseli area in Kenya along routes that will be blocked if the plantations in the Ol Molog and Rongai areas are expanded (see Newmark *et al.*, chapter 5).

Studies conducted in the Aberdare mountains in Kenya suggest that the replacement of indigenous forest with softwood plantations will not affect water infiltration rates and stream flow (Edwards and Blackie, 1981). However, it is recommended that stream flows on Mount Kilimanjaro should be carefully monitored before and after indigenous forest is cleared for plantation to determine whether this observation holds for the Kilimanjaro Forest Reserve.

The impact of illegal felling within the Kilimanjaro Forest Reserve cannot be assessed using the methods presented in this report. However, this impact is thought to be considerable since forest density categories portrayed on the 1987 maps indicate a pronounced thinning of the forest in a number of areas. The softwood plantations appear to create a buffer zone between the indigenous forest and the densely populated farmland areas because felling is particularly severe in the southwestern section of the forest which is unprotected by plantations. The population of the Chagga is increasing at a rate greater than 3% per annum and demands for firewood and timber have resulted in the depletion of trees in river valleys and peripheral areas of the forest (O'kting'ati and Mongi, 1986). In order to assess this impact, it would be necessary to reinterpret the original 1958 aerial photography using the system of forest classification employed in the 1987 forestry maps.

The montane forest on Mount Kilimanjaro forest is a unique ecosystem with many endemic species. Future development on the mountain requires careful planning to coordinate the requirements for improved land use, conservation, and tourism.

Acknowledgements

The authors would like to thank Mr. Tarimu and Mr. Olsson of the Tanzania Forestry Department, Arusha, for making available the 1987 maps and aerial photography without which this study would not have been possible. We are also indebted to the Ordinance Survey, Southampton, England for their assistance in providing the 1958 photography for our examination. Dr. M.D. Gwynne, Director of UNEP-GEMS in Nairobi, very kindly extended to us the use of the Geographical Information System computer facilities of GEMS, and of the UNEP aircraft for a mission to Tanzania conducted in connection with this study.

Chapter 3

The natural forest of Mount Kilimanjaro

B.C. Mwasaga

Abstract

Most of the rare and endemic flora of Tanzania are found in the moist montane forests. Mount Kilimanjaro has a rich and diverse flora that include over 1800 species of flowering plants and 700 species of lower plants. Extensive human disturbance of the montane forest has occurred in the past on Mount Kilimanjaro. Evidence of qualitative change in the montane forest in the Kiraragua catchment area and in the Maua and Marangu corridors as a result of past human disturbance is presented. This evidence is the small average diameter for all trees; the presence of many early successional species; the rarity of many economically important species; and the presence of a few large diameter economically unimportant species.

Introduction

Tanzania has over 10,000 species of vascular plants – the second highest number of any country in Africa (IUCN, 1986). Over 1120 vascular plants are endemic to Tanzania and most of these endemic plants are found in the moist montane forests of Tanzania (IUCN, 1986). Moist montane forests such as the forests on Mount Kilimanjaro deserve special attention because of their unique and important flora.

Closed broad-leaved forests cover less than 2% of Tanzania or approximately 14,400 km^2. However, these forests are disappearing at a rate of approximately 100 km^2 per year (IUCN, 1986).

The current montane forest on Mount Kilimanjaro, a remnant of a more extensive forest that has been steadily reduced by conversion to farmland, is now restricted to the elevations between 1820 m – 3050 m. Unfortunately the current montane forest on Mount Kilimanjaro is being degraded by cutting and fires. This chapter reviews the current status of the montane forest on Mount Kilimanjaro.

Vegetation belts

The wealth and variety of plants on Mount Kilimanjaro add considerably to the mountain's interest. More than 1800 species of angiosperms within 163 families and 760 genera (Gilbert, 1974) and 720 species of bryophytes and lichens (Pócs, chapter 4) have been identified on Mount Kilimanjaro.

The vegetation changes with altitude and it is convenient to recognize five major vegetation belts:

Woodland and bushland belt

The vegetation of the plains at the lower elevations of Mount Kilimanjaro is a woodland and bushland belt. On the wetter southern slopes of Mount Kilimanjaro, the upper limit of this belt is 900 m while on the drier northern slopes this belt reaches up to 1500 m – 1650 m. This belt is very susceptible to fire and can be characterized as a mosaic of *Acacia spp.* thorn bushland and *Combretum/Terminalia* woodland.

Cultivated belt

The cultivated belt constitutes the replacement of the lower part of the montane forest belt. With the exception of a narrow (8 km) corridor of native vegetation on the northwestern slope (Newmark *et al.*, chapter 5), the cultivated belt completely encircles the mountain. This belt reaches its highest point in the Machame and Marangu regions (1900 m) on the southern slope but in most other areas on the southeastern and western sides of the mountain it extends no higher than 1700 m.

The principle crops that are grown in this belt are coffee, bananas, taro, maize, beans, finger millet, potatoes, cabbage, carrots, beets, onions, turnips, and tomatoes (see O'Kting'ati and Kessy, chapter 8).

Montane forest

The lower and upper boundaries of the montane forest varies with aspect. The lower boundary of the montane forest is approximately 1700 m on the southern side and 2200 m on the northern side. The upper boundary of the montane forest reaches nearly 3000 m in places along the southern side and 2800 m on the western and northern sides.

The montane forest also varies with elevation with a general decline in species richness at the upper elevational limits of the forest. Tree species characteristic of the southern side include *Xymalos monospora*, *Conopharyngia usambarensis*, *Macarnaga kilimandscharica*, and *Hagenia abyssinica*. On the more xeric western side, *Juniperus excelsa*, *Illex mitis*, *Olea africana*, *Olea kilimandscharica*, *Podocarpus spp.*, *Agauria salicifolia*, *Cassipourea malosana*, *Calodendrum capensis*, *Casearia battiscombei*, and *Hypercium revolutum* are common species. On the northern size *Entandophragma stolzii*, *Podocarpus gracilior*, *Cassipourea malosana*, and *Fagaropsis angolensis* are dominant (Greenway, 1965).

Variations on a local scale within this belt are also important. Glades, grassy openings in the forest whose origin are probably attributed to human-induced fires (Wood, 1965a), are characterized by such flora as *Erica arborea*, *Hagenia abyssinica*, *Hypericum lanceolatum*, and *Nuxia congesta*. Topographic features particularly valleys containing streams permit the montane forest to extend beyond its normal upper limit while such features as ridges and spurs have the opposite effect.

Ericaceous belt

The ericaceous belt extends from the upper limit of the montane forest to an elevation of approximately 4000 m. *Philippia excelsa*, *Hypericum revolutum*, *Hagenia abyssinica*, *Nuxia congesta*, and *Rapania rhododendroides* are woody species common to this belt (Greenway, 1965). Many of these species grow to 6 m – 7 m.

As a result of frequent fires along the upper regions of the montane forest, the ericaceous belt has replaced the montane forest in many areas. In regions of intense fires, the woody species have been replaced by a grassland.

Aspect exerts a major influence on composition and structure of the ericaceous belt. The vegetation is more dense on the southern and eastern sides of the mountain than on the western and northern sides.

Alpine belt

The alpine belt extends from the top of the ericaceous belt approximately 4000 m to the upper altitudinal limit of plant growth. The lower regions of the alpine belt are characterized by such flowering plants as *Helichrysum newii*, *Helichrysum cymosum*, *Senecio telekii*, *Senecio schweinfurthii*, *Senecio cottonii*, and *Lobelia deckenii*. In addition there are a number of tussock grasses that are quite common including *Pentaschistis borussica*, *Festuca spp.*, *Koeleria spp.*, and *Keniochloa spp.* (Greenway, 1965).

Human influences on the montane forest

The montane forest on Mount Kilimanjaro has been greatly influenced by human activities. Much of the original montane forest has been previously cut (Wood, 1965b) and thus a very large proportion of the forest today consists of secondary vegetation. In addition, along the southern and eastern sides of the montane forest portions of the forest have been opened up through livestock grazing and collection of forage.

There has also been a significant qualitative change in the montane forest on Mount Kilimanjaro as a result of past human disturbance. I have examined the composition and structure of the montane forest within the Maua and Marangu corridors and the Kiraragua catchment (Mwasaga, 1984). The Maua and Marangu corridors are located on the southern sides of Mount Kilimanjaro and are included within Kilimanjaro National Park. The Kiraragua catchment is on the southwestern side of the mountain and is located within the Kilimanjaro National Park and Forest Reserve.

Evidence of past human disturbance within the Maua and Marangu corridors and the Kiraragua catchment is fourfold. Firstly, there is a high density of relatively small diameter trees and a relative rarity of large diameter trees. The average diameter of trees in these areas is 10 – 25 cm. Secondly, the species composition of the forest consists of many early successional species such as *Diospyros abyssinica*, *Croton megalocarpus*, *Celtis africana*, *Fagaropsis angolensis*, *Teclea simplicifolia*, *Euclea divinorum*, and *Drypetes natalensis*. Thirdly, such economically important species such as *Olea capensis*, *Olea europeae*, and *Podocarpus falcatus* are relatively rare. And fourthly, most of the large diameter trees that remain in these areas are economically unimportant species such as *Agauria salicifolia*, *Rauvolfia caffra*, and *Macranga kilimandscharica*.

Even if all future cutting of trees were banned in the montane forest on Mount Kilimanjaro the forest composition may have been permanently changed. Given the current stand composition in the Maua and Marangu corridors and in the Kiraragua catchment area it is highly improbable that such species as *Podocarpus falcatus*, *Olea capensis*, *Olea europeae* will predominate in the forest in the future. Possible replacement may be *Cassipourea malosana* and *Juniperus excelsa*. Although these species are currently relatively rare in the areas examined they are the major canopy trees in other nearby volcanic mountainous regions such as Ngorongoro and Mount Rungwe.

Chapter 4

The significance of lower plants in the conservation of Mount Kilimanjaro

T. Pócs

Abstract

Mount Kilimanjaro has a very high diversity of lower plants. The byroflora consist of nearly 600 species, while the lesser known lichen flora are approximately 120 species. The level of endemism is unusually high for cryptogams. 25% of the bryoflora are Afroalpine and East African montane endemics. Two species of liverwort and 10 moss species are strict endemics to only Mount Kilimanjaro.

The cryptogamic plants, mainly the bryophytes and lichens, play a very important role in water interception and catchment at the higher elevations of the mountain. The destruction of the moss and lichen cover through logging and burning has a detrimental effect on the catchment capacity and therefore will have far reaching effects on both the people and agriculture on the lower slopes of the mountain.

Due to the small size of the lower plants, their protection necessitates the conservation of their habitat. The most important vegetation zones, where the lower plants occur in highest densities, are the mossy montane rainforest belt (2400 m – 2700 m on the southern slopes), the giant heather *Erica* forest (2700 m – 3100 m), the subalpine ericaceous *Philippia* belt (3100 m – 3900 m), and in certain alpine habitats such as the giant groundsel *Senecio* moorland, *Helichrysum* - *Pentaschistes* alpine tussock, and rocky cliffs (3900 m – 4500 m).

Introduction

Mount Kilimanjaro has an unusually high species diversity among lower plants. 120 species of lichen and 596 species of bryophyte are known from the mountain. Although the lichens are still imperfectly known, the bryoflora is among the best investigated in tropical Africa (Kis, 1985). From the higher belts, Höhnel, a member of the Teleki Expedition in 1887, collected the first bryophytes which were identified and published by Müller (1888). Since this time, many collectors and authors have contributed data to the cryptogamic flora of Mount Kilimanjaro. I have investigated the bryophytes of Mount Kilimanjaro during the last 20 years and I and R. Ochyra plan to write a comprehensive bryoflora of the mountain.

The known number of bryophytes on Mount Kilimanjaro is nearly equal to the number of bryophytes of a smaller European country. Of the 596 known species, 415 species are mosses and 181 species are liverworts. The highest species diversity is within the mossy montane rainforest and in the subalpine ericaceous belts. The flora is rich in endemic and rare species. In this chapter, I discuss the diversity of lower plants on Mount Kilimanjaro, describe the altitudinal distribution of the bryophytic vegetation, and attempt to draw conclusions about the conservation value of the bryophytes and lichens.

Diversity and endemism of bryophytes on Mount Kilimanjaro

12 species of bryophytes are strict endemics to Mount Kilimanjaro (table 4.1) and they represent 2.0% of the total bryoflora. These species occur almost exclusively at high altitudes in the subalpine – alpine vegetation and flora islands (see Spence and Pócs, 1989). It is also notable that the majority of the strict endemics occur in the older parts of the mountain mostly on Mawenzi.

Table 4.1 The strict endemic species of mosses and liverworts on Mount Kilimanjaro.

Species	Locality	Altitude (m)
Colura kilimanjarica Pócs & Jovet-Ast	Umbwe route	2900
C. hedbergiana Pócs	Kilimanjaro and Meru	2900–3400
Brachymitrion pocsii (A.Kop.) A. Kop.	Mweka route	2890
Cratoneurum subcurvicaule P.Varde	Mawenzi	4700
Cyclodictyon perlimbatum Broth.	Marangu route	2000–2400
Cynodontium tanganyikae P.Varde	Horombo hut	4000
Encalypta hedbergii P. Varde	Mawenzi	4400–4800
Pocsiella hydrogonioides Bizot	Umbwe route	2890
Tortula cochlearifolia P. Varde	Mawenzi	4800
Ulota tanganyikae P. Varde	Mawenzi	4800
Zygodon barbuloides Broth. ex Malta	Kibo, Mawenzi	3750–4800
Z. robustus Broth. ex Malta	around Horombo hut	3650–3850

The number of Afroalpine endemics – species which occur only on other high mountains of East Africa – is much higher than the number of strict endemics. On Mount Kilimanjaro, there are 83 species of Afroalpine endemic mosses (Spence and Pócs, 1989) and 20 species of Afroalpine endemic liverworts (table 4.2) representing 11% of the total Hepatic flora. The vegetation zones on Mount Kilimanjaro that are richest in Afroalpine endemics are the upper montane giant heather *Erica* forest (2700 m – 3100 m), the subalpine ericaceous *Philippia* belt (3100 m – 3900 m), the giant *Senecio* moorland and rocky habitats, and the alpine tussock vegetation above 4000 m primarily in the sheltered rock crevices and spring bogs.

Table 4.2 The Afroalpine endemic species of liverworts on Mount Kilimanjaro.

Andrewsianthus kilimanjaricus	*Kurzia irregularis*
Bazzania roccatii	*Lepidozia stuhlmannii*
Chandonanthus cavallii	*Lophozia decolorans*
C. hirtellus giganteus	*Metzgeria convexa*
Colura berghenii	*M. elliottii*
C. saroltae	*Plagiochila colorans*
Diplophyllum africanum	*P. ericicola*
Fossombronia grandis	*Riccardia compacta*
Gongylanthus richardsii	*Scapania esterhuyseniae*
Jungermannia pocsii	*Symphyogyna volkensii*

Additionally there are 22 East African montane subendemic liverwort species – species that occur throughout the archipelago of East African montane forests – which represent 12.0% of the hepatic flora of Mount Kilimanjaro (table 4.3). These species occur exclusively in the forest belt on Mount Kilimanjaro between 1600 m – 2800 m.

The three endemic groups contain altogether 44 liverwort species or 24.3% of the hepatic flora of Mount Kilimanjaro.

From a conservation point of view, the most important bryophytes are the strict endemics and the Afroalpine endemics that are restricted to a very few other high mountains such as the Ruwenzoris, Aberdares, and the Virungu mountains, Mount Kenya, Mount Elgon, and Mount

Table 4.3 The East African montane subendemic species of liverworts on Mount Kilimanjaro.

Aphanolejeunea fadenii	*Plagiochila barteri*
Bazzania pumila	*P. lastii*
Calypogeia afrocaerulea	*P. squamulosa*
Cololejeunea malanjae	*Porella abyssinica*
C. mocambiquensis	*P. hoehnelii*
Colura usambarica	*P. subdentata*
Jungermannia abyssinica	*Radula allamanoi*
J. mildbraedii	*R. evelynae*
Lepidozia abyssinica	*R. holstiana*
Leptoscyphus hedbergii	*R. recurvifolia*
Lopholejeunea lacinita	*Tylimanthus ruwenzorensis*

Meru. Spence and Pócs (1989) analysed the distribution patterns in the Afroalpine moss flora using Jaccard coefficients. They found when comparing the alpine moss flora of Mount Kilimanjaro, Mount Meru, Mount Kenya, Mount Elgon, and the Aberdare and Ruwenzori mountains that the alpine moss flora on Mount Kilimanjaro and Mount Kenya had the closest relationship.

Biogeographically disjunct species of liverworts on Mount Kilimanjaro

There are also many other interesting phytogeographically disjunct elements on Mount Kilimanjaro which contribute to the high diversity of the flora. Many of the species belonging to these disjunct elements are extremely rare and some of the disjunct species are found on the African continent only on Mount Kilimanjaro. In this portion of this chapter, I shall restrict my discussion to liverworts because comparatively more is known about the biogeographic distribution of liverworts than mosses or lichens.

Five species of liverworts found on Mount Kilimanjaro have their main distribution within the Madagascar – Mascarene islands (table 4.4). They occur very sporadically on the African mainland. This element occurs more frequently on the Precambian crystalline Eastern Arc mountains of Tanzania (see Pócs, 1975; 1982b) than on Mount Kilimanjaro. This is most likely due to the fact that the breakup of Gondwanaland during the Cretaceous predated the formation of Mount Kilimanjaro.

Table 4.4 Species of liverworts with isolated occurence on Mount Kilimanjaro that are within the Lemurian (Madagascar–Mascarene–Seychelles) element (5 species; 2.8% of the hepatic flora of Mount Kilimanjaro).

Aphanolejeunea moramangae
Cololejeunea usambarica
Diplasiolejeunea symoensii
Plagiochila boryana
Radula madagascariensis

Nine species of liverworts are southern temperate element (table 4.5). Gradstein *et al.*, (1983) discuss the distribution pattern of the southern temperate hepatic element and include in their analysis most the species shown in table 4.5. These species are found in the mossy montane rainforest belt on Mount Kilimanjaro. Another nine species of liverwort are northern temperate in distribution (table 4.6). Gradstein and Váña (1987) describe in detail the distribution of northern temperate liverworts in the tropics.

There are also a number of bicontinental disjunct elements. Two groups worth mentioning are the Afro-American disjuncts (table 4.7) and the Afro-Asian (Palaeotropic) element (table 4.8). Gradstein *et al.* (1983) discuss the former while Pócs (1976b, in press) has dealt in detail with the latter phytogeographic element.

The remainder of the hepatic flora of Mount Kilimanjaro (96 species and 53.4% of the hepatic flora) has a wider tropical African, pantropical, or cosmopolitan distribution.

Table 4.5 Species of liverworts on Mount Kilimanjaro that are within the southern temperate element (9 species; 5.0% of the hepatic flora of Mount Kilimanjaro).

Adelanthus decipiens	*Clasmatocolea vermicularis*
A. lindenbergiana	*Colura calyptrifolia*
Aphanolejeunea mamillata	*Lepidozia cupressina*
Bazzania decrescens	*Telaranea nematodes*
B. nitida	

Table 4.6 Species of liverworts with isolated occurence on Mount Kilimanjaro that are within the northern temperate (boreal) element (9 species; 5.0% of the hepatic flora of Mount Kilimanjaro).

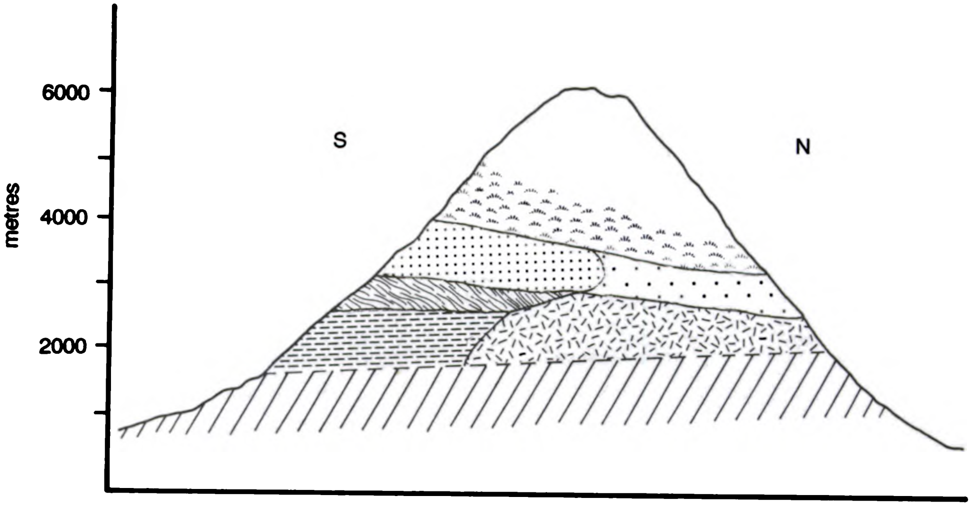
Anastrophyllum minutum	*Jungermannia sphaerocarpa*
Blepharostoma trichophyllum	*Lepidozia pearsonii* (Atlantic)
Calypogeia arguta	*Marsupella emarginata*
C. fissa	*Tritomaria exsecta*
Chiloscyphus cuspidatus	

Table 4.7 Species of liverworts with isolated occurence on Mount Kilimanjaro that are Afro-American disjuncts (11 species; 6.0% of the hepatic flora of Mount Kilimanjaro).

Aphanolejeunea exigua (tropical)
Chiloscyphus breutelii (syn.: *Ch. muhavurensis*, Andean)
Ch. martianus (tropical)
Gymnocoleopsis multiflora (Andean)
Herbertus subdentatus (Andean)
Isotachys aubertii (Andean)
Leucolejeunea xanthocarpa (tropical)
Marsupella africana (Andean)
Metzgeria agnewii (Andean)
Plagiochila vermiculosa (tropical montane)
Symphyogyna brasiliensis (tropical montane)

Table 4.8 Species of liverworts with isolated occurence on Mount Kilimanjaro that are within the Afro-Asian (Palaeotropic) element (7 species; 3.9% of the hepatic flora of Mount Kilimanjaro).

Calycularia crispula	*Gottschelia schizopleura*
Cephaloziella kiaerii	*Metzgeria consanguinea*
Chandonanthus hirtellus	*Ptychanthus striatus*
	Radula holstiana



The cultivated zone (coffee, wheat, bananas, plantation forests of *Pinus* and *Cupressus*.)

Montane rainforest (dominated by *Ocotea*).

Mossy montane rainforest (dominated by *Podocarpus* or *Erica*).

Subalpine ericaceous heath (dominated by *Philippia*).

Montane mesic and dry evergreen forest (dominated by *Cassipourea* and *Casearia* or by *Olea* and *Juniperus*).

Subalpine ericaceous bush (dominated by *Stoebe*, *Anthospermum*, *Artemisia*).

Alpine tussock (dominated by *Helichrysum*, *Pentaschistes*).

Alpine desert (dominated by bare rock and ice).

Figure 4.1 The vegetation belts on Mount Kilimanjaro.

The distribution of bryophytes on Mount Kilimanjaro

Bryophytes are found in all of the vegetation belts (figure 4.1) of Mount Kilimanjaro. Although Hedberg (1951) already established the vegetation belts of the high African mountains, I developed further his treatment with special reference to the bryophytes and to the vegetation of the drier side of Mount Kilimanjaro (Pócs 1976a and present chapter). In the lower montane rainforest belt on the southern slopes between 1800 m – 2400 m the most important bryophyte substrates are the trunks and big branches of trees followed by fallen logs and rock cliffs. Bryophytes mostly *Lepidoziaceae* and *Neckeraceae* form a moderately thick cover on trunks.

On the branches the hanging synusia of different *Meteoriaceae* are common (*Aerobryidium subfilamentosum*, *Squamidium brasiliense*, *Papillaria africana*, *Pilotrichella spp.*).

In the mossy montane rainforest between 2400 m and 3100 m the bryophytes form a much thicker cover on the stems and branches of the woody plants. The thickness of this cover often exceeds the diameter of the trunk or branch. The common species at this elevation are *Herbertus subdentatus*, *Dicranoloma billarderi*, and *Antitrichia curtipendula*. A very unique community which normally includes *Rhizofabronia sphaerocarpa*, *Leiomela africana*, and *Lejeunea cyathearum* develops on the stems of the tree fern *Cyathea manniana*.

The forest floor in this vegetation belt particularly above 2700 m which is dominated by giant heather *Erica arborea* is thickly covered by a carpet of bryophytes which include such liverworts as *Plagiochila col*orans and *P. ericicola* along with such mosses as *Campylopus jamesonii*, *Hypnum aduncoides luteum*, or even *Hylocomium splendens* which is found in boreal spruce forests. The relatively thin trunks and branches of *Erica arborea* are also covered by an interesting liverwort community consisting of *Cheilolejeunea pluriplicata*, *Drepanolejeunea physaefolia*, *Plagiochila corniculata*, *P. subalpina*, and several endemic *Colura spp*. This same community also occurs at higher elevations on the subalpine ericaceous bushes.

The subalpine ericaceous (*Philippia*, *Stoebe*, *Euryops*) bush belt extends roughly from 3100 m to 4000 m. The humidity within this vegetation belt decreases with altitude which has an important influence on the distribution of bryophytes. The ground is covered by various species of *Breutelia*, *Campylopus*, and *Cladonia* (e.g., Afroalpine endemic *Cladonia hedbergii*). In depressions and on the wetter slopes, giant groundsel *Senico johnstonii* stands develop which provide a rich bryophyte habitat. Many spring bog mosses are found on the ground below the giant groundsel including *Hygrohypnum hedbergii*, *Philonotis seriata*, and *Sanionia uncinata*. The trunks of the giant groundsel harbour such interesting Afroalpine species as *Tortula cavallii* and *Leptodontiopsis fragilifolia*. In total, I have observed about 40 epiphyte species on the *Senico* trunks (Pócs, 1982a).

The gorges, cliffs, and other volcanic rocky habitats in this vegetation belt are rich in endemic and rare bryophytes and lichens (3 species of *Andreaea*, *Chandonanthus cavallii*, *Diplophyllum africanum*, *Gymnmytrion laceratum*, *Marsupella africana*, and *Schizymenium spp.*). The bare, more open ground among the bushes is also very interesting. Here a community of tiny liverworts and mosses is formed by the almost invisible *Gongylanthus richardsii* (Afroalpine), *Aongstroemia julacea* (very disjunct, also in the Andes and Asian mountains) and several Afroalpine endemic *Funariaceae*.

The most peculiar bryophyte habitat in the ericaceous bush and alpine tussock belts is decomposing leopard dung which normally consists of hyrax hairs and bones. The dung is consistently colonized after several years by a moss *Tetraplodon bryoides*. This same species is found in boreal and arctic regions and also occurs in decomposing dung and other organic material of animal origin.

From 4000 m and upwards, bryophytes become sparse as a result of the increasing aridity with altitude. Semidesert and desert like conditions exist in the alpine vegetation belt. The bryophytes and lichens depend heavily upon mist precipitation and therefore they often occupy the southern sides of cliffs and stones facing the mist carrying winds. On these rocky faces, *Andreaea*, *Grimmia*, *Marsupella* are dominant among the bryophytes and *Umbilicaria* and *Lasallia* are dominant among the lichens. Yellowish beards of the lichen *Usnea articulata* and the blackish brown beards of *Bryoria* hang down in large masses from the wind exposed cliffs absorbing the mist in the form of droplets from passing clouds.

Other important habitats in the alpine zone for bryophytes are the protected lava caves that contain such species as *Rhizofabronia perpilosa* and dripping rocky crevices such as the Zebra Rocks. Spring bogs which occur in many places are also important habitat in the alpine vegetation belt for bryophytes. *Senecio cottonii* frequently forms stands at these spring bogs and such species as *Brachythecium spectabile*, *Calliergon sarmentosum*, and *Cratoneurum fillicinum* form the ground layer and remind the observer of boreal fens.

Near and above 5000 m, only *Grimmiaceae* moss species and *Umbilicaria* lichen species are sparsely found on the volcanic rocks. The uppermost bryophyte that I have recorded on Mount Kilimanjaro is *Schistidium apocarpum* from the Western Breach of Kibo at an altitude of 5050 m. I have also recorded two lichen species, *Omphalodina melanophthalma* and *Umbilicaria aprina*, at the same site at an altitude of 5400 m.

In the alpine belt, a very peculiar habitat develops as a result of the nightly freezing and the daily thawing of the upper layer of soil. Ice crystals that form in the soil at night loosen and move the topsoil of the alpine semidesert and desert. This form of solifluction can be tolerated only by organisms that lay loosely on the ground and that can easily change their position. Examples among lichens include *Coelocaulon aculeatum* and *Xanthoria elegans*. The latter species which occur in large numbers forms bright yellow granules and gives a distinctive colour to the alpine desert soils in the Saddle between Kibo and Mawenzi. Examples of mosses that are adapted to the daily movement of the topsoil include *Grimmia spp.* (Hedberg, 1964). These species change their position on a daily basis due to the movement of the soil surface and as a result ball-shaped colonies develop with shoot apices in all directions. Such 'moss balls' are described also in other arctic and desert areas of the world.

Altitudinal distribution of liverworts along the southern slope of Mount Kilimanjaro

The altitudinal distribution of liverworts along the southern slope of Mount Kilimanjaro (table 4.9) is based on my own published and unpublished data and on the records of A.J. Sharp and others (in Bizot *et al.*, 1976; Bizot and Pócs, 1974; 1979; 1982; Bizot *et al.*, 1979; 1985; Ochyra and Sharp, 1988). The altitudinal distribution from 750 m – 4500 m follows a south – north transect: Rau Forest – Moshi – Kibosho – Mweka route – Shira Plateau (figure 4.3).

This transect contains 107 of the 181 liverwort species or 59.7% of the known hepatic species of Mount Kilimanjaro. It is worthwhile to analyse the altitudinal distribution of the hepatic species in the same way as was done in the Colombian and Peruvian Andes (Reenen and Gradstein, 1984; Gradstein and Frahm, 1987) and on the Huon Peninsula in Papua New Guinea (Enroth, 1990). As soon as the complete list of all bryophytes on Mount Kilimanjaro is developed it will be possible to conduct a detailed comparison of the three sites. Nonetheless, the hepatic data presented in table 4.9 yield interesting information.

The altitudinal distribution of hepatic taxa is bimodal (figure 4.2). 25 – 26 species are encountered at 2500 m and 30 species are found at 2800 m. These modal peaks coincide very well with both the lowermost limit as well as the uppermost limit of a number of species thus

Table 4.9 The altitudinal distribution of liverworts along a south-north transect on the southern slope of Mount Kilimanjaro, 750 m–4200 m.

Species	Altitude (m)	Species	Altitude (m)
Acanthocoleus chrysophllus	2900–2950	*Herbertus subdentatus*	2300–3275
Adelanthus decipiens	2150–2670	*Isotachys aubertii*	3000
A. lindenbergianus	2530–2900	*Jungermannia abyssinica*	3800
Anastrophyllum auritum	2820–3800	*J. mildbraedii*	2000
A. minutum	2985–3660	*J. pocsii*	3800
Andrewsianthus kilimanjaricus	2985	*Lejeunea cyathearum*	1920
Aphanolejeunea exigua	1800–2800	*L. eckloniana*	2150
A. fadenii	1900	*L. flava*	2590–2830
A. mamillata	1800–2800	*L. longirostris*	2850
A. microscopica	1900	*L. rhodesiae*	1350–1830
A. moramangae	1900	*Lepidozia cupressina*	1880–2900
Arachniopsis diacantha	2800	*L. pearsonii* var. *lacerata*	2530–3140
Asterella dissoluta	2985	*L. stuhlmannii*	1940–2890
A. volkensii	2900–3000	*Leptoscyphus hedbergii*	2000–2500
Bazzania decrescens	1830–2890	*L. infuscatus*	2150
B. nitida	1900–2150	*Lethocolea congesta*	2850–3800
B. pumila	1880–2200	*Lopholejeunea laciniata*	1800
B. roccatii	2620–2890	*L. abortiva* var. *fragilis*	1800
Blepharostoma trichophyllum	2600–3660	*Lophozia decolorans*	3350–3660
Brachiolejeunea tristis	1400	*Marchantia polymorpha*	3800
Calypogeia afrocaerulea	1900–2000	*M. wilmsii*	1000–1300
C. arguta	2100	*Marsupella africana*	3800–4200
Cephalozia vallis-gratiae	2100–3800	*M. emarginata*	3330–3600
Chandonanthus cavallii	3260–3600	*Metzgeria agnewii*	2500–2700
Ch. hirtellus	1830–2130	*M. convexa*	3800
Ch. h. giganteus	2590–3660	*M. elliottii*	3800
Cheilolejeunea brevifissa	2590–2830	*Microlejeunea africana*	1830–2830
Ch. pluriplicata	3020–3800	*Notothylas flabellata*	1000–1200
Chiloscyphus breutelii	2985	*Plagiochila barteri*	1990–3890
Ch. concretus	1700–1800	*P. boryana*	2250–2750
Ch. cuspidatus	2800–2850	*P. colorans*	280–-2850
Ch. difformis	1600	*P. ericicola*	2580–2900
Ch. lucidus	2150	*P. squamulosa* var. *sinuosa*	1800
Cololejeunea malanjae	2440–2830	*P. terebrans*	2530–2700
C. pusilla var. *obtusifolia*	1830	*Porella abyssinica*	2830–2900

Species	Altitude (m)	Species	Altitude (m)
C. usambarica	1830–1900	*Porella hoehnelii*	2530–2900
Colura digitalis	1600	*P. subdentata*	2830
C.hedbergiana	3000	*Ptychanthus striatus*	1800–1960
C. saroltae	3015	*Radula allamanoi*	2230–2250
C. usambarica	3000	*R. boryana*	2150
Cyathodium africanum	750	*R. meyeri*	1350
Dumortiera hirsuta	1000–1460	*R. stipatiflora*	2840–2890
Frullania angulata	2150–2600	*Riccardia fastigiata*	1450
F. apicalis	3200	*R. limbata*	1800
F. arecae	1800–2900	*R. longispica*	1800–2300
F. capensis	3800	*Riccia fluitans* s.l.	750–1200
F. depressa	2850–2950	*Scapania esterhuyseniae*	3800
F. ericoides	1650	*Schiffneriolejeunea polycarpa*	1350
F. obscurifolia	2900-3050	*Symphyogyna podophylla*	3800-4000
F. shimperi	1720–2900	*Syzygiella geminifolia*	1840–1930
Gongylanthus ericetorum	3330	*Targionia hypophylla*	1000–1400
G. richardsii	3300–3600	*Taxilejeunea conformis*	2000–3000
Gottschelia schizopleura	1800	*Tritomaria exsecta*	2900–3030
Gymnomitrion laceratum	3800		

indicating a natural altitudinal zonation of bryophytes. At 2500 m, the mossy montane rainforest is structurally most complex while at 2800 m the giant heather *Erica* forest provides highly suitable habitat for bryophytes with its relative openess, special bark substratum, and its acidic, peaty soil.

Smaller modal peaks in numbers of hepatic species correspond with 3300 m (the most structurally complex portion of the subalpine *Philippia* heath) and 3800 m (the *Senecio* moorlands on Shira Plateau). The smaller modal peak at 1800 m is artificial because this represents the lower edge of the forest reserve.

In summary, on the southern slope of Mount Kilimanjaro the maximum number of hepatic species occur between 2500 m – 2900 m which corresponds with the mossy montane rainforest and giant heather forest. The maximum number of hepatic species on Mount Kilimanjaro is found slightly higher than in New Guinea (2200 m – 2500 m) and lower than in the investigated areas of the Andes (2700 m – 3300 m).

Hydrological values of the lower plants on Mount Kilimanjaro

The hydrological importance of lower plants, especially bryophytes and lichens, is usually underestimated in tropical montane environments. Lower plants represent a very high amount of the biomass in certain communities (Pócs, 1980). In the mossy elfin forests of the Uluguru

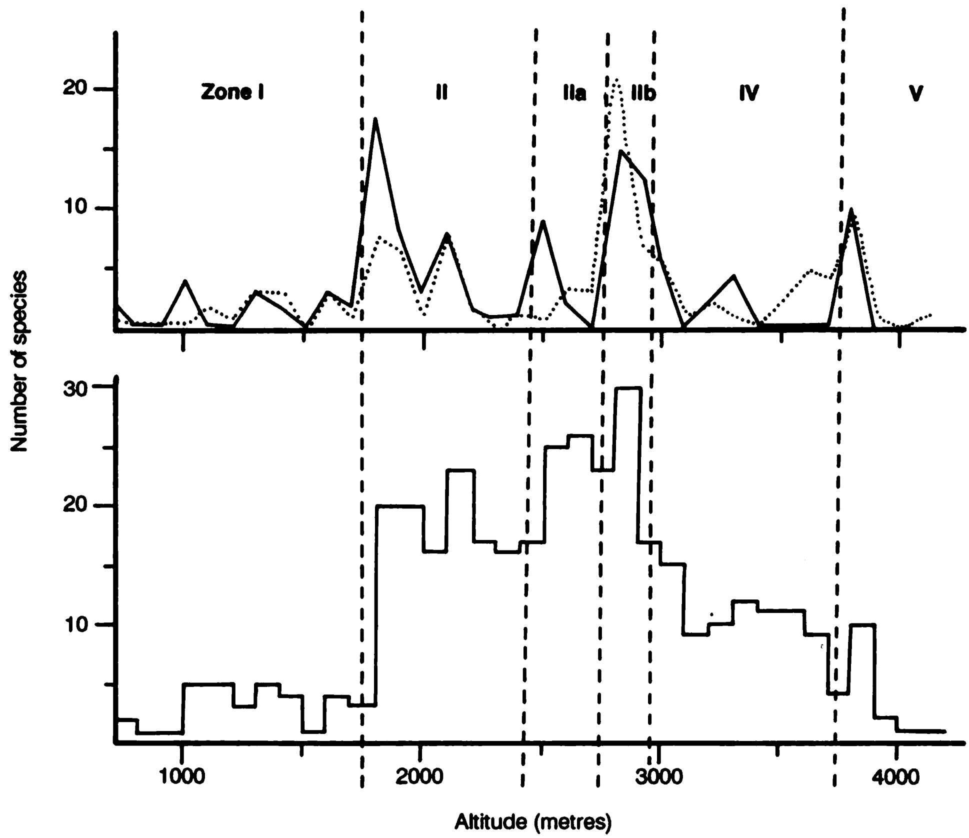


Figure 4.2 The number of liverwort species in relationship to altitude on the southern slope of Mount Kilimanjaro along the following transect: Rau Forest–Moshi–Mweka route–Shira Plateau. In the upper graph, the number of lowermost occurrences (solid line) of liverworts and uppermost occurrences (dotted line) of liverworts are recorded in 100 m intervals. In the lower graph, the number of species is recorded at every 100 m intervals.

Mountains in Tanzania, which are similar in many aspects to the giant heather *Erica* forest on Mount Kilimanjaro, the biomass of the moss cover with its humus content may exceed 12,000 kg dry weight per ha in comparison to 8,000 kg dry weight per ha for the foliage (Pócs, 1980). A very similar biomass for lower plants were reported in the upper mossy montane rainforest of the Colombian Andes (Veneklaas, 1990).

Additionally, the moss cover has a much higher interception capacity than the foliage. The interception capacity of the moss cover is 400% – 500% of its dry weight in comparison to 60% – 175% of the dry weight for the foliage. According to my estimates, the moss-lichen cover in the Uluguru Mountains can intercept during one rain storm upwards of 50,000 l per ha and approximately 40% of the annual precipitation (Pócs, 1980). In comparison the canopy foliage

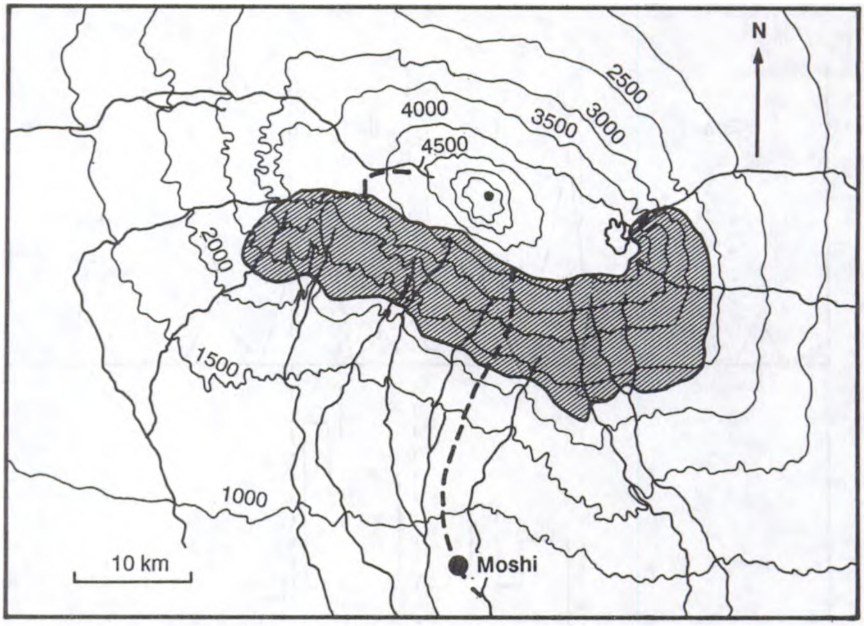


Figure 4.3 The area on Mount Kilimanjaro with the highest conservation value for lower plants. This area contains the highest biomass and species diversity of bryophytes and lichens. The analysed transect (Rau Forest–Moshi–Mweka route–Shira Plateau) is shown by a broken line.

intercepts 6000 l per ha during a single rain storm. Veneklass (1990) estimated that the lower plants in the montane rainforest of the Colombian Andes intercept around 18% of the annual rainfall.

On Mount Kilimanjaro the area of highest density of bryophytes and lichens is approximately 200 km^2 and is located between 2200 m and 4000 m on the southern, southwestern, and eastern sides of the mountain (figure 4.3). The interception capacity of this area is roughly one billion during a single rain storm. Given that this area is located directly above the most important agricultural lands on Mount Kilimanjaro, its critical importance as a water source area is obvious.

The lower plants are also important in terms of regulating the water flow and reducing the loss of water through evaporation. The water that is intercepted by the moss-lichen cover is released slowly and at the same time the cover of mosses and lichens reduces the loss of water through evaporation especially from the soil surface. This preserves soil moisture and a continuous supply of water to the watercourses. The vegetative cover with its highly interceptive epiphytic mosses and lichens are also important in preventing soil erosion.

An additional advantage of the epiphytic cover for the ecosystem is its humus production. The litter accumulated by the epiphytes, including their own decaying organic matter, is quickly converted into humus by fungi and microfauna. The biomass of the 'aerial' humus in the

Uluguru Mountains is equal to 2453 kg dry weight per ha. The continual rain of aerial humus contributes to the fertility of highly leached lateritic soils.

Implications for conservation

Mount Kilimanjaro has a very high diversity of lower plants as well as many endemic and rare species even in comparison to the higher vascular plants. The lower plants play a critical role in water interception and catchment on Mount Kilimanjaro.

Due to their small size, lower plants can only be protected by protecting their habitat. The vegetation belts with the highest diversity and biomass of lower plants are the mossy montane rainforest, the giant heather forest, the subalpine ericaceous bush, and the giant groundsel moorland on the southern, southwestern, and eastern slopes between 2200 m and 4000 m.

Fortunately much of these habitats fall within Kilimanjaro National Park. However most of the lower forest below 2700 m is outside of the national park and much of this forest has been extensively logged in the past. Additionally, fierce fires particularly in the upper forest edge and in the ericaceous vegetation have been very destructive. The collection of firewood around the tourist huts particularly the removal of the giant heather *Erica arborea* has been deterimental to the bryophytes.

The following measures should be taken to protect the lower plants:

- All legal and illegal logging on Mount Kilimanjaro should be stopped immediately particularly above 2200 m.
- Firewood collecting by tourists and porters if allowed should be restricted to dead and fallen branches.
- Greater efforts should be taken to prevent fires particularly in the ericaceous forests and bushes.
- The importance of lower plants in terms of their diversity, endemism, rarity, and water interception value should be included in broader educational campaigns and in the more popular books on Mount Kilimanjaro oriented towards tourists.
- Any reforestation program on Mount Kilimanjaro should use native species such as *Ocotea usambarensis* and *Podocarpus latifolius* because they provide suitable substrate for epiphytes.

Chapter 5

Local extinctions of large mammals within Kilimanjaro National Park and Forest Reserve and implications of increasing isolation and forest conversion

W.D. Newmark, C.A.H. Foley, J.M. Grimshaw, O.R. Chambegga and A.G. Rutazaa

Abstract

We examine the implications of increasing isolation and forest conversion within Kilimanjaro National Park and Forest Reserve (KNP/FR) on the large mammal fauna by reviewing and comparing the historical status of a species as documented in the literature with its current status.

The klipspringer *Oreotragus oreotragus* and the mountain reedbuck *Redunca fulvorufula* have become locally extinct within KNP/FR during the last 45 years. Increasing isolation of KNP/FR most likely contributed to the natural extinction of these species.

Crawshay's hare *Lepus crawshayi*, baboon *Papio cynocephalus*, spotted hyaena *Crocuta crocuta*, black-backed jackal *Canis mesomelas*, side-striped jackal *Canis adustus*, white-tailed mongoose *Ichneumia albicauda*, and warthog *Phacochoerus aethiopicus* have been added to the previous checklists for the large mammals found within KNP/FR. More intensive field research may account for the addition of these species to the reserve's checklist and/or the conversion of a portion of the montane forest at its lower elevations to a variety of secondary disturbed vegetation types may have permitted these species to move into the reserve.

We suggest that increasing isolation and forest conversion have differentially affected and will continue to affect the large mammal fauna on Mount Kilimanjaro. Increasing isolation would most adversely affect the moorland fauna while forest conversion would most adversely affect the large mammal fauna restricted to the montane forest. We propose a model to evaluate the potential future impacts of increasing isolation and forest conversion on the large mammal fauna of Kilimanjaro.

Introduction

The impact of commercial poaching on selected large mammal populations in East Africa during the last 15 to 20 years has been severe. However, a less dramatic but a more serious problem for the long-term survival of the majority of large mammals in the smaller East African protected areas is the loss of critical habitat adjacent to the protected areas and their resulting isolation. Kilimanjaro National Park and Forest Reserve (KNP/FR) has not been immune to this problem.

The concern about the impact of increasing isolation of protected areas in East Africa upon the large mammal fauna is not new (Miller and Harris, 1977; Miller, 1978, Soulé *et al.*, 1979; Western and Ssemakulaa, 1981; East, 1981, 1983; Borner, 1985). According to island biogeography theory (MacArthur and Wilson, 1967), the number of species on any isolate whether it is an oceanic or habitat island is determined by an interaction between species colonization and extinction. Species colonization is influenced primarily by the distance that an isolate lies from a potential source pool while species extinction is influenced principally by population size which in turn is influenced by the size of the isolate. As protected areas become increasingly isolated, the distance of a protected area from potential source pool increases while the effective size of the conservation area decreases. The predicted effects of a reduction in colonization and a decrease in the effective size of the protected area is an increase in the number of local extinctions within a protected area. Evidence in support of this prediction comes from not only studies of faunal communities on a variety of habitat islands (see Diamond, 1984) but also from large mammal communities in protected areas in North America (Newmark, 1987).

All workers who have previously examined the relationship between the increasing isolation and the capability of East African protected areas to maintain large mammal populations have agreed that smaller East African protected areas will most likely lose large mammal species in the future as these reserves become increasingly isolated. However, disagreement exists as to the magnitude of this future loss. In large part, this disagreement is a result of the different approaches that have been taken to estimate the potential impact of increasing isolation upon the large mammal fauna. The approaches used have included extrapolating post-Pleistocene extinction rates for mammals on the Sundra shelf in southeast Asia to East African reserves (Soulé *et al.*, 1979); comparing species – area relationships for reserves with species – area relationships for ecosystems in East Africa (Western and Ssemakula, 1981); or calculating the number of large mammal species within a group of reserves with estimated populations below a certain value (East, 1981, 1983).

One of us (Newmark, in prep.) has recently initiated a study to evaluate the impact of the increasing isolation of the northern Tanzanian national parks upon the large mammal fauna using a different approach. This study is attempting to identify those species of large mammal that have become locally extinct within the parks during the last fifty years as a result of the increasing isolation. KNP/FR is one of the protected areas that is included in this study. It is hoped that by studying the patterns of recent extinctions it will be possible to evaluate the long-term potential impact of increasing isolation upon the large mammal fauna of East Africa.

The potential impact upon large mammal populations of forest conversion and increasing isolation of KNP/FR is relatively complex. We propose a model (figure 5.1) to describe this process. We feel that this model may not only be useful in studying the potential impact of increasing isolation and forest conversion upon the large mammal fauna of KNP/FR but may also assist managers in monitoring future changes in the park fauna. However, given the preliminary nature of our investigation, we intend that this model be viewed as a series of hypotheses rather than as a statement of future reality.

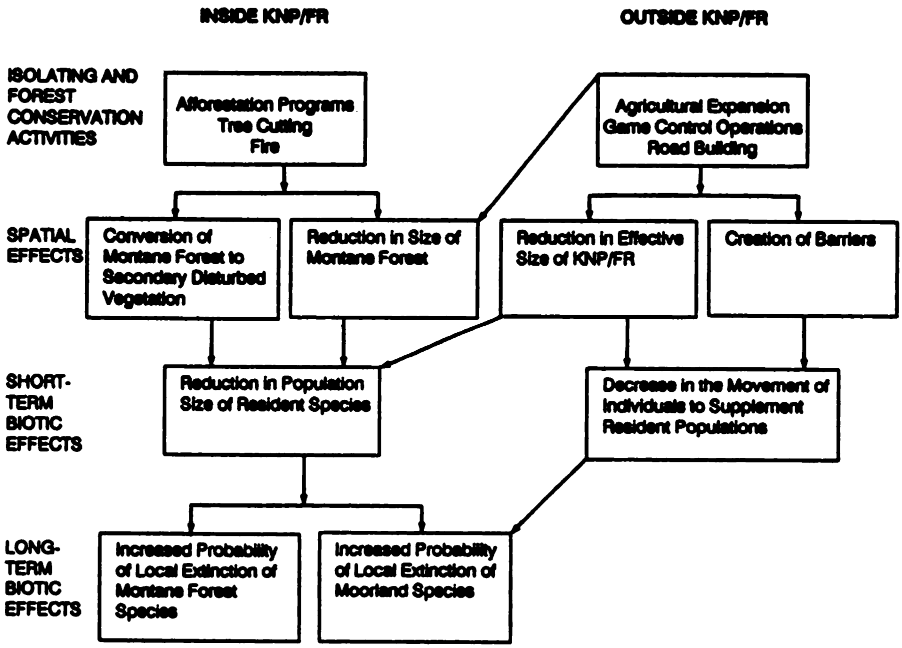


Figure 5.1 The potential spatial effects, short-term biotic effects, and longer-term biotic effects of isolating and forest conversion activities inside and outside of Kilimanjaro National Park and Forest Reserve upon resident large mammal populations.

Methods

The local extinction of large mammal species in KNP/FR is determined by comparing the historical status of a species, as documented in the literature, with its current status. The historical status of large mammals on Mount Kilimanjaro is comparatively well known. The first systematic study of the mammals of Mount Kilimanjaro was conducted in 1910 by Lönnberg as part of a Swedish expedition to Kilimanjaro. However, the collections from this expedition were all from locations below 6000 feet (1829 m) (Moreau, 1944). Moreau (1944) published the first checklist for mammals found in the montane forest and moorland habitats on Mount Kilimanjaro. Moreau developed his checklist based upon his own observations as well as the observations of M.S. Moore of the Game Department and the collections by B. Cooper for the British Museum. Swynnerton (1949) subsequently expanded Moreau's checklist based upon his field work on the Shira Plateau. Guest and Leedal (1954), as part of the University of Sheffield Kilimanjaro expedition, added several new moorland species to previous checklists and verified the presence of several other species. Much of this previous work was then synthesized by Child (1965) who developed a checklist for the montane forest, moorland, and the lowland habitats in the immediate vicinity of Mount Kilimanjaro. Child (1965) also added a number of species to previous checklists based upon his own collections.

We have documented the current status of large mammals in KNP/FR based upon our own field work over the last three years as well as interviewing all the long-term rangers and guides as to the current status of large mammals in KNP/FR. Much information on the status of mammals on the northern side of Mount Kilimanjaro is derived from the observations made by members of the Kilimanjaro Elephant Project (see Foley and Grimshaw, in press) based at Kilimanjaro Timbers from March through December, 1990.

Previous researchers on Mount Kilimanjaro (Moreau, 1944; Guest and Leedberg, 1954; Child, 1965) have made a distinction in their checklists between the mammal fauna utilizing the montane forest and the mammal fauna utilizing the moorland. The moorland has been defined by these workers as the ericaceous and alpine vegetation zones (see Mwasaga, chapter 3). This distinction is generally valid. However, since the establishment of KNP/FR portions of the lower elevations of the montane forest have been converted to a variety of secondary disturbed vegetation types and as a result the lower boundary of KNP/FR in places no longer follows the lower boundary of the montane forest. In our updated checklist of the large mammals of KNP/FR (table 5.1) we include those species of large mammal that we or people whom we interviewed have observed within the legal boundaries of KNP/FR.

We employed the following procedures in interviewing rangers and guides. We presented to the rangers and guides all of the colour plates from Dorst and Dandelot (1970) and asked them to identify any species they have previously seen in KNP/FR. If a ranger or guide identified a species, we subsequently asked them where in the reserve they had sighted the species, the frequency they have sighted the species, and the last time they saw the species.

In order to derive an index of natural history competency for each ranger or guide, we 'marked' each of the interviewee's species checklist. We used the following marking system to evaluate each checklist. We subtracted two points for citing a species as occurring in KNP/FR that could not possibly occur because the known range for the species (Kingdon, 1971, 1974, 1977, 1979, 1982; Dorst and Dandelot, 1970; Haltenorth and Diller, 1977) does not overlap KNP/FR. However, if this same 'mistaken' species could be easily confused with a species that is very similar in appearance and is known to have previously occurred in KNP/FR, we subtracted one point. We also subtracted two points for failing to identify each of the following common species: blue monkey *Cercopithecus mitis*, black and white colobus *Colobus abyssinicus*, bushpig *Potamochoerus porcus*, eland *Taurotragus oryx* (for rangers working in the moorland and alpine zone), bushbuck *Tragelaphus scriptus*, Abbot's duiker *Cephalophus spadix* (for rangers working on the southern side of Kilimanjaro), elephant *Loxodonta africana* (for rangers working on the northern and western sides), tree hyrax *Dendrohyrax arboreus*, and African buffalo *Syncerus caffer*.

We neither credited nor subtracted any points for (1) citing a species as currently occurring within KNP/FR that had not previously been recorded for the reserve if the species is known to exist on the lower slopes of Mount Kilimanjaro; or (2) for sighting a rare or uncommon species known to have previously occurred on Kilimanjaro. A 'perfect' score could potentially be obtained by correctly identifying all of the common species found in the location that a ranger or guide has previously worked. Each common species was given a value of two points. Final scores were then expressed as a percentage and were used as an index of natural history competency for the observer. We report in table 5.1 only the most competent observer to document the current status of large mammals in KNP/FR.

Results

Two species of large mammal, the mountain reedbuck *Redunca fulvorufula* and klipspringer *Oreotragus oreotragus*, have become locally extinct within KNP/FR during the last 45 years. In addition, seven species of large mammal – Crawshay's hare *Lepus crawshayi*, baboon *Papio cynocephalus*, spotted hyaena *Crocuta crocuta*, black-backed jackal *Canis mesomelas*, side-striped jackal *Canis adustus*, white-tailed mongoose *Ichneumia albicauda*, and warthog *Phacochoerus aethiopicus* – have been added to the mammal species checklist for KNP/FR.

The local extinction of the klipspringer within KNP/FR is not surprising given the known distribution of the klipspringer in Africa and its apparent historical rarity on Mount Kilimanjaro. The moorland of Mount Kilimanjaro represents the upper altitudinal limit of the klipspringer in Africa (Haltenorth and Diller, 1977) and thus the moorland habitat of Kilimanjaro was probably always very marginal for this species. Only two previous sighting records exist for this species. Gillman (1923) reported that a companion of his, F.J. Miller, sighted this species on Kilimanjaro at 9800 feet (2987 m). Moreau (1944) subsequently reported that M.S. Moore of the Tanganyika Game Department sighted this species at 12,500 feet (3810 m). Though Child (1965) lists the klipspringer on his checklist of mammals for the upper Kilimanjaro habitat, he does not provide any additional evidence for this species presence.

The mountain reedbuck is one of the rarer antelopes in Tanzania and is restricted to elevations above 1500 m (Rodgers and Swai, 1988). Moreau (1944) reported sighting several times what he thought was this species on the north side of the mountain between 9,000 and 11,000 feet (2743 m – 3353 m). Moreau (1944) also stated that M.S. Moore thinks he saw this species at 9,000 feet (2743 m). Swynnerton (1949) reported sighting this species on the Shira Plateau. The last documented record for this species within KNP/FR is provided by Child (1965) who stated that members from the Kilimanjaro Mountain Club had told him that they had sighted this species at 16,000 feet (4877 m). We have sighted this species 6 km outside and to the west of the Kilimanjaro Forest Reserve boundary several times during March and April, 1990 at 1950 m (6000 feet) on Simba Farm. According to the farm manager, herds up to 12 animals have been sighted during the last three years on this farm. Given the general rarity of this species throughout Tanzania, its very sedentary nature (Kingdon, 1982), and the infrequency with which this species has been sighted within KNP/FR in the past, the local extinction within KNP/FR of this species is not surprising.

Through our field work and interviews, we have added Crawshay's hare, baboon, black-backed jackal, side-striped jackal, spotted hyaena, warthog, and white-tailed mongoose to the previous checklists of the large mammals found within either the montane forest or moorland zones of KNP/FR. It is possible that most of these species were found historically within KNP/FR but were overlooked because of their relative rarity or because they were considered to be species that were normally not associated with the montane forest or moorland zones and were therefore excluded from previous checklists. However, an alternative explanation for the current presence of these species is that timber felling and fires at the lower elevations of the montane forest have converted this habitat in certain places into a secondary disturbed woodland/bushland and has thus permitted these species which were not formerly found in KNP/FR to enter the reserve.

Implications of increasing isolation and forest conversion

We feel that certain patterns exist among these extinctions that may allow us to evaluate the potential implications of increasing isolation and forest conversion upon the large mammal fauna of Mount Kilimanjaro.

However, before we discuss the effects of increasing isolation and forest conversion upon large mammal populations in KNP/FR it is important to note that the probability of extinction of any population is influenced predominantly by population size (see Diamond, 1984). Smaller populations are more prone to extinction because they are more adversely affected by the random variation in the survival and reproductive success of individuals, genetic inbreeding and the founder effect, disease, parasites, predation, and natural catastrophes (Shaffer, 1981; Gilpin and Soulé, 1986; Soulé, 1987). Thus, any exogenous factor such as habitat loss or poaching that significantly reduces the population size of large mammals in KNP/FR will increase the likelihood of the local extinction of a population.

We suggest that the loss of habitat outside and inside of KNP/FR has differentially affected and will continue to differentially affect the large mammal fauna of KNP/FR. The loss of critical habitat and its subsequent impact upon the large mammal fauna of KNP/FR can be divided into four phases: the initial isolating and forest conversion activities, the immediate spatial effects, the short-term biotic effects, and the longer-term biotic effects.

Isolating and forest conversion activities

Evidence exists for human presence on the slopes of Mount Kilimanjaro for over 3000 years (Fosbrooke and Sasson, 1965) and continual residency for the last 2000 years (Schmidt, 1989). However, the loss of critical habitat outside KNP/FR has predominantly occurred since the beginning of this century. The principle factor responsible for the loss of habitat outside and adjacent to KNP/FR has been agricultural expansion on the lower slopes of Mount Kilimanjaro. The introduction of large-scale commercial coffee and wheat farms around the southern and western sides of the lower slopes of Mount Kilimanjaro by European settlers was probably responsible for much of the early large-scale loss of critical habitat on these sides of the mountain during the early part of this century. Subsequently, the spread of small-scale agricultural activities has been the dominant factor contributing to the loss of critical habitat outside of the reserve. The small-scale agricultural conversion of habitat on Mount Kilimanjaro has been most pronounced during the last 25 years on the eastern and northeastern sides of the mountain. Currently, all but an approximately 8 km strip of land on the northwestern side of Kilimanjaro is under cultivation.

With the expansion of agricultural activities around the base of Mount Kilimanjaro has also come the inevitable conflicts between wildlife and crops which have resulted in programs to control or eliminate the wildlife that were damaging the crops. According to Wildlife Division records, wildlife officers have killed 1425 large mammals between 1977 and 1989. In addition, as human numbers have increased on the lower slopes of Kilimanjaro, so has the incidence of road and building construction, and livestock grazing.

The combined effects of these agricultural and human activities have been that the large mammal fauna on Kilimanjaro are becoming increasing isolated, both spatially as well as functionally. However, this isolation is relative as species differ as to their tolerance of human disturbance and activities.

A loss of critical habitat has also occurred inside KNP/FR following its establishment. The loss of habitat inside the boundaries of KNP/FR is primarily restricted to the montane forest. The principal factors responsible for the loss of habitat inside KNP/FR have been the conversion of portions of the native forest into exotic softwood plantations, fire, and licensed and unlicensed cutting of native vegetation.

Approximately 6,125 hectares or 6.3% of the montane forest (Lamprey *et al.*, chapter 2) have been converted to exotic softwood plantations. The earliest planting of exotic softwood species began along the northeastern side of Mount Kilimanjaro in the 1920's followed by the somewhat later establishment of softwood plantations along the northwestern side in the 1950's (Wood, 1965b).

A second very important factor that has contributed to the loss of montane forest is fire. Most fires in KNP/FR are of human origin although there is evidence of lighting caused fires (Wood, 1965a). Poachers, pastoralists, as well as careless tourists and guides have been cited as the cause of most fires in KNP/FR. Fire has been reported to be a major factor in the expansion of certain glades and the destruction of much of the natural cedar stands located on the northwestern side of Mount Kilimanjaro (Wood, 1965a). In addition, fires that have started in the moorland and have spread down into the montane forest are probably the principle factor responsible for opening up the montane forest at its upper elevational limits.

Spatial effects

The spatial effects of habitat loss vary according to whether the loss has occurred inside or outside KNP/FR. The loss of critical habitat outside the reserve has and will continue to have a twofold effect. First, the effective size of KNP/FR – that is the area that was formerly utilized by the park fauna – has been reduced. Though the exact area formerly used by the park fauna outside the current boundaries is unknown, we do know based upon the current movement of selected large mammals in KNP/FR that the original range of many of the large mammals in KNP/FR was considerably larger. For example, elephants are known currently to move annually from KNP/FR into Amboseli National Park (Moss, 1988). Rangers have also reported sighting eland, buffalo, and African wild dog moving in and out of KNP/FR along the northern side of KNP/FR. Wildlife in the past used a much larger area on the southern, eastern, and western sides of Kilimanjaro. According to village elders, who were interviewed by Mweka students in April 1988 as part of a study to determine the historical distribution of large mammals on the southern, eastern, and western sides of Kilimanjaro status, wildlife was quite abundant on the lower slopes of these sides of Mount Kilimanjaro until approximately the 1930's.

A second spatial effect that has accompanied the loss of habitat adjacent to KNP/FR is the creation of impediments to the movement of large mammals between lands adjacent to Mount Kilimanjaro and the reserve itself. These impediments may be either physical impediments, such as fences or ditches, or psychological impediments such as game control activities, or human presence.

The loss of critical habitat inside of KNP/FR has had two relatively immediate spatial effects. First, there has been a reduction in the size of the montane forest of approximately 6.3% as a result of the conversion of the montane forest into softwood plantations (Lamprey *et al.*, chapter 2). A second spatial effect has been the expansion of the secondary disturbed vegetation types particularly at the lower elevations of the montane forest as a result of timber cutting and fire.

Fire and unlicensed cutting of the montane forest has converted much of the forest, particularly at the lower elevations of the forest reserve, into a variety of secondary disturbed vegetation types. In regions that have been extensively commercially logged, the forest is primarily a secondary growth with a dense understory below a sparse canopy of trees. At the lower elevations of the montane forest, much of the montane forest has been converted into a secondary disturbed woodland/shrubland on the southern and eastern sides and a secondary disturbed bushland on the western and northern sides.

Biotic effects

As previously mentioned a distinction has been made historically between the mammal fauna utilizing the montane forest and the mammal fauna utilizing the moorland or upper Kilimanjaro habitats and that this distinction is generally valid. Of the 33 species of large mammals that are documented as occurring in KNP/FR either in the past or present (table 5.1), 6 species are restricted to the moorland, 19 species are restricted to the montane forest, and 8 species are found in both the moorland and montane forest. We suggest that the loss of habitat inside and outside of KNP/FR will differentially affect the montane forest and the moorland mammalian fauna.

Impact of a decrease in movement of lowland individuals to the moorland

The local extinctions of the mountain reedbuck and klipspringer in KNP/FR since the turn of this century is most likely due to their historic rarity. The general sparsity of large mammals in the moorland is not a recent phenomenon. Moreau (1944) noted that Volkens, a German naturalist who visited Kilimanjaro during the early 1890's did not mention encountering a single mammal in his hike through the moorlands. Moreau (1944) also noted that Captain Moore of the Tanganyika Game Department found in 1944 the large mammal fauna to be very scarce in the moorland.

However, the increasing isolation of KNP/FR during this century may have contributed to the local extinction of the klipspringer and the mountain reedbuck species. The moorland fauna on Mount Kilimanjaro are fauna that are normally associated with lower elevational grassland and savannah habitats surrounding Mount Kilimanjaro. The occasional movement of individuals or groups of individuals from these lower regions to the moorland was probably always very important in maintaining viable large mammal populations in the moorland. Given the general rarity of the moorland fauna, we would expect that if in the future KNP/FR becomes increasingly more isolated and the potential for immigration decreases, the probability of the local extinction of the moorland fauna would increase.

The increasing isolation *per se* of KNP/FR should have less of an immediate effect on the montane forest fauna because the large mammal populations in the montane forest have

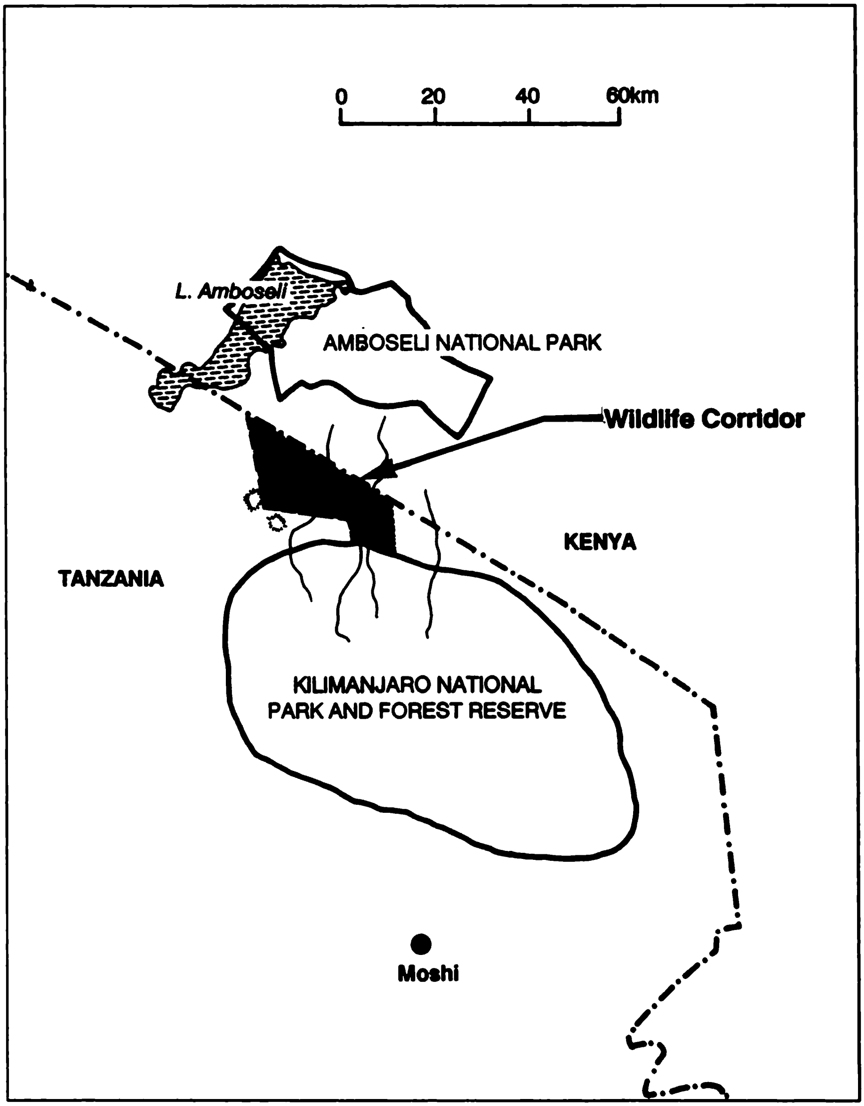


Figure 5.2 Location of the remaining wildlife corridor on the northwestern side of Mount Kilimanjaro that links the upper habitats on Mount Kilimanjaro with the surrounding lowland habitats.

probably been effectively isolated for much longer than the moorland fauna by the savannah habitat below the forest and the moorland habitat above the forest. However, the complete isolation of KNP/FR could adversely affect the montane forest mammalian fauna by restricting the occasional movements of individuals from lowland regions that could supplement resident montane forest populations. Of the 25 species of large mammals that are found in the montane forest of Mount Kilimanjaro, all but five species, the greater galago *Galago crassicaudatus*, black and white colobus *Colobus abyssinicus*, bushpig *Potomochoerus porcus*, Abbot's duiker *Cephalophus spadix*, and suni *Neotragus moschatus*, have been recorded in Amboseli National Park (Williams, 1967) which is the closest adjacent protected area. Thus, the loss of the remaining corridor of undisturbed habitat linking KNP/FR with Amboseli National Park could adversely affect in the future the montane forest mammalian fauna.

Impact of forest loss and conversion on the montane forest fauna

The probability of local extinction for the montane forest fauna should increase in the future as a result of forest loss and the conversion of the montane forest into a variety of secondary disturbed vegetation types. Forest loss and conversion should adversely affect the montane fauna by reducing the population size of these species and thus in the future the rare montane forest species should be most seriously threatened by these activities.

Implications for the management of KNP/FR

The future protection of large mammal populations in KNP/FR can be enhanced by firstly ensuring that the remaining wildlife corridor on the northwestern side of KNP/FR that links the upper habitats on Mount Kilimanjaro with the surrounding lowland habitats be maintained and secondly banning all cutting of native vegetation in KNP/FR.

The wildlife corridor on the northwestern side of Kilimanjaro is approximately 8 km in width and is situated between Lerangwa and Mlima Nyuki (figure 5.2). Currently this corridor passes through land that has been used exclusively by the Maasai for livestock grazing and firewood collecting. Permanent settlements and cultivation are banned by the Maasai in this area. With the acceptance of the Maasai, this land should be given a protected area status that would permit the movement of wildlife but would also guarantee to the Maasai their traditional uses of the land.

The extensive cutting of timber in KNP/FR in the past has altered much of the original vegetation (Wood, 1965b; Mwasaga, chapter 3). While certain species of mammal such as elephant and buffalo may have benefited from the conversion of the original montane forest into a variety of secondary disturbed vegetation types, other species such as Abbot's duiker, which is listed as a globally threatened species (East, 1988), may have been adversely affected. Most commercial timber cutting in the past has involved the construction of roads in KNP/FR. These roads have facilitated the penetration of the reserve by individuals poaching wildlife and illegally cutting timber. Thus until the impact of timber felling upon the large mammal fauna is better known all timber felling should be banned within KNP/FR.

Table 5.1 Checklist of the large mammals of Kilimanjaro National Park and Forest Reserve.

Species	Historical Status	Source †	Current Status	Observer Competency Index	Distribution within KNP/FS	Habitat of sighting	Date of Last Sighting
Primates							
Greater galago *Galago crassicaudatus*	present	1, 3	present	*	entire reserve	montane forest	1990
Blue monkey *Cercopithecus mitis*	present	1, 2, 3	present	*	entire reserve	montane forest	1990
Black and white colobus *Colobus abyssinicus*	present	1, 2, 3	present	*	entire reserve	montane forest	1990
Baboon *Papio cynocephalus*	absent		present	*	northern & western sides	montane forest	1990
Insectivora							
Hedgehog *Erinaceus albiventris*	present	1	present	85	entire reserve	montane forest	1989
Procaviidae							
Tree hyrax *Dendrohyrax validus*	present	1, 3	present	*	entire reserve	montane forest	1990
Rodentia							
Crested porcupine *Hystrix cristata*	present	1, 3	present	*	entire reserve	montane forest & moorland	1990
Lagomorpha							
Crawshay's hare *Lepus crawshayi*	absent		present	85	Mawenzi	moorland	1989
Carnivora							
Black-backed jackal *Canis mesomelas*	absent		present	*	northern side	montane forest & moorland	1990
Side-striped jackal *Canis adustus*	absent		present	*	KilimanjaroTimbers	montane forest	1990
Civet *Civettictis civetta*	present	1, 2, 3	present	85	entire mountain	montane forest	1989
White-tailed mongoose *Ichneumia albicauda*	absent		present	*	KilimanjaroTimbers	lower edges of montane forest	1990
Slender mongoose *Herpestes sanguineus*	possibly present		present	*	KilimanjaroTimbers	montane forest	1990
Blotched genet *Genetta tigrina*	present	3	present	*	entire reserve	montane forest	1990
Spotted hyaena *Crocuta crocuta*	absent		present	*	northern & western sides	montane forest	1990

Species	Historical Status	Source †	Current Status	Observer Competency Index	Distribution within KNP/FS	Habitat of sighting	Date of Last Sighting
African wild dog *Lycaon pictus*	present	2, 3	present	85	entire reserve	montane forest & moorland	1989
Serval cat *Felis serval*	present	1, 2, 3	probably present	50	entire reserve	moorland	1989
Lion *Felis leo*	present	3	present	*	northern & western sides	montane forest & moorland	1990
Leopard *Felis pardus*	present	1, 2, 3	present	*	entire reserve	montane forest & moorland	1990
Proboscidae							
Elephant *Loxodonta africana*	present	1, 2, 3	present	*	northern & western sides	montane forest	1990
Perrissodactyla							
Black rhinoceros *Diceros bicornis*	present	1,3	possibly present	85	northern side	montane forest	1979
Artiodactyla							
Warthog *Phacochoerus aethiopicus*	absent		present	85	northern & western sides	lower edges of montane forest	1989
Bushpig *Potamochoerus porcus*	present	1, 2, 3	present	*	entire reserve	montane forest	1990
Giraffe *Giraffa camelopardalis*	present	3	present	85	northwestern side	montane forest	1989
African buffalo *Syncerus caffer*	present	1, 2, 3	present	*	entire reserve	montane forest & moorland	1990
Eland *Taurotragus oryx*	present	1, 2, 3	present	*	entire reserve	moorland	1990
Bushbuck *Tragelaphus scriptus*	present	1, 3	present	*	entire reserve	montane forest & moorland	1990
Abbot's duiker *Cephalophus spadix*	present	1, 3, 4	present	85	southern & western sides	montane forest	1989
Harvey's red duiker *Cephalophus harveyi*	present	1, 3, 4	present	*	entire reserve	montane forest & moorland	1990
Bush duiker *Sylvicapra grimmia*	present	3, 4	present	*	entire reserve	moorland	1990
Suni *Neotragus moschatus*	present	1, 3	present	*	northern side	montane forest	1990
Klipspringer *Oreotragus oreotragus*	present	1	absent			moorland	1944
Mountain reedbuck *Redunca fulvorufula*	present	1, 2, 3	absent			moorland	1965

† 1 = Moreau (1944); 2 = Guest and Leedahl (1954); 3 = Child (1965); 4 = Kingdon (1982)
** Species that we have personally sighted.*

Chapter 6

Recreational impacts of tourism along the Marangu route in Kilimanjaro National Park

W.D. Newmark and P.A. Nguye

Abstract

The recreational impacts of trail erosion and firewood collection along the Marangu route are examined in this chapter. Trail erosion is measured from 3.5 km below Mandara hut until the last water point between Horombo and Kibo huts. Firewood collection is measured at four known collection sites around Mandara and Horombo huts.

Trail erosion is most serious below Mandara hut. This is principally a result of the higher rainfall that is received along this portion of the trail, the steepness of the slope, past vehicular use, and the lack of waterbreaks. Firewood collection is becoming a major problem around Horombo hut. Porters are forced now to collect firewood up to 4 km away from Horombo hut because of the lack of firewood immediately around the hut.

The establishment of waterbreaks and the placement of woodchips along the Marangu route should significantly reduce trail erosion. The use of propane and kerosene stoves for cooking will eliminate the need for firewood collection along the Marangu route.

Introduction

East Africa's national parks and game reserves are among the world's most famous and visited protected areas. However, as the number of visitors to East African protected areas has grown during the last 30 years, the incidence of reported adverse recreational impacts upon parks resources has also increased (Western, 1974; Kumpumula, 1979; Western and Henry, 1979). Mount Kilimanjaro is one of the best known natural features of the African continent as well as a World Heritage Site. Kilimanjaro National Park earns the most foreign exchange of any national park in Tanzania. Since its establishment in 1972, the number of visitors has more than tripled to over 12,000 in 1989 (figure 6.1). Virtually all tourists who visit Kilimanjaro National Park come to climb the mountain and most use the Marangu route.

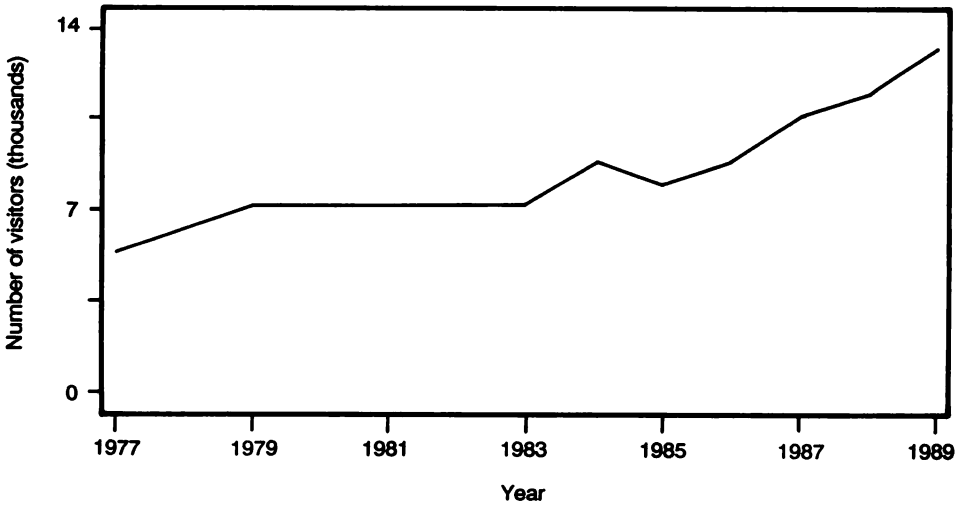


Figure 6.1 The number of visitors to Kilimanjaro National Park between 1977–1989.

As a result of the heavy use of the Marangu route a number of adverse recreational impacts from tourism are becoming apparent which include: litter, graffiti on the hut walls, improper sewage disposal, trampling of alpine vegetation, trail erosion, and firewood collection. In this chapter, we will focus on what we feel are two of the more serious impacts of tourism along the Marangu route: trail erosion and firewood collection. We will also discuss techniques for mitigating these recreational impacts along the Marangu route.

Methods

We evaluated the extent of trail erosion along the Marangu route by measuring the width and depth of the trail at 100 m intervals starting approximately 3.5 km below Mandara hut and continuing to the last water point between Horombo and Kibo huts. We defined the width of the trail as the width of exposed soil. If there were multiple trails, we measured the width of the trail as the distance between the outer most edges of exposed soil. The depth of the trail was measured at the midpoint of the trail along a tape that was held perpendicular to the outer edges of the trail.

We evaluated the impact of firewood collection upon the vegetation around Mandara and Horombo huts by recording the frequency of cut or broken vegetation in regions that we knew were used by the porters to collect firewood. Around Mandara hut, we measured the frequency of trees whose major lateral branches or trunk had been cut using a point-center quarter method. Around Horombo hut, we measured the frequency of shrubs whose major lateral branches had been broken using 4 X 4 m quadrat method. All measurements were conducted by Diploma II students from the College of African Wildlife Management between April and May of 1989.

Results and Discussion

Trail erosion

Trail erosion is a function primarily of soil type, slope, precipitation, water drainage patterns, and intensity and type of use. The most extensively eroded section of the Marangu route is below Mandara hut (table 6.1). The average depth of this portion of the trail is 30 cm and the average width of the trail is 3.8 m. This portion of the Marangu route is probably the most eroded for several reasons. Firstly, this portion of the route is at an elevation on the mountain that receives the greatest amount of precipitation. Over 2000 mm of precipitation is received annually along this portion of the Marangu route. Secondly, the lower portions of this section of the route were historically open to vehicular use and are currently used by park vehicles in rescue operations. The past vehicular use of this portion of the Marangu route has probably been a significant factor in promoting trail erosion. Finally, there are very few waterbreaks along this portion of the trail. As a result, water is not being diverted off to the side of the trail, rather it tends to flow down the trail which dramatically increases the rate of trail erosion.

Table 6.1 Trail erosion along the Marangu route.

Section of Marangu Route	Depth of Trail (cm) (Mean ± SD)	N	Width of Trail (m) (Mean ± SD)	N
3.5 km below Mandara hut – Mandara hut	30.0 ± 15.6	32	3.8 ± 1.8	32
Marangu hut – Horombo hut	25.2 ± 15.0	63	3.0 ± 1.8	63
Horombo hut – Last Water Point (new trail)	15.4 ± 10.5	44	3.6 ± 1.9	44
Horombo hut – Last Water Point (old trail)	26.1 ± 12.2	49	2.9 ± 1.5	49

The second most extensively eroded section of the Marangu route is the old trail between Horombo hut and the last water point. This portion of the Marangu route has been closed because of trail erosion. The average depth of this portion of the Marangu route is 26 cm and the average width is 2.9 m. This portion of the mountain is particularly prone to soil erosion because the soils are of a volcanic ash origin and are relatively fragile and the absence of any waterbreaks to divert water off of the trail. Of the four sections of the Marangu route that we measured, the least eroded section is the new trail between Horombo hut and the last water point. This section is probably less eroded because it has received less cumulative use than the other portions of the trail that we examined. Unfortunately, there are not any waterbreaks along this section of the trail so that in the future it is quite likely that this section of the trail will erode.

Although we did not measure trail erosion beyond the last water point, from our own observations there appears to be relatively little trail erosion. This is a result predominantly of the gentle slope of this portion of the trail and the low precipitation that falls at this elevation. This portion of the Marangu route should require little future maintenance in order to minimize trail erosion.

Firewood collection

Firewood has been and continues to be the predominant source of fuel for cooking and heating at Mandara, Horombo, and Kibo huts. However, the cumulative impacts of past firewood collection are starting to become pronounced in certain areas and a very serious in other areas.

The impact of firewood gathering around Mandara hut is less obvious than at the other upper huts along the Marangu route. This is due to the greater availability of firewood and the fewer number of people that normally stay at Mandara hut in comparison to Horombo hut. However, past firewood gathering is probably responsible for the opening in the forest around Mandara hut. Currently, the majority of firewood collecting around Mandara hut is occurring in the forest immediately below the hut. 25% of all trees in this site have been cut (table 6.2). The predominant species that is being cut is *Philippia excelsa*. If left unchecked, firewood gathering around Mandara hut will soon open up the forest below the hut.

Table 6.2 Impact of firewood collection at known firewood collection sites in the vicinity of Mandara and Horombo huts.

Location of Site	Proportion of Vegetation Cut or Broken (Mean ± SD)	N
Below and adjacent to Mandara hut	25.0 ± 24.6	40
4 km from Horombo hut	79.7 ± 26.0	21
3 km from Horombo hut	98.4 ± 4.8	20
1 km from Horombo hut	100.0 ± 0.0	21

The impact of firewood gathering around Horombo hut is more serious than around Mandara hut. Most of the large dead woody stems of the shrubs around Horombo hut have been collected and in the region immediately around Horombo the porters have started to collect the woody bases of the shrubs. This latter practice is very destructive and normally results in the plant being killed. As a result of the virtual absence of firewood immediately around Horombo hut, porters are now forced to collect firewood quite some distance away from the hut. We measured the frequency of cut vegetation at three known firewood collection sites utilized by porters. At, the first site, approximately 4 km from Horombo hut, 79% of all the dead stems had been broken. At the second site, approximately 3 km from Horombo hut, 98% of the dead stems had been broken, and at the third site, approximately 1 km from Horombo hut, 100% of the dead stems had been broken (table 6.2). The principal species that porters are collecting are *Stoebe kilimandscharica* and *Anthospermum usambarensis*.

Mitigative measures

Trail erosion

Without future maintenance of the Marangu route trail, problems of trail erosion will continue resulting in a further deepening and a widening of the trail. If left unchecked, the attractiveness of the Marangu route could potentially decline resulting possibly in a decrease in the number of visitors to the park.

The problems of trail erosion along the Marangu route could be mitigated by developing an extensive system of waterbreaks to divert water from flowing down the trail (Hendee *et al.*, 1978). In most portions of the trail, ditches could be dug or logs could be placed perpendicular to the trail to divert water from flowing down the trail. Additionally, steps could be constructed in the steepest portions of the trail.

In the more extensively eroded and wetter portions of the Marangu route, the trail may need to be 'hardened' in order to prevent hikers from diverting around wet spots and enlarging the trail over time. Placing wood chips along the wettest sections of the trail is one technique to encourage hikers to remain on the trail (Hendee *et al.*, 1978).

Firewood collection

The collection of firewood around Mandara, Horombo, and Kibo huts is starting to have very serious local impacts on the vegetation of the park. Fortunately, a very simple short-term solution exists for reducing the impact of firewood collection around Mandara hut. A stand of exotic pine (*Pinus radiata*) is located 500 m from Mandara hut that could easily be cut and dried and subsequently used for both cooking and heating. Tanzania National Parks has a policy not to encourage the planting of exotic species in their parks and thus the ultimate removal of this pine plantation would be advantageous. Another short-term solution to the problem of firewood collection around Mandara hut would be the introduction of fuel efficient ceramic stoves. However in the long-term, kerosene and propane stoves should be introduced at all the huts along the Marangu route.

Chapter 7

The hydrology of Mount Kilimanjaro: An examination of dry season runoff and possible factors leading to its decrease

J.D. Sarmett and S.A. Faraji

Abstract

We examine in this chapter the historical change in the dry season (July – October) discharge of four rivers that originate on the slopes of Mount Kilimanjaro. The two primarily non-spring fed rivers, the Njoro juu and the Rau, show a decrease in dry season discharge for the time period for which discharge data are available (mid-1960's to late 1970's). Conversely, the two primarily spring fed rivers, the Kikuletwa and Mue do not show any decrease in dry season discharge for the time period for which discharge data are available (the late 1950's through the mid-1970's).

We conclude that a change in local climate is not responsible for the decrease in dry season discharge and that the most likely cause of the decrease has been the increase diversion of water from the rivers and possibly a change in land use.

Introduction

Mount Kilimanjaro plays a critical role in the hydrology of northern Tanzania. The Pangani River basin, one of the major river basins in Tanzania, depends largely on the water that flows from the rivers and streams originating from Mount Kilimanjaro. The entire population and much of the agriculture around the mountain as well as various large national projects such as the Tanganyika Planting Company irrigation scheme and the Nyumba ya Mungu, Pangani Falls, and the Kikuletwa hydroelectric power stations to mention a few are dependent upon the water released from the mountain. Thus, there is an absolute necessity to promote the conservation of the mountain.

Table 7.1 Location and data recorded at the meteorological and rainfall stations included in this study.

Station Name	Station No.	Altitude (m)	Watershed	Available Data: Rainfall	Air Temperature	Pan Evaporation
TPC Langasani	93. 37028	701	Kikuletwa River	x	x	x
Moshi	93. 37004	813	Njoro juu/Rau rivers	x	x	x
WD&ID-Moshi	93. 37091	838	Njoro juu/Rau rivers	x		
Rombo Mission	93. 37006	930	Ruvu River	x		
Lyamungu ARI	93. 37021	1250	Kikafu/Weruweru rivers	x	x	x
Kibong'oto Hospital	93. 37078	1250	Sanya River	x		

Table 7.2 Altitude, location, catchment area, date of establishment of the river gauging stations included in this study.

Station Name	Station Number	Altitude (m)	Location	Catchment Area (km^2)	Date of Establishment
Kikuletwa River	IDDC1	700	below Weruweru confluence	3880	April 10, 1952
Mue River	IDC6	700	Kahe – Taveta railroad bridge	280	Sept. 12, 1953
Rau River	IDC3A	700	Kahe Forest Reserve	270	Sept. 22, 1960
Njoro juu River	IDC35	770	upstream of forest reserve bldg.	24	Oct. 28, 1958

In recent years many long-term residents on Mount Kilimanjaro have noted that the hydrologic patterns on the mountain appear to have changed. Specifically many local people feel that many of the rivers and streams that were once perennial are now intermittent.

This chapter examines first whether dry season runoff patterns have changed and secondly what factor(s) may be responsible for this change. In principle, there are most likely three causes for any historical change: (1) a change in climate; (2) an increase in the use of water; and (3) a loss of vegetative cover and a change in land use patterns. However, because of the lack of any quantitative data on the change in vegetative cover and land use, we will primarily focus upon the first two hypotheses in this chapter.

Hydro – meteorological parameters

Rainfall

Rainfall is a very important parameter in determining discharge. We selected three rainfall stations and three meteorological stations with long and continuous records: TPC Langasani, Moshi, WD&ID – Moshi, and Lyamungu ARI meteorological stations which are located on the southern side of the mountain, Kibong'oto rainfall station situated on the western side of Mount Kilimanjaro, and Rombo rainfall station located on the eastern side of the mountain (table 7.1). The stations were selected to give an indication of the rainfall patterns at different altitudes and sides of the mountain.

WD&ID – Moshi and Moshi meteorological stations are within the Njoro juu and Rau watersheds, TPC Langasani is within the watershed of the Kikuletwa River, Lyamungu ARI is within the watershed of the Kikafu and Weruweru rivers tributaries of the Kikuletwa River, Rombo Mission is within the watershed of the Ruvu River, and Kibong'oto Hospital is located within the Sanya river watershed which is also a tributary of the Kikuletwa river.

The long-term evaluation of rainfall is based on the available monthly rainfall totals at these six stations.

Air temperature

Air temperature is an important parameter to examine for any change in climate. Air temperature for the period 1970 – 1989, the entire period for which these data are available, for Moshi, Lyamungu ARI, and TPC Langasani meteorological stations are considered in this study.

Pan evaporation

Evapotranspiration and rainfall are two very important factors that influence the water balance of any area. Unfortunately, evapotranspiration data are not available for Mount Kilimanjaro due to a lack of continuous data on air temperature, sunshine hours, and solar radiation. However, data are available on pan evaporation, which are generally indicative of the evaporation patterns of the area. Yet for a variety of reasons, including the difference in heat storage capacity of a pan and a lake and the difference in the exchange heat between

Table 7.3 Mean monthly and annual rainfall and reliability for six rainfall and meteorological stations located on Mount Kilimanjaro.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
STATION: TPC Langasani (Period: 1971–1988)													
Mean (mm)	41	22	84	165	84	12	7	9	13	30	54	40	561
Standard deviation	40	30	60	90	57	29	10	16	18	42	60	31	483
Coefficient of variation (%)	97	137	72	54	68	240	150	172	137	110	79	86	86
STATION: Moshi (Period: 1930–1988)													
Mean (mm)	40	42	108	334	167	30	18	14	16	34	58	52	879
Standard deviation	42	37	71	174	93	28	22	16	26	49	66	43	265
Coefficient of variation (%)	105	88	66	52	56	93	122	116	162	145	116	83	30
STATION: WD&ID-Moshi (Period: 1956–1988)													
Mean (mm)	52	43	98	297	154	38	24	17	14	35	59	52	887
Standard deviation	52	40	63	161	83	33	26	20	20	57	52	45	277
Coefficient of variation (%)	101	93	64	54	54	88	108	118	149	162	88	86	31
STATION: Rombo Mission (Period: 1930–1980)													
Mean (mm)	110	103	238	299	119	45	29	48	45	94	298	201	1623
Standard deviation	99	86	153	135	66	81	25	31	41	72	133	120	418
Coefficient of variation (%)	90	84	64	45	55	182	87	65	93	77	44	60	26
STATION: Lyamungu ARI (Period: 1935–1988)													
Mean (mm)	50	58	112	485	382	100	55	34	30	37	90	74	1520
Standard deviation	51	54	88	240	183	66	37	25	42	44	112	69	462
Coefficient of variation (%)	102	93	79	50	48	66	67	74	140	119	124	93	30
STATION: Kibong'oto Hospital (Period: 1932–1988)													
Mean (mm)	48	51	112	353	229	63	20	21	14	29	101	102	1132
Standard deviation	57	45	101	173	154	71	24	24	24	44	112	92	380
Coefficient of variation (%)	116	88	90	49	67	113	118	114	170	152	111	90	34

a pan and the surrounding atmosphere, the evaporation from the pan will differ from a larger body of water exposed to the same meteorological conditions.

We took pan evaporation data from Moshi, TPC Langasani, and Lyamungu ARI meteorological stations. These stations are located on the southern slopes of the mountain. Lyamungu ARI meteorological station is located at a higher elevation than Moshi and TPC Langasani meteorological stations (table 7.1). Pan evaporation data are reviewed for the period 1970 – 1989.

Discharge

The Kilimanjaro Region is among the first regions in Tanzania where discharge data were collected. In the early 1950's, 34 river gauging stations were established around the slopes of the mountain to record water levels and discharge data. However, most of these river gauging stations were closed in the late 1950's and early 1960's. Nine gauging stations continued to operate until the late 1970's when budgetary restraints forced their closure. We shall review the dry season discharge from four river gauging stations: the Njoro juu River (No. IDC35), Rau River (No. 1DC3A), Mue River (No. 1DC6), and the Kikuletwa River (No. IDDC1) (table 7.2).

We have selected these four gauging stations because the source of the majority of the flow these stations is very different. The discharge at the Njoro juu and the Rau river gauging stations is maintained principally by non-spring sources while the discharge of the Mue and Kikuletwa river gauging stations is maintained primarily by large springs. The difference in origin of the discharge of these four river gauging stations should help us review possible causes of any decrease in dry season runoff.

The Njoro juu River gauging station, established in 1958, is located 1.5 km from the town of Moshi at an altitude of 770 m. The catchment area of this station is 24 km^2.

The Rau River gauging station, established in 1960, is located 30 km from Moshi towards Kahe Forest Reserve at an altitude of 700 m. The catchment area of this station is 270 km^2.

The Mue River gauging station, established in 1953 is located 32 km from Moshi along the Kahe – Taveta bridge at an altitude of 700 m. The catchment area of this station is 280 km^2. The flow at this station is maintained primarily by the Miwaleni Springs.

The Kikuletwa River gauging station, established in 1952, is located a few meters downstream from the confluence on the Kikuletwa River with the Weruweru River at the Tanganyika Planting Company at an altitude of 700 m. Major rivers and springs that maintain the flow of the Kikuletwa River are the Sanya, Kware, Kikafu, Weruweru and Karanga rivers all originating from the western and southern sides of Mount Kilimanjaro and the Rundugai springs in the southern lowlands. The flow at this station is maintained principally by the Rundugai Springs. The catchment area of this station is 3880 km^2.

Table 7.4 The mean daily pan evaporation by month for the time periods 1970–1979 and 1980–1989 for three meteorological stations on Mount Kilimanjaro.

STATION: TPC Langasani													
Time Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Grand Mean
1970–1979 (mm/day)	6.8	6.8	6.6	4.7	4.2	3.9	4.1	4.8	5.9	6.5	6.8	6.7	5.65
1980–1989 (mm/day)	6.7	7.4	6.2	3.5	3.0	4.1	3.7	3.8	5.2	5.3	5.4	6.0	5.03
STATION: Moshi													
Time Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Grand Mean
1970–1979 (mm/day)	7.6	7.6	7.8	5.0	3.7	4.4	3.6	4.9	6.7	9.6	7.3	6.3	6.21
1980–1989 (mm/day)	7.4	9.3	8.5	5.6	4.1	3.5	3.7	4.5	6.3	8.3	7.8	6.8	6.54
STATION: Lyamungu ARI													
Time Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Grand Mean
1970–1979 (mm/day)	3.6	3.7	3.4	1.6	1.4	1.7	1.9	2.3	2.9	3.8	3.4	3.3	2.75
1980–1989 (mm/day)	4.5	4.9	4.3	3.1	2.4	2.3	2.1	2.4	3.5	4.3	3.6	3.8	3.43

Table 7.5 The mean daily temperatures by month for the time periods 1970–1979 and 1980–1989 for three meteorological stations on Mount Kilimanjaro.

STATION: TPC Langasani													
Time Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1970–1979 (°C)	25.0	25.3	25.6	24.1	22.9	21.0	20.4	20.9	22.3	24.0	24.8	24.9	24.7
1980–1989 (°C)	26.3	26.3	26.3	25.7	024.0	22.8	21.6	22.2	23.3	25.0	25.8	26.0	24.7
STATION: Moshi													
Time Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1970–1979 (°C)	24.9	25.4	25.3	24.0	22.7	21.2	21.0	20.9	22.3	23.7	24.5	24.8	23.4
1980–1989 (°C)	25.3	25.9	25.9	24.3	22.8	21.5	20.9	21.3	22.5	24.3	25.0	24.7	23.7
STATION: Lyamungu ARI													
time Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1970–1979 (°C)	20.2	20.4	20.5	19.8	18.2	17.0	17.4	16.6	17.1	19.0	19.9	20.1	18.9
1980–1989 (°C)	21.1	21.6	21.5	20.4	19.0	17.6	17.0	17.3	18.4	19.7	20.4	20.7	19.6

Results

Climatic Patterns on Mount Kilimanjaro

Altitudinal variation in rainfall

Rainfall varies with altitude on Mount Kilimanjaro with a general increase in rainfall between 300 m – 2000 m and then a decrease from 2000 m upwards. The mean annual rainfall for TPC Langasani, Moshi, WD&ID-Moshi, Rombo Mission, Lyamungu ARI, and Kibong'oto Hospital is 561 mm, 879 mm, 887 mm, 1623 mm, 1520 mm, and 1132 mm, respectively (table 7.3). The stations are located at 701 m, 813 m, 838 m, 930 m, 1250 m, and 1250 m, respectively (table 7.1).

Rainfall reliability

Long-term mean monthly rainfall data for the six stations reveal two rainy seasons and two dry seasons (figure 7.1). The 'long rains' normally occur between March and May while the 'short rains' usually come between November and December. The 'short rains' are more pronounced at higher elevations (figure 7.1).

The dry season normally occurs between July and October and between January and February. During the dry season the lower slopes of Mount Kilimanjaro in the vicinity of Moshi receive 14 mm – 38 mm while the upper elevations receive 14 mm – 100 mm (table 7.3).

There is great variation in monthly rainfall as indicated by the coefficients of variation for the six stations (table 7.3). June, August, September, and October have the highest coefficients of variation in mean monthly rainfall for the six rainfall and meteorological stations. Annual rainfall is more reliable than the monthly rainfall as indicated by the comparatively lower coefficients of variation for annual rainfall (highest C.V. ranges from 26% to 86%) than for monthly rainfall (highest C.V. range from 140% to 182%) (table 7.3).

Long-term trends in annual rainfall

According to the Water Master Plan for the Kilimanjaro Region (Department of Water, Energy and Minerals, 1977), there are not any long-term upward or downward trends in rainfall between approximately the mid-1930's when stations were established and 1976 on Mount Kilimanjaro. We conducted similar analysis for the six stations considered in this study using data from time of establishment through 1988. With the possible exception of the Kibong'oto Hospital, there appears not to be any long-term change in annual precipitation through 1988 at rainfall stations that we examined (figure 7.2). For the Kibong'oto Hospital rainfall station, which is located within the watershed of the Kikuletwa River, there appears to be an upward trend in precipitation after 1973.

Air temperature

Maximum and minimum mean daily temperatures vary with altitude (figure 7.3). The minimum mean daily temperature for TPC Langasani meteorological station at 701 m is 16.2°C in July, for Moshi meteorological station at 813 m is 12.8°C in August, and for Lyamungu ARI meteorological station at 1250 m is 11.8°C in August. Conversely the

Table 7.6 Mean dry season (July – October) discharge and 3 year moving averages for the Njoro juu, Rau, Mue, and Kikuletwa rivers.

Njoro juu River (Period: 1965-1978)

Year	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Mean discharge (m^3/sec)	1.17	1.23	1.28	1.84	1.18	1.28	1.63	1.37	1.11	0.92	0.85	0.50	0.58	0.84
3 year moving average	-	1.23	1.45	1.43	1.43	1.36	1.42	1.37	1.13	0.96	0.64	0.64	.64	-

Rau River (Period: 1969-1976)

Year	1969	1970	1971	1972	1973	1974	1975	1976
Mean discharge (m^3/sec)	0.25	1.01	-	0.73	0.50	0.67	0.13	0.01
3 year moving average	-	-	-	-	0.63	0.43	0.27	-

Mue River (Period: 1957-1975)

Year	1957	1958	1959	1968	1969	1970	1971	1972	1973	1974	1975
Mean discharge (m^3/sec)	3.52	3.78	3.60	-	3.80	3.75	3.21	3.23	3.36	4.28	3.21
3 year moving average	-	3.62	-	-	-	3.59	3.40	3.27	3.62	3.62	-

Kikuletwa River (Period: 1960-1976)

Year	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Mean discharge (m^3/sec)	20.29	13.72	9.66	16.80	22.76	12.30	14.60	24.76	24.62	17.59	14.14	22.66	20.12	18.60	22.22	20.19	19.18
3 year moving average	-	14.56	13.39	16.41	17.29	16.56	17.22	21.33	22.32	18.78	18.13	18.97	20.46	20.31	20.34	20.53	-

Table 7.7 Cumulative volume of water issued between 1950–1989 in the Njoro juu, Rau, Mue, and Kikuletwa rivers.

River	through 1959 (m^3/sec)	through 1969 (m^3/sec)	through 1979 (m^3/sec)	through 1989 (m^3/sec)
Njoro juu River	0.056	0.089	0.159	0.269
Rau River	0.046	1.475	1.499	1.502
Mue River	2.097	10.619	10.628	11.628
Kikuletwa River	4.153	6.624	7.049	7.106

maximum mean daily temperature for these same stations is 27.4°C in February, 35.4°C in March, and 33.2°C in February.

A comparison of the monthly mean temperatures for the period 1970 – 1979 with the period 1980 – 1989 indicates that the monthly mean temperatures have been on average slightly warmer during the period 1980 – 1989 (table 7.4). The difference in mean annual temperatures between the time periods 1970 – 1979 and 1980 – 1989 were 0°C at TPC Langasani, .3°C warmer at Moshi, and 1.3°C warmer at Lyamungu ARI.

Pan evaporation

There has been a variation in change in pan evaporation between 1970 – 1979 and 1980 – 1989 for TPC Langasani, Moshi, and Lyamungu ARI (table 7.5). At TPC Langasani, the pan evaporation for the period 1980 – 1989 was .62 mm/day less than for the period 1970 – 1979. Conversely, at Moshi, the pan evaporation for the period 1980 – 1989, was .33 mm/day more than for the period 1970 – 1979; while at Lyamungu ARI the pan evaporation for the period 1980 – 1989 was .68 mm/day more than for the period 1970 – 1979.

Conclusion regarding effects of climate

Although the mean monthly temperatures and pan evaporation for two of the three meteorological stations show a small increase for the period 1980 – 1989 in comparison to the period 1970 – 1979, there is not any noticeable long-term change in precipitation. Thus we conclude that any decrease in dry season runoff is not a result of a change in climate.

Change in dry season discharge

The mean dry season discharge in both the Njoro juu and the Rau rivers show a decrease between the 1960's and the 1970's (table 7.6, figure 7.4). The discharge in these two rivers are dependent largely upon non-spring sources.

In contrast, the mean dry season flow in the Kikuletwa and Mue rivers which are fed respectively by the Rundugai and Miwaleni springs shortly above their gauging stations do not show a decrease in discharge between the 1960's and the 1970's (table 7.6). This would suggest that the ground water table that maintains the Rundugai and Miwaleni springs has remained constant even though there has been a decrease in the dry season discharge in non-spring fed rivers.

The decrease in dry season discharge is probably common to most if not all non-spring fed rivers on Mount Kilimanjaro.

Given that there has not been a change in climate on Mount Kilimanjaro, we feel that a change in dry season discharge is principally a result of increased water diversion and possibly a result of changes in land use patterns.

Water diversion

The amount of water diverted, both authorized as well as unauthorized, from streams and rivers on Mount Kilimanjaro has increased tremendously during the last 40 years. The amount of authorized water that has been diverted from the Njoro juu, Rau, and Mue rivers has nearly quadrupled in the last forty years (table 7.7). The legal diversion of water in the Njoro juu River has increased from .056 m^3/sec in the 1950's to over .269 m^3/sec in the 1980's while the legal diversion of water in the Rau River has increased from .046 m^3/sec in the 1950's to 1.502 m^3/sec in the 1980's. Similarly, in the Mue River the legal diversions has increased from 2.097 m^3/sec in the 1950's to 11.628 m^3/sec in the 1980's and in the Kikuletwa River the legal diversions have increased from 4.153 m^3/sec in the 1950's to 7.106 m^3/sec in the 1980's.

Rivers other than the Njoro juu, Rau, Mue, and the Kikuletwa have also experienced a tremendous increase in legal diversion of water. In a survey that we conducted during December 1988 for the Lower Hai and Lower Rombo Agricultural Development Project, we noted that the Kikuletwa river upstream from Rundugai springs was dry. During that same period we also observed that the Sanya and Kware rivers, tributaries of the Kikuletwa River and also upstream from Rundugai springs, were also completely dry. Additionally, we noted that all of the waters of the Karanga, Wereweru, and Kikafu rivers were being diverted to the TPC farms during this same period.

In addition to the increase in authorized diversion of water from streams and rivers on Mount Kilimanjaro, there has most likely been an increase in unauthorized diversions as human population has increased.

Loss in vegetative cover and change in land use

Although we do not have quantitative data to examine how the loss in vegetative cover and the change in land use may have affected hydrological patterns, it is apparent that human activity along the slopes of the mountain has increased tremendously in the past 100 years. Cultivation of crops, fires, and felling of trees around water sources most likely have contributed to the decrease in the dry season discharge.

It is now generally accepted that the felling of forest will increase the magnitude of flood peaks and decrease the dry season flows (Bruen, 1989). Though the areal change in the montane forest within the Kilimanjaro Forest Reserve has been small between 1958 and 1987 (Lamprey *et al.*, chapter 2), there has been a dramatic change in land use outside of the forest reserve during the last 100 years. Lowland and upland areas on Mount Kilimanjaro that historically were used for grazing of livestock and for firewood collection are now being cultivated (O'Kting'ati and Kessy, chapter 8).

Thus we conclude that the loss of vegetative cover and the change in land use on Mount Kilimanjaro has also most likely contributed to the decrease in dry season discharge of many rivers and streams.

Recommendations

The need to have good and reliable streamflow and meteorological data cannot be overstated. Given the hydrological importance of Mount Kilimanjaro, it is vital that past hydrological stations on Mount Kilimanjaro be reopened and monitored.

In addition, measures should be developed to conserve water. Traditional furrows need to be rehabilitated and control gates built in order to assess the amount of water they abstract. Laws forbidding the felling of trees and the cultivating around water sources areas need to be enforced.

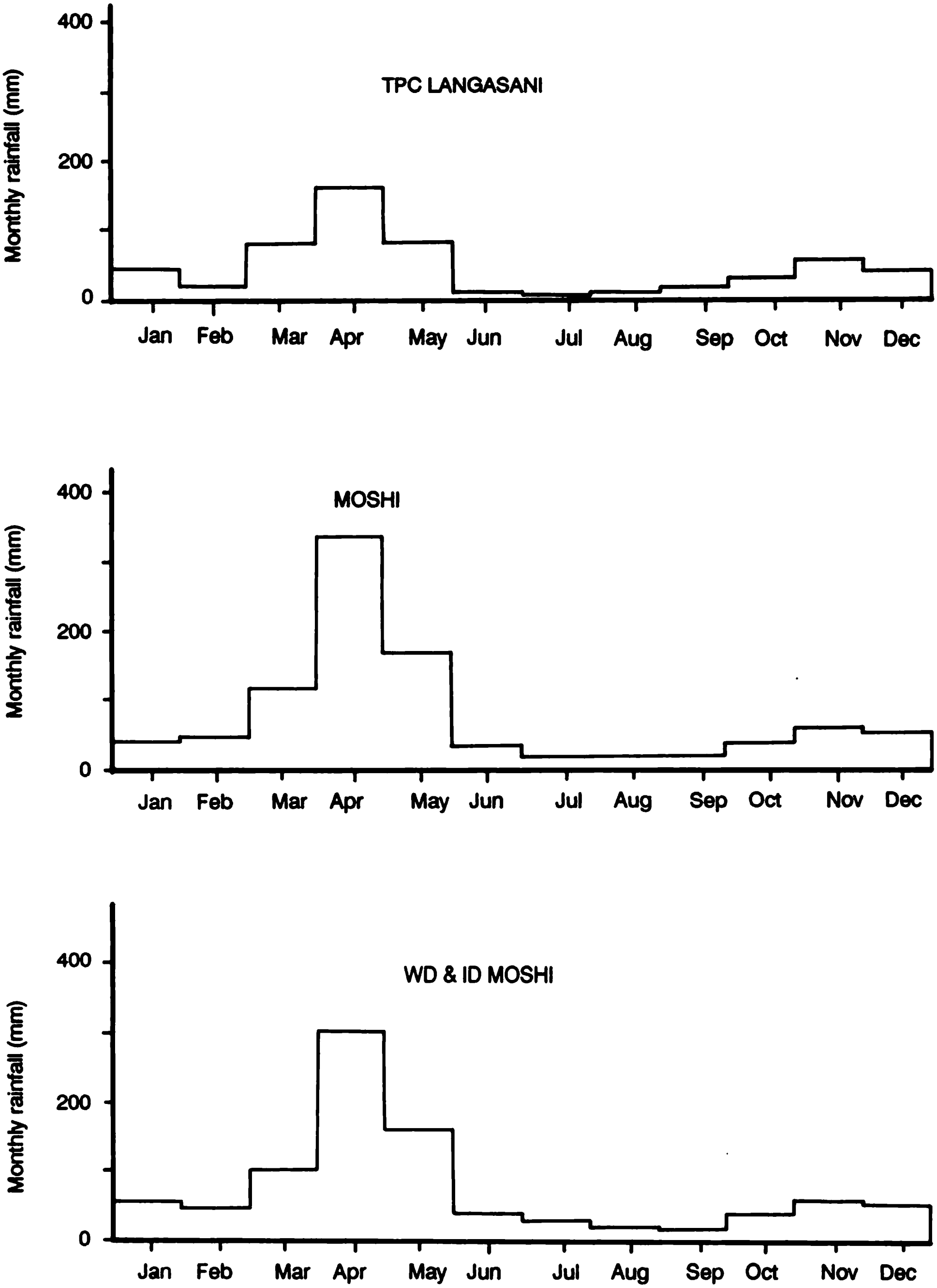
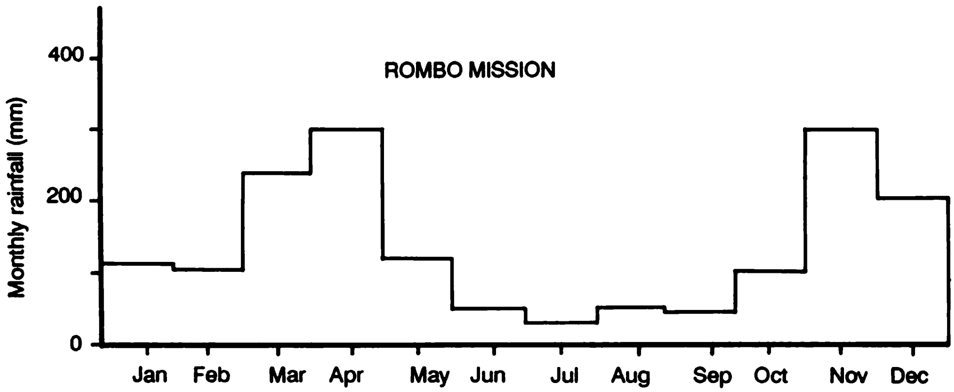
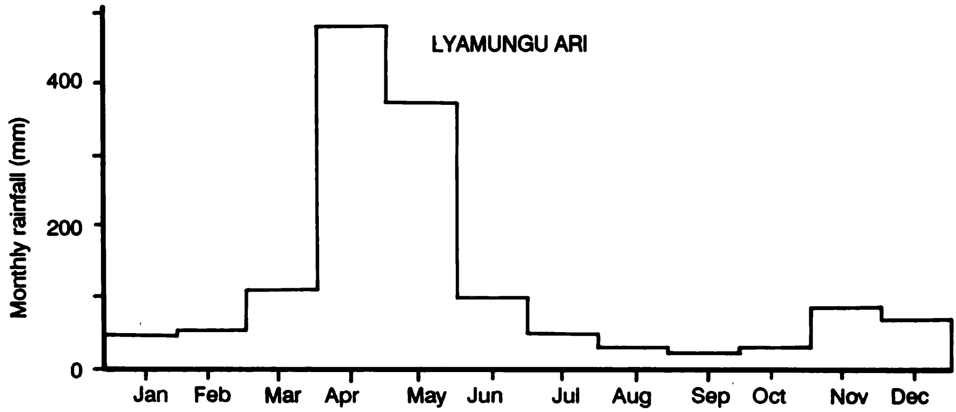
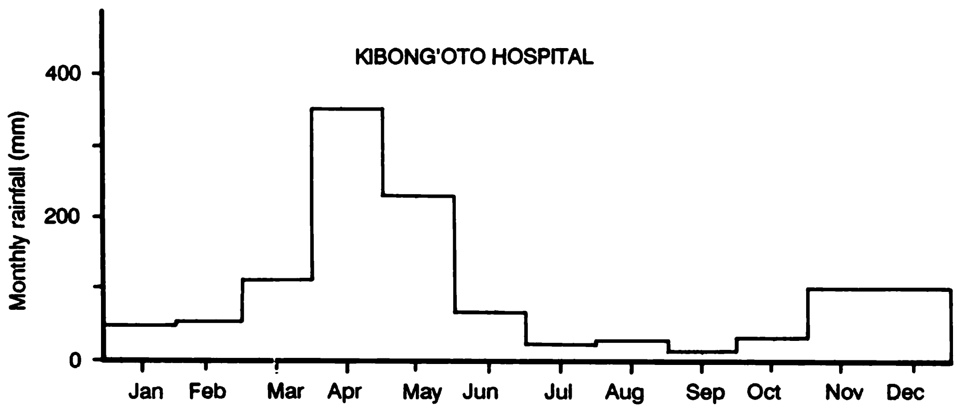


Figure 7.1 Mean monthly rainfall at six meteorological and rainfall stations on Mount Kilimanjaro.


ROMBO MISSION
Monthly rainfall (mm)
400
200
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


LYAMUNGU ARI
Monthly rainfall (mm)
400
200
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


KIBONG'OTO HOSPITAL
Monthly rainfall (mm)
400
200
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

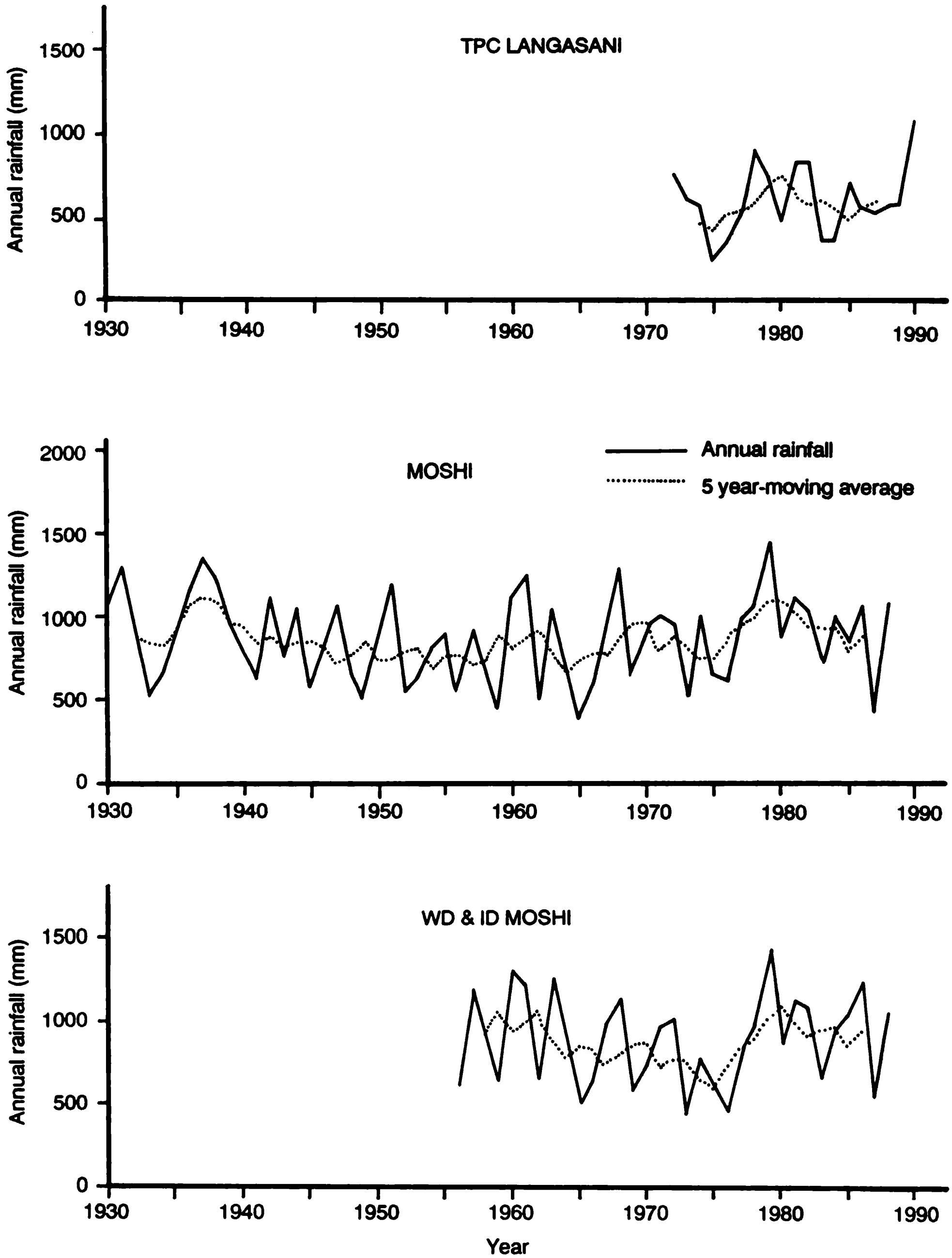
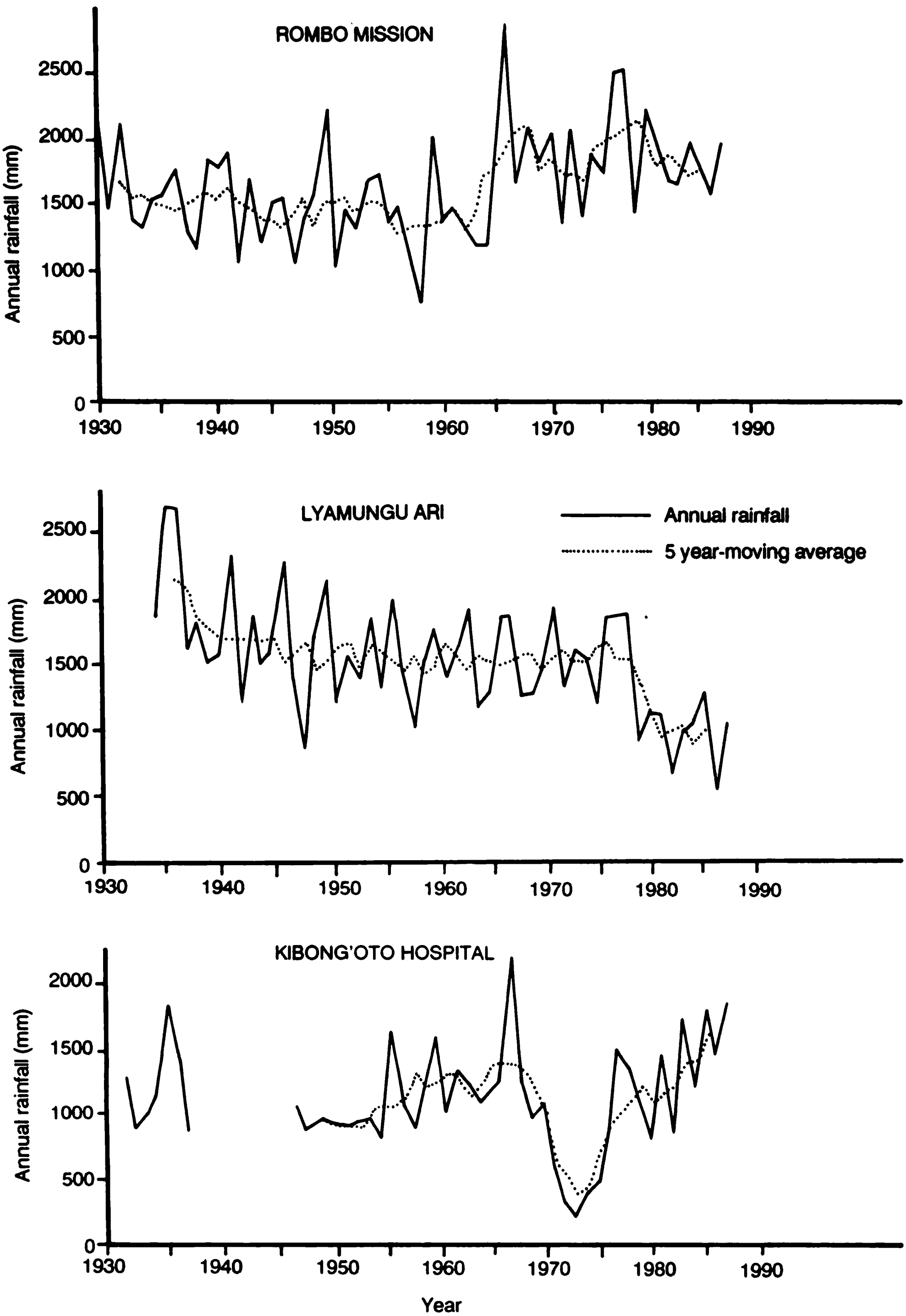


Figure 7.2 Annual rainfall and five year moving averages of rainfall for six rainfall and meteorological stations on Mount Kilimanjaro.


ROMBO MISSION
Annual rainfall (mm)
2500
2000
1500
1000
500
0
1930
1940
1950
1960
1970
1980
1990
LYAMUNGU ARI
Annual rainfall
5 year-moving average
Annual rainfall (mm)
2500
2000
1500
1000
500
0
1930
1940
1950
1960
1970
1980
1990
KIBONG'OTO HOSPITAL
Annual rainfall (mm)
2000
1500
1000
500
0
1930
1940
1950
1960
1970
1980
1990
Year

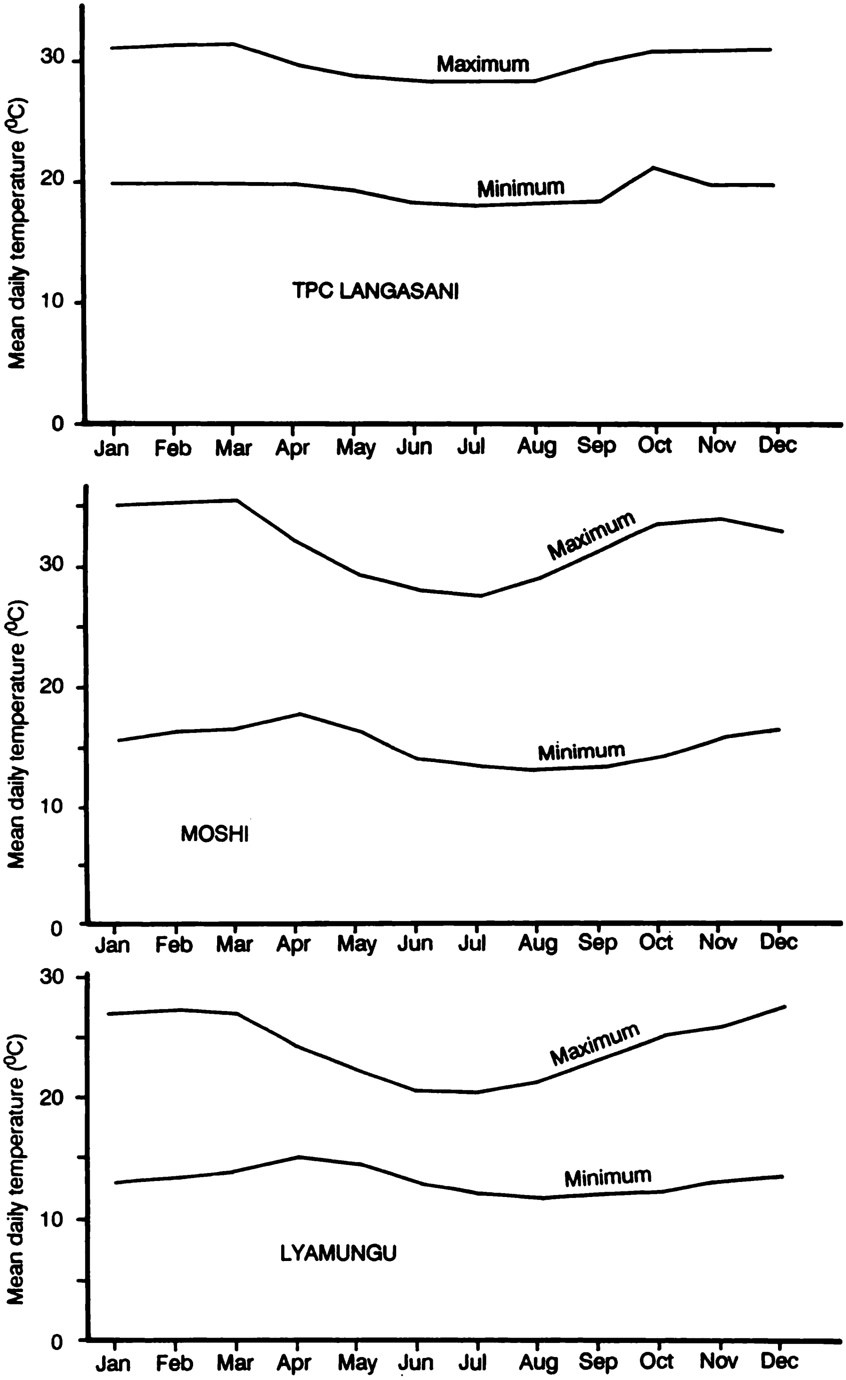


Figure 7.3 Maximum and minimum mean daily temperatures at TPC Langasani (701 m), Moshi (813 m), and Lyamungu ARI (1250 m) meteorological stations.

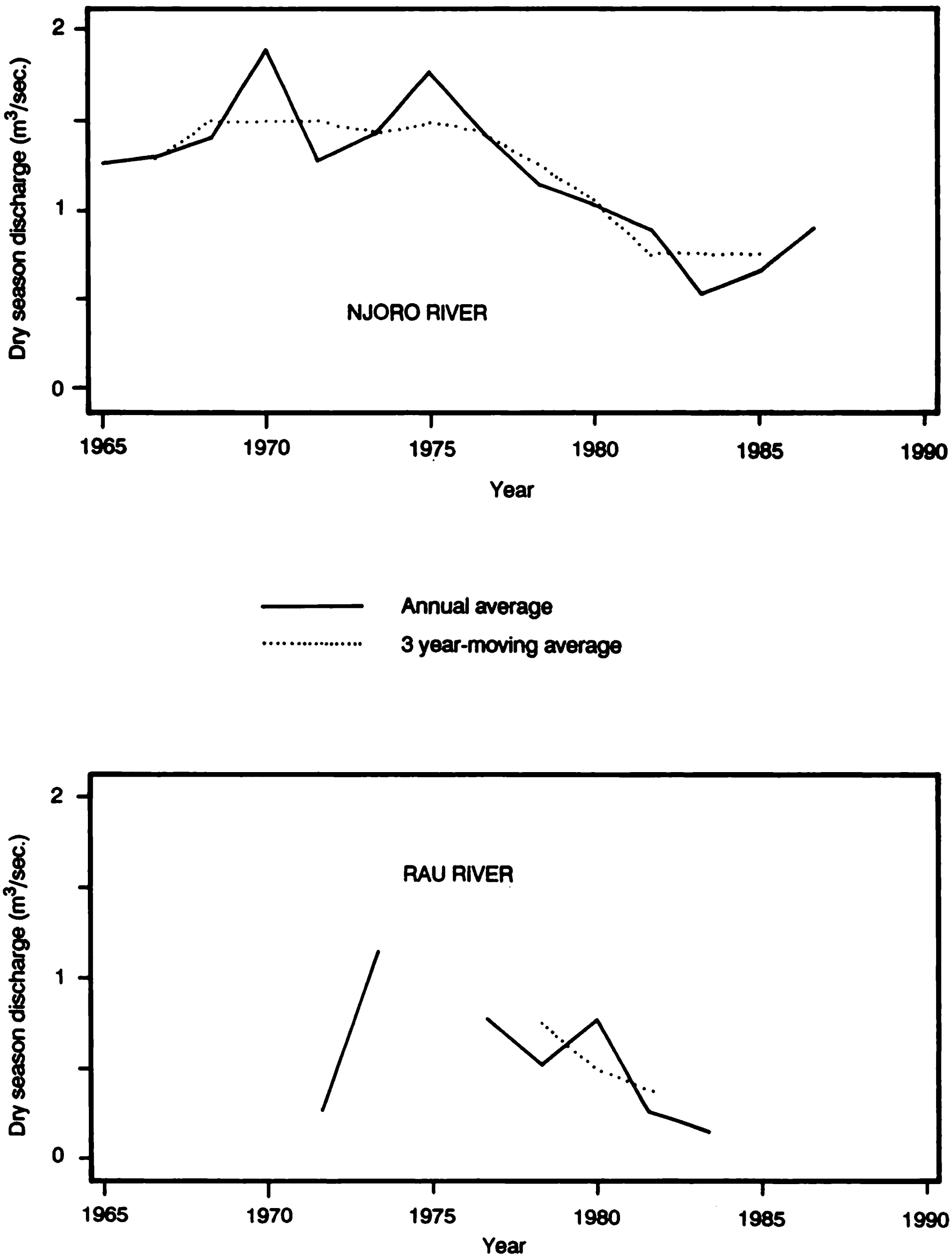
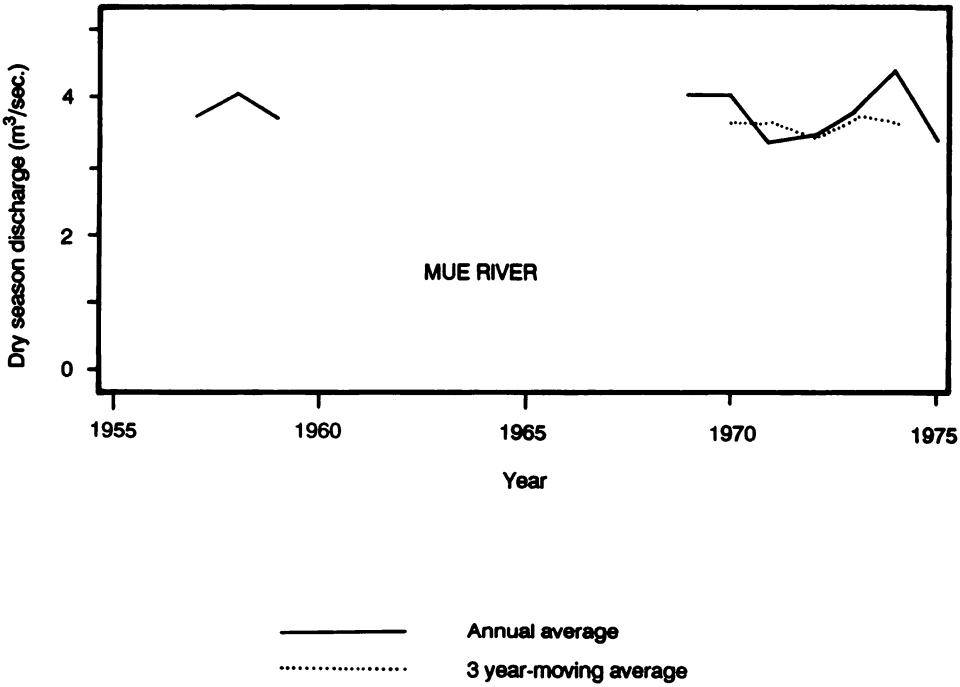
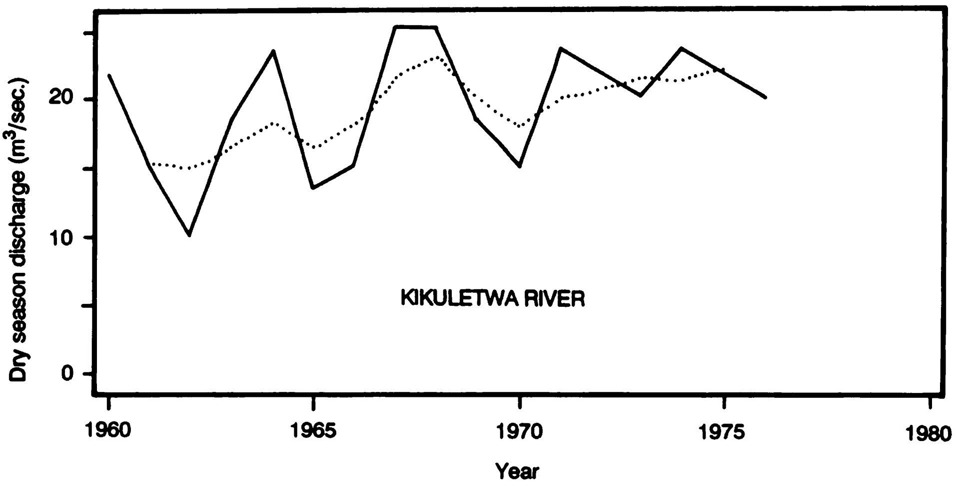


Figure 7.4 Dry season discharge (July –October) in the Njoro juu, Rau, Mue, and Kikuletwa rivers for the time periods 1965–1978, 1969–1976, 1957–1975, 1960–1976, respectively.



Dry season discharge (m³/sec.)
4
2
0
MUE RIVER
1955
1960
1965
1970
1975
Year
Annual average
3 year-moving average



Dry season discharge (m³/sec.)
20
10
0
KIKULETWA RIVER
1960
1965
1970
1975
1980
Year

Chapter 8

The farming systems on Mount Kilimanjaro

A. O'Kting'ati and J.F. Kessy

Abstract

This chapter describes the farming systems on Mount Kilimanjaro and examines the trends in agricultural production and the environmental impacts of agricultural activities. Much of the data presented in this chapter has been gathered through a survey that was carried out in 1988 in the wards of Old Moshi, Kirua Vunjo and Kilema in south Kilimanjaro. The wards were divided into lowland zone (500 m – 700 m), middle zone (700 m – 1400 m), and high zone (1400 m – 2000 m). A total of 48 farmers from the lowland zone (16 from each ward), 150 farmers from the middle zone (50 from each ward), and 99 farmers from the high zone (33 from each ward) were surveyed.

Per capita output of maize and beans has increased between 1964 and 1988 while per capita agricultural output of coffee has declined between 1972 and 1986. Per capita output of millet has fluctuated between 1964 and 1988. Additionally, the per capita number of cattle, sheep, and goats per capita have declined between 1960 and 1980. The numbers of pigs per capita has increased during this same period. Nonetheless there has been a deficit between demand and supply of cereals and starches on Mount Kilimanjaro in recent years.

Beginning in the early 1960's, there was a dramatic increase in the clearing of forested land adjacent to many rivers and streams for cultivation and collection of fodder. This has resulted in extensive soil erosion and increased siltation of downstream hydroelectric facilities.

Introduction

The slopes of Mount Kilimanjaro are agriculturally of great importance to Tanzania both regionally as well as nationally. In the Kilimanjaro Region, agriculture contributes over 40% of the region's GDP and employs 81.6% of the region's economically active population (JICA, 1977).

Coffee is the largest source of foreign exchange for Tanzania and accounts for about 40% of Tanzania's foreign exchange earnings (Marketing Development Bureau, 1979). Mount

Kilimanjaro is one of the most important coffee growing regions in Tanzania. Small holder farmers on Kilimanjaro contribute approximately 30% of the country's mild-arabica coffee in 1985/86. In addition to coffee, the other major cash crops are sugar cane, sisal, pyrethrum and cotton.

The slopes of Mount Kilimanjaro are also important in terms of food crops. The major food crops include bananas, beans, maize, rice, and millet.

The farming systems on Mount Kilimanjaro vary by altitude. In the upper and middle altitudinal zones much of the farming systems involves permanent cropping especially in areas where perennial crops like coffee and bananas are grown. Coffee is intercropped with bananas, maize, taro, beans, and yams in these zones.

Land use is based on kinship structures which are patrilineal in terms of ownership and inheritance. As human populations have increased so have the demands for food, fuelwood and fodder. This has lead to deforestation and highly accelerated soil erosion and a general decline in land productivity (Avery, 1979; O'Kting'ati, 1985). This chapter reviews the farming systems on Mount Kilimanjaro and discusses the trends in agricultural production as well as the ecological impacts of the past and current farming systems.

Physical/social background information

Approximately 13.3% of the Kilimanjaro Region or 175,560 ha of the land is currently cultivated. Of the total land area in the Kilimanjaro Region, 10% is classified as high fertility while 18% is classified as medium fertility (IBRD, 1974).

The soils of Mount Kilimanjaro are of volcanic origin and have a high base saturation and cation exchange capacity. Steep slopes in many areas of the mountain prevent farm mechanization and necessitate substantial erosion control in order to maintain high agricultural production. In other areas arability is limited by stoniness or by shallow petrocalcic horizon.

The rainfall pattern in this region is bimodal with short rains from November to December and long rains from March to May. The average rainfall ranges from 1000 mm to 1700 mm and it varies with elevation and aspect. More rainfall is received on the southern and eastern sides of the mountain because of the prevailing wind patterns (Ferdnandes *et al.*, 1984).

The Kilimanjaro Region covers about 1% of the total area of Tanzania but it contains over 5% of the country's population. The 1988 population census revealed that the population density on the slopes of Mount Kilimanjaro is about 264 people/km^2 with the rate of growth of about 2.1% per annum (Gamassa, chapter 1). But population densities of 500 – 1000 people per km^2 have been reported in some localities on Kilimanjaro (O'Kting'ati and Mongi, 1986; FAO, 1986).

Division of labour and specialization is a common phenomenon within the Chagga communities. Women and children are responsible for the farming of food crops (maize and beans on the lowlands), fodder and fuelwood collection, and the cooking, while men are responsible for the cultivation of the coffee and bananas on the land near their homes. The men are also responsible for the the development of the farms, building of new houses, and the school tuition for the children which they normally pay for with the money they earn from the sale of coffee. The women purchase daily minor household needs from the sale of milk, bananas, fruits and other food crops.

Methodology

A survey was carried out in the three wards in 1988. The wards were divided into three altitudinal zones: the lowland zone, 500 m – 700 m; the middle zone, 700 m – 1400 m; and the high zone, 1400 m – 2000 m. We randomly selected 48 farmers (16 from each ward) from the lowland zone, 150 farmers (50 from each ward) from the middle zone, and 99 farmers (33 from each ward) from the high zone. A different questionnaire was administered for each zone because the agricultural systems vary by altitude. Physical observation and enumeration were carried out for such things as livestock, crops, and size of farm plots.

Trends in human population and agriculture production were taken from the literature. In summarizing the livestock data for the decades of 1960 through 1980 we used a mean value for each decade.

The farming systems

Three distinct farming systems, which vary by altitude, can be recognized on Mount Kilimanjaro:

The lowland zone (500 m – 700 m)

The farming system in the lowland zone is one of the most intensive and mechanized of the three farming systems particularly in the open and flat regions. Maize and beans cultivation and livestock grazing are the primary agricultural activities. The farming system in the lowland zone has changed considerably during the last thirty years.

Prior to the mid-1960's, pastoralism and the cultivation of finger millet, an important ingredient in local beer, were the most important agricultural activities in this zone. These agricultural activities were conducted primarily by people who lived at higher elevations. There were very few permanent settlements historically in this zone.

By the mid-1960's, increasing numbers of people began to settle in areas between altitudes 600 m and 700 m. Many areas in the neighbourhoods of Kiboriloni, Msaranga, and Sango in the Old Moshi Ward, and lower Uparo and Nganjoni in Kirua Vunjo Ward, as well as Mandaka and Masaera in Kilema Ward were settled during this period.

Beginning in the mid-1970's, maize became an important food for people living in the higher altitudinal zones and increasing amounts of land in the lowland zone were placed under a mixed farming system of maize and finger millet cultivation. The size of many villages such as the Kiboriloni Sango area in the Old Moshi Ward increased considerably during the mid-1970's. Certain settlements in the neighbourhood of Njoro forest such as Msaranga started to develop farming systems that were traditionally more common to higher elevations due to an ample supply of ground water. Other settlements particularly those of Nganjoni in Kirua Vunjo Ward and Masaera in Kilema Ward expanded as a result of extensive use of the traditional *mfongo* irrigation system.

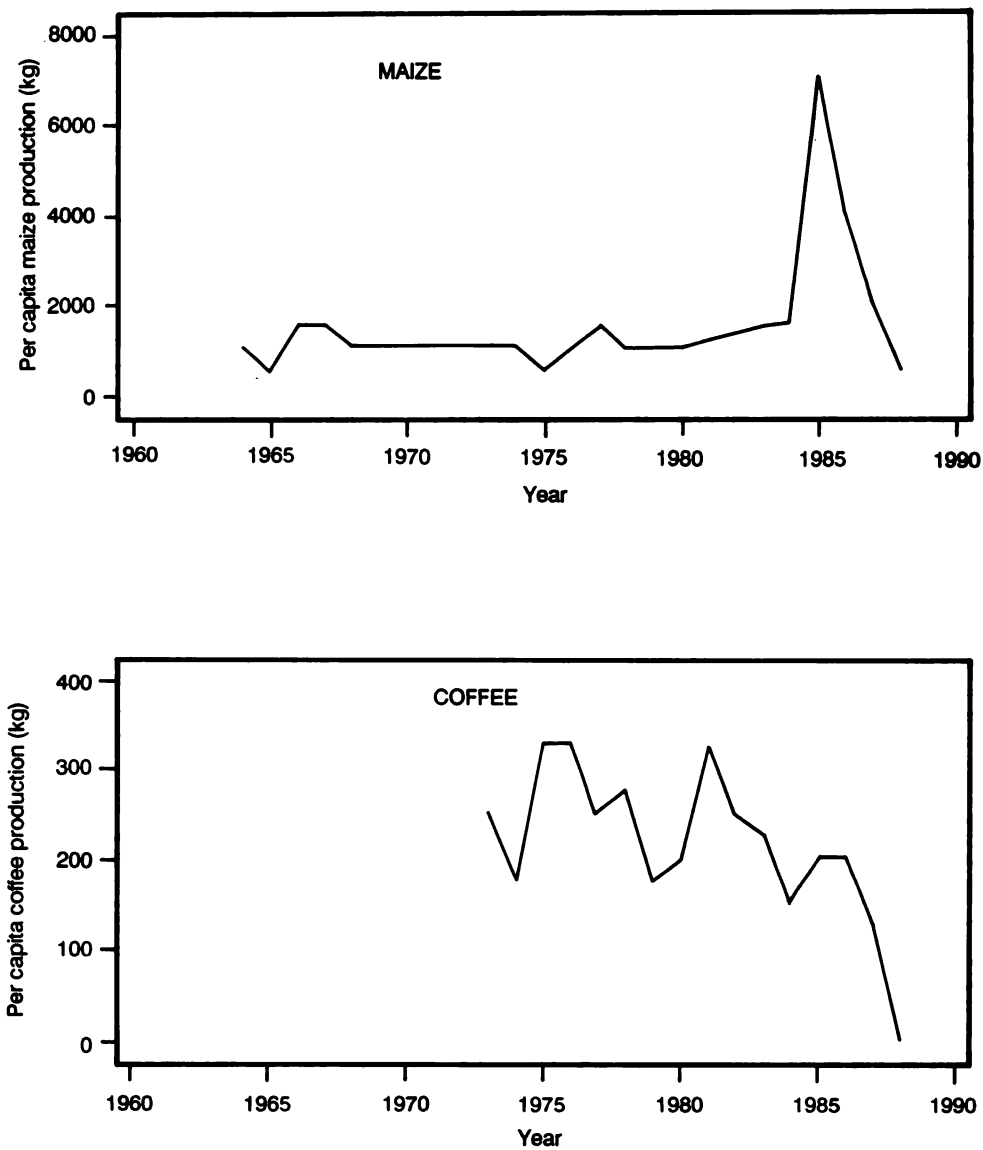
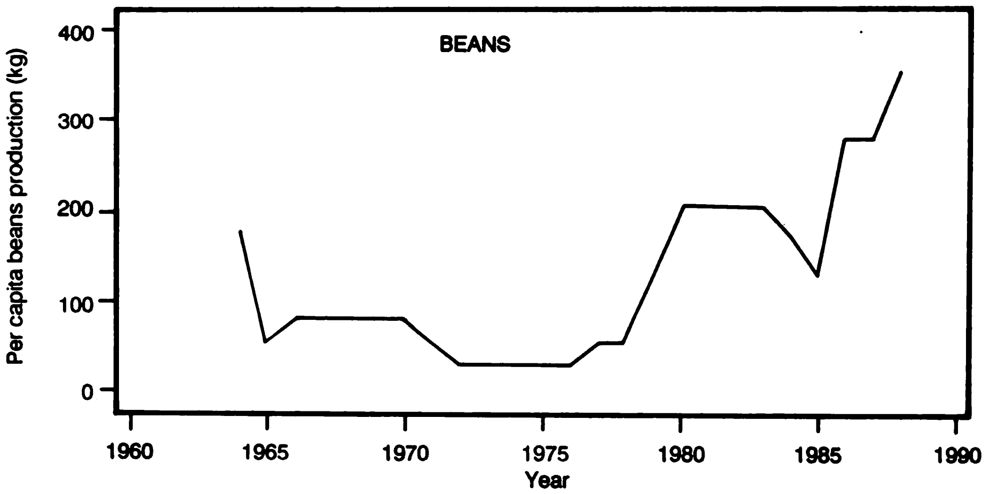
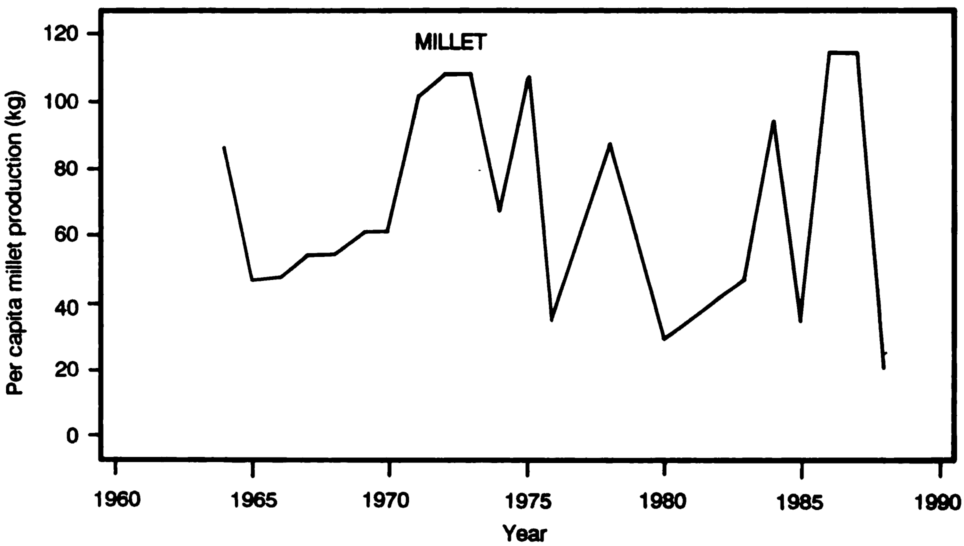


Figure 8.1 Per capita production of maize, coffee, beans and millet on Mount Kilimanjaro. The per capita production of maize, beans, and millet is for 1964–1988 and the per capita production of coffee is for 1973–1988.


BEANS
Per capita beans production (kg)
0
100
200
300
400
1960
1965
1970
1975
1980
1985
1990
Year


MILLET
Per capita millet production (kg)
0
20
40
60
80
100
120
1960
1965
1970
1975
1980
1985
1990
Year

A general intensification of mixed farming continued in this lower altitudinal zone during the 1970's. Farming systems in this zone became increasing mechanized particularly in the open and flat areas. Beans, sunflowers, and ground nuts were introduced extensively in this zone during this period. Between the 1960's and 1980's, the total hectares of fingermillet declined primarily because other regions in Tanzania such as Mpanda and Rukwa were able to grow this crop more efficiently.

The middle zone (700 m – 1400 m)

The farming system in the middle altitudinal zone is one of the oldest and most intensive in the country. The farming system in this altitudinal zone is an agroforestry system that has evolved over the last 200 years and has changed much less in the last thirty years than the farming systems in the lower and upper altitudinal zones.

The main components of this agroforestry system are coffee and bananas under various tree crops. The trees are grown for fruit, lumber production, animal fodder, and shade. The farms in this zone have a variety of shade tolerant food crops of which the main one is taro. Farmers plant fodder grasses such as *Setaria splendida*, Guatemala grass, elephant grass and Guinea grass for stall feeding livestock along the farm boundaries, the entries to the homes and footpaths, as well as along the contours of the sloping terrain. Unlike the lowland zone there is virtually no open grazing of livestock.

The farm plots in this zone are generally small with the average farms in Kilema and Kirua Vunjo being 0.50 ha and 0.54 ha, respectively.

Coffee is the main cash crop in this farming system. The farmers fetched 90 Tshs. per kg of parchment coffee in 1988 implying that an average farmer in Old Moshi, Kirua Vunjo and Kilema earned 21,780 Tshs., 33,120 Tshs. and 23,670 Tshs. respectively from coffee sales alone. If other outputs of the system (e.g., bananas, taro, livestock products) were evaluated this figure would be higher. Studies in Legho Mulo in Kilema revealed a per capita income of 7423 Tshs. resulting from agriculture (Kessy, 1988). This is above the national average of 5998 Tshs. (Fedha, Uchumi na Mipango, 1986).

The high zone (1400 m – 2000 m)

The farming systems in the high altitude zone are very similar to the farming systems in the middle altitudinal zone only that the growing conditions for most crops are less favourable because of the lower temperatures. As a result maize takes more than six months to mature whereas it takes only three months in the lower zones. Maize is harvested during June and July in the lower zones but in this zone it is harvested in February and March. Tuber crops are more abundant in this zone. Temperate fruit crops such as pears, plums, peaches, and others perform well. There is also a higher prevalence of bee-keeping among farmers in this zone.

Historically, the grazing of livestock and the collection of fodder was more extensively practiced in this zone. As human numbers in the middle altitudinal zone expanded, increasing numbers of people moved into this zone to cultivate.

Trends in livestock and crop production

There has been a general increase in the per capita production of maize and beans between 1964 and 1988 (figure 8.1). However, there was a significant drop in the per capita maize production in 1987/88 because of the drought conditions. The increase in per capita maize and beans production during the 1980's is a result of the adoption by farmers of more modern farming techniques. Most farmers are now planting maize in well spaced rows rather than simply scattering the seeds. This has enabled many farmers to increase their yields by over 100 percent.

Per capita coffee production has decreased between 1973 and 1988 (figure 8.1). This is due in part to the decreasing size of farms as a result of the Chagga inheritance system, the use of traditional farming techniques for coffee, and the comparatively low rate of return for coffee. Of these three factors, the latter two are probably the most important (Mlambiti, 1982).

Per capita millet production has fluctuated greatly between 1964 and 1988 (figure 8.1). However, the total hectares of millet has decreased during this time period as increasing amounts of lands were placed under maize and bean cultivation. The comparative advantage of other finger millet growing regions in Tanzania is an important factor in the decline of the total hectares of finger millet.

Although per capita maize and bean production has increased over time on Mount Kilimanjaro there has nonetheless been a deficit frequently between the demand and production for cereals and starches on Mount Kilimanjaro. In 1980, the demand for cereals (rice, maize, millet, sorghum, wheat) and starches (cassava, bananas) exceeded the production by 20,200 tonnes or 25% for cereals and 14,100 tones or 2% for starches according to a FAO (1986) report that cited the National Food Strategy (1984).

Cattle, sheep, and goat numbers per farmer have declined during the last three decades in the wards that we surveyed (figure 8.2). The most likely cause of this decline is the conversion of open pasture areas to agricultural production. The sale of livestock fodder in the wards that we surveyed has increased dramatically between the 1960's and 1980's (table 8.1). In the 1960's, the sale of fodder was virtually nonexistent. In the middle agricultural zone, women and children must now travel up to 10 km in search of fodder. The price of fodder has also increased over time and currently varies between 50 Tshs. and 150 Tshs. per bundle depending on the season.

Table 8.1 Numbers of stations selling livestock fodder in the lowland zone of Old Moshi, Kirua Vunjo, and Kilema wards between the decades of 1960 through 1980.

Decade	Ward		
	Old Moshi	Kirua Vunjo	Kilema
1960	0	0	0
1970	0	1	0
1980	1	2	1

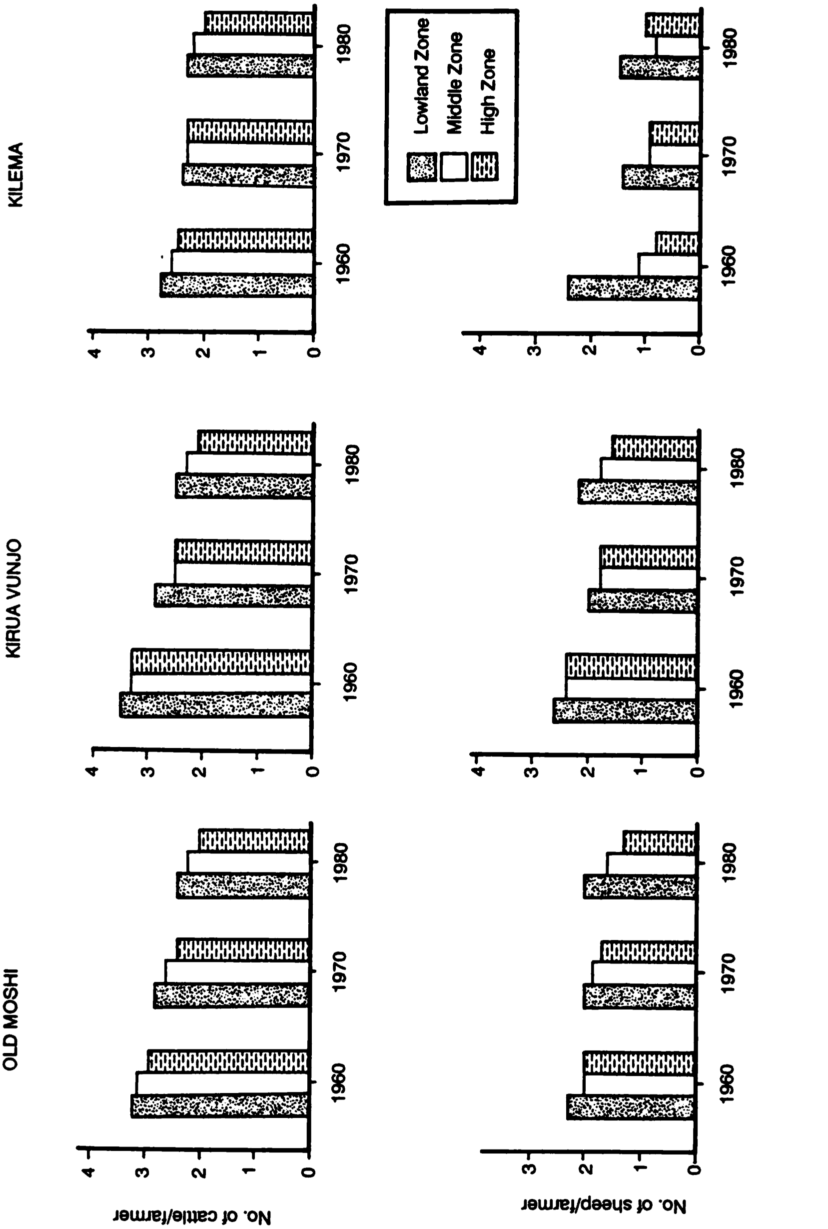
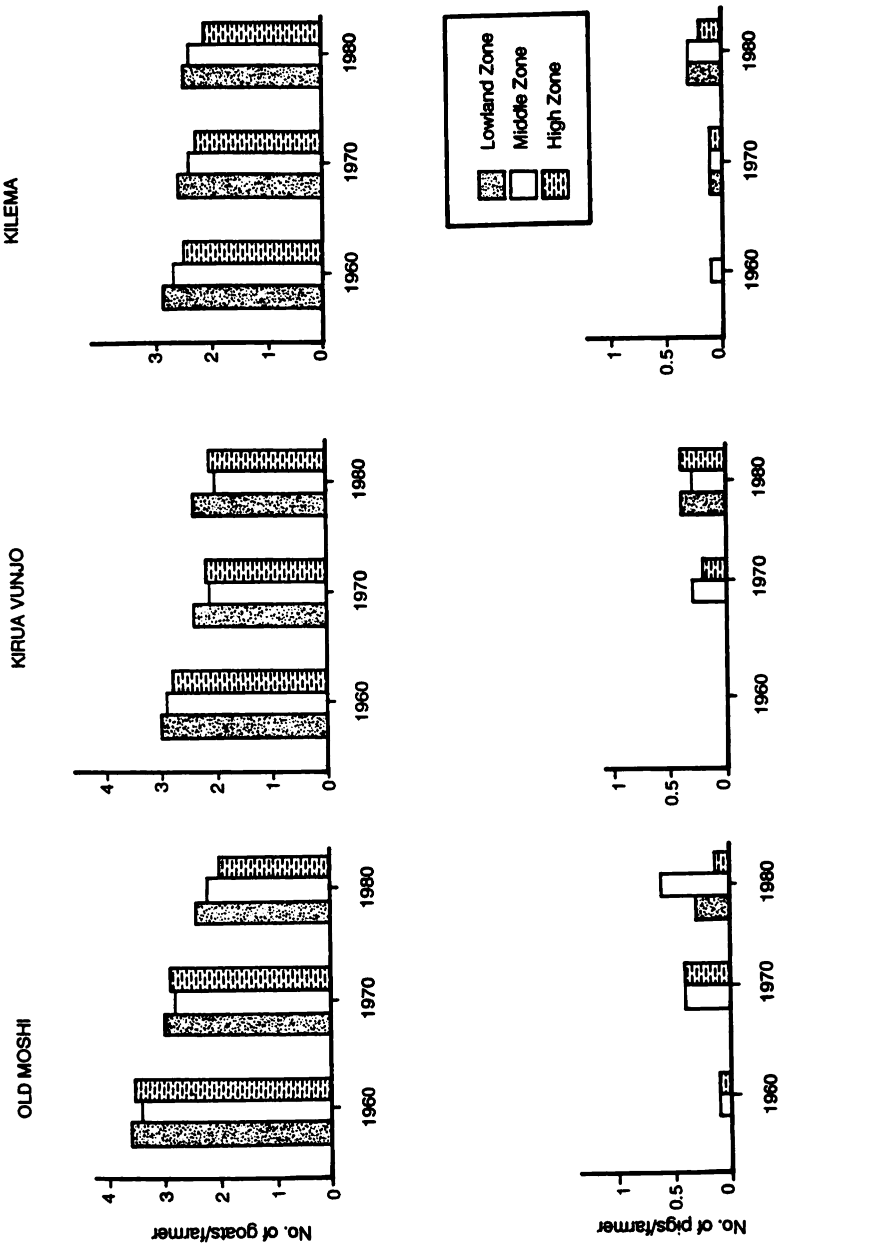


Figure 8.2 The number of cattle, sheep, goats, and pigs per farmer for the decades 1960, 1970, and 1980. Data are presented for the lowland, middle, and upper farming systems in the administrative wards of Old Moshi, Kirua Vunjo, and Kilema.


OLD MOSHI
KIRUA VUNJO
KILEMA
No. of goats/farmer
No. of pigs/farmer
1960
1970
1980
0
1
2
3
4
0.5
Lowland Zone
Middle Zone
High Zone

Although the number of cattle, sheep, and goats have declined between the 1960's and 1980's, the per capita numbers of pigs have increased in the wards that we surveyed (figure 8.2) principally because this type of livestock is less dependent on now scarce fodder and can utilize the brewery mash produced in brewing of the Chagga local brew.

Environmental impacts of the farming systems

As the human population has increased on Mount Kilimanjaro, the farming systems have expanded which has resulted in a variety of adverse environmental impacts. The repercussions from the agricultural expansion have been most pronounced in the lower agricultural zone.

During the early 1960's, there was a dramatic increase in the clearing of forests along river banks for expanded agricultural production particularly in the middle and upper zones. This resulted in many hills that were formerly forested being completely denuded as in the case of the region around Legho Mulo, Nanga, Sango, and Mbokomu. In addition, as pasture became scarce in the middle zone, increased grazing pressure and the collection of fodder were occurring along the river banks within this zone which prevented the natural regeneration of shrubs and trees that would otherwise stabilize the river banks. The loss of the forest cover along the river banks has resulted in extensive soil erosion and may have contributed to the intermittent nature of many rivers that were historically perennial (see Sarmett and Faraji, chapter 7). Hundreds of thousands of tons of soil are lost annually from the middle and upper altitudinal zones from soil erosion and much of this is deposited in the lower altitudinal zone or in many of the downstream dams such as Nyumba ya Mungu.

The areas that have been most affected by soil erosion in our survey are Mbokomu and Old Moshi. The Nanga and Mabungo streams which flow through this area contain water now only during the rainy season.

As agricultural activities and human settlements have expanded over time much of the wildlife that was formerly found along the slopes of Mount Kilimanjaro has disappeared. The loss of wildlife in the lowland zone has been particularly pronounced. In the recent past elephants, leopards, impala, and baboons were found in the lowland zone on the eastern, southern, and western sides of Mount Kilimanjaro. However by the mid-1970's this wildlife had virtually disappeared. Today, in the lowland zone these wildlife are found only on the northern side of Mount Kilimanjaro (Newmark *et al.*, chapter 5)

The use of pesticides and fungicides particularly in coffee production has adversely affected the soil fauna that are of critical importance in nutrient recycling and humus formation. The use of copper sulphate and other chemicals is known to eliminate many fungi and insects that play an important role in plant performance. In addition, DDT is still widely used as a pesticide although it has been banned in many other countries because of its health risks.

Many of these adverse environmental impacts can be mitigated through an active program of afforestation and regulation of chemicals. Trees and grasses should be replanted along the river banks, steep slopes, and open places on Mount Kilimanjaro. In addition, existing laws forbidding the cutting of trees adjacent to rivers and streams should be actively enforced.

Chapter 9

The history of the half-mile forestry strip on Mount Kilimanjaro

C.O. Kivumbi and W.D. Newmark

Abstract

The half-mile forestry strip on Mount Kilimanjaro has historically been a very important social forest. It was established in 1941 and was managed very successfully for 20 years by the Chagga Council during which the council emphasized the production of forest products for local use and for sell. In 1962, at time of independence the management of the half-mile forestry strip was transferred to the district councils which placed greater emphasis upon managing the half-mile forestry strip as a commercial forest. In 1972, the central government took control of the half-mile forestry strip and the primary objective of the management of the half-mile forestry strip became soil and water conservation. In 1987, the management of the half-mile forestry strip was transferred to the district councils who are currently managing the area for primarily forest products and watershed protection.

Introduction

The half-mile forestry strip (HMFS) on Mount Kilimanjaro is one of the oldest social and buffer forests in East Africa. It was established in 1941 under the Chagga Council to provide local people with wood and wood products. A review of the history* of the management of the HMFS on Mount Kilimanjaro is instructive in light of the current concern about the conservation of Mount Kilimanjaro. Such a review should be useful in providing forest managers with potential approaches towards improving the current management of the forest resources on Mount Kilimanjaro.

---

* Most of the pre-1946 history of half-mile forestry is taken from Baldwin (1946)

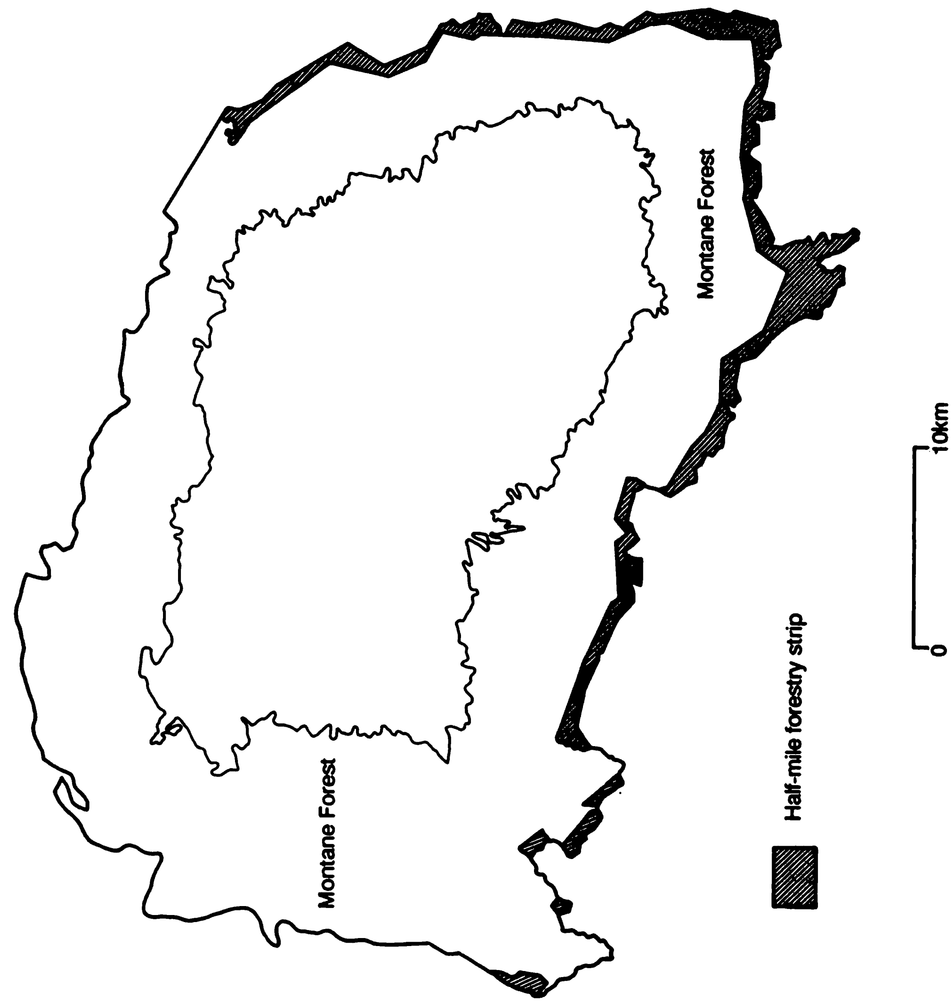


Figure 9.1 Location of the half-mile forestry strip on Mount Kilimanjaro.

Pre-1941 management of forests

The protection of the forests on Mount Kilimanjaro was initiated by the German colonial government in 1904 under the Forest Conservation Ordinance which converted nearly three-quarters of a million hectares of crown land into forest reserves (Schabel, 1990). The active management of the forests by the German colonial government on Mount Kilimanjaro began in 1908 with the establishment of a forestry office in Moshi. In 1921, the British colonial government gazetted the Kilimanjaro Forest Reserve (Wood, 1965a).

Under the colonial governments, the Kilimanjaro Forest Reserve was managed both for water catchment and for forest products. Forest products could only be collected with a valid forest license which meant that much of the traditional use of the forest by the Chagga was restricted.

With the establishment of the Kilimanjaro Forest Reserve and the transfer of the lands on the lower slopes of Mount Kilimanjaro to European colonialists, the Chagga were restricted particularly on the southern and eastern sides of Mount Kilimanjaro to a belt of land between the reserve and the European farms that ranged in width from a few hundred metres to four to five kilometres. It was during this period that many of the Chagga began to intensively plant trees on their farms.

In 1935, the forestry authorities began to work with the Chagga to establish black wattle *Acacia mearnsii* plantations on their lands for the purpose of building poles and tannin production. A total of 87 ha of black wattle plantations were planted on their lands during the late 1930's. However, it soon became apparent that the Chagga would not be able to meet all of their forest product needs from their own lands and thus the Chagga Council requested the colonial government provide a portion of the the Kilimanjaro Forest Reserve for use by local people.

Management of HMFS under Chagga Council

In August 1941, the colonial government approved the demarcation of a HMFS along the lower edge of the Kilimanjaro Forest Reserve for local use which was known initially as the Chagga Local Authority Strip. The area demarcated for local use stretched from the Kilelwa River on the eastern side around the southern side of Kilimanjaro to the Sanya River on the western side and covered an area of 8769 ha (figure 9.1). The width of the HMFS varied considerably from several hundred yards to several miles but averaged approximately one-half mile (.8 km), which thus has given its current name. Much of the original forest within the HMFS was of poor quality because of past exploitation and therefore an active afforestation programme was developed. However, of the original 8769 ha demarcated approximately half of this land was on slopes considered to be too steep to be afforested and therefore these portions of the HMFS were managed for watershed protection.

During the first two years following demarcation, the Chagga Council planted approximately 208 ha of forest using communal labour. However with the problems of maintaining free labour, the Chagga Council levied a forest-user tax of 50 cents in order to be able to hire full-time forest workers. Between 1944 and 1945 an additional 170 ha were planted. By the end of 1962 when the management of the HMFS was turned over to the Kilimanjaro district councils, a total of 450.4 ha of trees had been planted (table 9.1).

Within the HMFS a wide variety of trees species were initially planted for poles, timber, fuelwood, tannin, charcoal, quinine, and water conservation (table 9.1). The trees and the products from the trees were for both local use and sale. The tree species that were planted

Table 9.1 Hectares of tree species planted in the half-mile forestry strip between 1941–1962, 1963–1972, and 1987–1990.

Species	Period		
	1941 – 1962	1963 – 1972	1987 – 1990
Acacia mearnsii	52.2	35.8	-
A. melanoxylon	44.9	-	-
A. mollissima	47.6	30.0	-
Cryptomeria japonica	3.2	-	-
Cupressus lusitanica	98.6	26.7	129.1
Eucalyptus citriodora	23.6	19.2	-
E. maideni	20.0	1.0	-
E. resinifera	2.0	2.2	-
E. robusta	14.3	-	-
E. saligna	27.0	1.2	-
Grevillea robusta	3.9	-	-
Olea weltwitschii	.7	-	-
Pinus caribaea	2.4		-
P. patula	72.5	-	-
P. radiata	1.8	-	-
Pygeum africanum	3.8	-	-
Widdringtonia whytei	31.9	-	-
Total	450.4	116.1	129.1

for poles and fuelwood included *Eucalyptus saligna*, *E. robusta*, *E. resinifera*, *E. robusta*, *E. maidenii*, and *E. citriodora*. Additionally, *Pinus patula*, *P. radiata*, *P. caribaea*, *Cupressus lusitanica*, *Cryptomeria japonica*, and *Podocarpus spp.* were planted for timber while *Acacia mearinsii* was planted for tannin production. *Pygeum africanum* and *Rapanea spp.* were planted for purposes of water conservation while *Cinchona spp.* were established for quinine production. In addition, *Acacia melanoxylon* was planted to produce railroad ties while Milanje cedar *Widdringtonia whytei* was planted to provide decorative bows during the Christmas season.

The HMFS was managed by the Chagga Council as a social and buffer forest and emphasis was placed upon providing wood and wood products at a minimal price. In the harvesting of the black wattle for tannin, local people were permitted to collect after the bark was stripped the wood free of charge. The provision of wood and wood products at minimal cost was intended to compensate local people for their communal labour activities. Local people were also initially allowed to plant pyrethrum in the process of afforestation. The pyrethrum growers were required to pay rental fees which were in turn used to off set the cost of afforestation.

By providing the local people with most of the forest products at minimal cost, pressure that would otherwise have been placed on the remainder of the Kilimanjaro Forest Reserve was greatly reduced. The involvement of local people in the management of the half-mile buffer strip was probably very important in developing the current awareness by local people of the important hydrological values of the Kilimanjaro National Park and Forest Reserve (see Newmark and Leonard, chapter 10)

In the early stages of the HMFS, the Chagga Council provided the finances and labour for planting, thinning, and harvesting while the Central Government was responsible for providing and covering the expenses of the field supervisory staff. By the late 1950's, the Chagga Council had sufficient trained staff to take over the supervision of the HMFS. The Chagga Council was very successful in enforcing forestry regulations within the HMFS during this time period and in preventing the grazing of livestock and the felling of trees adjacent to streams and rivers outside of the HMFS. The Chagga Council had a special investigative unit to ensure that the forest workers themselves were abiding by all of the forestry regulations.

The financial management of the HMFS by the Chagga Council was quite sound even though the Chagga Council was receiving less royalties from their forest products than the central government. For many of the forestry products, the Chagga Council was receiving only one-quarter of the royalties that the central government was receiving. Between 1941 and 1961, the costs of the management were offset by the revenues generated from selling wood and wood products. In 1959, shortly before the HMFS was turned over to the district councils, the HMFS had a positive balance of £5,005.

Management under district councils and central government

In 1962 at time of independence, the management of the HMFS was turned over to the Kilimanjaro district councils. The emphasis in the management of the HMFS changed considerably under the district councils. The district councils during the 1960's were more interested in managing the HMFS as a commercial forest rather than a social forest because the district councils did not have the capability of controlling and managing the HMFS as did the Chagga Council. However because of the comparatively low rate of return from the HMFS, the district councils managed the HMFS less actively than the Chagga Council. A total of 116 ha of trees were planted by the districts councils in the HMFS between 1963 and 1972 (table 9.1).

With the abolishment of the district councils in 1972, the central government took over the management of the HMFS and the jurisdiction of the HMFS was placed within the South Kilimanjaro Catchment Project. The primary objective of the South Kilimanjaro Catchment Project was the promotion of soil and water conservation and thus it became difficult to address the previous social forestry objectives of the HMFS within this project. In addition, the personnel that were managing the HMFS during this time period had little expertise in plantation forestry.

The afforestation activities that occurred while the HMFS was managed as part of the South Kilimanjaro Catchment Project was restricted to enrichment planting in gaps in the forest adjacent to streams and rivers. Native species were used and they included *Albizzia spp.*, and *Rauvolfia caffra*, *Ficus sycommonrus*, and *Rytigynia spp.* (pers. comm., M.I.L. Katigula).

One effect of the transfer of the HMFS to the central government was that the HMFS was managed under ordinances governing national forest reserves and thus royalties for cutting trees within the HMFS were raised and local people were denied the privilege of collecting many forest products freely or at minimal cost as they had under the Chagga Council. This created considerable resentment among local people particularly since they had contributed considerably in terms of labour for planting and thinning of the trees, demarcating the boundary, and fighting fires. As a result many local people resorted to illegal cutting of trees and even arson.

In 1987, the management of the HMFS was handled back to the district councils of Hai, Moshi Rural, and Rombo. Part of the reason for the transfer from the central government to the district councils was to encourage the social forestry aspects of the HMFS. The district councils were also given the responsibility for setting royalties and selling forest products. The primary emphasis to date of these councils has been to improve the management of the commercial forests within the HMFS although watershed protection remains an important objective for the portions of the HMFS that are covered by native vegetation. A total of 129.1 ha of *Cupressus lusitanica* has been planted by Moshi Rural and Rombo districts between 1987 and 1990 (table 9.1). Unfortunately, the rate of tree felling is currently exceeding the rate of replanting in many areas even though emphasis has been placed upon the development of nursery stock.

Chapter 10

Attitudes of local people toward Kilimanjaro National Park and Forest Reserve

W.D. Newmark and N.L. Leonard

Abstract

We examine in this chapter the conservation attitudes of local people living adjacent to Kilimanjaro National Park and Forest Reserve (KNP/FR). A questionnaire was distributed to 206 local people.

Over 84% of local people surveyed are opposed to the abolishment of KNP/FR. Support or opposition to the abolishment of KNP/FR by local people is expressed in utilitarian values. Of the individuals that are opposed to the abolishment of the reserve, the most common justification for their opposition is that KNP/FR protects the watershed on Mount Kilimanjaro (55% of all responses) while the second most common justification is that the reserve generates revenue through tourism (17% of all responses). Additionally, 63% of local people feel that poachers are people who are breaking the law.

We then examine how resource use patterns and problems and past interactions with KNP/FR affect conservation attitudes using two models. Under model one, the 'no response' answers to questions regarding attitudes toward conservation are excluded. Under model two, the 'no response' answers are combined with the positive response to abolishing KNP/FR and the negative response to viewing poachers as people who break the law. Affluence is an important factor influencing attitudes toward the abolishment of KNP/FR. More affluent individuals are more likely to oppose the abolishment of KNP/FR. In addition, individuals who have experienced problems of theft are less likely to condone poaching.

Introduction

Virtually all major problems facing protected areas worldwide contain a human component. In Tanzania, the most common problems confronting protected area managers are poaching, wildfires, illegal gathering of wood and building poles, and human encroachment within the

Table 10.1 Questions asked of local people to examine conservation attitudes, resource use patterns and problems, and past interactions with KNP/FR protected area.

Attitudes toward KNP/FR and people who poach

1a. How would you feel if Kilimanjaro National Park were abolished?
1b. Why?
2. Do you view poachers as people breaking the law?

Resource use patterns and problems

3. How long have you lived here?
4. How big is your parcel of land?
5. How far do you have to walk to collect water?
6. How often do you collect water per day?
7. How often do you slaughter a cow, goat, sheep, or chicken?
8. How often do you eat meat per month?
9. Do you sell any of the slaughtered livestock/poultry or do you eat it all?
10. What crops do you grow?
11. What types of problems do you have with your crops?
    a. poor soil
    b. soil erosion
    c. disease/insects
    d. too much or too little rain
    e. flooding
    f. insufficient land
12. What types of problems do you have with your livestock/poultry?
    a. predators
    b. disease/parasites
    c. insufficient land for grazing
    d. theft

Past interaction with the KNP/FR and KNP/FR managers

13a. Has anyone from Kilimanjaro National Park ever come to your village?
13b. And if so for what reason?
14a. Do wildlife cause you problems?
14b. And if so what types of problems?
15. What species of wildlife cause you problems?
16. Are measures you take to control wildlife effective?

protected area. All of these problems involve people and most frequently involve local people. Thus, it is not surprising that a common belief among the general public both within and outside of Tanzania is that local people are opposed to conservation.

This chapter presents results that suggest local people strongly support the presence of Kilimanjaro National Park and Forest Reserve (KNP/FR) and have an appreciation of the hydrological importance of this protected area and its capacity to generate foreign exchange for the country. Additionally, local people do not condone poaching.

Methods

Local conservation attitudes were assessed using a questionnaire. The questionnaire was designed to examine two factors: firstly, the attitudes of local people toward the abolishment of KNP/FR and poaching; and secondly whether conservation attitudes are influenced by current resource use patterns and problems and/or past interactions with the protected area. Local people were asked 16 open ended and fixed response questions (table 10.1). Questions related to resource use patterns and problems were placed at the beginning of the questionnaire in order to encourage an open discussion between the interviewee and the interviewer.

Interviews were conducted by Diploma II students from the College of African Wildlife Management during April and May of 1988. The students interviewed a total of 206 adults in 20 villages within 12 km of the reserve boundary. All interviews were conducted in Swahili however the answers were recorded in English.

Although all questions that referred to a specific protected area were stated in terms of Kilimanjaro National Park (table 10.1), local people generally do not make distinction in terms of the administration of Kilimanjaro National Park and Kilimanjaro Forest Reserve. We therefore interpret all responses as referring to the both Kilimanjaro National Park and Kilimanjaro Forest Reserve.

In the cross tabulation analysis, we used two models. Under model one, the 'no response' answers to questions 1a and 2 (table 10.1) were excluded from the analysis. Under model two, the 'no response' answers were lumped with a positive response to the abolishment of KNP/FR and a negative response to viewing poachers as people breaking the law. It was assumed under model two that individuals who did not answer questions 1a or 2 held either neutral or negative conservation attitudes. Cross tabulation analyses were conducted using Students T and Chi-square tests.

There are three potential sources of bias in our results. Firstly, a relatively small geographic area around Mount Kilimanjaro was surveyed. Questionnaires were distributed in villages within walking distance of the College of African Wildlife Management, Mweka. We feel that this potential bias is not serious for two reasons. Firstly, the majority of the people living around the base of Mount Kilimanjaro are located along the eastern and southern sides of the mountain and thus the people living adjacent to College of African Wildlife Management should be representative of the wider population. And secondly, the results for the KNP/FR do not differ from the results recorded for five other protected areas in Tanzania (Newmark *et al.*, in press).

A second potential source of bias is that it was not possible to 'randomly' select interviewees because of the lack of complete population lists for the villages. Interviewees were selected on the basis of chance encounter in the village which may have induced a limited statistical bias in our results.

A third potential source of bias that may be affecting our results was that students from the College of African Wildlife Management, whom the local people may view as potential authoritarian figures, administered the questionnaire. Thus local people possibly may not be freely expressing their feelings. Though it is very difficult to estimate the extent to which response bias may be affecting our results, we feel that our results reflect quite accurately the opinion of local people because the attitudes of local people living adjacent to KNP/FR are consistent with the attitudes of local people living adjacent to five other protected areas in Tanzania (Newmark *et al.*, in press), Rwanda (Weber, 1986) and Natal Province in South Africa (Infield, 1988).

Results

Local people living adjacent to Kilimanjaro National Park and Forest Reserve strongly oppose its abolishment. 84% of the local people surveyed oppose the abolishment of KNP/FR (table 10.2). This strong opposition to the abolishment of KNP/FR is contrary to much common belief that local people in Tanzania oppose the establishment of protected areas. Our findings are also consistent with other recent studies regarding the attitudes of local people toward the establishment of protected areas in Africa (Pennington, 1983; Harcourt *et al.*, 1986; Leonard, 1987; Infield, 1988; Newmark *et al.*, in press)

Table 10.2 Responses to questions related to attitudes toward conservation.

Question	Response	%	N
1a – Abolish KNP/FR	yes	8.7	18
	no	84.5	174
	no response	6.8	14
2 – Poachers are law breakers	yes	63.1	130
	no	20.9	43
	no response	16.0	33

Pennington (1983) reported in a survey of 527 Tanzanian secondary school students that 81% of the students were opposed to using national park land for crops. Additionally, Infield (1988) found that only 6% of the local people living adjacent to the Umfolozi/Hluhluwe/Corridor Complex Game Reserve in Natal, South Africa support the abolishment of the conservation area. Furthermore, Harcourt *et al.* (1986) stated that over three-quarters of farmers living adjacent to a national park in Rwanda are opposed to the government making the land available to cultivation.

Local people living adjacent to KNP/FR also have a relatively high level of understanding as to the regional importance of KNP/FR. The most frequent justification given by people for their opposition to the abolishment of KNP/FR (table 10.3) is that the reserve protects the watershed on Mount Kilimanjaro (55% of all responses) while the second most frequent justification is that the reserve earns valuable foreign exchange for the nation (17% of all responses). The third most frequent justification given by local people for their opposition to the abolishment of KNP/FR is that the reserve protects wildlife (6% of all responses).

The emphasis by local people in explaining their support for KNP/FR in utilitarian terms is a reflection of what is most salient to them. Local people require water, imported fertilizers, and pesticides in order to grow most of their crops (see table 10.4 for resource use problems) and thus the expression by local people of support for KNP/FR in terms of watershed protection and the generation of foreign exchange is a reflection of these needs. Conversely, the relatively low expression of support for KNP/FR in terms of wildlife protection is most likely a result of the comparatively low utility of wildlife to most local people. Additionally, most interactions of local people with wildlife are negative. Over 69% of all local people living adjacent to KNP/FR report problems with wildlife (table 10.5).

Table 10.3 Justification for support or opposition to the abolishment of Kilimanjaro National Park and Forest Reserve.

Position	Reason	%	N
Support KNP/FR	protects watershed	55.1	109
	earns foreign exchange	17.2	34
	protects wildlife	6.1	12
	future generations	3.5	7
	provides employment	2.5	5
	natural heritage	1.0	2
	important cultural site	.5	1
	other	13.1	26
	no response	1.0	2
Oppose KNP/FR	need land	66.7	12
	access to timber	27.8	5
	no response	5.6	1

The highly utilitarian justification by local people of their support for KNP/FR is also consistent with findings by Pennington (1983) who reported that 96% of the 600 secondary school children that she interviewed stated that the purpose of national parks in Tanzania is to earn foreign exchange for the government.

Of the people who favour the abolishment of the KNP/FR, the justification is also couched in utilitarian terms (table 10.3). Two-thirds of those individuals who favour the abolishment of KNP/FR state that the abolishment would provide more land for farming and grazing while one-quarter state that they would then be permitted to gather firewood and building poles in this area.

Table 10.4 Resource use patterns by local people living adjacent to Kilimanjaro National Park and Forest Reserve.

Question		X̄	N
3 – length of residency (years)		41.2	201
4 – size of land (ha)		1.7	198
5 – distance to collect water (m)		91.8	181
6 – frequency of water collection per day		3.7	159
7 – frequency of slaughtering livestock per year		9.2	131
8 – frequency of eating meat per month		8.0	187
Question	**Response**	**%**	**N**
9 – use of meat	sell all	7.8	16
	eat all	41.3	85
	sell + eat	21.4	44
	no response	29.6	61
10 – crops	cash	1.5	3
	subsistence	4.9	10
	cash + subsistence	88.8	183
	no response	4.9	10
11a – poor soil	yes	5.3	11
	no	83.5	172
	no response	11.2	23
11b – erosion	yes	12.6	26
	no	77.2	159
	no response	10.2	21
11c – crop disease and insects	yes	84.0	173
	no	10.2	21
	no response	5.8	12
11d – problems with rain	yes	3.9	8
	no	85.9	177
	no response	10.2	21
11e – flooding	yes	6.8	14
	no	82.0	169
	no response	11.2	23
11f – too little land	yes	89.8	185
	no	7.8	16
	no response	2.4	5
12a – problems with predators	yes	25.2	52
	no	64.6	133
	no response	10.2	21
12b – livestock disease and insects	yes	63.1	130
	no	30.6	63
	no response	6.3	13
12c – lack of grazing land	yes	75.7	156
	no	20.4	42
	no response	3.9	8
12d – theft of livestock	yes	24.3	50
	no	63.6	131
	no response	12.1	25

Table 10.5 Past Interactions with KNP/FR and KNP/FR managers by local people living adjacent to KNP/FR.

Question	Response	%	N
13a – past visit by KNP/FR employees	yes	4.4	9
	no	94.7	195
	no response	1.0	2
13b – reason for visit	discuss problems	.5	1
	shopping	2.9	6
	drinking	1.5	3
	no response	96.1	198
14a – wildlife problems	yes	69.4	143
	no	27.2	56
	no response	3.4	7
14b – type of wildlife problem	damage crops	67.5	139
	kill livestock	4.9	10
	no response	26.7	55
15 – problem species	monkeys	44.4	116
	bushpig	9.6	25
	rodents	8.8	23
	birds	6.5	17
	mongoose	4.2	11
	leopard	1.5	4
	no response	24.9	65
16 – wildlife control measures effective	yes	37.9	78
	no	42.2	87
	no response	19.9	41

The opposition by local people to the abolishment of KNP/FR is consistent with their attitudes toward people who poach. Over 63% of those interviewed agree with the statement that people who poach are breaking the law. The principal form of poaching in KNP/FR is the illegal gathering of firewood and cutting of timber according to the monthly warden reports for Kilimanjaro National Park. The generally lower level of opposition to poaching than to the abolishment of KNP/FR is probably a result of the widespread need of local people for firewood and building material.

The attitude of local people living adjacent to KNP/FR that people who poach are breaking the law is consistent with the attitudes of local people living adjacent to Mikumi and Lake Manyara national parks and the Selous Game Reserve (Newmark *et al.*, in press).

Factors affecting attitudes toward abolishment and poaching

In order to examine whether resource use patterns and problems and past interactions with KNP/FR influence attitudes toward conservation, we examine whether resource use patterns and problems and past interactions with KNP/FR differ between individuals who hold 'positive' conservation attitudes from individuals who hold 'negative' conservation attitudes.

Affluence is the factor that most consistently differentiates individuals who oppose the abolishment of KNP/FR from individuals who support the abolishment of KNP/FR (table 10.6). Under model one, individuals that oppose the abolishment of KNP/FR ate significantly more meat per month ($p < .001$) and slaughtered significantly more animals per year ($p < .001$) than individuals that support the abolishment of KNP/FR (table 10.6). Similarly under model two, individuals that oppose the abolishment of KNP/FR ate significantly more meat per month ($p < .008$) than those individuals that support or hold neutral attitudes toward the abolishment of KNP/FR (table 10.6). The frequency with which someone eats meat per month and can afford to slaughter an animal is related to the affluence of an individual which suggest that more affluent individuals are less likely to support the abolishment of KNP/FR than more affluent individuals.

The importance of affluence in affecting attitudes toward the abolishment of KNP/FR is consistent with results of Infield (1988) who reported that more affluent households living adjacent to the Umfolozi/Hluhluwe/Corridor Complex Game Reserve in Natal, South Africa consistently held more positive attitudes toward conservation. The importance of affluence in affecting attitudes toward the abolishment of KNP/FR is probably a result of at least two factors. Firstly, affluence affects the relative dependency of an individual upon a resource. Individuals who are very poor and whose immediate survival depends upon utilizing a resource can not afford to conserve. Conversely, individuals that are more affluent have the option of conserving for today so as to consume tomorrow (Infield, 1988). Secondly, more affluent

Table 10.6 The effect of affluence on attitudes toward abolishment of Kilimanjaro National Park and Forest Reserve under models one and two.

Model One

	Abolishment of KNP/FR				
	Support		Oppose		
Question	$\bar{X} \pm SD$	(N)	$\bar{X} \pm SD$	(N)	p
7 – frequency livestock is slaughtered per year	2.2 ± 2.2	5	9.4 ± 12.2	118	<.001
8 – frequency of eating meat per month	1.7 ± .8	12	8.6 ± 8.1	162	<.001

Model Two

	Abolishment of KNP/FR				
	Support/Neutral		Oppose		
Question	$\bar{X} \pm SD$	(N)	$\bar{X} \pm SD$	(N)	p
8 – frequency of eating meat per month	4.1 ± 5.0	25	8.6 ± 8.1	162	<.008

individuals are normally better educated and it is documented that individuals with higher levels of education are generally more likely to support conservation (Pennington, 1983; Infield, 1988).

Tables 10.7 The effect of affluence and resource use problems on attitudes toward people who poach under models one and two.

Model One

Question	Response	Attitudes toward people who poach: Breaking the law %	N	Not Breaking the law %	N	p
12d – theft of livestock	yes	36.2	42	8.8	3	<.005
	no	63.8	74	91.2	31	
15 – wildlife control measures effective	yes	44.2	46	66.7	28	<.024
	no	55.8	58	33.3	14	
		$\bar{X} \pm SD$	N	$\bar{X} \pm SD$	N	p
4 – size of land (ha)		1.6 ± .9	125	2.4 ± 1.9	43	<.001

Model Two

Question	Response	Attitudes toward people who poach: Breaking the law/Neutral %	N	Not Breaking the law %	N	p
12d – theft of livestock	yes	36.2	42	12.3	8	<.002
	no	63.8	74	87.6	57	

Personal problems with theft is the most consistent factor that differentiates individuals who view poachers as people who are breaking the law from individuals who do not view poachers as people who are breaking the law. Under model one, local people who feel that people who poach are breaking the law report significantly more frequently ($p < .005$) that they experience problems of theft of livestock than those who do not feel that people who poach are breaking the law (table 10.7). Similarly under model two, local people who feel that people who poach are breaking the law report significantly more frequently ($p < .002$) problems of theft of livestock than individuals who hold neutral attitudes or who feel that people who poach are not breaking the law (table 10.7).

Although greater affluence appears to be associated with opposition to the abolishment of KNP/FR, paradoxically under model one but not under model two greater affluence among local people living adjacent to KNP/FR appears also to be associated with greater tolerance toward viewing individuals who poach as not breaking the law (table 10.7). Under model one, individuals who do not feel that people who poach are breaking the law owned significantly more land ($p < .004$) than individuals who do feel that people who poach are breaking the law (table 10.7). This correlation may be a result of the linkage of affluence with education which in turn is normally associated with greater social tolerance. However, this result contradicts our findings from Mikumi and Lake Manyara national parks and the Selous Game Reserve. Less affluent individuals living adjacent to these protected areas are more likely to view people who poach as not breaking the law (Newmark *et al.*, in press). However, ecological and social differences between KNP/FR and Mikumi and Lake Manyara national parks and the Selous Game Reserve may be responsible for the differences between these reserves. Poaching in the latter parks is primarily for meat and not for firewood.

Finally under model one though not under model two (table 10.7) individuals who feel people who poach are breaking the law are less likely to report that they are effective in controlling wildlife ($p < .03$) than individuals who feel that people who poach are breaking the law. While this latter relationship may be spurious, it could however be a reflection of greater affluence among the former group which as suggested above is linked frequently with greater social tolerance. That is, individuals that own more land have a greater difficulty in controlling wildlife because they must control wildlife in a larger area and thus they tend to report that they are less successful in their efforts.

Nonetheless, we feel that the importance of affluence as a factor influencing attitudes of local people toward people who poach be interpreted cautiously because of the lack of concordance between models one and two and between KNP/FR and Mikumi and Lake Manyara national parks and the Selous Game Reserve.

Implications for the management of KNP/FR

These results suggest that local people living adjacent to KNP/FR strongly oppose the abolishment of the protected area, view people who poach as breaking the law, and recognize the hydrological importance of KNP/FR and its capacity to earn foreign exchange.

Projects in the future that may be designed to promote the conservation of Mount Kilimanjaro should make use of this support. However, a recognition of the important hydrological functions of KNP/FR by local people does not necessarily mean that local people will not continue to gather firewood and building poles within KNP/FR. Alternative sources for fuel and building material must be provided to local people. Future woodlot or soil conservation projects should emphasize that the planting of trees at the village level which will reduce the dependency of local people upon wood from KNP/FR and will promote the water catchment capacity of the mountain.

Acknowledgements

We thank the 1988 Diploma II students for conducting the questionnaire and J. Chuwa for data entry.

Chapter 11

An ecological approach to the inventory and monitoring of rainforest catchments in Tanzania

J.E. Bjørndalen

Abstract

Rainforests cover less than 2% of Tanzania's land surface, but are the primary water source for the country. There is much concern at present regarding the future of the natural catchment forests in Tanzania, their highly diversified biota, and their important water resources. A proposal for an inventory and monitoring programme for rainforest catchments is presented. The importance of the Mount Kilimanjaro catchment system is emphasised.

Introduction

The management of catchment forests is currently being widely discussed in Tanzania and many other tropical countries. Catchment forests are critical because they regulate the water balance, prevent soil erosion, provide high quality water to human populations, and are the habitat for many rare and endemic plants and animals. Most of the important catchment forests in Tanzania are submontane and montane rainforests and are located in the Eastern Arc Mountains of old, crystalline bedrock (e.g., Pare Mountains, Usambara Mountains, Nguru Mountains, Uluguru Mountains, and Uzungwa Mountains) and in isolated volcanic mountains such as Mount Kilimanjaro, Mount Meru and the Ngorongoro Crater. Despite covering an area of less than 2% of Tanzania's land surface these forests assure a steady water supply to most of the major cities (e.g., Dar es Salaam, Morogoro, Tanga, Moshi, Arusha) and densely populated areas in Tanzania. Although many important catchment forests are set aside as forest reserves and national parks such as Mount Kilimanjaro, many of these are still threatened by increasing human impacts such as cultivation, grazing, and pitsawing.

What is catchment forestry?

Catchment forestry deals with (1) the management of forested watersheds in order to maintain and/or improve their water capacity; (2) the preservation of biological diversity; and (3) the production of timber from indigenous species and other forest products for local consumption and sustainable utilization. As a result of the broad objectives for which catchment forests are managed, the inventory and monitoring of these forests require close cooperation between several scientific fields such as ecology, taxonomy, hydrology, meteorology, soil sciences, silviculture, and social sciences. Catchment forestry includes aspects which are seemingly difficult to combine: nature conservation with resource utilization and economic development.

And who is the catchment forester – the silviculturist or the ecologist? In fact, both professional groups are needed and they complement each other. The *silviculturist* has ideas about enrichment and border planting, the use of indigenous species for catchment afforestation, silvigenetics, and the raising of tree seedlings from nurseries. The *ecologist* has ideas about biological diversity, structure and function of the rainforest ecosystems, the interactions between biotic and abiotic factors, and changes in ecosystems due to natural processes and human impacts.

Goals for a catchment forest inventory

The goals for a scientific inventory of natural rainforests serving as catchment systems are: (1) to provide a documentation of the catchment value and hydrological properties of the forest; (2) to elucidate the rainforest ecosystem and the diversity of the biota; and (3) to document changes in ecological and hydrological parameters caused by human influence.

Research and monitoring in catchment forests

Research and monitoring are needed in order to achieve the above goals. The basic technique is to establish permanent plots and study sites which allow a variety of researchers to carry out specific investigations over a long period of time. A maintained network of permanent plots can be valuable for monitoring long-term changes in the ecosystem and the hydrological parameters. The plots should be properly marked and should be designed so as to permit multipurpose use and random sampling techniques. In other rainforest regions such as Latin America and Southeast Asia a relatively few intensively investigated areas have provided a considerable proportion of our knowledge about rainforest ecology and rainforest biota.

In addition to a system of permanent plots, the use of remote sensing techniques including the interpretation of aerial photos and satellite imageries is useful in monitoring the overall changes in the forest cover in and around the forest reserves and may form the basis for vegetation maps and other thematic maps (see Lamprey *et al.,* chapter 2).

Topics to be studied

Table 11.1 outlines the types of research that are needed to contribute to the knowledge of the proper management of natural catchment forests. This research includes elements of biology, hydrology, climatology, and soil sciences. It is important also to consider the local socio-economic environment because of the obvious relationship between the forest and local communities (water supply, sustainable use of forest products, negative human impacts) as well as the silvicultural and land use aspects of the catchment forest. The wide possibility of topics to be studied illustrates the extreme complexity of managing a catchment forest. Most of this presentation is derived from a suggestion for a scientific inventory of a catchment area with submontane/montane rain forest in the Nguru Mountains in the Morogoro Region of Tanzania (Bjørndalen, 1990).

Comprehensive inventory – realism or utopia?

The comprehensive and somewhat idealistic inventory of natural catchment forests as outlined in table 11.1 requires a large staff of scientists and students and adequate long-term funding. The relative importance of the topics will vary and thus priorities are necessary. A national and international network of scientists who are interested in working on the inventory and monitoring of catchment forests needs to be identified and their research should be encouraged through various channels.

It is important to coordinate and stress the multidisciplinary nature of the inventory. Knowledge will be gained incrementally over several years based on multipurpose research in selected rainforest catchments. Such areas will serve as important reference localities for future research, teaching, and management.

Currently, the political climate for carrying out and funding environmental studies of tropical forests is very favourable, especially as a consequence of the Brundtland Commission Report. Many European development organizations such as NORAD, SIDA, DANIDA, FINNIDA, and EEC, are supporting various forest projects with ecological implications in Tanzania. A comprehensive programme for the management of the Eastern Arc forests will soon be initiated by the Forestry and Beekeeping Division. Thus, very important and well defined steps are being taken towards implementing the Tanzania Tropical Forestry Action Plan.

Much information about vegetation, flora, fauna, and to a certain extent ecological relationships is already available from many important catchment forests in Tanzania. The Usambara Mountains have been extensively investigated since the classical work of Moreau (1935). A comprehensive study of the East Usambara Mountains has been recently presented by Hamilton and Bensted-Smith (1989), and valuable information will also be available in the symposium proceedings from the Usambara Integrated Rainforests Project held in Morogoro in 1989 (Hedberg and Hedberg, 1990). Information about the forests on Mount Kilimanjaro has been included in works by Hedberg (1951), Salt (1954), Greenway (1965), Hamilton (1982), Hermansen *et al.*, (1985), and chapters presented in this book. Pócs (1974, 1976a, 1976c, 1980) and Pócs *et al.*, (in press) have published a series of papers about the vegetation of the Uluguru and Nguru mountains. Polhill (1968) has proposed conservation measures proposals for many other of the most biologically important forests in Tanzania while Rodgers and Homewood (1982) have evaluated the biological conservation values of the Uzungwa Mountains. Of the more general papers dealing with natural catchment forests in Tanzania, papers by Pócs (1982c, 1988), Hermansen *et al.*, (1985), Lovett (1985), and Bjørndalen (in press) can be mentioned.

Table 11.1 Data useful for the inventory and monitoring of rainforests serving as catchment forests (after Bjørndalen, 1990).

Water relationships/forest hydrology.

- amount and seasonality of precipitation
- fog condensation
- crown interception
- throughfall
- stemflow
- role of epiphytes in capturing and retarding water movement
- evapotranspiration from the vegetation
- evaporation from the soil.
- water infiltration into soil
- chemical and physical properties of the soil
- thickness of leaf litter
- decomposition processes
- role of mycorrhiza and the root systems of forest trees
- ground water movement
- surface runoff
- discharge

Flora

- structure
- main vegetation types
- floristic composition
- cover and abundance of individual species
- ecological characteristics
- altitudinal zonation
- dependent life forms (epiphytes, lianas, climbers, etc.)
- succession and gap regeneration
- vegetation mapping
- checklists (vascular plants, bryophytes, lichens, fungi)

Fauna

- abundance
- distribution
- checklists (mammals, birds, reptiles, amphibians, selected invertebrate groups)

Ecological relationships

- bioclimatic relationships
- ecophysiological relationships
- mutualism
- competition
- epiphytism
- parasitism
- pollination
- dispersal biology
- herbivory
- chemical defence mechanisms

Physical environment

- climate
- geology
- topography
- hydrology
- soils
- soil erosion

Silvicultural management

- border planting demarcation
- enrichment planting
- properties of indigenous species

Land use

- land use patterns and trends
- impact of present land use patterns on catchment forest

Extension activities

- transmission of knowledge to local, regional, and national authorities
- transmission of knowledge to local people
- participation of local people
- agroforestry
- village woodlots

The data collected in the inventory and monitoring of a catchment forest must be presented in a form which is useful for other scientists, students, catchment forest personnel, and decision makers. Only a broad ecological understanding throughout all of society can guarantee the sustainable utilization and management of the natural catchment forests and assure that the forests of Mount Kilimanjaro and other mountains will continue to supply water in the future.

The synthesis of the results derived from the various detailed investigations is a very important foundation for management plans for natural catchment forests. However, the implementation of plans depend frequently upon political and socio-economic conditions which are often beyond the control of the scientists.

There are also many practical limitations to the implementation of management plans for catchment reserves. They include the lack of trained and motivated personnel, insufficient funding for transport and for equipment to patrol the reserves, administrative problems, conflicting political interests, and the need for the cooperation and understanding of local people (they often lack information, knowledge, and alternatives). Another serious limitation lies in the illegal felling of trees. But the most important limitation for a successful, operating management plan is probably that much of the basic ecological knowledge about the rainforest ecosystem is missing.

The importance of the catchment forests on Mount Kilimanjaro

Mount Kilimanjaro is one of the most important catchment areas in Tanzania. The Pangani River Basin, one of the most economically important river basins in Tanzania, has its origin in part on the slopes of Mount Kilimanjaro. The water from the Pangani River and its tributaries is used extensively for irrigation of cash crops (e.g., sugar cane, coffee, sisal) and to generate hydroelectricity (e.g., Nyumba ya Mungu, Pangani Falls, and Kikuletwa power stations) throughout northern Tanzania. Thus, the degradation of the rain forest on Mount Kilimanjaro has effects far beyond the local environment.

Alarming signs of deterioration of the montane forest on Mount Kilimanjaro exist. More than 6% of the natural forest has been converted to softwood plantations. This has resulted in the natural forest being split into two relatively isolated blocks (Lamprey *et al.*, chapter 2). In addition, there has been extensive loss of natural vegetation within the forest reserve on Mount Kilimanjaro. However, this loss is less easy to document using remote sensing techniques. The increasing isolation of Kilimanjaro National Park and Forest Reserve has contributed to the local extinction of several large mammals while forest conversion may have permitted several large mammals species not found historically on Mount Kilimanjaro to colonize the reserve (Newmark *et al.*, chapter 5). Additionally, even if hydrological records are not continuous, there are indications of a decrease in the dry season runoff patterns during the last decades of some of the rivers on Mount Kilimanjaro (Sarmett and Faraji, chapter 7).

The importance of preserving the montane rain forest on Mount Kilimanjaro is obvious. Only the intact rain forest can sustain the intricate process of water movements through vegetation and soil. The conservation of the bryophytes and lichens on the stems, branches, and twigs of the woody plants in the upper montane zone is particularly important in order to ensure the interception of large amounts of rain water (Pócs, chapter 4).

The biological values of Mount Kilimanjaro are generally well known and information about the flora and fauna can be found in papers by such authors as Hedberg (1951), Salt (1954), Greenway (1965), and Lamprey (1965) as well as various chapters in this book. Hermansen *et al.,* (1985) have also recently produced a vegetation map of the Himo watershed on Mount Kilimanjaro.

A comprehensive inventory and monitoring programme for the catchment forests on Mount Kilimanjaro should be given a high priority. The pressure on the forests and waters resources of Mount Kilimanjaro will continue to increase and thus there is a need to preserve the catchment forests *now*.

Chapter 12

The importance of Mount Kilimanjaro and the need for its integrated management and conservation

S.B. Misana

Abstract

This chapter examines the importance of Mount Kilimanjaro and the need for its integrated management and conservation. Mount Kilimanjaro is a highly productive area, however, intensive use has led to over-exploitation of resources and subsequent degradation in some areas of the mountain.

The importance of Mount Kilimanjaro stems from its rich natural resource base. A combination of good soils and favourable climate have given rise to spectacular development in agriculture. The forests of the mountain serve a number of vital functions including safeguarding and ensuring a stable supply of water for irrigation and domestic use, prevention of soil erosion and flood damage, windbreaking, temperature moderation, and drought prevention. Furthermore, the spectacular scenery of the snow-capped Kibo Peak makes Mount Kilimanjaro one of the major tourist attractions in the country.

However, because of population pressure on the resources and the fragility of the ecosystem, Mount Kilimanjaro is experiencing serious deforestation, soil erosion and general land degradation. In order to reverse this trend, the formulation of an integrated management and conservation programme should be developed. Such a programme needs to combine the conservation of natural resources with the provision of basic resource requirements of adjacent communities. Additionally an integrated research programme should be developed that would provide the scientific basis for the development of an integrated management and conservation programme for Mount Kilimanjaro.

Introduction

Mount Kilimanjaro is a mountain ecosystem that has unique resources and many opportunities for the development of its people, the surrounding areas, and the nation as a whole. With its

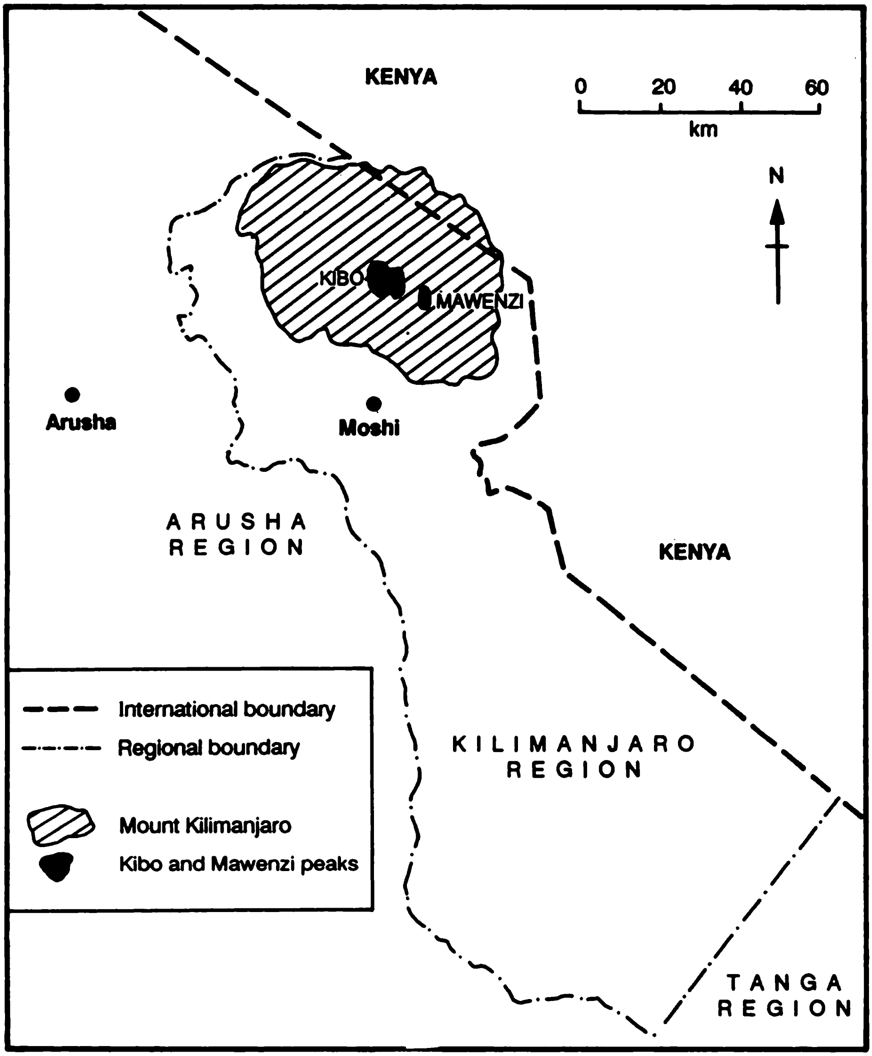


Figure 12.1 Location of Mount Kilimanjaro.

fertile soils and favourable climate, the mountain is a concentration of human settlements and intensive human use of natural resources. The mountain is also a focal point for tourism because of its high scenic value.

According to Maro (1988), mankind has intensively managed and utilized land, water, and other resources on Mount Kilimanjaro for over a century and a half and has achieved as a result a very high and stable standard of living. The mountain features clear highland-lowland gradients and interactions between natural and human systems. There are also important ecological-agricultural gradients and socio-economic interactions with the surrounding lowlands.

Mount Kilimanjaro is a highly productive but fragile area in which the intensive land use has led to over-exploitation of resources and subsequent degradation in some parts of the mountain. Given that Mount Kilimanjaro is one of the most agriculturally productive areas in the country and that the mountain offers unique resource development and conservation possibilities, it is important to maintain the valuable natural resource base for the economic progress of the region and the entire country. This calls for the development of appropriate management strategies and their effective integration into the resource use decision making process.

This chapter examines the importance of Mount Kilimanjaro in the socio-economic development of the Kilimanjaro Region and the need for its integrated management and conservation. It also outlines research priorities for the sustainable development of the area.

The physical resource base of Mount Kilimanjaro

The importance of Mount Kilimanjaro stems from its rich natural resources base and that it is the region's primary natural resource. Its varied relief, climate, vegetation, and soils have led to land use differentiation.

Relief and drainage

Mount Kilimanjaro located in northeastern Tanzania (figure 12.1) is a huge volcanic cone with two major peaks, Kibo (5895 m), the highest peak in Africa, and Mawenzi (5150 m). The mountain has a base radius of about 50 km. Major relief features include lowlands below 900 m and highlands which rise to over 3,048 m. Mount Kilimanjaro area can be classified into three major altitudinal zones (JICA, 1977b):

- The mountain zone above 1800 m (forest reserve and national park)
- The highland zone between 1200 m and 1800 m
- The lowland zone below 1200 m

The slopes of Mount Kilimanjaro vary by aspect and elevation. The southern slopes are the steepest and have been severely eroded over time by heavy rainfall. Slopes exceeding 25 degrees are found in river valleys and on sloping ash cones on the southern side. At elevations above 1200 m on the southern side and 1400 m on the eastern side, the slopes exceed 15 degrees. Below 1200 m on the southern and eastern sides the terrain is relatively flat with slopes between 0–5 degrees. In comparison to the slopes on the southern and eastern side, the northern slopes are generally gentle with a gradient of 5–10 degrees.

A number of important rivers and streams drain the area. The highland zone particularly on the southern side of the mountain has many permanent rivers, streams, and springs which supply clean water for domestic use and irrigation. The main rivers on the south and southeastern facing slopes are the Kikafu, Weruweru, Karanga, Rau, Mue, Himo, and Sagana. In the lowland zone, there are fewer rivers and streams and most of them are intermittent due to underground seepage, high evaporation, and human diversion of water (see Sarmett and Faraji, chapter 7).

The rivers that drain Mount Kilimanjaro run into the Pangani River on the south side and the Lumi river on the east side. Many seasonal swamps are also found on the south side.

Climate

The climate is diverse and varies also with elevation and aspect. Rainfall generally increases with altitude. On the southern slopes the average annual rainfall at 800 m is approximately 800 mm and increases to 2,500 mm at 1500 m. Above 1500 m the rainfall decreases with altitude so that the top of Mount Kilimanjaro receives on average less than 400 mm. More rainfall falls on the southern and southeastern slopes of the mountain than on the northern or western slopes. Because of variation of cloud cover with altitude, potential evaporation tends to decrease with altitude.

Temperatures are moderated at middle altitudes such that the variation in mean monthly temperature is between 22–26°C between the altitudes of 600 m and 1050 m (JICA, 1977b). Cloud cover particularly during the rainy season tends to reduce maximum temperature and raise minimum temperatures.

The cool season runs from June to September with mean temperature of 20–22°C and maximum temperature of 35°C.

Most places on the mountain experience their maximum rainfall in April or May and their minimum from July to September. Moisture deficits normally occur in the lowlands from September to March (Maro, 1974). In the highlands, only a slight deficit is experienced from January to March.

Soils

The Kilimanjaro soils are very varied, most of them having been derived from volcanic rocks. The northern, western, and southern sides of the mountain are covered by deep fertile soils. On the eastern side, in the central and northern Rombo District, the silica containing rocks tend to resist weathering thus giving rise to shallow stony soils.

Vegetation

The vegetation of Mount Kilimanjaro area is primarily determined by rainfall, temperature, and soils. However, in many areas, man has greatly altered the vegetation through such activities as slash and burn farming, grazing of livestock, felling of trees, and harvesting of grass so that only remnants are found.

The lowlands are characterised by scattered trees and scrub mainly due to repeated slash and burn cultivation and eventual abandonment of the fields as well as overgrazing.

The montane forest zone occurs between the altitudes of 1800 m and 3000 m. Local variation exists in the vegetation of the montane forest zone due to slope and precipitation.

The alpine zone occurs above 3000 m. Because of its legal status as a national park, this area has been comparatively less disturbed by human activities

The contribution of Mount Kilimanjaro to regional socio-economic development

The socio-economic contribution of Mount Kilimanjaro may be analysed in terms of agriculture, forestry, and tourism.

Agriculture

There has been a spectacular development of agriculture on Kilimanjaro during the last one hundred fifty years. A combination of good soils and favourable climate have given the Chagga a firm foundation on which to build the agricultural system which exists today. Coffee is the primary crop in the highland zone. The first coffee was planted at the Kilema Mission over 80 years and this, according to Brewin (1965), marked the beginning of a period of sustained development on Kilimanjaro. However, even before coffee was introduced, permanent cultivation of bananas was taking place particularly in the highland areas where the soils are very fertile. Detailed records for cultivation around Marangu date back as far as 1886 (Meyer, 1891). On the southern half of the mountain the cultivated zone is found between 1200 m and 1800 m.

The agricultural systems on the southern and eastern slopes of Kilimanjaro differ within the highland and the lowland zones. The highland zone has been continuously cultivated for a longer time. Intensive mixed cultivation of coffee and bananas is practised here because of adequate rainfall. Maize is also grown to some extent. Dairy cattle are kept on a stall-feeding system. Because of the favourable environmental conditions, this zone is the most densely populated in the region with a population density in some parts exceeding 500 people per km^2 (JICA, 1977a). The area also has a very high socio-economic level in comparison with most other areas of the country as indicated by income and education (JICA, 1977a).

The lowland zone is comparatively sparsely populated due to lower rainfall and less fertile soils. However as a result of population pressures within the highland zone, people are being forced to move down to the lowland zone. Since the 1960's, cultivation of maize, beans, sisal, cotton, and sugar cane has become increasingly important in this zone (see O'Kting'ati and Kessy, chapter 8). In the extensive lowland areas to the west, the Maasai continue to engage in nomadic pastoralism.

Agricultural production largely depends on small holder farmers. A typical farmer in a highland zone has some plots *kihamba* for coffee and bananas in the vicinity of his house and some additional plots *shamba* in the lowland zone on which he grows maize, beans, or other crops. Large scale farms are also found in some localities. These include the NAFCO wheat farms in West Kilimanjaro and the Tanganyika Planting Company (TPC) sugar cane plantations in Moshi Rural District.

Irrigation for agricultural development in the Kilimanjaro Region has become increasingly important although irrigation has been practiced by the Chagga in the highland zone for hundreds of years (Pike, 1965; Ramsay, 1965; JICA, 1977a). Sir Harry Johnston noted in 1884, according to Pike (1965), that virtually all of the ridges in the highland zone had an irrigation channel.

Approximately 18% of the cultivated land in the Kilimanjaro Region is irrigated. Water consumption by irrigation accounts for over 80% of total water use in the region. The most extensive use of water takes place in the catchment areas on the southern slopes of Mount Kilimanjaro. The total water use ranges from 10% to 35% of total discharge of each catchment during an average year JICA (1977c).

Irrigated areas are concentrated in Moshi Rural District where traditional furrows are very widespread. Traditional furrows consume about 85% of total surface water (JICA, 1977C). Large scale irrigation of primarily state-owned farms account for the remainder of the water used for irrigation.

The intensive use of upstream water during the dry season deprives farmers downstream of water. Thus in the lowland areas, the main source of irrigation and domestic water is underground water obtained mostly from natural springs. There is intensive use of underground water in the open flat plain to the south of Kilimanjaro.

Forestry

The forests on Mount Kilimanjaro are a rich natural resource and serve a number of functions. As catchment areas, they ensure a safeguard of stable supply of water for irrigation and domestic use. They also prevent damage which might occur from landslides and loss of top soil. Other functions include windbreaking, prevention of flood damage, temperature adjustment, improvement of soil quality and drought prevention through reduction of evaporation.

Apart from the conservation function, forests on Mount Kilimanjaro are also a source of various forest products including timber, honey, fuelwood, and poles. Production forests around Mount Kilimanjaro include the Rau, Kahe, and Kilimanjaro forests and cover an area of about 187,793 ha (JICA, 1977b). The softwood plantations within the Kilimanjaro Forest Reserve accounts for a considerable portion of the current commercial timber production in the country. The native forests on the southern slopes contain several commercially important hardwood species including *Podocarpus milanjianus* and *Ocotea usambarensis* both of which have been extensively exploited in the past for timber. Before the Second World War, there was only small scale cutting of *Ocotea usambarensis*, however, the war led to a tremendous demand for timber mainly for sleepers (Wood, 1965b). Thus, production rose from 141.5 m^3 in 1941 to 16,499 m^3 in 1942. The demand for forest products has been steadily increasing within the region. In 1976, the annual production (mainly softwoods) from forests within the Kilimanjaro Region was estimated at 30,000 m^3 (JICA, 1977b).

Tourism

Mount Kilimanjaro is one of the major tourist attractions in Tanzania and Kilimanjaro National Park earns the most foreign exchange of any national park in the country. The spectacular scenery of snow-capped Kibo Peak is the mountain's major attractant to tourists and mountaineers. The national park includes all of the mountain above tree line and six lowland forested corridors

Tourism is one of the more effective ways for the government of Tanzania to earn foreign exchange. Though not well developed, the industry provides economic gains to the nation. The park is embraced in the northern tourist circuit which is the richest of the three tourist zones in the country in terms of both natural scenery and wildlife.

Though data on income earned from tourism throughout the Kilimanjaro Region is limited, Mount Kilimanjaro nonetheless contributes substantially to the regional tourism industry.

The future of Mount Kilimanjaro

Mountain ecosystems are generally fragile and are susceptible to over-exploitation. This is the case now with Mount Kilimanjaro. Population pressure have forced more people to seek a livelihood on the limited areas of good land. At the same time, migration into previously uncultivated and increasingly marginal areas is becoming more common. The forests have been over-exploited and damaged by fires. The result has been deforestation, soil erosion, and general land degradation in some parts of the mountain.

On the southern slopes of Mount Kilimanjaro, serious erosion occurs principally in valleys at altitudes of 900 m – 1,000 m. Erosion at this altitude is a result of excessive development of the coffee belt, deforestation, and the planting of annual crops on steep slopes (JICA, 1977b).

Associated with the problem of deforestation is the fact that water sources have been disrupted. Many traditional irrigation furrows are drying up due to increasing water use and land use change. The shortages of water will adversely affect agriculture and thus may have not only regional but also national repercussions.

Against this background, the formulation of an integrated management and conservation programme for Mount Kilimanjaro must be given the highest priority. Within this programme, focus must be on sustainable development which means the improvement of the quality of human life through the rational, efficient, and sustainable utilization of available resources for present and future generations. This implies that the conservation policy of the mountain should not ignore the increasing requirements of the local people for food, fuel, and timber as well as the ecological capacity of the mountain to provide these products.

An integrated management and conservation programme would need to consider the major uses of the mountain which include tourism, timber, water, and energy production, agriculture, and pastoralism. At the same time, such a programme would need to focus on the conservation of the natural environment, particularly the forests on Mount Kilimanjaro. A distinction must be made between catchment and production forests with special efforts directed at maintaining the catchment values of the forest on Mount Kilimanjaro.

In areas that have been excessively disturbed in the past, particularly steep slopes on the eastern and southern side of the mountain in the cultivated zone, afforestation projects should be undertaken. Additionally, the maintenance of soil fertility needs to be encouraged. In many cases improved methods of cultivation and soil and water conservation measures should be introduced.

It is evident based upon the other chapters presented in this book that significant environmental changes have occurred on Mount Kilimanjaro and its surroundings over the last 100 years. In order to clarify further the magnitude of these changes and to assist in the development of an integrated management and conservation programme, an integrated research programme needs to be developed. Such a programme should provide additional information on the structure, pattern, and functioning of the Kilimanjaro ecosystem with the objective of raising the carrying capacity of the mountain to the maximum sustainable level.

This research would provide the scientific basis for dealing with problems related to the structure, pattern, and functioning of the Mount Kilimanjaro ecosystem and identifying the key processes involved. Such information can contribute substantially to the improvement of its management and conservation. The research should also provide the scientific basis for dealing with problems related to rational utilization and conservation of resources and resource systems and to human settlements.

Specific research activities should focus on (1) inventorying resource use and degradation as it relates to current as well as historical land use and socio-economic patterns; (2) determining the resource potential of the area by focusing on the resource dynamics of the area; (3) identifying, assessing, and reversing key degradation processes and rehabilitating resources bases that are on the threshold of irreversibly losing their potential for production or regeneration; and (4) conserving the genetic, natural, and cultural resources as well as improving the sustainability of agricultural systems on Mount Kilimanjaro.

The success of efforts to promote the conservation of Mount Kilimanjaro will depend upon the active participation and cooperation among the local people, the government, and the international community.

Chapter 13

Priorities for the conservation of Mount Kilimanjaro

W.D. Newmark

It is apparent based upon the preceding chapters that human activities on Mount Kilimanjaro have had and are currently having adverse impacts upon the water, forest, and wildlife resources. It is very unlikely that the current pressures on the resources on Mount Kilimanjaro will decrease in the future as the human population and demand for resources increase.

A wide variety of programmes and activities should be developed in order to promote the conservation of Mount Kilimanjaro. The following recommendations for promoting the conservation of Mount Kilimanjaro are presented in terms of temporal priority and were jointly endorsed by the authors of the preceding chapters.

1. Given the extreme importance of Mount Kilimanjaro as a watershed, all authorized cutting of the native montane vegetation should be banned immediately and increased efforts should be undertaken by Tanzania National Parks, the Forestry and Beekeeping Division, and the Wildlife Division to prevent all unauthorized cutting of trees within Kilimanjaro National Park and Forest Reserve and along all streams and rivers below the reserve.

2. The long-term viability of many large mammal populations found within the Kilimanjaro National Park and Forest Reserve is quite likely dependent upon the maintenance of the remaining wildlife corridor on the northwestern side of Mount Kilimanjaro that links the upper habitats of Mount Kilimanjaro with the surrounding lowland habitats. The area between Lerangwa and Mlima Nyuki should be given protected area status. However, it is important that the Maasai who have exclusively used this area should not be adversely affected by any change in administrative status of this area. Grazing and firewood collecting as practiced by the Maasai in the past have been fully compatible with movement of wildlife between the upper and lower habitats on Mount Kilimanjaro and thus the Maasai should be permitted to carry out these land use practices in the future. However, cultivation within this corridor should be prohibited.

In order to ensure that the existing wildlife corridor on the Kenyan side of the Tanzanian-Kenyan border is maintained, the Wildlife Division and Tanzania National Parks should establish a dialogue with the Kenyan authorities.

3. All of the river and stream gauging stations on Mount Kilimanjaro that were formerly monitored should be reestablished so as to permit the monitoring of the discharge of the major rivers and streams. In addition, control gates should be rehabilitated so as to more effectively control water use.

4. Kilimanjaro National Park should be expanded to include all of the montane forest with the exception of the softwood plantations on the northwestern and northeastern sides of Mount Kilimanjaro and the half-mile forestry strip. Such an expansion would provide maximum protection to the catchment values of Mount Kilimanjaro and to the World Heritage Site status of Mount Kilimanjaro. The current boundaries of the World Heritage Site includes all of the montane forest, ericaceous, and alpine zones of the mountain.

   In addition, the inclusion of all of the montane forest within Kilimanjaro National Park would give maximum protection to the most important zone biologically on Mount Kilimanjaro. 69% of the flowering plant species, 78% of the bird species, and 80% of the larger mammal species that are found above the cultivated zone on Mount Kilimanjaro are restricted to the montane forest based upon species distribution data of Gilbert (1974), Lamprey (1965) and Newmark *et al.*, (chapter 5), respectively. The montane forest on Mount Kilimanjaro also contains the largest known global population of Abbot's duiker (Kingdon, 1982), a species which is listed as globally threatened (East, 1988).

5. An integrated conservation plan should be developed for Mount Kilimanjaro that defines priority land uses and activities in specific areas and promotes environmentally sound farming systems and reforestation activities. Such a plan should promote coordination among existing development projects. Local people should be actively involved in the development and implementation of an integrated conservation plan. As a portion of a broader integrated conservation plan for Mount Kilimanjaro, a management plan should be developed for Kilimanjaro National Park.

6. In order to reduce the demand for wood and wood products from the montane forest on Mount Kilimanjaro, an extensive afforestation programme should be developed. A portion of the afforestation programme should include the rehabilitation of the half-mile forestry strip. A careful review of the management of the half-mile forestry strip while under the guidance of the Chagga Council should be made when designing future programmes for its management. Consideration should be given to further decentralize the management of the half-mile forestry strip so as to give local people more responsibility for the planting, thinning, and harvesting of trees as well greater access to the wood and wood products at a minimal price. Greater emphasis in the management of the

half-mile forstry strip should be placed upon fuelwood rather than timber production.

In addition, an active programme of replanting trees along the rivers and streams on Mount Kilimanjaro needs to be developed and existing laws preventing the cutting of trees along rivers and streams should be actively enforced. Within Kilimanjaro National Park the use of firewood for cooking and heating for tourists should be banned and kerosene or propane stoves should be installed at all of the major huts on the mountain.

7. An expanded programme of both short-term and long-term research is necessary in order to address many of the resource problems of Mount Kilimanjaro. Much of this research could be coordinated through the development of a permanent catchment forest study site on Mount Kilimanjaro. Initial emphasis in research should be given to developing a complete inventory of the fauna and flora of Mount Kilimanjaro and interpreting the 1958 aerial photography in terms of forest cover types so as to identify qualitative changes in the montane forest between 1958 and 1987. In addition emphasis should be placed upon determining the impact of forest conversion on wildlife populations and the minimum width of forested corridors in order to permit the movement of altitudinal restricted wildlife, particularly avifauna, between the northern and southern sides of the mountain.

   Longer term research projects on Mount Kilimanjaro should focus on documenting the dynamics of plant and animal communities both within the montane forest as well as within the ericaceous and alpine zones.

   Research should also be encouraged in the cultivated zone to further identify factors responsible for land degradation and to identify techniques and methods to reverse these processes. The extent of authorized as well as unauthorized diversion of water from the rivers and streams on Mount Kilimanjaro needs to be carefully documented.

8. Mucn of the avifauna on Mount Kilimanjaro is altitudinally restricted. To permit the movement of altitudinal restricted wildlife between the northern and southern sides of Mount Kilimanjaro, several corridors of native vegetation should be planted that would completely bisect the softwood plantations at lower and middle elevations.

References

Anderson, G.D. 1982. The soil and land use potential of the southern and eastern slopes of Kilimanjaro, Tanzania. Institute of Resources Assessment, University of Dar es Salaam and International Development Program, Massachusetts.

Avery, D. 1979. Soil erosion, conservation and non-commercial energy in the Third World. An anotated bibliography. School of Natural Resources, University of Michigan.

Baldwin, R.R. 1946. Native authority afforestation on Kilimanjaro. *Tanganyika Notes and Records* 21:81-84.

Bizot, M., Friis, I., Lewinsky, J., and Pócs, T. 1976. East African Bryophytes, IV. *Lindbergia* 4:259-284.

Bizot, M., and Pócs, T. 1974. East African Bryophytes, I. *Acta Acad. Paed. Agriensis* 12:383-449.

Bizot, M., and Pócs, T. 1979. East African Bryophytes, III. *Acta Bot. Acad. Sci. Hung.* 28:15-64.

Bizot, M., Pócs, T., and Sharp, A.J. 1979. Results of a bryogeographical expedition to East Africa in 1968, II. *J. Hattori Bot. Lab.* 45:145-165.

Bjørndalen, J.E. 1990. Inventory and monitoring of rainforest catchments. Some ideas concerning establishment of a reference area in Nguru Mountains, Morogoro Region. Department of Forest Biology, Sokoine University of Agriculture, Morogoro.

Bjørndalen, J.E. (in press). Tanzania's vanishing rainforests – assessment of nature conservation values, biodiversity and importance for water catchment. *in*: Pimentel, D. and Paoletti, M.G. (eds.) *Biotic diversity in agroecosystems*. Elsevier, Amsterdam.

Bock, M. (1942). Pflanzugen und Farmen im Siedlungsgebiet Moschi am Kilimandscharo Anbau 1939. map, scale 1:100,000. Berlin.

Borner, M. 1985. The increasing isolation of Tarangire National Park. *Oryx* 19:91-96.

Brewin, D.R. 1965. Kilimanjaro agriculture. *Tanganyika Notes and Records* 64:115-117.

Bruen, M. 1989. Hydrological considerations for development in the Eastern Usambara Mountains. *in*: Hamilton, A.C. and Bensted-Smith, R. (eds.) *Forest Conservation in The East Usambara Mountains, Tanzania*. pp. 117-140. IUCN, Gland.

Bureau of Statistics. 1982. 1978 Population Census. Vol. IV: A Summary of Selected Statistics. Ministry of Planning and Economic Affairs. Dar es Salaam.

Bureau of Statistics. 1983. 1978 Population Census. Vol. VIII: Population of Tanzania. Ministry of Economic Affairs and Development. Dar es Salaam.

Bureau of Statistics. 1989. 1988 Population Census Preliminary Report. Ministry of Finance and Economic Affairs, Dar es Salaam.

Central Statistical Bureau. 1968a. Recorded population changes 1948-1967. Ministry of Economic Affairs and Development Planning, Dar es Salaam.

Central Statistical Bureau. 1968b. Preliminary results of the population census taken on the night of 26th-27th August 1967. Ministry of Economic Affairs and Development Planning. Dar es Salaam.

Child, G.S. 1965. Some notes on the mammals of Kilimanjaro. *Tanganyika Notes and Records* 64:77-89.

Department of Water, Energy and Minerals. 1977. Water Master Plan – Kilimanjaro Region. Final Report. Vols. I-VII. Dar es Salaam.

Diamond, J.M. 1984. 'Normal' extinctions of isolated populations. *in*: Nitecki, M.H. (ed.), *Extinctions*. pp. 191-246. University of Chicago Press, Chicago.

Dorst, J. and Dandelot, J. 1970. *A field guide to the larger mammals of Africa*. Collins, London.

East R. 1981. Species-area curves and populations of large mammals in African savanna reserves. *Biol. Conserv.* 21:111-126.

East, R. 1983. Application of species-area curves to African savannah reserves. *Afr. J. Ecol.* 21:123-128.

East, R. 1988. Antelopes: Global survey and regional action plans. Part I. East and Northeast Africa. IUCN, Gland.

Edwards, K.A. and Blackie, J.R. 1981. Results of the East African catchment experiments 1958-1974. *in*: Lal R. and Russell, E.W. (eds.) *Tropical Agricultural Hydrology: Watershed Management and Land use*. pp. 163-188. John Wiley, New York.

Enroth, J. 1990. Altitudinal zonation of bryophytes on the Huon Peninsula, Papua New Guinea. A floristic approach, with phytogeographic considerations. *Tropical Bryology* 2:61-90.

FAO. 1986. Rehabilitation of Traditional Schemes (Phase I), Tanzania. AG: TCP/URT/4522, Mission Report, Rome.

Fedha Uchumi na Mipango, 1986. Hali ya Uchumi wa Taifa katika mwaka 1986. Government printers, Dar es Salaam.

Fernandes E.C.M., O'kting'ati, A., and Maghembe, J.A. 1984. The Chagga home gardens: a multistoried agroforestry cropping system on Mount Kilimanjaro (Northern Tanzania). *Agroforestry Systems* 2:73-86

Foley, C.A.H., and Grimshaw, J.M. (in press). Kilimanjaro Elephant Project Final Report. Friends of Conservation, Nairobi.

Fosbrooke, H.A. and Sasson, H. 1965. Archaeological remains on Kilimanjaro. *Tanganyika Notes and Records* 64:62-64.

Gamassa, D.M. 1989. Land use conflicts in arid areas: a demographical and ecological case study; the Kwakuchinja Wildlife Corridor in northern Tanzania. Masters Thesis. Agricultural University of Norway. Aas.

Gilbert, V.C., Jr. 1974. *Plants of Mt. Kilimanjaro*. Office of Environmental Interpretation, U.S. National Park Service, Washington, D.C.

Gillman, C. 1923. An ascent of Kilimanjaro. *Geog. J.* 61:1-27.

Gilpin, M.E. and Soulé, M.E. . 1986. Minimum viable populations: processes of species extinction. *in* Soulé, M.E. (ed.) *Conservation biology: the science of scarcity and diversity.* pp. 19-34. Sinauer Associates, Sunderland, Massachusetts.

Gradstein, S.R. and Frahm, J.P. 1987. Die floristische Höhengliederung der Mooseentland des BRYOTROP-Transektes in NO-Peru. *in* Frey, W. (ed.) Mooseflora und vegetation in Regenwäldern N0-Peru. Ergebnisse der Bryotrop-Expedition nach Peru 1982. *Beih. Nova Hedwigia* 88:105-113.

Gradstein, S.R. and Pócs, T. 1989. Bryophytes. *in*: Lieth, H. and Werger, M.J.A. (eds.) *Tropical Rain Forest Ecosystems*. pp. 311-325. Elsevier, Amsterdam.

Gradstein, S.R., Pócs, T., and Váňa, J. 1983. Disjunct Hepaticae in tropical America and Africa. *Acta Bot. Hung. 29: 127-171.*

Gradstein, S.R. and Váňa, J. 1987. On the occurrence of Laurasian liverworts in the tropics. *Mem. New York Bot. Garden* 45:388-425.

Greenway, P.J. 1965. The vegetation and flora of Mount Kilimanjaro. *Tanganyika Notes and Records* 64:97-107.

Guest, N.J. and Leedal, G.P. 1954. Notes on the fauna of Kilimanjaro. *Tanganyika Notes and Records* 36:43-49.

Haltenorth, T. and Diller, H. 1977. *A field guide to the mammals of Africa including Madagascar*. William Collins, London.

Hamilton, A.C. 1982. *Environmental history of East Africa*. Academic Press, London.

Hamilton, A.C. and Bensted-Smith (eds.). 1989. *Forest conservation in the East Usambara Mountains, Tanzania*. IUCN, Gland.

Harcourt, A.H., Pennington, H., and Weber, A.W. 1986. Public attitudes to wildlife and conservation in the third world. *Oryx* 20:152-154.

Hedberg, O. 1951. Vegetation belts of the East African mountains. *Svensk Bot. Tidskrift.* 45:140-202.

Hedberg, O. 1964. Features of Afroalpine plant ecology. *Acta Phytogeogr. Suecica* 49:1-144.

Hedberg, I. and Hedberg, O. (eds.) (in press). The Usambara integrated rainforest project workshop at the Sokoine University of Agriculture, Morogoro, March 13-27, 1989. Uppsala.

Hendee, J.C., Stankey, G.H., and Lucas, R.C. 1978. *Wilderness Management*. Forest Service, USDA. Mis. Pub. No. 1365.

Hermansen, J.E., Benedict, F., Corneliussen, T., Hofsten, J., and Venvik, H. 1985. Catchment forestry in Tanzania, status and management. NORAD Consultancy Report 17-18. Institute for Environmental Analysis and FORINDECO, Norway.

Hillman, J.C., Cunningham-van Someren, G.R., Gakahu, C.G., and East, R. 1988. Kenya. *in*: East, R. *Antelopes Global Survey and Regional Action Plans Part 1. East and Northeast Africa*. pp. 41-52. IUCN, Gland.

IBRD, 1974. Agricultural and rural development studies. Statistical annexes, Vol. I-III. Ministry of Agriculture, Dar es Salaam.

Infield, M. 1988. Attitudes of a rural community towards conservation and a local conservation area in Natal, South Africa. *Biol. Conserv.* 45:21-46.

Isard, W. O., Bramhall, D.F., Carrothers, G.A.P., Cumberland, J.H., Moses, L.N., Price, D.D., and Schooler, E.W. 1966. *in* Isard, W. *et al.* (eds.) *Methods of Regional Analysis: An introduction to Regional Planning*. pp. 5-50. John Wiley, New York.

IUCN. 1986. *Review of the protected areas system in the Afrotropical Realm*. Gland, Switzerland.

JICA. 1977a. The Kilimanjaro Region Integrated Development Plan Summary Report. Vol. I. Overseas Technical Cooperation. Japan International Cooperation Agency, Japan.

JICA. 1977b. The Kilimanjaro Region Integrated Development Plan Summary Report. Vol. II. Overseas Technical Cooperation. Japan International Cooperation Agency, Japan.

JICA. 1977c. Water Master Plan, Kilimanjaro Region. Vol. V. Technical report: Irrigation. Ministry of Water, Energy and Minerals, Dar es Salaam.

JICA. 1980. Feasibility report on Lower – Moshi Agricultural Project Data Book. Japan International Cooperation Agency, Japan.

JICA. 1989. Feasibility study on Lower Hai and Lower Rombo Agricultural Development Project. Japan International Cooperation Agency, Japan.

Kessy, J.F. 1988. Socio-economic implications of improving land use strategies in mountaineous communities. Unpublished Special Project, Sokoine University of Agriculture, Morogoro.

Kingdon J. 1971. *East African Mammals: An Atlas of Evolution in Africa*. Vol. I. Academic Press, London.

Kingdon J. 1974. *East African Mammals: An Atlas of Evolution in Africa*. Vols. IIA and IIB. Academic Press, London.

Kingdon J. 1977. *East African Mammals: An Atlas of Evolution in Africa*. Vol. IIIA. Academic Press, London.

Kingdon J. 1979. *East African Mammals: An Atlas of Evolution in Africa*. Vol. IIIB. Academic Press, London.

Kingdon J. 1982. *East African Mammals: An Atlas of Evolution in Africa*. Vols. IIIC and IIID. Academic Press, London.

Kis, G. 1985. Mosses of south-east tropical Africa. An annotated list with distributional data. Inst. Ecol. Bot. Acad. Sci. Hung., Vácrátót.

Koponen, J. (1986). Population growth in historical perspective – the role of changing fertility. *in* Boesen, J. *et al.*(eds). *Tanzania: Crisis and struggle for survival.* pp. 31-57. Scandinavian Institute of African Studies. Uppsala.

Kumpumula, M. 1979. The influences of visitors on the predators of Amboseli National Park. Masters Thesis, University of Nairobi, Kenya.

Lamprey, H.F. 1965. Birds of the forest and alpine zones of Kilimanjaro. *Tanganyika Notes and Records* 64: 69-76.

Leonard, N.L. 1987. An assessment of the interaction between Arusha National Park and adjacent areas. Post-graduate Diploma dissertation (unpublished). College of African Wildlife Management, Mweka.

Lovett, J.C. 1985. An overview of the moist forests of Tanzania. Final report on the Tanzania Forest Habitat Evaluation Project supported by World Wildlife Fund. *Tanzania National Scientific Research Monographs*.

MacArthur, R.H. and Wilson, E.O. 1967. *On the theory of island biogeography*. Princeton University Press, Princeton.

Marketing Development Bureau of Tanzania (MDB). 1979 Price policy recommendations for the 1980: Agricultural price review. Vol. I. Summary and price proposals. Dar es Salaam.

Maro, P.S. 1974. Population and land resources in northern Tanzania: the dynamics of change 1920-1970. Ph.D. thesis, University of Minnesota.

Maro, P.S. 1988. Agricultural land management under population pressure: the Kilimanjaro experience, Tanzania. *Mountain Research and Development*. 8:273-282.

Mbaruku, H. 1983. Population of Tanzania. *in*: Bureau of Statistics. 1978 Population of Tanzania Census Vol. VIII. Ministry of Planning and Economic Affairs.

Meyer, H. 1891. *Across East African glaciers*. (English translation), George Philip, London.

Miller, R.I. 1978. Applying island biogeographic theory to an East African reserve. *Environ. Conser*. 5: 191-195.

Miller, R.I. and Harris, L.D. 1977. Isolation and extirpation in wildlife reserves. *Biol. Conserv*. 12: 311-315.

Ministry of Agriculture and Livestock. 1987. Annual review of coffee. Dar es Salaam.

Ministry of Lands, Natural Resources and Tourism. 1989. Tropical Forestry Action Plan 1990/91- 2007/08. Dar-es-Salaam, Tanzania.

Mitten, W. 1886. The mosses and Hepaticae collected in Central Africa by the late Right Rev. James Hannington, Bishop of Mombasa, F.L.S., F.G.S., etc. and some others, included those gathered by Mr. H.H. Johnston on Kilimanjaro. *J. Linn. Soc. Bot.* 22:298-329.

Mlambiti, M.E. 1982. Agricultural sector analysis for Kilimanjaro Region. A basis for decision making and planning. Ph.D. dissertation. Sokoine University of Agriculture, Morogoro.

Moreau, R.E. 1935. A synecological study of Usambara, Tanganyika Territory, with particular reference to birds. *J. Ecol.* 23:1-43.

Moreau, R.E. 1944. Kilimanjaro and Mount Kenya: some comparisons, with special reference to the mammals and birds and with a note on Mount Meru (with a bibliography of Kilimanjaro by C. Gillman). *Tanganyika Notes and Records* 18:28-66.

Moss, C. 1988. *Elephant Memories: Thirteen years in the life of an elephant family.* Morrow, New York.

Müller, C. 1888. Die Moosewelt des Kilima-Ndscaro's. *Flora* 71:403-418.

Mwasaga, B.C. 1984. Vegetation – environment relations within the Kiraragua Catchment of Mount Kilimanjaro. Masters thesis. University of Dar es Salaam. Dar es Salaam.

Newmark, W.D. 1987. A land-bridge island perspective on mammalian extinctions in western North American parks. *Nature* 325:430-432.

Newmark, W.D., Leonard, N.L., Sariko, H.I., Gamassa, D.M., and Ndosi, O.M. (in press). Conservation attitudes of local people living adjacent to five protected areas in Tanzania. *Biol. Conser.*

Ochyra, R. and Sharp, A.J. 1988. Results of a bryogeographical expedition to East Africa in 1968, IV. *J. Hattori Bot. Lab.* 65:335-377.

O'Kting'ati, A. 1985. An analysis of the economics of agroforestry in Kilimanjaro. Ph.D. dissertation. Sokoine University of Agriculture, Morogoro.

O'Kting'ati, A., Maghembe, J.A., Fernandes, E.C.M., and Weaver, G.H. 1984. Plant species in the Kilimanjaro agroforestry system. *Agroforestry Systems 2:177-186.*

O'kting'ati, A. and Mongi, H.O. 1986. Agroforestry and the small farmer: a case study of Kilema and Kirua Vunjo in Kilimanjaro. *International Tree Crops Journal* 3: 257-265.

Pennington, H. 1983. A living trust: Tanzanian attitudes towards wildlife and conservation. Masters Thesis. Yale University, New Haven.

Pike, A.G. 1965. Kilimanjaro and the furrow system. *Tanganyika Notes and Records* 64:95-96.

Pócs, T. 1974. Bioclimatic studies in the Uluguru Mountains (Tanzania, East Africa). I. *Acta Bot. Acad. Hung.* 20:115-135.

Pócs, T. 1975. Affinities between the bryoflora of East African and Madagascar. *Boissiera* 24:125-128.

Pócs, T. 1976a. Bioclimatic studies in Uluguru Mountains (Tanzania, East Africa). II. Correlations between orography, climate and vegetation. *Acta Bot. Acad. Sci. Hung.* 22:163-183.

Pócs, T. 1976b. Correlations between the tropical African and Asian bryofloras, I. *J. Hattori Bot. Lab.* 41:95-106.

Pócs, T. 1976c. Vegetation mapping in the Uluguru Mountains (Tanzania, East Africa). *Boissiera* 24:477-498.

Pócs T. 1980. The epiphytic biomass and its effect on the water balance of two rainforest types in the Uluguru Mountains (Tanzania, East Africa). *Acta Bot. Acad. Sci. Hung.* 26:143-167.

Pócs T. 1982a. Tropical forest bryophytes. *in*: Smith, A.J.E. (ed.) *Bryophyte Ecology*. pp. 59-104. Chapman and Hall, London.

Pócs T. 1982b. Examples of the significance of historical factors in the composition of bryofloras. *Beih. Nova Hedwigia*. 71:305-311.

Pócs, T. 1982c. The forest flora and vegetation of the old crystalline mountains of Tanzania and their importance for soil and water conservation. *in*: Seminar/workshop of forest conservation in Tanzania, Tanga 16-18 February, 1982.

Pócs, T. 1988. The importance of catchment forests to Tanzania. Professional inaugural lecture, Sokoine University of Agriculture, Morogoro. (mimeographed).

Pócs, T. (in press). Correlation between the tropical African and Asian bryofloras, II.

Pócs, T., Temu, R.P.C., and Minja, T.R.A. (in press). Short survey of the natural vegetation and flora of the Nguru Mountains. *in*: Hedberg, I. and Hedberg, O. (eds.) The Usambara integrated rainforest project workshop at the Sokoine University of Agriculture, Morogoro, March 13-27, 1989. Uppsala.

Polhill, R.M. 1968. Tanzania. *in*: Hedberg, I. and Hedberg, O. (eds.) Conservation of vegetation Africa south of the Sahara. *Acta Phytogeogr. Suec.* 54:166-178.

Ramsay, J.C. 1965. Kilimanjaro – sources of water supplies. *Tanganyika Notes and Records* 64:92-94.

Reenen, G. van and Gradstein, S.R. 1983. A transect analysis of the bryophyte vegetation along an altitudinal gradient on the Sierra Nevada de Santa Marta, Colombia. *Acta Bot. Neerl.* 32:163-175.

Rees, J. 1985. *Natural Resources: Allocation, Economics and Policy*. Methuen, London.

Repetto, R. and Holmes, T. 1983. The role of population in resource depletion in developing countries. *Population and Development Review* 9:609-632.

Rodgers, W.A. and Homewood, K.M. 1982. Biological values and conservation projects for the forests and primate populations of the Uzungwa Mountains, Tanzania. pp. 53-65. *Biol. Conserv.* 24:285-304.

Rodgers, W.A. and Swai, I. 1988. Tanzania. *in*: East, R. (compiler) *Antelopes Global Survey and Regional Action Plans Part 1. East and Northeast Africa.* IUCN, Gland.

Salt, G. 1954. A contribution to the ecology of upper Kilimanjaro. *J. Ecol.* 42:374-423.

Schabel, H.G. 1990. Tanganyika forestry under German colonial administration, 1891-1919. *Forest and Conservation History* 34:130-141.

Schmidt, P.R. 1989. Early exploitation and settlement in the Usambara Mountains. *in*: Hamilton, A.C. and Bensted-Smith, R. (eds.) *Forest Conservation in The East Usambara Mountains, Tanzania.* pp. 75-78. IUCN, Gland.

Shaffer, M.L. 1981. Minimum population size for species conservation. *Bioscience* 31: 131-134.

Soulé, M.E., (ed.) 1986. *Conservation biology: the science of scarcity and diversity.* Sinauer Associates, Sunderland, Massachusetts.

Soulé, M.E., (ed.) 1987. *Viable populations for conservation.* Cambridge University Press, Cambridge.

Soulé, M.E., Wilcox, B.A., and Holtby, C. 1979. Benign neglect: a model of faunal collapse in the game reserves of East Africa. *Biol. Conserv.* 15:259-272.

Spence, J.R. and Pócs, T. 1989. Distribution patterns in the Afroalpine moss flora of East Africa. *in*: Mahaney, W.C. (ed.) *Quarternary and Environmental research on East African Mountains.* pp. 291-307. Balkema, Rotterdam.

Sywnnerton, G.H. 1949. Report of a safari to explore the Shira Plateau, West Kilimanjaro. *Ann. Rep. Game Dept. Tang.*.

UNEP, 1988. *People, Parks and Wildlife: Guidelines for Public Participation in Wildlife Conservation, Case Studies in Kenya.* Nairobi.

Veneklass, E. 1990. Rainfall interception and aboveground nutrient fluxes in Colombian montane tropical rain forest. Ph. Thesis. Utrecht.

Western, D. 1974. Road development plan for Amboseli National Park, based on criteria and rational for reconciling conservation and recreation use. IBRD Report. Kenya.

Western, D. and Henry, W. 1979. Economics and conservation in Third World national parks. *Bioscience* 29:414-418.

Western, D. and Ssemakula, J. 1981. The future of the savannah ecosystems: ecological islands or faunal enclaves? *Afr. J. Ecol.* 19:7-19.

Williams, J.G. 1967. *A field guide to the national parks of East Africa*. Collins, London.

Wood, P.J. 1965a. The forest glades on Kilimanjaro. *Tanganyika Notes and Records* 64:108-110.

Wood, P.J. 1965b. A note on forestry on Kilimanjaro. *Tanganyika Notes and Records* 64:111-114.

Yamada, K. 1975. Notes on Radula from Tanzania, East Africa. *J. Jap. Bot.* 50:115-118.

Yeager, R. 1989. *Tanzania: an African experiment*. Second edition. Westview Press, Boulder.

Contributors

Jørn Erik Bjørndalen
Department of Forest Biology
Sokoine University of Agriculture
P.O. Box 3010, Chuo kikuu
Morogoro, Tanzania

O.R. Chambegga
College of African Wildlife Management, Mweka
P.O. Box 3031
Moshi, Tanzania

S.A. Faraji
Water Research Division
Maji Ubungo
P.O. Box 35066
Dar es Salaam, Tanzania

Charles A.H. Foley
11 Weston Avenue
Milton Portsmouth
U.K.

Deo-Gratias M. Gamassa
College of African Wildlife Management, Mweka
P.O. Box 3031
Moshi, Tanzania

John M. Grimshaw
53 Courthouse Road
Maidenhead Berkshire SL6 6JA
U.K.

J.F. Kessy
Faculty of Forestry
Sokoine University of Agriculture
P.O. Box 3009
Morogoro, Tanzania

O.C. Kivumbi
Regional Forestry Office
P.O. Box 56
Singida, Tanzania

Hugh F. Lamprey
WWF-East Africa Regional Office
P.O. Box 62440
Nairobi,
Kenya

(current address)
Little Widefield Farm
Inwardleigh
Okehampton
Devon EX20 3DA
U.K.

Richard H. Lamprey
UNEP/GEMS
P.O. Box 47074
Nairobi, Kenya

(current address)
P.O. Box 70919
Dár es Salaam
Tanzania

Nancy L. Leonard
1314 NW 39th Dr.
Gainesville, Florida 32605
U.S.A.

Frances Michelmore
UNEP/GEMS
P.O. Box 47074
Nairobi, Kenya

S.B. Misana
Department of Geography
University of Dar es Salaam
P.O. Box 35051
Dar es Salaam, Tanzania

Balekebajobege C. Mwasaga
Tanzania National Parks
P.O. Box 3134
Arusha, Tanzania

William D. Newmark
College of African Wildlife
Management, Mweka
P.O. Box 3031
Moshi, Tanzania

(current address)
Department of Biology 0116
University of California, San Diego
La Jolla, California 92093
U.S.A.

Pascal A. Nguye
College of African Wildlife
Management, Mweka
P.O. Box 3031
Moshi, Tanzania

Aku O'Kting'ati
Faculty of Forestry
Sokoine University of Agriculture
P.O. Box 3009
Morogoro, Tanzania

Tamás Pócs
Department of Forest Biology
Sokoine University of Agriculture
P.O. Box 3009
Morogoro, Tanzania

(current address)
Institute of Ecology and Botany of the
Hungarian Academcy of Sciences
Vácrátót H-2163
Hungary

A.K. Rutazaa
College of African Wildlife
Management, Mweka
P.O. Box 3031
Moshi, Tanzania

J.D. Sarmett
Water Department
P.O. Box 324
Moshi, Tanzania

Index

Other titles in this series:

1. The Gola Forest Reserves, Sierra Leone
   Wildlife conservation and forest management
   A.G. DAVIES

2. Transmigration and the Environment in Indonesia
   The past, present and future
   ANTHONY J. WHITTEN, HERMAN HAERUMAN,
   HADI S. ALIKODRA and MACHMUD THOHARI

3. Conservation Planning in Indonesia's Transmigration Programme
   Case studies from Kalimantan
   JOHN DAVIDSON

4. The Management of Tropical Moist Forest Lands
   Ecological Guidelines
   DUNCAN POORE and JEFFREY SAYER

5. Buffer Zone Management in Tropical Moist Forests
   Case studies and guidelines
   SARA OLDFIELD

6. L'Equilibre des Ecosystèmes forestiers à Madagascar
   Actes d'un séminaire international
   LALA RAKOTOVAO, VERONIQUE BARRE et JEFFREY SAYER

7. Hunting and Wildlife Management in Sarawak
   JULIAN CALDECOTT

8. Rare Tropical Timbers
   SARA OLDFIELD

9. La Conservation des Ecosystèmes forestiers de L'île de la Réunion
   C. DOUMENGE et Y. RENARD

10. La Conservation des Ecosystèmes forestiers du Cameroun
    STEVE GARTLAN

11. La Conservation des Ecosystèmes forestiers d'Afrique centrale

12. La Conservation des Ecosystèmes forestiers du Congo
    PHILIPPE HECKETSWEILER

13. La Conservation des Ecosystèmes forestiers du Zaire
    CHARLES DOUMENGE

14. La Conservation des Ecosystèmes forestiers du Gabon
    CHRIS WILKS

15. Forest Conservation in the East Usambara Mountains, Tanzania
    ALAN HAMILTON

Series editors: Mark Collins and Jeffrey Sayer

Published by IUCN and funded by the World Wide Fund for Nature (WWF)

This book is part of
THE IUCN CONSERVATION LIBRARY
For a free copy of the complete catalogue please write to:
IUCN Publications Services Unit,
219c Huntingdon Road, Cambridge, CB3 ODL, UK