Forest Restoration Handbook

for Moist Forests in Kenya

April 2010

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Photographs from Mau Forests Complex

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Forest Restoration Handbook for Moist Forests in Kenya

Edited by:
Kigomo B.N., Kimiti J.M. and Tuwei P.K.

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 it stores, filters and regulates water flows.

Mau Forests Complex, the largest closed-canopy forest ecosystem and water tower, covers close to 400,000 ha. 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 for 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 Mau Forests Complex 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

Acknowledgement

This handbook is a product of the Kenya Forestry Research Institute (KEFRI) and the European funded FOREAIM Project No. INCO-CT-2005-51-790 under the Sixth Framework Programme. The project's objective was to enable sustainable restoration of degraded tropical forest by developing tools, technologies and recommendations for end users of research in important moist forest ecosystems in Africa. Besides KEFRI, other project partners were: CIRAD (International Co-operation Centre in Agronomic Research for Development), France; IRD (Institute of Research in Development), France; CEH (Centre for Ecology and Hydrology), United kingdom; INA-NLH (Norwegian University of Life Sciences), Norway; University of Antananarivo, Madagascar; FOFIFA (Centre in Agronomic Research for the Rural Development), Madagascar, and University of Makerere, Uganda (for further details also visit the project website http://foreaim.cirad.fr/home). The handbook reports on results and experiences of the Kenyan component, which was implemented within and around the Mau Forests Complex.

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.

The authors appreciate Mr. Paul K. Tuwei of KEFRI for his contribution in the editorial and production of this handbook.

Last but not least the financial support from the Government of Kenya, through the Director KEFRI, and the EU (FOREAIM Project Contract No. INCO-CT-2005-51-790) during the implementation of the project and production of this handbook is highly acknowledged.

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 an 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.

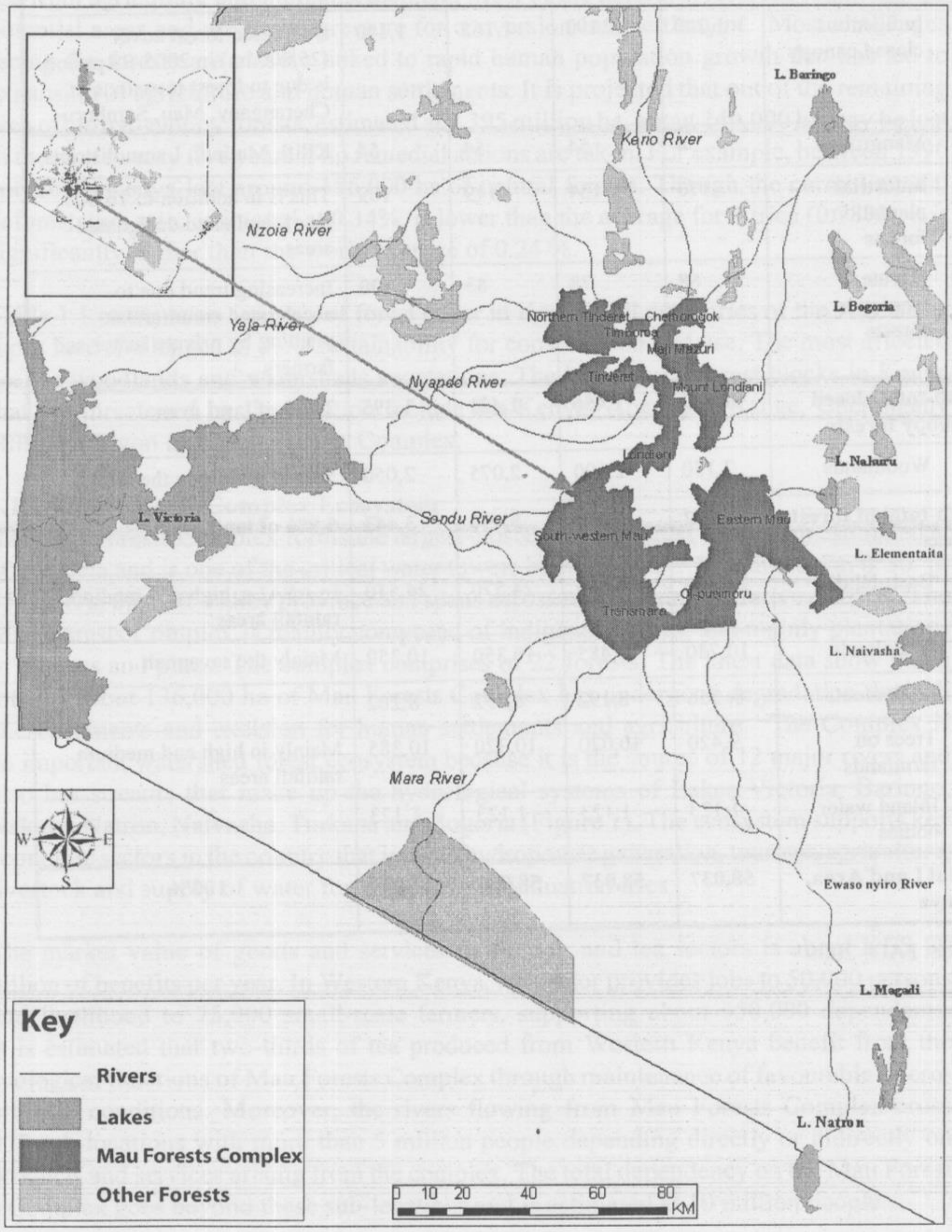

Figure 1 Map of Kenya showing Mau Forests Complex and its watershed system

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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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 farm 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.

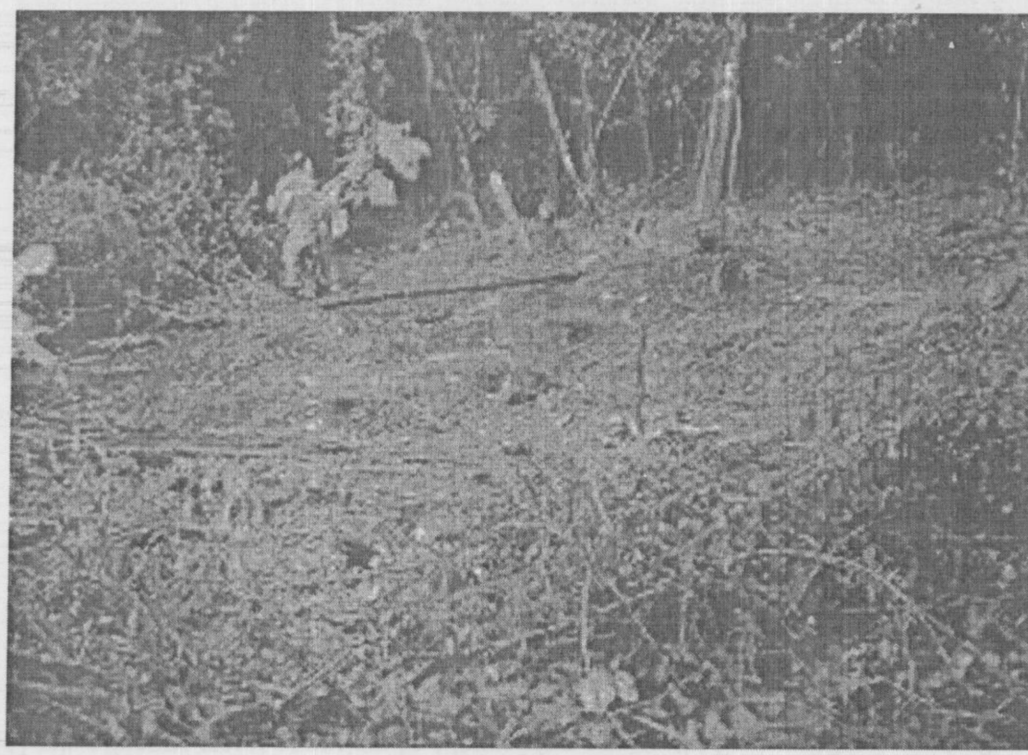

Plate 4.1 Gap created by charcoal kiln at Kedowa, Mau Forests Complex.
Photo by C.J. Amwatta Mullah

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.

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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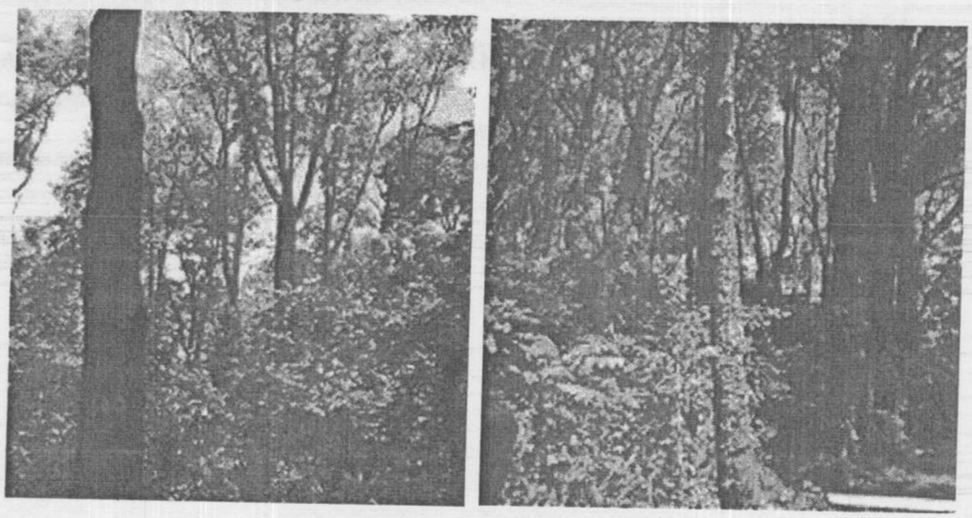
Chapter Seven

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

The chapter provides a brief profile on propagation requirements of some commercial tree species necessary to consider during the rehabilitation of Mau Forests Complex.

1. *Prunus africana* (iron wood, prunus)



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, Taiṭa 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 breast height diameter 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).

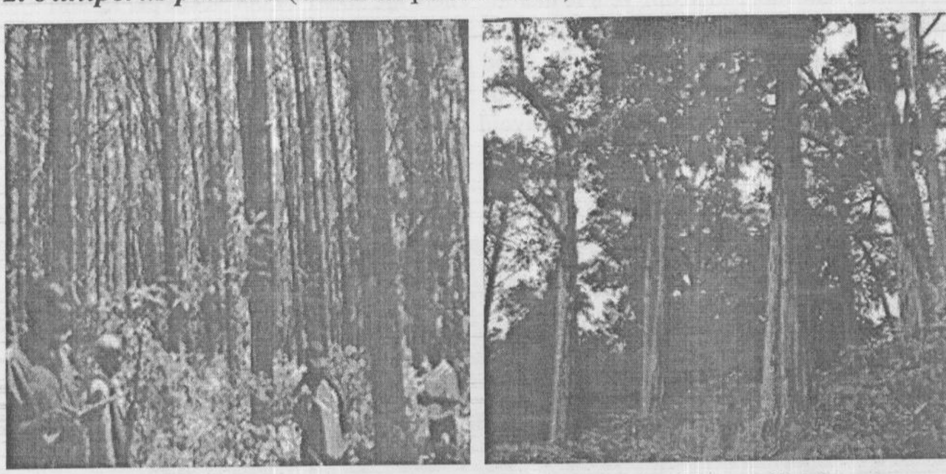
Conservation and reproduction strategy

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.

2. Juniperus procera (African pencil cedar)



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.

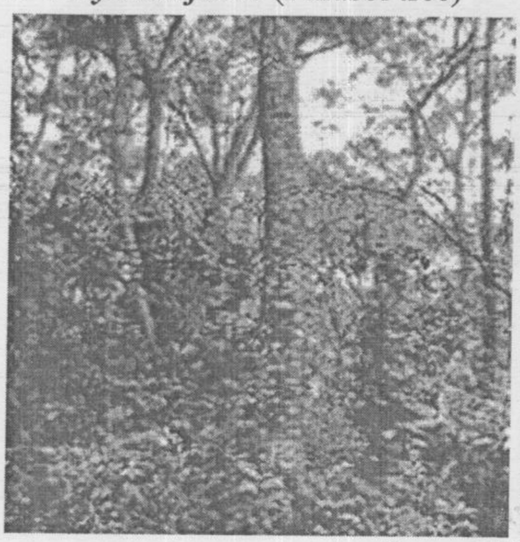
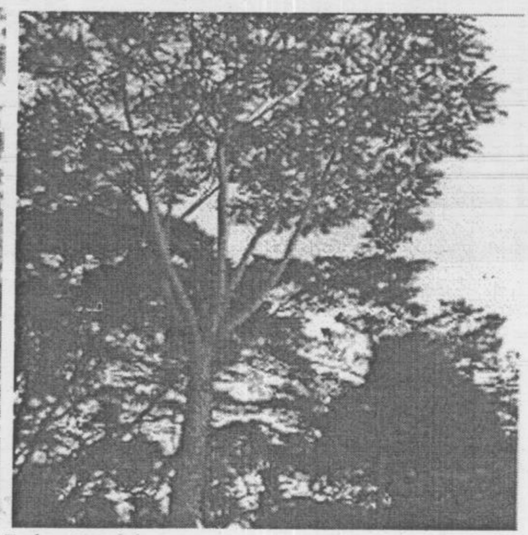
Uses

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.

3. *Polyscias fulva* (Parasol tree)

12 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.

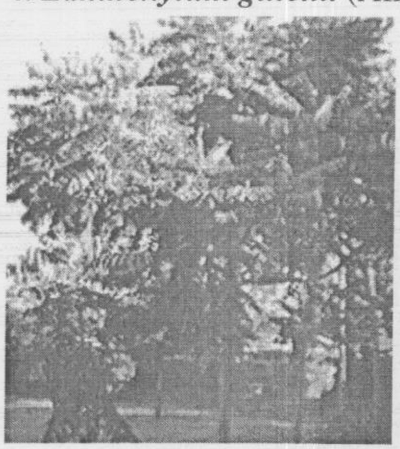
Conservation and reproduction strategy

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.

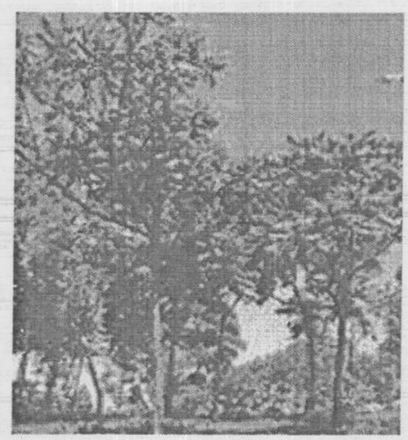
Propagation

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.

4. Zanthoxylum gillettii (African satinwood)



15 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.

5. Albizia gummifera

30 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.

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%).

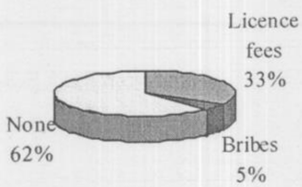


Figure 8.1 Costs incurred by traders of forest products in Mau Forests

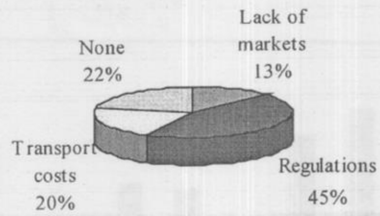


Figure 8.2 Challenges facing traders extracting forest products in Mau Forests

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.

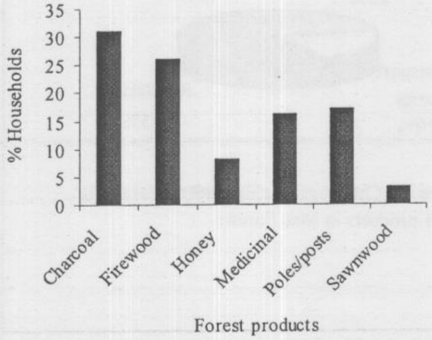


Figure 8.3 Households that traded in extracted forest products in Mau Forests Complex

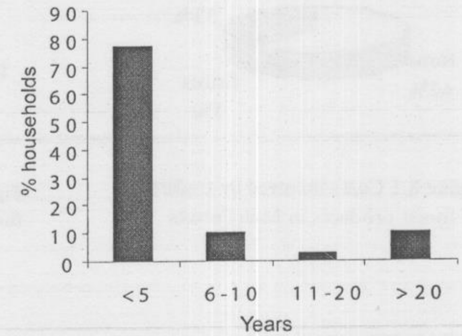


Figure 8.4 Period household traded in forest products in Mau Forests

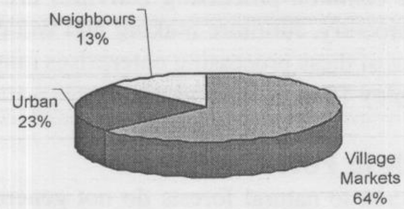


Figure 8.5 Main markets for traded forest products in Mau Forests Complex

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
- 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 $LogV = -4.2224 + 0.9673\log d^2 h$ 1

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

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

For *Podocarpus latifolia* (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.

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Tree Species Suitable for Restoration of Water Catchment Forests

Species	Family name	Common name
Acacia xanthophloea	Mimosaceae	Fever tree, Naivasha thorn
Albizia gummifera	Mimosaceae	
Bischofia javanica	Euphorbiaceae	Javanese bishopwood
Brachylaena huillensis	Asteraceae	Silver oak
Bridelia micrantha	Euphorbiaceae	
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
Croton macrostachyus	Euphorbiaceae	Broad-leaved croton
Dombeya rotundifolia	Sterculiaceae	Wild Pearl / Drolpeer
Dombeya torrida (D. goetzenii)	Sterculiaceae	
Diospyros abyssinica	Ebenaceae	
Ficus thonningi	Moraceae	Bark-cloth fig, common wild fig, strangler fig
Hagenia abyssinica	Rosaceae	African redwood
Juniperus procera	Cupressaceae	The African pencil cedar
Khaya anthotheca	Meliaceae	East African mahogany
Macaranga kilimandscharica	Euphorbiaceae	Macaranga
Maesopsis eminii	Rhamnaceae	umbrella-tree
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 yellowwood
Polyscias kikuyuensis	Araliaceae	bitter almond, iron wood, red stinkwood
Polyscias fulva	Araliaceae	parasol tree
Prunus africana	Rosaceae	Red stinkwood
Schrebera alata	Oleaceae	Wng-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
Selected bamboos and palms		