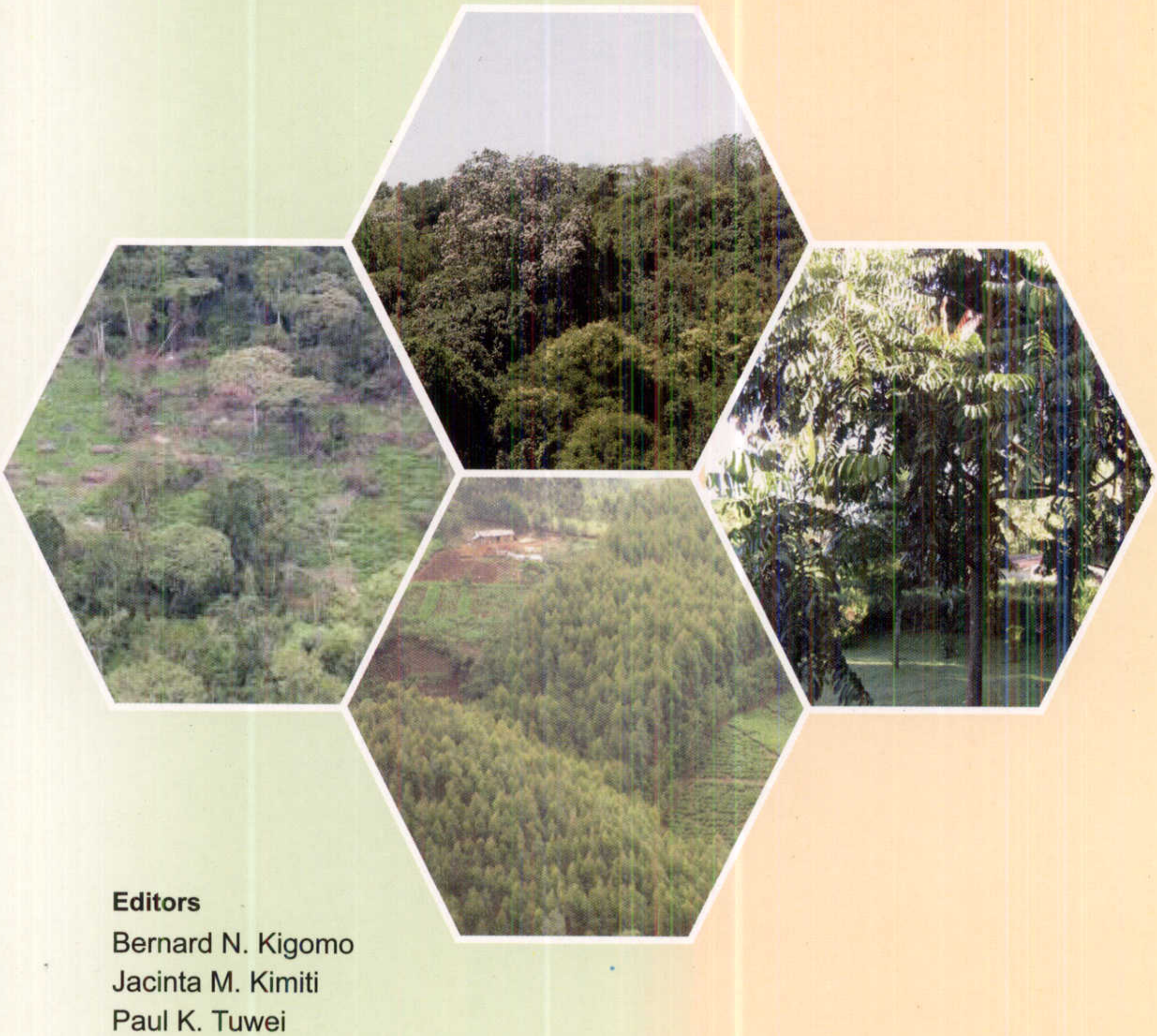
Forest Restoration Handbook for Moist Forests in Kenya



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KENYA FORESTRY RESEARCH INSTITUTE

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Forest Restoration Handbook for Moist Forests in Kenya

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Photographs from Mau Forests Complex

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Edited by:
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Table of Contents

Foreword

Deforestation and forest degradation have altered many of Kenya's indigenous forests and woodlands to an extent that none of the forest blocks have any resemblance to its original forest cover. Due to human activities virtually all the forest blocks in Kenya are fragmented and in high-degraded forms that only differ in scale. Natural vegetation in forests provide the buffer between the soil surface and processes that cause degradation by soil displacement. Natural forests, in particular provide some of the richest depositories of biological diversity and critical biotic carbon stocks. Furthermore, natural forests are sources of high prime timber, habitats for animals, sources of herbal medicine for 70% of rural population in Kenya and firewood. Natural forests are also important in watershed management for they store, filter and regulate water flows.

Mau Forests Complex, the largest closed-canopy forest ecosystem and water tower, covers close to 400,000 ha. However, the forests have undergone massive degradation. This degradation has led to decline in the availability of forest goods and services resulting to reductions in agricultural production, local shortages of timber and fuel wood and loss of biological diversity. Degradation has also led to critical reduction in water percolation, river flows and increased flush floods. In order to maintain the potential of such natural forests, conservation of all the component species should be done through stoppage of destructive activities. Restoration interventions should be undertaken to safeguard biodiversity and environmental services. These interventions must be guided by informed causes of actions that have scientific basis to facilitate success. A four-year project was therefore initiated in the Mau Forests Complex to: assess and characterise the extent of degradation in forests and adjacent agro-ecosystems, develop tools for restoration, synthesize, share and disseminate results of the project experiences.

This handbook, therefore, attempts to outline experiences on causes and extent of degradation in Kenya in general and Mau Forests Complex in particular and proposes measures and considerations that should be taken in restoring cleared and degraded natural forests. Chapters One, Two and Three gives the background, status and role of various stakeholders in degradation and restoration of the Mau Forests Complex. Chapter Four provides insights on the role of natural regeneration and succession in restoration; Chapter Five, on planning for restoration and the available options; while Chapter Six outlines impacts of forest degradation on soil and water resources. Chapter seven outlines characteristics of the main tree species suitable for enrichment of water catchment forests. Chapter Eight presents market access of wood and non-wood forest products from the Mau Forests Complex while Chapter Nine is on the economics and use of indigenous tree species. An annex is provided as guide on species suitable for rehabilitation of degraded moist forests.

The handbook provides facts, proposals and interventions to guide restoration of degraded forests based on Mau Forests Complex experiences. This handbook is recommended to scholars and those involved in restoration of degraded natural forests.

Ben E. N. Chikamai (PhD)
Director - KEFRI

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The authors wish to recognize the contribution of several scientists during the implementation of the project. Notable among them include Drs. Jean-Marc Bouvet (overall project coordinator), David Odee, Jean-Luc Chotte, Didier Lesueur, Julia Wilson, Stephen Cavers and Prof. Ørjan Totland in planning, experimental design, layout and guidance in data collection and analysis. The national coordination team was led by Dr. Bernard N. Kigomo assisted by Dr. Jacinta M. Kimiti. The following technical and field staffs are also acknowledged: Emmanuel Makatiani, Milton Esitubi, John Ochieng, Mary Gathara, George Omolo, Boaz Ngonga, William Bii, Florence Muindi, Gervas Nyaguti, Julius Kirui, Evans Ontiri, Joseph Maritim, Milka Sarinji and Moses Tzobe in experimental plot establishment, data collection and entry. Several stakeholders around Mau Forests Complex who were involved in the implementation of the project are also recognized for their participation and contribution.

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Acronyms

ADRA	- Adventist Development and Relief Agency
ASALs	- Arid and Semi Arid Lands
CBOs	- Community Based Organizations
CEH	- Centre for Ecology and Hydrology
CFAs	- Community Forest Associations
CIRAD	- International Co-operation Centre in Agronomic Research for Development
CITES	- Convention on International Trade in Endangered Species
FAO	- Food and Agricultural Organization of the United Nations
FDGO	- Forest Department General Order
FOFIFA	- Centre in Agronomic Research for the Rural Development
FOMAWA	- Friends of Mau Watershed
FOREAIM	- Bridging Restoration of Degraded Forestry Landscapes of East Africa and Indian Ocean Islands
GPS	- Global Positioning System
INA-NLH	- Norwegian University of Life Sciences
IUCN	- International Union on Conservation of Nature
IRD	- Institute of Research in Development
KEFRI	- Kenya Forestry Research Institute
KES	- Kenya Shilling
KFS	- Kenya Forest Service
MPN	- Most Probable Number
NGO	- Non-Governmental Organization
NPV	- Net Present Value

UNEP	- United Nations Environment Programme
WHO	- World Health Organization
WRMA	- Water Resource Management Authority
WWF	- World Wide Fund for Nature

Chapter One

Background

David K. Langat, Bernard N. Kigomo and Joshua K. Cheboiwo

1.0 Global Perspective

Forests play a crucial role in sustaining natural and human environments. They provide a wide range of economic and social benefits to humankind. These include direct use of various forest products and services for domestic and generation of income. Production and trade in forest products create employment, attract investments and generate incomes to various players in the market value chains hence contribute to the national economies. Other important features of forests include water and soil conservation, hosting of unique landscapes, cultural, spiritual and recreational sites. Maintaining and enhancing functional integrity of forests is a critical undertaking in sustainable forest management. According to FAO 2009 report on forest resource assessment, there is a worldwide deforestation and is continuing at alarming rate mainly through conversion of forests land to agricultural land and human settlement. It is estimated that between the years 2000 and 2005, 7.3 million ha yr^{-1} of forest land was lost. Most of the loses occurred in Africa and Latin America. Large forest areas have already been converted to human use in Africa and with anticipated doubling of population in the next 25 years, it is expected that this will lead to immense pressure on forest resources. This pressure is expected to lead to 30% loss of the remaining forests and woodlands. However, rapid deterioration and dwindling forest resources in the tropics has raised concern on the sustainability of forest resource flows. Thus when forests are lost or degraded, we loose more than the trees that they contain but also other services and products obtained from the forests.

There are international efforts aimed at restoration of degraded forests through conservation and rehabilitative planting to support biodiversity conservation, mitigate the impacts of climate change, and improve the livelihoods of the forest dependent communities. To achieve these noble objectives, knowledge and information on socio-economic factors, including roles of local communities and other stakeholders in forest degradation process and restoration options are essential steps in implementation and evaluating progress towards sustainable forest management.

1.1 Overview on Natural Forests in Kenya

Kenya has 3.467 million ha of forest cover, which is equivalent to 5.9% of its land area. Out of this, 1.395 million ha or 2.4% of total land area comprises of indigenous closed canopy forests, mangroves and plantations in both public and private lands. However, the forest cover has continued to decline.

Degradation and loss of the forest cover has been attributed mainly to competing land use from agriculture and human settlement. Most of the natural forests are found in high potential areas and are under pressure for conversion into settlement. Most challenges facing the forests are closely linked to rapid human population growth that has led to expansion of agriculture and human settlements. It is projected that out of the remaining area of closed-canopy forests, estimated at 1.395 million ha, about 240,000 ha may be lost in the next twenty five years if no remedial actions are taken. For example, between 1990 and 2005, Kenya lost around 186,000 ha of natural forests. Though the current annual deforestation rate, estimated at 0.34%, is lower than the average for Africa (0.78%), it is significantly higher than the world average of 0.24%.

Table 1.1 presents an analysis of forest cover in Kenya. All categories of the vegetation types face challenges in their sustainability for conservation and use. The most affected are the woodlands and watersheds vegetations. The key natural forest blocks in Kenya that are threatened by degradation include Mt Kenya, Aberdares Range, Cherangany Hills, Mt Elgon and Mau Forests Complex.

1.1.1 Mau Forests Complex Ecosystem

The Mau Forests Complex forms the largest closed canopy forest ecosystem estimated at 400,000 ha and is one of the critical water towers in the country. It is situated at 0°30' S, 35°20'E in the Rift Valley province and spans across several administrative districts. The Mau Forests Complex is mainly composed of indigenous forest and mainly plantations of cypress and pines. The complex comprises of 22 forests. The latest data show that a total of about 136,000 ha of Mau Forests Complex has undergone degradation through encroachments and excision for human settlements and agriculture. The Complex is an important watershed forest ecosystem because it is the source of 12 major rivers and also has streams that make up the hydrological systems of Lakes Victoria, Baringo, Nakuru, Natron, Naivasha, Turkana and Bogoria (Figure 1). The ecosystem supports key economic sectors in the country that include hydropower generation, tourism, agriculture, livestock and supply of water for domestic and industrial uses.

The market value of goods and services in tourism and tea sectors is about KES 20 billion of benefits per year. In Western Kenya, tea sector provides jobs to 50,000 persons and livelihood to 75,000 small-scale farmers, supporting about 650,000 dependents. It is estimated that two-thirds of tea produced from Western Kenya benefit from the ecological functions of Mau Forests Complex through maintenance of favourable micro-climatic conditions. Moreover, the rivers flowing from Mau Forests Complex cross 478 sub-locations with more than 5 million people depending directly or indirectly on products and services arising from the complex. The total dependency on the Mau Forests Complex goes beyond these sub-locations and is estimated at 10 million people.

Table 1.1 Analysis of forest cover and related land uses in Kenya from 1990 to 2008

Category of forest cover type	Area ('000 ha)				Remarks
	1990	2000	2005	2008	
Indigenous closed canopy	1,240	1,190	1,165	1,140	Decreased forest cover (25,000 ha) in 2005-08 period is due to forest invasions in Cherangany, Mau, Samburu
Mangroves	54	54	54	54	Kilifi, Malindi, Lamu districts
Industrial plantation forests	170	134	119	109	This is in addition to 16,000 ha of unplanted designated areas
Private plantation forests	68	78	83	90	Increasing trend due to accelerated commercial planting by private sector and farmers
Sub-total closed canopy forests	**1,532**	**1,456**	**1,421**	**1,395**	**2.4% of land area**
Woodlands	2,150	2,100	2,075	2,050	Spread mainly in the ASALs
Sub-total of forest areas	**3,682**	**3,556**	**3,496**	**3,443**	**5.9% of land area**
Bush land	24,800	24,635	24,570	24,510	In ASALs, high and medium rainfall areas
Grasslands	10,730	10,485	10,350	10,350	Mainly the savannah
Settlements	8, 256	8,192	8,152	8,202	Towns, villages and shopping centres
Trees on farmlands	9,420	10,020	10,320	10,385	Mainly in high and medium rainfall areas
Inland water bodies	1,123	1,123	1,123	1,123	Mainly portion of Lake Victoria and lakes in the Rift Valley
Total Land Area, Kenya	**58,037**	**58,037**	**58,037**	**58,037**	**100%**

Source: FAO, 2009

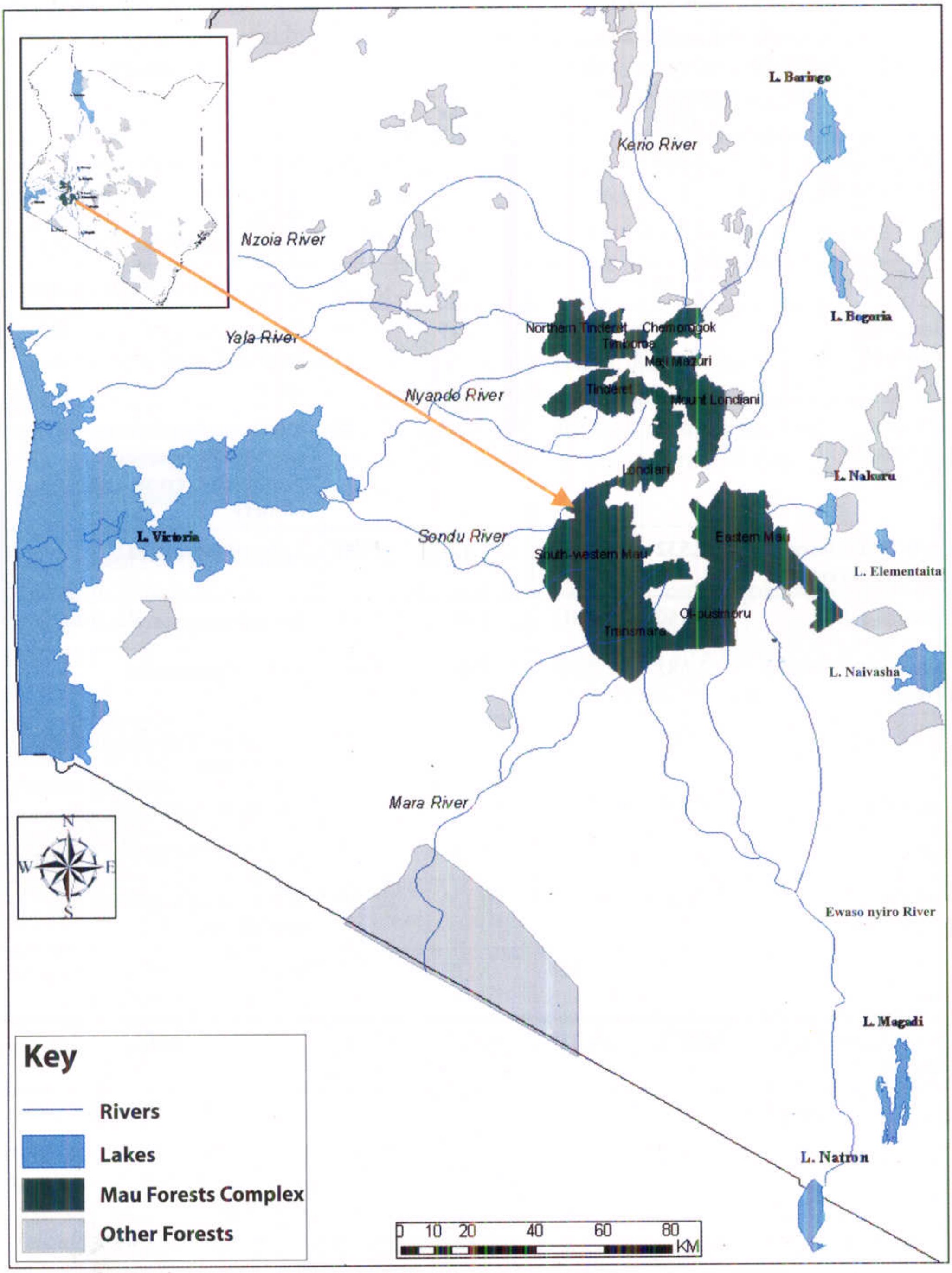

Figure 1 Map of Kenya showing Mau Forests Complex and its watershed system

In addition, the Complex provides water for domestic and industrial uses in adjacent areas and urban centers (Bomet, Egerton University, Elburgon, Eldama Ravine, Kericho, Molo, Nakuru, Narok and Njoro). The complex has a high potential to support the national energy needs through hydropower generation that is estimated at 535 Megawatts. This would contribute 57% of the current total electricity generation in Kenya.

The flora of Mau Forests Complex consists of heterogeneous patterns of vegetation cover that include over 280 vascular plant species consisting of 200 genera and 95 families. The vegetation species recorded include 64 trees, 38 shrubs, 46 climbers and 132 herbaceous plants. The Mau Forests Complex can be classified into four distinct vegetation zones: bamboo, mixed bamboo/forest transition, closed canopy forests of *Podocarpus latifolius*, *Prunus africana*, *Albizia gummifera*, *Olea capensis*, and open canopy of *Neoboutonia* species. The forest has been greatly disturbed by human activities through unsustainable logging, bark stripping, livestock grazing and other forms of harvesting. The excisions of between 2001 and 2007 have in particular induced tree felling and land clearing for agricultural purposes.

Owing to its high altitude and rapid descent to adjoining lowlands, Mau Forests Complex is a reservoir of unique biological diversity that includes rare animal species. Some of the animals include Bongo, Yellow duiker, Red duiker, Golden cat, Tree hyrax, Giant forest hog, Spotted hyena, Rare golden cat, and Yellow backed duiker. Primates include Red-tailed blue monkey, Bush babies, and Black and White colobus monkeys. The forest hosts over 200 species of butterflies, 20 of which are known to be forest dependent species. Forty-nine of Kenya's 67 Afro-tropical highland bird species are known to occur in the Mau Forests Complex. These include, Grey throated barbet, Luh der's bush shrike, Equatorial akalat, Red-chested owlet, Banded prinia and Black-faced rofous warbler. Of these bird species, 11 are listed in the CITES I and II categories, including the Verreaux eagle, Amani sunbird and Taita thrush. Others include regional endemic species, such as Hartlaub's turaco, the Restricted range huntrer's cisticola and Jackcon's francolin.

1.1.2 Economic value of Mau Forests Complex

The Mau Forests Complex is an international resource of extreme environmental, economic and socio-cultural importance. The merits of rehabilitating the complex have been debated lately and are, thus, obvious to most people.

Although a comprehensive economic valuation of the Mau Forests Complex has not been carried out, the often-quoted annual economic value of US$ 300 million is a gross underestimation. Estimates carried out put the annual economic value of the forest ecosystem at US$ 1.3 billion. This value is based on benefits accrued from the Complex (Table 1.2).

Table 1.2 Value estimates of products and allied environmental benefits of Mau Forests Complex

Economics Benefits	Estimated Value (million US $)
Climate regulation and carbon fixing	89.0
Tourism sector	65.8
Recreation	44.8
Livestock production support	106.9
Fisheries production support	21.1
Cultural value	0.8
Energy	131.6
Wood products	33.6
Non- wood products	126.0
Genetic resources capacity	16.4
Floriculture, tea and coffee	163.2
Subsistence agriculture	72.4
Ecosystem services	98.0
Soil erosion control	368.0
Total	**1338**

1.1.3 Threats to Mau Forests Complex

The Mau Forests Complex is currently facing various threats including extensive conversion of natural forests and plantation forests to agricultural land and human settlement. The underlying causes of deforestation and degradation of Mau Forests Complex have been identified as follows:

a. *Lack of appreciation of total value of forests*

   There is a critical lack of recognition of real values and integral role that forests play in sustaining life support systems. The socio cultural, economic and ecosystem services are not fully reflected in national accounts. This leads to deforestation because of unrealized opportunity cost of maintaining/losing forest resources.

b. *Weak enforcement of forest policies and legislation*

   The country has established forest policy and legislation but the problem has been weak enforcement. For example, livestock grazing is provided for in the Forests Act, 2005 but has been widely abused through unregulated overstocking. Though charcoal production is outlawed in natural forests, charcoal burning has been going on due to several factors that include under funding, low staffing, inadequate infrastructure, and lack of clear frameworks for community participation in forest protection and management. Forest excisions have not been guided by the laid down regulations in the Forest Policy and Act.

c. *Macro-economic policies*

   Kenya is an agriculture-based economy with aspiration to fast tracking industrialization to diversify its economic base. The government strategy lays much emphasis on the expansion of agricultural sector and industrial development to create employment and earn the country foreign exchange. However, forest and environmental conservation in the past received less emphasis in funding priority and political support. Furthermore, forest ecosystems support the agricultural sector.

d. *Political interference*

There has been prolonged political interference that has led to arbitrary decisions on natural resource management that have weakened established laws, technical aspects of management, norms and traditional values.

e. *Population growth*

The growing population and the shrinking productive agricultural land has forced migration of people from densely populated regions into the Mau Forests Complex. This coupled with poverty and lack of alternative livelihoods has forced the local people to clear forests or get involved in illegal forest extractive activities.

f. *Growing commercialization of forest products*

The rapid urbanization in the adjacent settlements and towns has increased demand for forest products especially sawn wood, poles, posts, firewood and charcoal sourced mostly from Mau Forests Complex.

1.1.4 Rationale for restoration of Mau Forests Complex

Given the high levels of degradation of the Mau Forests Complex, there is urgent need for restoration of the ecosystem. The aim should be to restore the functions of the forest ecosystem to its optimal potential. The restoration may involve large-scale afforestation or reforestation using both indigenous and exotic tree species. However, forest restoration process must take into consideration the social, economic and biological functions. The process should address the root causes of forest loss and degradation. The restoration package may include techniques, such as agroforestry in surrounding farmlands, enrichment planting, open gaps planting and natural regeneration. The restoration activities should involve a range of stakeholders in planning and decision making to enhance acceptable and sustainable management. Enhancing capacity of stakeholders in forest restoration needs and skills be preliquisite requirement.

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Chapter Two

Overview on Natural Forest Degradation in Kenya

David K. Langat, Joshua K. Cheboiwo and Titus Suter

2.0 Introduction

Large areas of natural forests in Kenya are highly degraded largely due to human related activities that include human settlements, cultivation, overgrazing, logging, charcoal burning, wildlife damage and frequent fires. The continued deforestation and degradation of forest ecosystems is already raising concern among stakeholders at national and international levels due to their impacts on the integrity of the forest ecosystem and its potential to provide adequate forest products and services. The declining access and availability of forest products and services to competing needs increases the potential risk of conflicts over these resources.

The emerging concerted efforts to halt the rate of deforestation and forest degradation has prompted efforts towards ecosystem restoration. These are largely as a result of decreasing and fluctuating supply of forest products and services, and climate change among other factors. The government of Kenya recognizes the important role the environment plays in supporting the productive sectors of the economy and hence its inclusion as one of the pillars of Vision 2030. To achieve the noble objectives of Vision 2030, the Government has committed itself to protect the critical water towers that are at various levels of deforestation and degradation.

In the recent past, there have been efforts in forest restoration of the water towers with limited success because the efforts were only aimed at planting trees without due consideration of the socio-cultural, political, economic realities and ecosystem processes. Thus, it is desirous that there is proper understanding of these factors for meaningful natural forest restoration processes.

2.1 Processes of Forest Degradation

Natural processes such as floods, erosion, drought and forest fires have shaped natural landscapes over time. The changes overtime have influenced species abundance, diversity and composition in the forest landscapes. However, in the recent times human activities have greatly influenced the character and dimensions of the changed landscapes. These have been mainly through various activities such as selective harvesting, encroachment, frequent fires and overgrazing.

2.1.1 Selective timber harvesting

Selective timber harvesting in Kenya's forests was one of the pioneer forest management practices since 1890s. The planned selective harvesting system in indigenous forests was discontinued in 1986 due to mismanagement, mainly over harvesting. The over harvesting activities have overtime significantly altered forest structures, flow of environmental services and forest resources.

2.1.2 Encroachment and land excisions

The need for land by the growing population living adjacent to forests has been one of the greatest single factor leading to deforestation and forest degradation in Kenya. The population pressure has accelerated forest encroachment, land excisions and political interference in forest governance. The process has been aggravated by poverty, demographic growth and institutional weaknesses.

2.1.3 Fires

Forest fires have caused considerable damage to forest ecosystems in Kenya. The fires are accelerated by adverse weather conditions, arsonists, community apathy, charcoal burning activities, and inadequate fire protection facilities and measures. Forest fires have caused enormous biodiversity and economic losses (Table 2.1). Annual forest fires are estimated at KES 4 million and 27 million in suppression and damage costs, respectively. Approximately 8000 ha of planted forests, natural forests and bushland/ grassland are damaged each year.

2.1.4 Overgrazing

Livestock grazing is a common activity in most of Kenya's moist forests. Grazing in forests is provided for in the Forests Act, 2005. As a management tool, this practice is appropriate for suppression of weeds in young forest plantations as it reduces biomass that could otherwise pose fire hazards in the dry seasons. Grazing in natural forests is detrimental to natural regeneration and species composition. As a rule, goats are not allowed in forests due to their detrimental grazing and browsing habits. Livestock grazing in forest areas has surpassed the carrying capacity of most forest ecosystems leading to degradation.

2.2 Indicators of Forest Degradation

The Food and Agriculture Organization of the United Nations (FAO) has defined forest degradation as changes within a forest that affect its structure and function thereby lowering its capacity to supply products and services. Degraded forests are characterized by low productivity, biodiversity and capacity to provide ecological goods and services. Repeated disturbances or over-exploitation can lead to loss of the original vegetative cover some of which may be replaced by invasive species. The following are the main indicators of degraded forests.

Table 2.1 Losses arising from forest fires from 1980 to 2008 in Kenya

Year	Area burnt (ha)				Tangible loss in KES			Number of fires
	Plantation	Natural forest	Bush and grass	Total	Suppression cost	Damage cost	Total cost	
1980	178	4,951	14,834	9,963	773,660	3,827,040	4,600,700	79
1981	957	3,227	6,031	10,215	759,180	16,404,320	17,163,500	98
1982	217	7,838	-	8,055	79,180	443,680	522,860	21
1983	239	40	27,847	28,126	75,380	12,226,500	12,301,880	43
1984	401	176	23,517	24,094	562,920	8,346,080	8,909,000	66
1985	371	157	275	803	103,600	1,101,000	1,204,600	28
1986	541	384	4,511	5,436	3,727,040	15,550,540	19,277,580	70
1987	282	99	545	926	120,220	224,780	345,000	37
1988	188	155	3,792	4,135	177,420	639,080	816,500	30
1989	231	175	2,356	2,762	105,000	1,203,600	1,308,600	46
1990	85	331	12,183	12,599	128,600	366,060	494,660	36
1991	1,705	236	6,697	8,638	456,420	2,996,340	3,452,760	64
1992	6,170	5,494	13,302	24,966	5,859,300	99,127,400	104,986,700	180
1993	1,731	515	1,718	3,964	500,820	11,901,420	12,402,240	48
1994	690	69	1,914	2,673	3,187,700	37,847,500	41,035,200	40
1997	4,726	2,961	7,729	15,416	45,727,733	51,979,918	97,707,651	121
1999	1,449	317	2,041	3,807	25,878,790	28,606,232	54,485,022	59
2000	861	1,230	886	2,977	560,694	38,624,954	39,185,648	38
2001	601	487	1,383	2,471	781,673	4,986,078	5,767,751	67
2002	783	4,229	3,041	8,053	862,835	9,689,043	10,551,878	89
2003	302	2,361	2,349	5,012	2,537,475	12,038,876	14,576,351	72
2004	214	893	3,783	4,890	1,865,958	27,893,436	29,759,394	56
2005	1,068	4,683	4,902	10,653	5,800,000	270,000,000	275,800,000	163
2007	2	5	18	25	27,000	84,000	111,000	5
2008	1,020	147	351	1,518	570,714	20,107,549	20,678,263	86

2.2.1 Biodiversity loss

This is a process where variety of life forms in a specific ecological community decreases. Activities like continued cultivation, logging, grazing and frequent occurrence of fires can reduce populations of living organisms of all forms.

2.2.2 Habitat loss

Forest and woodland clearance and overgrazing are major causes of habitat loss. Habitat loss results in exposure of soils, which leads to soil erosion, loss of fertility, soil biota and hydrological properties.

2.2.3 Loss of forest products and services

Degraded forests have low productivity and hence reduced ability to sustainably provide adequate flow of forest products and ecological services.

2.2.4 Microclimatic change

Forest degradation lead to changes in microclimate within forest ecosystems. The microclimate change affects species composition and diversity, and productivity.

2.2.5 Species invasion

Repeated disturbances or over-exploitation create open gaps in forest ecosystems. This may alter species composition or cause disappearance of the original species, some of which may be replaced by invasive species.

2.3 Conclusion

Kenya's forest ecosystems are at critical stages of degradation. For these forests to continue providing essential products and services, there is need for urgent action to save them from further destruction. This can be achieved by restoration process that takes into consideration the socioeconomic interests of stakeholders and biological conditions of the forest ecosystems. This further calls for change in policies, legislation and institutional structures to reflect multi-dimensional aspects of forest restoration. It is important that a landscape approach to forest restoration is adopted with active involvement of local residents bordering the forests. The development of sustainable forest restoration programs should be based on careful balancing of ecological and economic objectives. These may involve targeting restoration activities, which enhance the livelihood opportunities of the local population such as firewood extraction, honey production and eco-tourism.

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Chapter Three

The Role of Local Communities in Forest Restoration

David K. Langat and Joshua K. Cheboiwo

3.0 Introduction

Human activities have negatively changed forests resulting in loss of biodiversity, reduced ecosystem services and scarcity of important wood and non-wood forest products. Forest restoration is a critical input to sustainable management of forest resources. The success of forest restoration largely depends on community participation especially their goodwill and traditional knowledge in resource use and conservation. This is particularly important where local communities are highly dependent on forest resources.

3.1 Socioeconomic Issues in Forest Restoration

There are a number of stakeholders that need to be considered for successful forest restoration. This may include diverse communities and businesses that either work within the forest or utilize the forest products or indirectly benefit from the presence of the forest. The stakeholders' needs and interests influence the success or failure of any restoration activity. Similarly, social and economic issues have to be taken into consideration in the restoration process. These include livelihood strategies, forest dependence, poverty levels, gender and literacy levels.

3.2 Socio-cultural Issues

Forests provide spiritual and cultural values to local people. The restoration process needs to take into consideration some of these values. To do this, traditional knowledge must be harnessed in order to sustain continued forest resource conservation and sustainable use. Areas of sociocultural importance should be identified in the forest sites to be restored. The Kipsigis ethnic group bordering extensive areas of West Mau, for instance, have special reference to Mt. Blacket forest and would like the forest to remain conserved and restored with indigenous species of spiritual, cultural and medicinal values e.g. *Olea africana*, *Podocarpus latifolius*. It is important to identify these plants and sacred sites for conservation in collaboration with local people.

Table 3.1 Plant species of cultural and medicinal significance among the Kipsigis community of Mau Forests Complex

Species	Local name	Plant form	Use
Olea africana	Emitiot	Tree	Cultural, medicinal
Ekebergia capensis	Araruet	Tree	Medicinal
Podocarpus latifolius	Saptet	Tree	Cultural
Toddalia asiatica	Chebindorweet	Climber	Medicinal
Acokanthera schimperi	Keliot	Tree	Medicinal
Periploca linearifolia	Sinendet	Climber	Cultural, medicinal
Warburgia ugandensis	Soget	Tree	Medicinal
Senna didymobotrya	Senetwet	Shrub	Medicinal, cultural

3.3 Characteristics of Forest Adjacent Communities

Most of the communities living adjacent to Mau Forests Complex are smallholder farmers with land holdings ranging between 2 and 4 ha. In most parts of Kericho District, tea growing and dairy farming are the main sources of income while in the nearby Nakuru District, the main activities include dairy, sheep and beef farming, and vegetable production. The Maasai community, found mostly in the south, uses the Mau Forests Complex reserve as grazing and watering areas. Forest grazing is critical to the Maasai during droughts when thousands of cattle are moved from distant places to the forests.

Box 3.1 Household dependence on forest resources

The characteristics of communities living adjacent to West Mau forest were determined based on 132 sample households in 5 sampling sites; Kahurura, Kuresoi, Sirikwa, Kedowa and Itare. The findings in West Mau showed that most households were predominantly farmers (72%) but had diversified their income sources by participating in combination of income-generating activities (Figure 3.1). The households adjacent to Mau Forests Complex extracted various products from the forests such as sawn wood, poles, posts, tool handles, charcoal and firewood. The non-wood forest products included honey, water, grass and fibres. The fibres were used for making tea baskets and medicinal products. In the West Mau the dependence on forest resources showed that 75% of households extracted firewood, 50% timber, 23% charcoal, 46 % non-wood forest products and 43% grazed their livestock in the forest (Figure 3.2). The results showed that West Mau forest is an important source of various forest products for the households living adjacent to it.

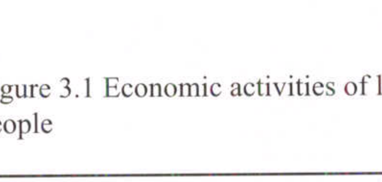

Figure 3.1 Economic activities of local people

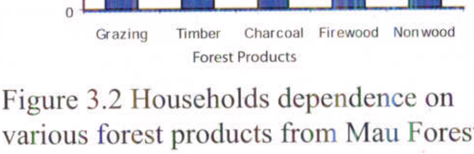

Figure 3.2 Households dependence on various forest products from Mau Forests

Plate 3.1 Sheep grazing in a degraded open forest area in Sirikwa, West Mau Forest block. Photo by D. Langat

3.4 Considerations in Forest Restoration

When planning any restoration project, it is important to consider the current forest use and the potential impacts it may have on local community access, use, and safety. It is imperative that specific areas for harvesting firewood, livestock grazing, collection of medicinal plants, honey and other forest products are identified. It is also important to avoid activities that will hinder the process of forest restoration. In addition, it is important to collect information on biophysical status of a forest to facilitate planning and zoning of forest areas for sustainable use by local communities.

3.5 Tree Species Selection for Restoration

Tree species selection for forest restoration should consider local community needs and technical aspects that include the level of degradation, species diversity and restoration objectives. Species preferences are obtained from socioeconomic surveys. The final choice of tree species is dictated by the restoration objectives i.e. productivity, conservation value, recreational value and multifunctional use. Some of the priority species for restoration that were obtained through a socioeconomic survey in Southwest and West Mau forests are listed in Table 3.2.

Table 3.2 Priority list of tree species for restoration based on local community prioritization in Mau Forests Complex

Species	Local name (Kipsigis)	Use
Olea europaea ssp africana	Emitiot	Firewood, charcoal, poles, cultural
Prunus africana	Tendwet	Timber, medicine
Albizia gummifera	Seyeet	Timber, firewood
Juniperus procera	Tarakweet	Poles, posts, timber
Podocarpus latifolius	Saptet	Timber, cultural
Allophylus abbysinica	Mororta	Firewood
Nuxia congesta	Chorwet	Firewood
Syzygium spp.	Lemeywet	Poles
Hagenia abbysinica	Bondet	Timber, firewood
Ekebergia capensis	Araruet	Medicine

3.6 Working with Diverse Stakeholders

3.6.1 Stakeholder analysis in forest restoration

Various stakeholders have interest in the use of adjacent forest resources. It is, therefore, important to identify all stakeholders within a restoration area and their needs with regard to the uses and responsibilities in relation to their expectations. Involving local stakeholders in forest restoration processes will inculcate some sense of ownership and commitment for sustainable forest resource management.

There are key questions that have to be addressed to facilitate the process for analysis and involvement of stakeholders in forest restoration (Box 3.2). The stakeholder analysis is undertaken through discussions with key informants. The interests and needs of each stakeholder should be given special focus after exhaustive identification of all stakeholders. Special needs are explored using focused group discussion approaches.

Box 3.2 Important questions in stakeholder analysis

- Which institutions have interests in forest restoration?
- Have all stakeholders' interests been identified?
- Are stakeholders aware of forest restoration processes?
- How will various stakeholders contribute to the restoration efforts?
- How will various stakeholders benefit from the restoration efforts?
- Are the interests of the stakeholders captured in forest policy and legislation instruments?

There are diverse stakeholders with interest in Mau Forests Complex emanating from their use or mandates. Based on analysis undertaken in the area, government agencies, local community based organizations, NGOs have a stake in the use and conservation of Mau Forests Complex and their role in forest restoration should be recognized (Box 3.3).

Box 3.3 Stakeholders and their interests in Mau Forests Complex

Stakeholder	Type of organization	Interests
Kenya Forest Service	Government agency	Forest establishment Forest protection Licensing of forest users Promotion of tree growing on farms
Kenya Wildlife Service	Government agency	Protection of animal (s) habitat Protection of animal (s) People and wild life conflicts
Tea Companies	Tea industry	Protection of forest to sustain positive forest influence on tea productivity Tree planting in farms Small power generations Social responsibility obligation
Friends of Mau Watershed (FOMAWA)	Local NGO	Promotion of tree growing on private farms to ease pressure on Mau forests Provision of advisory service on tree growing and management Advocacy for conservation of Mau
District Environmental Committee	Interdepartmental committee	Environmental protection Licensing and policy guidance
Ogiek Welfare Council	Community Association	Advocacy on minority rights Access rights to forest uses for cultural and honey collection Protection of cultural identity and promotion of non-consumptive uses Forest protection and restoration
World Wide Fund for Nature (WWF)	International NGO	Forest Restoration Habitat protection
Ministry of Agriculture	Government Ministry	Soil and water conservation
Water Resources Management Authority (WRMA)	Government agency	Protection of watersheds, springs, rivers, licensing and regulations
Saw Millers Association	Forest industry	Adequate supply of wood materials to run their mills
Country Vision Forest Association	Local community based organization (CBO)	Forest conservation Income generation from activities like honey production Collection of minor forest produce
Tulwap Kugo Ecotourism Group	Local CBO	Protection of cultural sites Development of Ecotourism sites in the forest
Londiani Community Forest Users Association	Local Forest Association	Access to forest products Participate in forest management
Adventist Development and Relief Agency (ADRA)	Church organization	Forest restoration Awareness creation on environmental conservation Promotion of energy saving devices
Local users	Forest adjacent community	Access to forest products (firewood, poles, honey etc) for home use and for sale Participation in forest management Access to cultural sites

3.6.2 Use of local knowledge in forest restoration

Local knowledge and conservation ethics are useful in forest restoration. Traditional knowledge is invaluable in identification of tree species for restoration, especially where published information is not available. In most instances, local people may be the only source of ecological knowledge on plant identification, flowering, seeding patterns, species associations, ecological plant niches, forest uses and traditional management techniques.

3.7 Economic Opportunities

Forest restoration activities should explore the potential opportunities in which local stakeholders can improve their livelihoods. Such activities may create direct income opportunities for the local people immediately or thereafter. The capacity of the local stakeholders to fully participate and benefit from restoration activities can enhance their incomes and act as an incentive for their active participation. Local opportunities like establishment of tree nurseries, bee keeping and small handicrafts are examples of business opportunities that can attract local people to participate in forest restoration activities.

3.8 Eco-tourism

Eco-tourism is an emerging non-consumptive economic opportunity that can generate benefits to the local communities and enhances participation in forest restoration. Most forests have unique biota, fauna and landscapes, which offer good opportunities for development of eco-tourism enterprises such as guided forest walks, bird watching, environmental education programs, picnics and mountain biking, among others.

3.9 Off-forest Interventions to Support Forest Restoration

3.9.1 Promotion of on-farm tree planting

The high demand for various forest products for domestic use and trade is one of the major causes of forest degradation in natural forests. Thus it is necessary to promote tree planting on farms to ease pressure on natural forests and meet the growing demand of forest products. Some of the preferred indigenous species for planting by local communities are: *Dombeya torrida*, *Podocarpus latifolius*, *Zanthoxylum gillettii*, *Polycias fulva*, *Croton megalocarpus*, *Prunus africana* and *Dodalia abbysinica*. The preferred exotic tree species include; *Grevillea robusta*, *Eucalyptus* spp., *Cuppresus lusitanica* and *Acacia mearnsii*.

There is need to create awareness amongst the local population about the importance of tree planting on farms. One approach in promoting tree planting in farms is by using individuals or groups of people to establish model farms. This approach would enhance adoption of tree planting technologies to meet local needs for wood products and surplus for sale. To enhance promotion of on-farm tree planting, long-term research on management and provision of quality seed is needed to support intensive tree growing on farms.

3.9.2 Establishment of tree nurseries

For effective forest restoration, there is need to expand the number of tree nurseries to supply seedlings of both indigenous and exotic tree species. In the past, the Kenya Forest Service and private nurseries focused on production of mainly exotic seedlings and less emphasis was placed on indigenous tree species. There is need, therefore, to promote production of indigenous tree seedlings. However, more research is needed to address poor germination of most indigenous species and nursery management.

3.9.3 Building awareness and capacity of stakeholders in forest restoration

Under the new forest policy and legislative (Forests Act, 2005) framework the local communities are encouraged to form Community Forest Associations (CFAs) that should play key roles in forest management. But most CFAs lack capacity to effectively participate in forest restoration. There is need, therefore, to create awareness and build capacity of CFAs. This include, roles and obligations, benefit sharing framework, development of joint management plans and negotiation skills, among others.

3.10 Conclusion

Forest restoration has to incorporate considerations on ecosystem, socioeconomic and cultural values. It is important also to consider the effects and impacts of forest restoration on people living adjacent to restoration areas. The restoration process should use existing local organizations, traditional structures and right incentives to enhance forest restoration activities of degraded forests. Further, restoration efforts should be backed by policy and legal framework that promote equity and benefit sharing.

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Chapter Four

Natural Forest Regeneration and Succession: An Option for Restoration of Degraded Forests

Collins Jared Amwatta Mullah, Ørjan Totland and Kari Klanderud

4.0 Introduction

Natural forest succession occurs where forest is abandoned or temporarily fallowed after clear-felling, selective logging, fires, windstorm, charcoal burning, etc. Such disturbances in natural forest vary in scale, intensity and frequency. This can trigger a variety of successional process resulting in fragmented landscapes with a range of habitat types such as, old forest growth, successional habitats, grasslands/glades and fallows of varying habitat quality.

One important effect of forest succession is the interaction between trees and other plants of successional community. Grasses and forbs are the first plants to colonize abandoned sites. Thus, before woody species can attain dominance, they have to compete with the initial herbaceous vegetation. Competition between woody species and the initial vegetation is a major determinant of tree species growth and survival. The vegetation succession on these disturbed sites will generally proceed towards a closed forest (secondary forest). Such newly created secondary forests, are important for providing extractable resources, ecosystems services and biodiversity. However, these forests have fewer tree species than the original primary forests.

4.1 Natural Regeneration and Succession

Forest succession is a directional non-seasonal cumulative change in the types of plant species that occupy a given forest through time. It involves the process of colonization, establishment and extinction of plant species. Succession begins when an area of forest is made partially devoid of vegetation through natural or man made disturbances such as tree fall, lightning, disease and pest infestation, fires, volcanic eruptions, windstorms, clear felling and climate change. Intact and disturbed forests differ in the rate and size of gap creation. Gaps in disturbed forests are often larger and may appear more frequently than those created under natural conditions. Therefore, knowledge on the patterns and processes of species regeneration in small and large gaps is essential to the design of forest management systems based on the natural forest dynamics in Kenya.

Disturbances in natural forests vary in scale, intensity and frequency and can trigger a variety of successional processes. Such disturbances may occur through small tree falls or selective cuttings that form small canopy gaps, usually filled by tree species already present as seeds, saplings, re-sprouts or overhanging canopy trees. Sprouts are especially important for the regeneration of some tree species like *Allophylus abyssinica* (stems) and *Ocotea usambarensis* (roots) in the canopy gaps in the case of Kenya. In a natural forest, free from human disturbances, most regeneration comes from established trees, reflecting the species composition of a pre-disturbance community. This is not the case with natural forests in Kenya that are under constant human disturbances and such forests show evidence of constant changing in floristic composition. For instance, fires play an important role in the regeneration cycle of some forest tree species like *Juniperus procera* (Cedar), *Olea europaea* and *Nuxia congesta*. After fire, Cedar seedlings invade the gaps, leading to a regenerating forest, where broad-leaved species like Olea become established. If the number of Cedar trees established after fire is high, a pure Cedar forest results by suppression of other species. In case a burnt area is mainly invaded by broad-leaved species, these will constitute the canopy with scattered Cedar trees emerging. Therefore, either way, the floristic composition of the postfire forest will be different from the pre-fire condition.

Plate 4.1 Gap created by charcoal kiln at Kedowa, Mau Forests Complex.
Photo by C.J. Amwatta Mullah

Large scale natural disturbances that remove vegetation several hundreds of hectares undergo different processes of succession than simple closure of canopy gaps. This is because re-vegetation processes after damage by wind or fire leave many seeds, seedlings and older plants alive and can readily respond to the increased light and soil resource availability. The initial floristic composition in a disturbed forest is mainly determined by regeneration, which further depends on composition of soil seed bank and sprouting of stumps and roots. In some Kenyan cases, clear felling followed by the *shamba* system that involves clearing and uprooting of stumps and roots, limits regeneration. Soil seed bank will therefore play a major role in the regeneration of abandoned fallows. It is also likely that seeds dispersed from the nearby natural forests will contribute directly to regeneration, or may become incorporated into the seed bank in the abandoned fallows.

Natural forests in Kenya are going through both recovery and degradation simultaneously. Indeed, the forest plant community is composed of numerous patches of various sizes at different stages of successional developments. The initial stages of recovery are composed of grasses and herbs, shrubs and some tree seedlings. However, evidence show that most primary forest tree species will remain absent from many regenerating patches of forest for a large number of years. For example, in the Itare block of Mau forest, only 35% of the tree species recorded in a secondary forest was found in nearby regenerating forest after 19 years of abandonment.

Box. 4.1 A case of natural regeneration in Mau Forests Complex

In Mau Forests Complex there are many sites that have undergone disturbances such as cultivation through *shamba* system and failed commercial plantations. The sites are naturally regenerating with woody vegetation and have become a common feature in our natural forest landscapes. A study in southwest Mau, Itare block showed that a 19-year-old regenerating forest area was characterized by a relatively uniform composition of mostly pioneers and non-pioneer light-demanders. While such forests may not deliver all the attributes of a secondary forest, it can provide ecological benefits. The forests as early as at this successional stage can be manipulated through silvicultural practices such as selective thinning and enrichment planting to accelerate forest succession. The management of regenerating forests has implications to the future forest structure and floral compositions and hence provision of forest goods and services.

In most regenerating forest ecosystems, woody species are strongly affected by free ranging livestock. This is because domestic animals retard tree regeneration through grazing, trampling and uprooting. However, domestic animals may enhance tree species survival by reducing competition from dense and closed grass that limits establishment and growth of seedlings. Generally, grazing will enhance establishment and survival of non-palatable species thus reducing tree species diversity.

Plate 4.2 Livestock grazing in abandoned fallows at Kedowa, Mau Forests Complex. Photo by C. J. Amwatta Mullah

4.2 Species Diversity and Composition in Degraded Forests

The availability of growing seedlings to fill large openings is important in the dynamics of forest recovery. However, major differences may occur between species in the frequency and density of seedling recruitment. Continuous forest disturbances are crucial for the dynamics and stability of natural forest systems, and directly affect species diversity and composition. In heavily disturbed forests, the tree species diversity declines drastically. The species composition emerging from abandoned fallows is determined by several factors such as degree of disturbance, soil nutrient status and seed dispersal from neighbouring forests. For example, the first woody dominants to appear in the abandoned fallows at Itare block of Mau forest were *Albizia* and *Neoboutonia* because the species are found in the adjacent forests. Similarly, the primary species that were predominant in the regenerating forest seedlings and saplings also coexisted with secondary pioneer forest species such as *Prunus africana* and *Hagenia abyssinica*. Since the secondary pioneers had no mature trees within the vicinity, their presence may have been through long-term seed banks in the abandoned fallows and long distance dispersal mechanisms. The population of the primary species found in the abandoned fallows were low and totally absent from regenerating forests. These species were represented by 1-5 mature individuals per site (15 ha) in the secondary forest and less than 3 in the most advanced recovered areas of the abandoned fallows. This may be far fewer than necessary to maintain viable populations and may be lost from the secondary forests due to reduced recruitment abilities coupled with potential losses at juvenile and saplings stages. In such situations restoration strategies are necessary if a resemblance of the original population is to be restored.

Box 4.2 Forest recovery trends in Itare Forest block of Mau Forests Complex

Studies from Itare forest block showed that tree species diversity and abundance decreased gradually with increasing distance from the edge of surrounding natural forest after 19 years abandonment of *shamba* system. The colonization pattern by tree species was high in the areas close to the natural forest edge and sparse in zones further away. Studies elsewhere have established that species diversity of disturbed areas approaches that of mature forest after 100 years. The findings indicated that species composition will not resemble mature forest, since dominant species of primary forest, if present, do occur at low abundance. Preliminary finding on regeneration trends in Itare forest block showed that natural recovery into a closed forest canopy is not possible in the short term of 20 years.

4.3 Invasive Species

Invasion of degraded forests by alien plants frequently occur after disturbances. The invasive plant species take advantage of openings created by disturbances in their colonization and establishment. They may exert severe negative consequences on biodiversity by displacing indigenous tree species and disrupting forest community structure.

Box 4.3 Invasive species at Mau Forests Complex

Studies from Kedowa block identified invasion of Mexican green ash (*Fraxinus pennsylvanica*) in abandoned fallows and gaps in the forest. The species was introduced in mid 1950s as fire breaks in plantations where there were high fire frequencies. The study in Kedowa further revealed that Mexican green ash was the dominant species in these stands, comprising about 80% of the total basal area of the regenerating forest. The current evidence indicates that, although most indigenous species invasions have a weak impact on ecosystems, invasive exotic species can alter an ecosystem. Although the conditions in the secondary forest might not directly favour invasive species, their dominance in the zones undergoing transitions is enough evidence that the species are changing the composition and diversity in such areas. It is imperative that due consideration is taken after forest disturbances to take care of invasive species through intervention measures that favour restoration of indigenous species.

Plate 4.3 Invasion of abandoned fallows by *Fraxinus pennsylvanica* in Kedowa, Mau Forests Complex. Photo by C. J. Amwatta Mullah

4.4 Forest Species Succession Cycles

4.4.1 Pioneer and non pioneer classes

In terms of forest succession, attempts have been made to group tropical forest tree species into ecological classes. Two classes are recognized in most classifications, namely pioneer and non-pioneer species. Pioneer species are those that require full light for both germination and establishment; they are fast growing and have low-density timber. Non-pioneers are late successional species that germinate and establish below a closed forest canopy. They regenerate from seed banks in small gaps to form the next growth cycle. These seedlings are replaced in larger gaps by pioneer species that germinate from seed after gap creation. Shade-tolerant species form the next growth cycle where gaps are small, and as gap size increase progressively the more light-demanding species take over in the next growth cycle. On mountain forests, intensive selective logging of high value timber species like *Ocotea usambarensis* and *Hagenia africana* leave big gaps which are rapidly closed by pioneer species such as *Macaranga kilimandscharica* and at higher altitudes by *Neoboutonia macrocalyx* and *Tabernaemontana stapfiana*. In the absence of fires, tree species whose seed dormancy is broken by scarification such as *Juniperus procera*, *Olea capensis*, *Hagenia abyssinica*, *Clutia abyssinica*, *Dombeya torrida* and *Nuxia congesta* may not be represented in normal successional stages in disturbed forest areas. For instance, due to low frequencies in fire incidences at Itare forest block, only mature trees of *Olea africana* was found. This was in contrast to Londiani forest block that experiences frequent fires, where all tree growth stages were present (seedlings, saplings and mature trees). Generally, large forest disturbances create large areas consisting of pioneer species making it necessary to intervene by active planting of non-pioneers within such forests.

In typical moist forests in Kenya, clear-felled areas were followed by *shamba* system cultivation that was abandoned between 1983 and 2002 after the government ban on cultivation in public forests. The cultivators removed most tree stumps, destroyed soil seed banks and removed seedlings. Therefore, abandoned fallows in former *shamba* system areas may not have seed banks of primary forest species and distribution of remnant sources of forest seeds becomes an important determinant of seed availability and seedling recruitment.

Large-scale colonization of open land by large-seeded tree species like *Prunus africana* and *Macaranga kilimandscharica* were, for the case of Mau, confined to less than 15 m from the forest edge. The wind-dispersed primary pioneer tree species like *Neoboutonia macrocalyx* colonized distances longer than 35 m from the forest edge. Such pioneer species colonize open areas because their small seeds are present in large quantities. It has been established that replacement of early pioneers by the late pioneers generally take as long as 30-50 years. It takes about a century to restore most of the forest ecosystem functions though the new forest may not have the same tree species as were present before clear felling. Unaided natural forest succession, which is the case for forests in Kenya, may offer a way of restoring forest ecosystems. Natural regeneration potentially will save costs incurred in seedling production and planting but may not attain the desired species diversity.

4.5 Selection of Tree Species for Restoration of Mau Forests Complex

Information on propagation and management of most indigenous species is limited. This has resulted in the use of only a small number of tree species in past restoration efforts. The current concerns over environment and biodiversity in forest ecosystems require an increase in diversity of target restoration species. Useful factors to consider as criteria for forest restoration include growth, survival and ecological suitability of the tree species.

Box 4.4 Potential species for restoration of Mau Forests Complex

The identification of potential tree species for restoration of degraded forests was based on data on species abundance and composition in abandoned recovering forest fallows and secondary forest in Itare forest block. This was guided by the assumption that existing tree saplings are good predictors of future floristic composition of the forest and therefore are suitable candidates for restoration. The persistence of these saplings in contrasting habitat conditions in the forest is an indication of their potential ability to thrive under the prevailing forest conditions. From the findings it is evident that the following species are suitable for restoration of degraded moist forests:

Albizia gummifera	*Polyscias fulva*
Allophylus abyssinica	*Ekebergia capensis*
Neoboutonia macrocalyx	*Periploca linearifolia*
Psychotria mahonia	*Senna didymobotrya*
Olea capensis	*Nuxia congesta*
Toddalia asiatica	*Hagenia abyssinica*

4.6 Conclusion and Recommendations

In general, forest regeneration in large areas of abandoned fallows cannot rely on passive succession process aided by only a few remnant species. This is because recruitment is slow as it relies on the species composition of nearby intact forests. It is suggested that attaining species diversity is possible if natural succession of pioneers is actively enriched with plantings of late-successional tree species. Development of criteria for selection of tree species for restoration should be done early in the planning in order to accelerate forest recovery to facilitate provision of the expected goods and services.

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Chapter Five

Natural Forest Restoration Options

Joram M. Mbinga and Michael M. Okeyo

5.0 Introduction

Natural forest restoration is the process of rehabilitating an ecosystem to as close as possible to pre-disturbance conditions and functions. The restoration process re-establishes the general structure, function and self-sustaining behavior of the ecosystem. The need to repair a habitat and restore forest structure and function is recognized throughout the humid tropical zones as a component of sustainable forest management. Natural forest restoration involves planning, evaluation of restoration options, and actual restoration activities.

5.1 Forest Restoration Planning

Forest restoration planning is needed in decision-making on how much intervention is required in a given forest ecosystem. The planning processes helps in determining the level and extent of forest degradation and interventions to be undertaken. The process takes into consideration key issues in a degraded site which include, determination of physical and vegetation characteristics of the site. Other issues to be considered include formulation of restoration goals, designing of potential intervention measures, sourcing of planting materials, and protection of rehabilitated sites.

5.1.1 Determination of physical characteristics of a site

This involves delineation of restoration site boundaries using maps, forest blocks, and compartments that show most aspects of the landscape. Use of Global Positioning System (GPS) is recommended for geographical referencing of the restoration site. Information on soils, hydrology and topography should be described. This information is useful in evaluation to contrast the site before and after restoration. Photographs of the site should be taken and labeled before and after restoration process.

5.1.2 Vegetation characteristics of a site

The existing vegetation of the site to be restored should be described to indicate its status. The description should include species composition, community structure (woodland, bush land, forest) and life forms (herbaceous, perennial, succulent, shrub and evergreen trees). A reference restoration model should be developed to represent the future conditions which the restoration is designed to achieve. This Model will later be used for restoration evaluation. The reference could consist of pre-disturbance condition if it is known.

5.1.3 Formulation of restoration goals

Goals are the ideal states and conditions that forest restoration efforts attempt to achieve. The goals should clearly state the degree and timeframe within which the forest will be fully restored. Where degradation pressure is low, some ecosystems can be successfully restored.

5.1.4 Designing potential intervention measures

This involves listing of biotic interventions that are needed for successful restoration of degraded ecosystems. The list should include desirable species and site modifiers (mycorrhizal fungi and nitrogen fixing bacteria) and invasive species to be controlled or removed.

5.1.5 Source of restoration materials

In cases where there is need to rehabilitate by tree planting, superior sources of planting materials such as seeds, seedlings and cuttings should be identified. Some of the planting material can be sourced commercially while others can be raised in local nurseries. Information on where these planting materials are found should be sought and made available.

5.1.6 Protection of restored sites

There is need to plan for long-term protection and management of restored sites against external threats such as grazers, arsonists and fires. Security of the restored site should be constantly reviewed after site restoration in order to enhance protection. The local communities should be recruited to actively participate in the protection of restored sites through public awareness meetings and education on the importance of the sites.

5.2 Natural Forest Restoration Options

5.2.1 Passive restoration

Forest restoration can be achieved by simply protecting the site from further disturbances in order to allow natural processes of regeneration through colonization and succession. This approach is most successful where degradation is not extensive and residual forest patches remain either on site or adjacent to the site. The best sites for passive restoration are places where disturbances occurred in the past and some recovery has already started. The approach is best suited for the middle to high altitude areas where the rainfall is at least 1000 mm per annum. The wet and moist conditions promote rapid plant growth and allow young seedlings to out-compete short shrubs and herbs and recruit quickly into saplings and eventually establish a canopy.

Passive restoration can occur where disturbances were slight or short-lived. Recent disturbed sites are likely to have a large pool of seed, seedlings and live stumps. Sites close to patches of intact forests are also favourable because colonization is likely to be faster.

Passive restoration is advantageous where degradation is in small gaps and there are limited financial resources. Therefore, the approach may be used over large degraded areas. Experience in Kakamega forest indicates that passive restoration method can be used successfully even in previously harvested plantation forests. However, there are problems associated with passive restoration. These include long-term costs of protecting the sites from disturbances such as fire, grazing, weeds and pest infestation.

5.2.2 Active restoration

Active forest restoration is achieved through human interventions. This approach is most successful where resources are available and there is need to accelerate restoration of degraded sites. Methods used in active restoration include; enrichment planting, gap planting and mixed species planting.

Enrichment planting

Enrichment planting method is applied in degraded forest stands using seedlings of desired tree species. The method has been used as a way of increasing the level of biodiversity in forest ecosystems that have been disturbed by removal of certain key species. Gaps or strips are opened up in the canopy and seedlings of the desired species are planted using pre-determined spacing.

Box 5.1 Examples of enrichment planting in Kenya

In Kakamega forest, enrichment planting has been done at a spacing of 15 m between the strips and 3 m within the strips. In Kedowa block of Mau forest, tree species that were identified by the local communities to be useful in restoration planting included: *Prunus africana*, *Polyscias fulva*, *Zanthoxylum gillettii*, *Albizia gummifera*, *Croton megalocarpus* and *Juniperus procera*. The same species have been successfully used in the restoration of disturbed sites in Kakamega and Kobujoi forests.

Gap planting

Gap planting approach is suitable where there are large openings or gaps within a natural forest. The method involves planting seedlings to fill the existing gaps. The tree species for planting in such openings should be carefully selected to fit the prevailing environmental conditions. Gap planting was done in 1940s – 1960s using species including *Zanthoxylum gillettii*, *Prunus africana*, *Juniperus procera*, *Bischofia javonica* and *Maesopsis eminii* in Timboroa, Kakamega and South Nandi. Gap planting using single or mixed species is suitable for medium shade-demanding tree species. It is recommended that big seedlings of about 45 cm tall should be used.

Plate 5.1 Degraded forest suitable for gap planting.
Source: UNEP

Mixed species planting

This method is widely used in most Kenyan forests and is applicable where the entire site is largely devoid of woody vegetation and where direct large-scale intervention is required. It involves planting a wide range of indigenous species that are native to the site. The planting should cover the entire target site with planting densities ranging from 1100 to 1600 stems per hectare in a mixed pattern. Weeding is undertaken until canopy closure. The site should also be protected against grazing or browsing.

5.3 Conclusion

Natural forest restoration is influenced mainly by human activities. For successful natural forest restoration, planning must be undertaken. Important tasks for forest restoration process involve understanding how the ecosystems were degraded, levels of degradation and how to efficiently initiate recovery. Various natural forest restoration options are available and their uses depends on the level of forest degradation.

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Chapter Six

Impact of Forest Degradation on Soil and Water Resources

Jacinta M. Kimiti and Jonathan Njuguna

6.0 Introduction

Soils are formed from weathering of rocks as a result of long-term changes of environmental factors that include rainfall and temperature variations. Soil play a role in sustainable functioning of forest ecosystems by acting as anchors of plants, reservoir of nutrients and housing diverse living organisms. A soil sample may contain various organisms such as bacteria, fungi, protozoa and nematodes. These organisms play a vital role in the sustainable functioning of a forest ecosystem. The soil organisms in any forest ecosystem act as primary drivers of nutrient cycling, organic matter decomposition, determination of soil physical structure and soil water holding capacity among others. Forest ecosystems are also known for their water retention and purification capacity through infiltration processes that are enhanced by the vegetation cover.

When forest ecosystems are degraded, there is exposure of soil that lead to an increase in soil temperature and a decrease in soil moisture. These changes results in reduction in population of soil organisms and their functioning and hence affect biological processes in the forest. Further, degradation process lead to increased water surface run-off, soil erosion and affects water quality and quantity. In severe cases it may lead to long-term changes in elements in the hydrological cycles that affect levels of water flow in rivers, drying up of small streams and quality of extractable water. The impact of forest degradation in most water towers in the country such as Mau Forests Complex is of major concern to various stakeholders.

6.1 Effect of Forest Degradation on Soil Nutrients

Degradation of natural forests leads to reduction of litter inputs in forest floor, decrease in shading, increase in soil temperature and an increased microbial breakdown of the litter available in the forest floor. The soil microbial activity leads to release of nutrients from the forest litter that include nitrogen (N) in form of nitrates that may either be taken up by plants, lost to the atmosphere by denitrification, leached or washed away by run-off. Phosphorus (P) is one of the most essential plant nutrients that can be lost from a forest ecosystem as a result of forest degradation. Its primary source is mineral apatite found in primary rocks. In forest ecosystems, organic matter and complex compounds in the soil are the main sources of P. Therefore, processes that leads to decreased soil organic matter in a forest floor decreases of P levels in forest soils.

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6.2 Predicting Forest Degradation Using Bio-indicators and Soil Characteristics

To determine effective bacteria or fungi in the forest soils involves use of methods such as most probable number (MPN), which gives the counts of viable bacteria and fungi in the soils. The biodiversity of soil microbial communities is measured by various population indices that emphasize various attributes such as species richness (number of species), equitability (even presence of individuals of various species) or combination of the two. Soil chemical analysis methods are used to determine presence and quantities of essential nutrients in forest soils. This information can be used to predict the level of degradation in a forest ecosystem.

Box 6.1 Rhizobia populations and soil phosphorus levels in degraded sites of Kedowa Forest Block of Mau complex

Results of soil rhizobia counts and chemical analysis from three levels of degraded forest sites at Kedowa Forest Block revealed that highly degraded lower slopes had lower rhizobia populations and reduced available soil phosphorus. Rhizobia counts ranged from 1.0×10^4 cells g^{-1} soil in the least degraded sites to 1.6×10^3 cells g^{-1} soil in the most degraded sites while Phosphorus levels ranged from 5.6 kg P ha^{-1} to 2.7 kg P ha^{-1}, respectively. These observations indicated that degradation of forests can significantly lower rhozobia populations and phosphorus levels in a forest ecosystem. This can reduce plant growth and development.

Degraded forests are likely to have soil conditions not favourable for establishment of high nutrient demanding climax tree species. Therefore, restoration of such sites may involve the following options:

1. Long term natural plant succession process that take many years to build the necessary nutrient levels.
2. Introduction of pioneer plant species to accelerate natural plant succession process including nitrogen fixing plants such as *Albizia* and *Acacia* species.
3. Supplementation of nutrients sources such as inorganic and organic fertilizers during planting.
4. Introduction of rhizobial strains such as KEFRIFIX manufactured by the Kenya Forestry Research Institute.

6.3 Effect of Forest Degradation on Soil Erosion and Water Infiltration

Forest degradation lead to loss of vegetation cover resulting in reduction in rainfall interception, water infiltration, and increased water runoff in forest ecosystems. The water runoff increases soil erosion and loss of essential plant nutrients. Water runoff and soil erosion are accelerated in steep slopes leading to formation of gullies and ravines, siltation of rivers and dams, and flooding of plains.

Box 6.2 Predicting forest degradation using runoff, water quality, infiltration rates and soil erosion

(i) Water runoff

Water runoff is the water flow which occurs when soil is infiltrated to full capacity and excess water from rain or other sources flow over the ground. Studies in Kedowa Forest Block of Mau Forests Complex showed that when an average rainfall of 5 mm occurred in a site with two levels of degradation, discharge runoff were 4% and 16% for less and more degraded levels, respectively. This indicated that runoff increased with increasing level of degradation.

(ii) Soil erosion

Soil erosion is the process by which top soil is lost (mainly blown away by wind or washed by rain), having been loosened by such activities as deforestation. Soil erosion can be measured using guarded plots connected to water sampler traps that are set in selected sites. The water generated in the plots is directed to a calibrated sampler that collects only one percent of the runoff. The collected soil is filtered and dried before weighing to determine the amount of soil lost from the site.

(iii) Water infiltration

This is the process of water movement from soil surface by gravity, capillary action and soil porosity to lower levels of soil structure where it is stored in various forms. It is one stage in the hydrological water cycle that is essential for functioning of water catchments. The water flow through the soil is measured by infiltro-metre, a hollow cylindrical ring with a hollow tube that is driven into the soil for use in determining the rate of water seepage through the soil structure. This is achieved by supplying water into the ring and recording the amount of water that flows into the soil for a given period under various levels of forest degradation.

(iv) Loss of soil nutrients

These are nutrients contained in the leached water and eroded soil. The nutrients in both water solution and eroded soil are determined by soil and water chemical analysis.

(v) Water quality assessment

Water quality assessment considers the physical, chemical and biological characteristics of water. The assessment is most frequently used by reference to a set of standards against which compliance can be assessed. The most common standards used to assess water quality relate to drinking water. The water quality measurements are done by chemical analysis methods which are similar to those for plant nutrients. World Health Organisation (WHO) standards specify acceptable levels of foreign substances in water for various uses. In general, less degraded forest ecosystems have high water purifying capacity and less water discharge in contrast to more degraded sites. Often, the effects of forest degradation are felt further downstream where siltation loads increase and water quality declines. Forest restoration can therefore help reverse some of the more severe impacts of forest degradation on water quality.

6.4 Conclusion and Recommendations

Forest degradation leads to reduction in phosphorus levels and rhizobial populations in the soil. It also leads to increased water runoff. It is therefore recommended that restoration of degraded sites should involve; long term natural plant succession process that build necessary plant nutrients, introduction of pioneer plant species to accelerate natural plant succession process, supplementation of nutrients, and introduction of beneficial micro organisms e.g rhizobia. KEFRI manufactures rhizobial inoculants for most indigenous nitrogen fixing trees. To reduce water runoff, it is recommended that degraded sites should be enclosed or replanted to increase vegetation cover.

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Chapter Seven

The Main High Value Tree Species for Rehabilitation of Degraded Mau Forests Complex

Joram M. Mbinga, Michael M. Okeyo, Jonathan C. Njuguna and Bernard M. Kamondo

7.0 Introduction

The chapter provides: species distribution and ecology, uses, conservation and reproduction strategy and propagation of some commercial tree species necessary to consider during the rehabilitation of Mau Forests Complex. These species include, *Prunus africana*, *Juniperus procera*, *Polyscias fulva*, *Zanthoxylum gillettii* and *Albizia gummifera*

7.1 *Prunus africana* (Iron wood, Prunus)

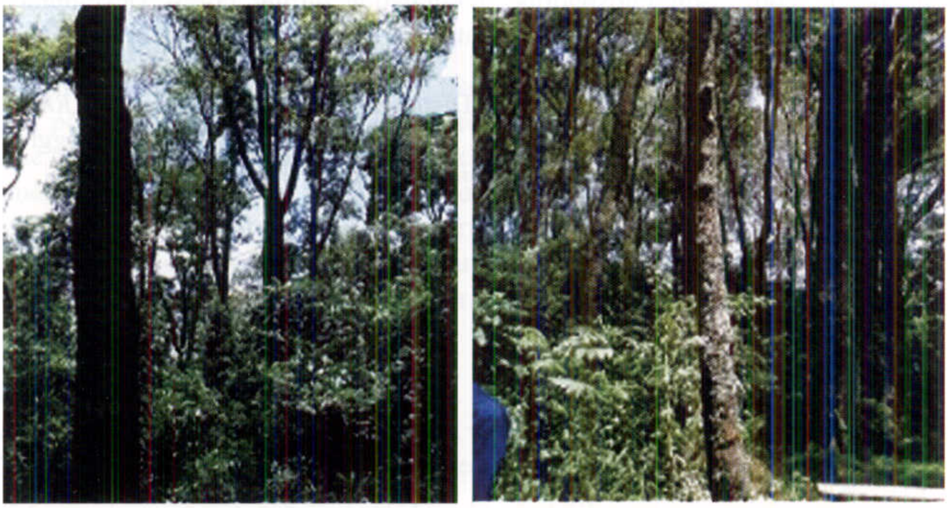

Plate 7.1 A 35 years old *Prunus africana* plantation

Species distribution and ecology

Prunus africana is an evergreen tree native to highland forests of Africa. It is found in Kenya, Angola, Cameroon, Ethiopia, Ivory Coast, Lesotho, Malawi, Mozambique, South Africa, Swaziland, Tanzania, Uganda, Zaire, Zambia, Zimbabwe, Southern Sudan, and Madagascar. In Kenya, prunus grows naturally in highland rainforest on slopes of Aberdares ranges, Cherangani hills, Chyulu hills, Kakamega forests, Nandi forest, Mau ranges, Mt. Kenya, Mt. Elgon, Nyiro hills, Taita hills, Timboroa and Tugen hills. It grows at an altitude range of 1500-2500 m above sea level (a.s.l.) in areas with a mean annual rainfall of about 1000 mm. It grows up to 30 m in height and attains a diameter at breast height of about 100 cm.

Uses

The most important uses of the species is timber and medicine. Prunus timber is used for heavy construction work and furniture. *Prunus africana* bark extract is widely used for the treatment of prostate cancer. The economic value of *P. africana* has led to its severe exploitation and has resulted to it being listed as an endangered species under appendix II of the Convention on International Trade in Endangered Species (CITES).

Conservation and reproduction strategy

Prunus africana populations are diminishing rapidly in the wild, though the species is now a favourite in agroforestry and afforestation campaigns. There is need to initiate optimum conservation strategies both *in-situ* and *ex-situ*. This requires a detailed knowledge of its ecology and reproductive biology. The species is known to be predominantly out-crossing and pollinated by insects and birds. Flowering and fruit set is cyclic with good flowering occurring at 2-3 year intervals. Large variation in timing of fruiting within years is common.

Propagation

Seeding variation and loss of viability with storage results in shortage of planting material. It is recommended that prunus seeds should be sown within three months of collection. There are about 5000 seeds per kg. Seeds of *P. africana*, sawn within three months of collection attain an average germination of 60-80%. The seeds can either be sown directly into tubes filled with soil and watered to drench twice a day under shade or sown in seedbeds. Seedlings take about 8-12 months to attain a height of 45 cm, which is the recommended size of tree seedlings for planting out in the forest. Wildlings are also used in planting programmes but these must be managed carefully to avoid over harvesting of seedlings in the wild.

7.2 *Juniperus procera* (African pencil cedar)

Plate 7.2 Juniperus procera plantations: at 25 years (left) and at 80 years (right)

Species distribution and ecology

Juniperus procera is an evergreen tree which grows to 40 m high with a straight bole. Its bark is grey-brown, cracking and peeling in long narrow strips. Leaves are prickly, scale-like and closely overlapping on branchlets. Mature seed bearing cones are purple blue and fleshy, round and about 8 mm across, containing 1-4 triangular seeds. The species occurs in highland forests of eastern Africa between 1800-3000 m a.s.l. where it forms associations with *Podocarpus* and *Olea*. *Juniperus procera* occurs in Mau Forests Complex, and also on slopes of Mt Kenya, the Aberdares Range, Tugen Hills, Mt Elgon and Loita forests. It is best in moderate rainfall areas but can survive dry conditions once established.

Uses

The most common uses are for poles and posts which are extremely resistant to termites and are durable in the ground. There is a big demand for fencing posts of *J. procera* and this puts the species at risk of overexploitation. Other uses are joinery timber, shingles and flooring. Currently, harvesting of *J. procera* in Kenya is restricted to avoid overexploitation.

Propagation

Fruits (cones) take more than one year to mature. There are about 40,000 seeds per kg and germination varies between 30 to 70% within 25 to 80 days. Seeds must be pre-treated by soaking in boiled water overnight for good germination to be achieved. Seedlings take about 12 months to attain plantable size of 30 cm. Wildlings are also often used in planting programmes but with caution to avoid depleting natural regeneration through its seedlings.

7.3 *Polyscias fulva* (Parasol tree)

Plate 7.3 Twelve years old *Polyscias fulva*

Species distribution and ecology

Polyscias fulva is a deciduous tree and one of the fastest growing indigenous tree species in Kenya. It grows to a height of 18-30 m with a straight slender bole to approximately 9 m before development of branches. The species grows in the wet upland forests at an altitude of between 1100-2800 m a.s.l. It occurs in tea growing areas of Kenya, and also other parts of Eastern, Southern, Central and Western African countries. It is a pioneer species often growing abundantly in secondary forest, as well as along river valleys. In closed forests only the old and mature dominant and co-dominant individuals occur.

Uses

The wood of *P. fulva* is white, soft and light. It is used for making beehive, food boxes and containers. It can also be carved into musical instruments, and on a large scale it is used in the veneer and plywood manufacturing.

Conservation and reproduction strategy

The level of domestication of *P. fulva* within and without its natural range is very low. In Kenya, it has been grown in small-scale mixed species plantations and in a few cases as pure stands. *Polyscias fulva* quickly colonizes and provide cover to degraded forest areas within its natural range thus protecting the environment and creating enabling conditions for forest recovery.

Propagation

Polyscias fulva seeds profusely but the seeds are eaten by monkeys and birds before they are collected. Thus studies on the species seeding calendar are important so as to know when the seeds are mature and ready for collection. There are about 200,000 seeds per kg. Seeds of *P. fulva* have a germination of about 70% in 35-45 days. Seedlings take about 8 months to attain a height of 45 cm, which is the recommended size of tree seedlings for planting. Wildlings are increasingly being used in replanting programmes.

7. 4 *Zanthoxylum gillettii* (African satinwood)

Plate 7.4 Fifteen years old *Zanthoxylum gillettii* trees

Species distribution and ecology

Zanthoxylum gillettii grows to a height of 18–35 m and a diameter of 30–90 cm; trunk usually straight and branchless for several metres (4–12 m), and is armed with conical woody prickles (1–3 cm) long. It is typically a forest tree species, but farmers in most parts of Kenya have retained individual trees in their farms. The species occurs in moist and dry forests in the Central highlands, South West Mau forest, and western Kenya between 1500 –2300 m a.s.l. It requires rainfall of 800-2400 mm annually.

Uses

Major uses of *Z. gillettii* include: heavy construction timber (roofing and door frames), furniture (making cabinets), paper and pulp industry, fuelwood, boat building and the bark is medicinal.

Propagation

Due to its multiple uses, the species is popular among local communities but they are unable to procure enough seedlings to meet their planting programmes. For successful propagation and conservation of *Zanthoxylum* species, there is need to generate scientific information on seed handling, germination and storability. Seedlings take about 12 months to attain a height of 45 cm, which is the recommended size of tree seedlings for planting. Wildlings are also commonly used for planting.

7.5 *Albizia gummifera* (Peacock flower tree)

Plate 7.5 Thirty years old *Albizia gummifera* trees

Species distribution and ecology

Albizia gummifera grows to 25 m high, has a flat crown and its trunk grows to 75 cm in diameter. The species grows from 0-2400 m a.s.l., in areas with mean annual rainfall of 1200-1800 mm, and in well-drained soils. The species is common from the slopes of the coastal hills to the higher mountains of central and western highlands of Kenya.

Uses

Albizia gummifera is important for medicine, fodder, bee-forage, shade, ornamental and in nitrogen (N) fixation. The species wood is good for timber (furniture), pole and fuelwood. The species being N-fixing is most recommended in rehabilitating sites which have lost a lot of N due to severe degradation.

Propagation

Seeds can be collected twice a year between May-June and November-January. Seed can be stored in airtight containers in a cool dry place for short (3months) to medium (1-2 years) term storage. The number of seeds range from 10,000 to 15,000 per kg and germination capacity is between 40-60%. Seedlings take about 12 months to attain a height of 45 cm, which is the recommended size of tree seedlings for planting out in the forest.

7.6 Conclusion on High Value Tree Species for Rehabilitation of Degraded Forests

The above mentioned are just some of the high value tree species suitable for planting under the various forest restoration options in Mau Forests Complex. The Appendix provides a more elaborate list of other tree species suitable for forest rehabilitation. In all cases, seedlings to be planted should be sourced from reputable local tree nurseries preferably within the region. This ensures that only species adapted to the local climatic conditions are planted to avoid failures. In severely degraded forests, planting holes should be at least 45 cm deep by 45 cm wide. Only healthy seedlings of 40-60 cm tall should be used for planting.

Chapter Eight

Market Access of Wood and Non-wood Forest Products from West Mau Forests

Martha M. Kapukha and Joshua K. Cheboiwo

8.0 Introduction

Natural forests provide a wide range of goods and services to forest adjacent communities, which include timber, fibre, fodder, water, food, firewood, charcoal and herbal medicine, among others. Knowledge and information on the products and services that accrue from natural forest will facilitate efficient and sustainable joint management of the resources by local communities and government agencies. Unsustainable extraction of forest products in the past has created deferential scarcity that has enabled emergence trade in tree products. The spatial scarcity has created conditions for exchange arrangements between forest product extractors and consumers.

8.1 Access to Forest Products from Natural Forests

In Kenya, forest adjacent communities encounter policy and market related constraints in extraction and trade in forest products from public forests. The draft Forest Policy 2005 and Forests Act, 2005 recognizes extraction of forest products by local communities. However, the Forest Act sets stringent conditions for access that include requirements for license, permit or management agreements for harvesting of forest products such as timber, firewood, honey, medicinal herbs and grass for subsistence purposes. All extraction for purpose of trade are prohibited unless under specific licensing procedures and at administrative prices. The Forest Act subjects forest products extractors to control measures on harvesting, transporting and selling in order to protect state forests from illegal extraction. Under such stringent conditions the extractors resort to illegal means to access such resources. Some of the challenges that forest product extractors face in Mau Forests Complex are demonstrated in Box 8.1.

Box 8.1 Access and marketing challenges faced by forest products extractors in Mau Forests Complex

Results from a socioeconomic survey of 132 households in Kahurura, Kerisoi, Sirikwa, Kedowa and Itare in South and West Mau showed that households faced several challenges in accessing and marketing of forest products. The costs incurred by households in extracting and trading in forest products were payments for grazing, firewood collection and license fees (Figure 8.1). Similarly, the results (Figure 8.2) showed that household members faced the following challenges: regulation (45%), transport costs (20%) and lack of markets (13%).

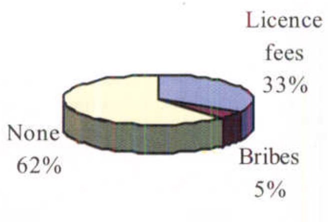

Figure 8.1 Costs incurred by traders of forest products in Mau Forests

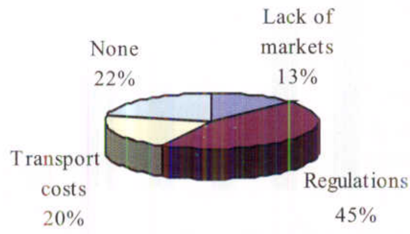

Figure 8.2 Challenges facing traders extracting forest products in Mau Forests

8.2 Processing of Timber and Non-timber Forest Products

Forests provide the raw materials for many small-scale rural enterprises such as furniture, production of agricultural tools and handicraft making. There is a wide range of forest and tree products, which undergo simple processing at the household and small-scale rural enterprise levels. Some common processing activities are charcoal making, pit sawing, honey processing, carpentry, furniture making and woodcarving. The average size of the work force for most of these processing enterprises range from 2 to 4 persons and less than one percent employ 10 or more workers.

8.3 Incomes From Trade in Forest Products

Most households living adjacent to natural forests do not generate sufficient incomes from their farms. Therefore they supplement their financial needs from sale of products extracted from forests. The direct benefits to forest adjacent communities can be improved if the extracted products are successfully marketed and the benefits flow back to them.

Box 8.2 Trade in forest products extracted from Mau Forests Complex

The high demands for forest products in urban areas have created markets for various forest products and extractors and traders have responded by collecting and trading in them. The most traded products are charcoal and firewood (Figure 8.3). The buyers are local consumers and merchants in local and distant urban markets (Figure 8.5). The findings indicated that most of the households preferred to sell their forest products within their local areas. This is to avoid risks involved in transporting products to lucrative markets because most extractions are illegal. Majority (78%) of the traders have been in the business for less than 5 years (Figure 8.4). This suggests that the environment for trade in forest products is not conducive. Though trade in forest products is a high-risk venture, the local people are involved in it due to limited livelihood opportunities and landlessness.

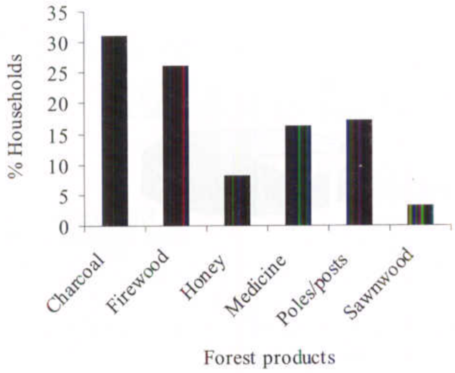

Figure 8.3 Households that traded in extracted forest products in Mau Forests Complex

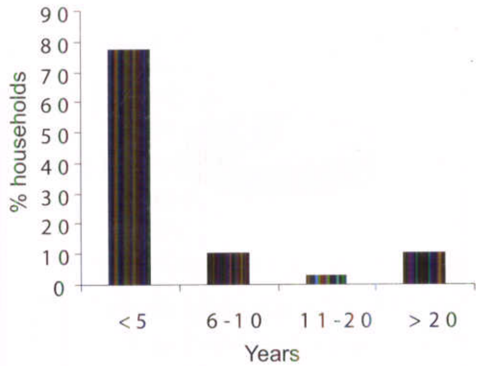

Figure 8.4 Period households traded in forest products in Mau Forests

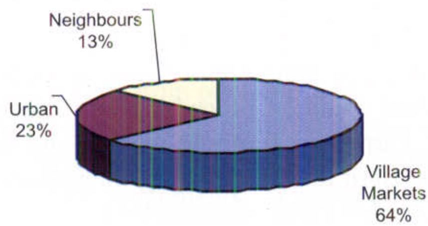

Figure 8.5 Main markets for traded forest products in Mau Forests Complex

Box 8.3 The prices variation for forest products extracted from Mau Forests Complex

The prices of wood and non-wood forest products from West Mau forest changes drastically on delivery to Nakuru Town, only 50 km away (Table 8.1). The price of a bag of charcoal at the forest gate is KES 250, KES 350 at nearby local markets and KES 500 in Nakuru. Similarly, a tonne of firewood was KES 400, 700 and 1500 respectively. The variation is due to demand and supply conditions at the market outlets, risks involved in the business and transport costs.

Table 8.1 Price variation of different forest products at various market outlets

Product/Prices	Forest gate (KES)	Nearby local markets (KES)	Nakuru Town (KES)
Firewood/tonne	250	350	500
Poles/piece (medium)	400	700	1500
Fencing posts/piece	60	100	150
Sawn wood/tonne	12,000	16,000	21,000
Honey/kilogram	100	150	200

8.4 Conclusion and Recommendations

The communities living adjacent to West Mau forest extract various forest products mostly for domestic use and small quantities are traded. Efforts to invest in processing and marketing of forest products are hindered by stringent harvest and movement regulations laid down by the government. Despite the stringent regulations on extraction and trade in forest products, many people access various products from West Mau forest and this has resulted in severe degradation of forest resources along forest boundaries.

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Chapter Nine

Economic Benefits of High Value Indigenous Tree Species for Restoration of Moist Forests

Joshua K. Cheboiwo, Mugabe R. Ochieng and Joram M. Mbinga

9.0 Introduction

Forests in Kenya continue to play a pivotal role in the economy as over 70% of the rural population relies on them for provision of various goods and services. Because of the loss in forest cover, an annual wood deficit of up to one million cubic meters by 2015 has been projected. To meet the rising demand, stakeholders in the forestry sector have been seeking ways of expanding commercial plantations, farm forests and restoration of the degraded natural forests. In the past most afforestation and reforestation investments targeted mainly use of exotic species in plantations establishment for timber production to ease pressure on natural forests. In the recent past there has been growing interest in the use of high value indigenous species in plantations establishment and rehabilitation of degraded forests. However, yields and economic potential of planting of indigenous species for timber production are not known. The information is important in assessing the suitability of using target species to generate benefits that are no longer available in degraded natural forests. The evaluation of economic viability of indigenous species involves species selection, analysis of establishment and management costs and calculation of benefits from round wood sales.

9.1 Species Selection

In the determination of candidate species the following methods were used: socioeconomic surveys, ecological surveys and collection of growth data. Socioeconomic surveys involved interviewing communities living adjacent to forests on their species preferences for use in their domestic needs and income generation. Ecological surveys included determination of suitability of the species in the moist forest ecosystem. An inventory was carried out to determine the occurrence of the species in seedlings, saplings and tree stages. Abundance of stumps from past exploitation was considered as evidence of demand of a particular species. The combinations of the above methods were used in the selection of priority candidate species for restoration and economic values. Based on the above criteria the following species were selected for the economic evaluation: *Prunus africana*, *Zanthoxylum gillettii*, *Juniperus procera* and *Polycias fulva*.

9.2 Establishment and Management Costs

The costs of establishing and maintaining plantations were obtained from records of costs involved in acquisition of seeds, seedlings, land preparation, staking, pitting, planting, maintenance, thinning, pruning and protection, among others. The costs were entered into records indicating the year in which it was incurred in the entire growing period to the time of harvesting.

9.3 Yield Estimation

In conventional forest practices trees and forest stands are sold in standing volumes measured in cubic metres (m^3). In forestry, diameter at breast height over bark (dbh) and total height of the trees are common measurements for determining tree and forest stocking volumes. In the calculation of specific tree yields, volume equations that are derived from dbh and height of specific tree species are used. Volume equations are sets of predictors of tree and stand wood quantity that uses dbh and height to estimate volume. Due to difference in growth parameters between tree species particularly in diameter, height and stem forms, the developed volume equations will differ among such tree species. Tree and stand volume estimation involve the following steps:

- Development of volume equations
- Development of yield tables, and
- Volume estimations

9.3.1 Development of volume equations

In the development of volume equations selective felling of trees at different ages and from different sites is undertaken. The diameter and lengths of the felled trees are measured at predetermined bole lengths in order to obtain data for determination of form factor and individual tree volumes. The data collected from the individual tree measurements were used in development of volume equations. The developed volume equations (Box 9.1) were used in the development of yield tables. The yield tables were developed by plotting mean annual increment (m^3 ha^{-1}) against age of the stand for any given species.

Box 9.1 Two examples of volume equations for indigenous species of Kenya

$LogV = -3.6321 + 2.2542\log d$, Or $LogV = -4.2224 + 0.9673\log d^2h$ 1

For *Juniperus procera* (Wachiori et al., 1996)

$LogV = -3.8645 + 0.9049\log d^2$ 2

For *Podocarpus latifolius* (Wachiori et al., 1996).

Where V =volume in m^3, d=diameter at breast height in cm, h=tree height in m

9.4 Use of Yield Tables to Estimate Wood Volume

In large-scale forest operations it is difficult to use volume equation to estimate standing volume. Yield tables are used to estimate expected wood volumes in m^3 for a given age and site for a species. From the yield table it is easy to estimate the volume by reading the measured parameters either height or diameter against the age. The total volume of a stand is obtained by multiplying tree volume by the number of trees in the stand.

Box 9.2 Volume Estimation for 4 Selected Indigenous species

The results presented (Figure 9.1) below are based on inventory data collected from 16 different sites involving 22 to 83 trees and ages ranging from 9 to 84 years within Mau Forests Complex, Cherangany Hills and Kakamega forests. The initial spacing varied from 2.5x2.5 m to 4x4 m. *Prunus africana* had a mean annual volume increment of 10.09 m^3 ha^{-1}; *Zanthoxylum gillettii*, 9.57 m^3 ha^{-1}; *Polyscias fulva*, 7.46 m^3 ha^{-1}; and *Juniperus procera*, 3.73 m^3 ha^{-1}.

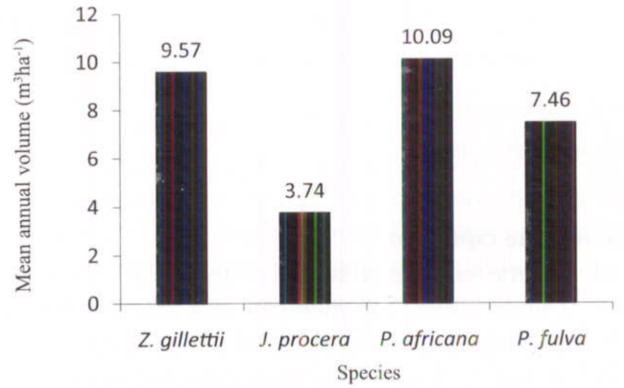

Figure 9.1 Mean annual increament in volume for 4 selected indigenous species

Box 9.3 Wood Volume for 4 indigenous species at various ages

The wood volumes (Figure 9.2) were calculated for ages between 38 and 60 years. *Prunus africana* and *Zanthoxylum gillettii* had relatively higher yields over all the selected ages, followed by *Polyscias fulva* and *Juniperus procera*. For example, at 48 years, *Prunus africana* yielded 484 m^3 ha^{-1}, followed closely by *Zanthoxylum gillettii* with 459 m^3 ha^{-1}, *Polyscias fulva* 358 m^3 ha^{-1} and *Juniperus procera* 179 m^3 ha^{-1}.

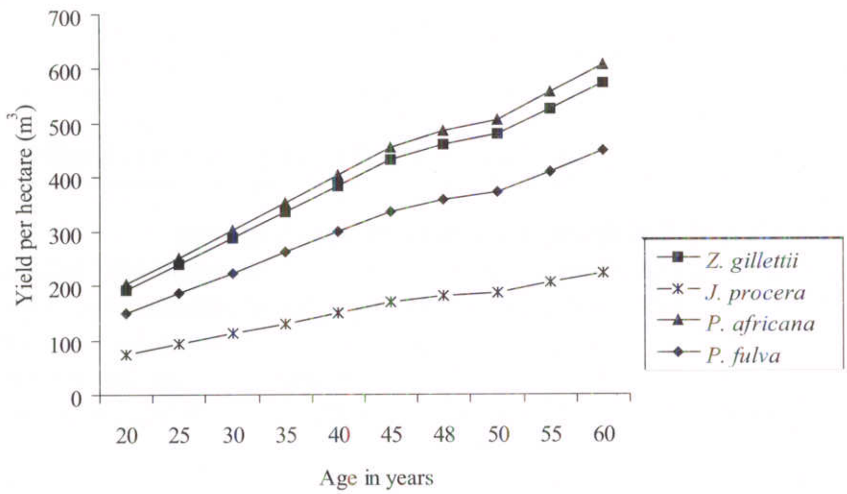

Figure 9.2 Wood yield for four selected indigenous species

9.5 Calculation of Benefits from Thinnings and the Final Crop

From the time the plantations are established to the time they are harvested a series of selective thinning are carried out to provide room for growth of the remaining growing stock. The produce from thinning are classified into various categories of poles. To establish prices of poles, market surveys are carried out in selected major wood product market outlets. Pole prices can also be obtained from regularly revised Forest Department General Orders (FDGO) available from Kenya Forest Service (KFS). The pole prices are used in determining revenues from thinnings by multiplying the number of poles removed in each thinning cycle by the price per pole.

The total revenue is obtained by summing the amount generated from selling thinnings and the amount obtained from harvesting the final crop. The revenue generated at the end of a rotation is usually discounted to the present day values by use of cost-benefit analysis tools. The cost benefits analysis tools take into consideration the period the costs were incurred during the growing period and interest rates of capital invested to transform the distant value into net present value (NPV).

Box 9.4 Financial analysis of growing 4 indigenous species

The Net Present Value (NPV) at 10% interest rates associated with growing the selected indigenous species in plantations at differing rotation periods were determined for different ages (Figure 9.3). *Zanthoxylum gillettii* at a rotation of 38 years generated a NPV of KES 2.35 million ha^{-1}. The species consistently performed better at all ages as compared to the other species. The lowest performing was *Juniperus procera* at a rotation of 38 years where it generated a NPV of KES 510,000 that marginally increased to KES 587,000 at 60 years.

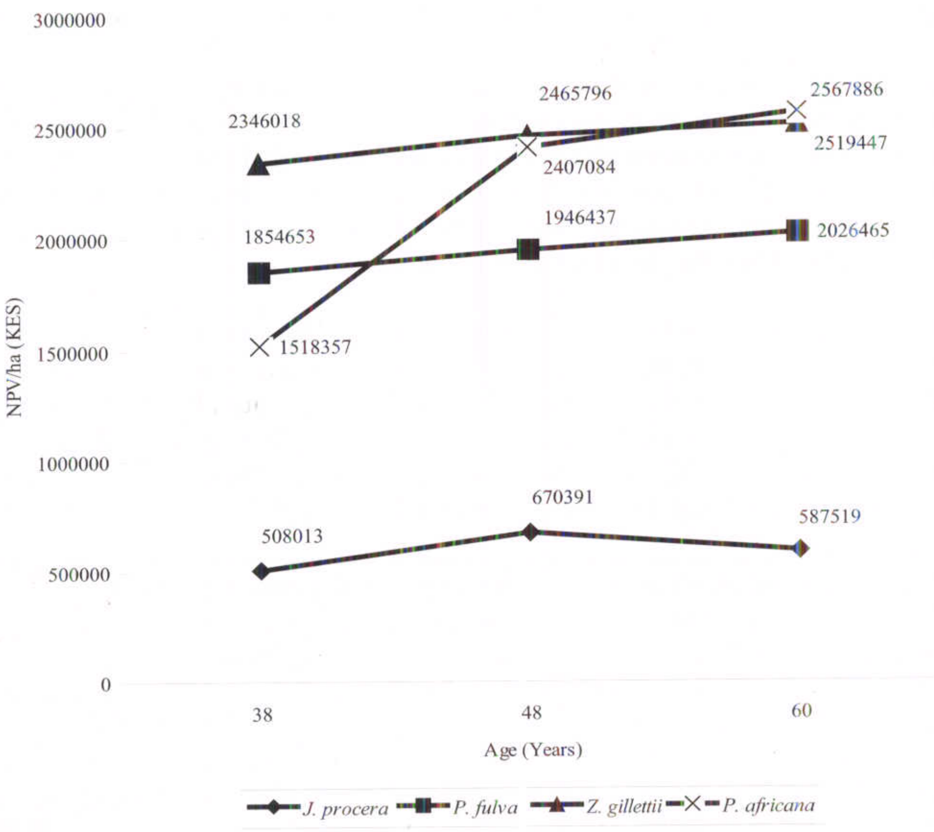

Figure 9.3 Net present values for 4 selected indigenous species

9.6 Conclusion and Recommendations

Based on financial considerations *Zanthoxylum gillettii*, *Polyscias fulva* and *Prunus africana* can be grown in commercial plantations. However, *Juniperus procera* generate less financial returns and would therefore be better used in enrichment planting schemes. The optimal financial rotation period for *Zanthoxylum gillettii*, and *Polyscias fulva* is 38 years while that of *Prunus africana* is 48 years. There is need for concerted efforts to initiate elaborate trial plantations that will generate sufficient data on the growth of major indigenous species of commercial importance. The data will enable development of volume equations and yield tables specific to each species and region. In addition to timber production, species such as *Prunus africana* and *Zanthoxylum gillettii* also produce medicinal products. Thus, there is need to develop yield and financial estimates for such other products.

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Appendix

Tree Species Suitable for Restoration of Water Catchment Forests

Species	Family name	Common name
Acacia xanthophloea	Mimosaceae/Fabaceae	Fever tree, Naivasha thorn
Albizia gummifera	Mimosaceae/Fabaceae	Peacock flower tree
Bischofia javanica	Euphorbiaceae	Javanese bishopwood
Brachylaena huillensis	Asteraceae	Silver oak
Bridelia micrantha	Euphorbiaceae	Bridelia tree
Calodendrum capensis	Rutaceae	Cape Chestnut
Cassipourea malosana	Rhizophoraceae	Pillarwood
Celtis africana	Celtidaceae	White stinkwood
Cordia africana (Cordia abyssinica)	Boraginaceae	Sudan teak, East African cordia
Croton megalocarpus	Euphorbiaceae	Croton tree
Croton macrostachyus	Euphorbiaceae	Broad-leaved croton
Dombeya rotundifolia	Sterculiaceae	Wild Pearl, Drolpeer, White dombeya
Dombeya torrida (D. goetzenii)	Sterculiaceae	Forest dombeya
Diospyros abyssinica	Ebenaceae	Giant diospyros, Abyssinian diospyros
Ficus thonningi	Moraceae	Bark-cloth fig, Common wild fig, Strangler fig
Hagenia abyssinica	Rosaceae	African redwood
Juniperus procera	Cupressaceae	African pencil cedar, Cedar
Khaya anthotheca	Meliaceae	East African mahogany
Macaranga kilimandscharica	Euphorbiaceae	Macaranga
Maesopsis eminii	Rhamnaceae	Umbrella tree, Musizi
Newtonia buchananii	Mimosaceae	Forest newtonia, Newtonia
Nuxia congesta	Loganiaceae	Bogwood, Brittle-wood
Ocotea usambarensis	Lauraceae	East African camphor
Olea europaea	Oleaceae	Olive, European olive
Olea falcatus (Olea welwitschii)	Oleaceae	Olive, Olivewood, Genuine olive
Podocarpus falcatus	Podocarpaceae	East African yellow wood, Oteninqua yellow wood, Podo
Podocarpus latifolius	Podocarpaceae	Real yellow-wood, Red-fruited podo
Polyscias kikuyuensis	Araliaceae	Bitter almond, Iron wood, Red stinkwood
Polyscias fulva	Araliaceae	Parasol tree
Prunus africana	Rosaceae	Red stinkwood, Prunus, Iron wood
Schrebera alata	Oleaceae	Wing-leafed wooden pear, Wild jasmine

Species	Family name	Common name
Spathodea campanulata	Bignoniaceae	African tulip tree, Flame of the forest, Fountain tree, Nandi flame, Nile flame, Squirt tree, Tulip tree, Uganda flame
Trichilia emetica	Meliaceae	Cape mahogany, Christmas bells, Natal mahogany, Red ash, Thunder tree, Woodland mahogany
Vebris nobilis (Techlea nobilis)	Rutaceae	Small fruited teclea
Vitex keniensis	Verbenaceae	Meru oak
Warburgia ugandensis	Canellaceae	East African green wood, East African greenheart, Greenheart, Kenya greenheart, Pepper-bark tree
Zanthoxylum gilletttii (Fagara macrophylla)	Rutaceae	Africa satinwood
Selected bamboos and palms	Poaceae (Gramineae) and Arecaceae	Various

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