REHABILITATION OF DEGRADED NATURAL FORESTS IN KENYA

A guide for forest managers and stakeholders in forest rehabilitation

Jared Amwatta Mullah, John Otuoma and Bernard Kigomo

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September 2013

Captions for cover photographs
Top: Boundary between human settlements and forest in western Mau showing progressive encroachment and disturbance of the forest edge

Bottom left: A degraded forest site in South Nandi prior to rehabilitation interventions. *Photo by J. Otuoma*

Bottom right: South Nandi degraded forest site 3 years after rehabilitation using dense planting technique. *Photo by J. Otuoma*

Layout and design: Peter Wainaina & Dorothy Ochieng

ISBN: 9966 – 7458 – 8 - 2

Published by:
Kenya Forestry Research Institute
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Printed by: Print Maxim

Foreword

Natural forests in Kenya serve many functions at the local, national and global levels. At the local level, natural forests provide local communities with water, fuelwood, herbal medicine, and other forest goods and services. However, degradation of natural forests is currently a major challenge in the country and a whole range of forest ecosystem services have been affected. For instance, degradation has led to; decline in hydrological functions, increase in carbon emission into the atmosphere, loss of biological diversity, and decline in soils productivity. The deterioration of such forest ecosystem services is often felt most at the local level, but it has implications also at the national and global level. Rehabilitating and restoring the degraded natural forests and forestlands to ensure sustainable provisions of forest products and services are undeniably priority.

This book provides information on techniques for rehabilitation of degraded natural forests. The guide is useful to; forest managers, conservationists, community forest associations, county governments, private landowners, non-governmental organizations, and researchers, involved in rehabilitation and restoration of degraded forests. It should be recognized that many people have a stake in forests and any rehabilitation, restoration, or management efforts must be made with their full participation.

The guide constitutes a substantial effort by KEFRI and her partners to further the cause of forest conservation and management as a key component of the social pillar of Kenya's Vision 2030. It is fully expected that the guide will stimulate the adoption of appropriate rehabilitation techniques and innovative management practices for conserving and improving the functions of natural forests in the country.

Ben N. Chikamai (PhD)
Director, **KEFRI**

Acknowledgement

This guide was developed with financial assistance from the Government of Kenya through the Ministry of Environment, Water and Natural Resources as KEFRI's input to the National Forest Programme (NFP) and REDD+. Apart from information from published literature, production of this document also relied on data obtained from KEFRI's forest rehabilitation activities in the Central Highlands, Rift Valley Eco-region and Lake Victoria Basin. We sincerely thank Dr. Joshua Cheboiwo and the KEFRI Editorial team namely; Dr Ebby Chagala-Odera, Bernard Kamondo, Paul Tuwei, Josephine Wanjiku and Dorothy Ochieng for their invaluable comments. We thank the Director KEFRI and Regional Directors of Central Highlands, Rift Valley and Lake Victoria Eco-region Forestry Research Programmes for availing institutional facilities during data collection and the development of this guide.

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DEFINITION OF SOME TERMS USED IN THE TEXT

Forest degradation: the loss of forest structure, productivity, species diversity, capacity to supply products and services caused by intensive and/or repeated disturbance with consequent inhibition or delay in forest regrowth.

Forest restoration: re-establishing the structure, productivity, species diversity and ecological functions of a degraded forest to closely match those of its original status. Forests that require restoration have been degraded, damaged, transformed or entirely destroyed from direct or indirect result of human activities

Forest rehabilitation: re-establishing the productivity and some, but not necessarily all, of the original ecological and structural services, and plant species diversity of a degraded forest.

Reclamation of forest land: recovery of the productivity at a degraded forest land, such as quarry site using exotic or indigenous tree species, mostly in monocultures. The original biodiversity is not recovered, but some of the original ecological services may be re-established over time.

1.0 INTRODUCTION

In Kenya, natural forests are important in providing environmental services such as watershed protection, biodiversity conservation, and carbon sink. These forests also provide a wide range of non-timber forest products such as firewood, food, honey and herbal medicine. Natural forests can also provide timber. However, timber harvesting was discontinued in 1986 due to mismanagement, mainly over-harvesting. Although a comprehensive economic valuation of all natural forests has not been carried out, it is for example estimated that the Mau Forests Complex alone has an annual economic value of US$ 1.3 billion. This value is based on benefits accrued from the complex.

Over the past three decades, increase in demand for forest goods and services, poor management, overexploitation, and competing land uses have led to deforestation and forest degradation. For example, between 1990 and 2005, Kenya lost around 186,000 ha of natural forests through deforestation and degradation. The Food and Agriculture Organization of the United Nations (FAO) has defined forest degradation as changes within a forest that affect the structure and function of a stand or site thereby lowering its capacity to supply products and services. Degradation is largely intensified by indiscriminate extraction of high value mature trees and over-extraction of non-wood products associated with natural forests with no regard for sustainable use. Ordinarily, degraded natural forests recover after disturbance events, but in Kenya this has been hampered by repeat anthropogenic (human related) disturbances. The repeat disturbances have adversely affected the capacity of natural forests to provide ecosystem, ecological, biodiversity and environmental functions on a sustainable basis. To rehabilitate degraded forests to their near original form, human intervention is therefore required.

In the past two decades, there have been efforts to rehabilitate natural forests in Kenya. However, there has been little success due to inadequate information on suitable rehabilitation techniques. This guide has therefore been developed to provide a set of recommended actions for rehabilitation, restoration and management of degraded forests The guide is reference material for; forest managers, conservationists, community forest associations, county governments, private landowners, non-governmental organizations, and researchers, involved in rehabilitation and restoration of degraded forests. The guide highlights: levels of forest degradation; planning for forest rehabilitation; forest rehabilitation approaches and methods; and management of rehabilitated sites.

2.0 LEVELS OF FOREST DEGRADATION

There are different levels of forest degradation whose characteristics must be taken into account when considering decisions on forest rehabilitation approaches and techniques. Practitioners of forest rehabilitation should therefore determine the characteristics of the level of degradation whether it is: Disturbed primary forest; Degraded secondary forests; Degraded forest land; or Invaded forest sites.

Disturbed primary forests

These are primary forests in which the initial tree cover has been adversely affected by unsustainable harvesting of wood and/or non-wood forest products such that its structure, ecological processes, functions and dynamics are altered beyond the short-term resilience of

the ecosystem. At this level of disturbance, the capacity of these forests to fully recover from exploitation in the short to medium term (10 – 50 years) is compromised. Appropriate forest rehabilitation techniques for this level of degradation include enrichment planting, scattered tree planting, and group-planting.

Degraded secondary forests

These are forests that result from excessive harvesting of wood and/or non-wood forest products, poor management, repeated incidences of fire, grazing or through natural disasters such as storms, fire, landslides and floods. The level of disturbance delays natural regeneration even after the causes of disturbances are no longer in play. Degraded secondary forests may also develop on land abandoned after; shifting cultivation, settled agriculture, grazing, or failed tree plantations that create intermittent natural forest gaps/openings. The tree cover in degraded secondary forest sites ranges between 10 and 50%. Secondary forests when extensively degraded change to woodlands comprising trees of over 8 m in height with open spaces between them and lacking a distinct understorey layer (Plate 1) or even to grasslands devoid of trees and completely colonized by continuous layer of grass. It is important to differentiate grasslands that develop as a result of forest degradation from natural glades as the latter are normally not rehabilitated. Appropriate forest rehabilitation techniques for this level of degradation include; scattered tree planting, group-planting, closed-spaced tree planting with a few species and dense planting using many tree species.

Plate 1. Degraded secondary forest in Kobujoi in South Nandi forest block (Photo by J. Amwatta)

Degraded forest land

This is forest land characterized by grass, herbs and shrubs growing in clear-felled primary or secondary forests. Natural regeneration of such sites is often hampered by grazing, forest fires, cultivation and lack of sources of regeneration propagules, such as remnant trees. In

cases where some vegetation is left in the landscape, the tree cover is normally less than 10%. Such degradation level is characterized by bushlands dominated by shrubs, scrub and saplings of 2 - 8 m in height (Plate 2). Appropriate forest rehabilitation techniques for this level of degradation include; group-planting, closed-spaced tree planting with a few species, and dense planting using many tree species.

Plate 2. Degraded forest land in Ndoinet Block of Mau East (Photo by J. Amwatta)

Invaded forest sites

These are areas which were previously cleared of most of their original forest cover by illegal timber harvesting, charcoal production, settled agriculture, pasture lands, roads and failed plantations where invasive woody species have spread and dominated the other species during natural re-establishment. Invasive woody species such as; *Lantana camara*, *Acacia mearnsii*, *Acacia melanoxylon*, *Fraxinus pennsylvanica*, *Solanum mauritianum* and *Cestrum paraqui* have modified the invaded sites resulting in close to monoculture plantation by aggressively regenerating, out-competing, and suppressing the non-invasive woody species leading to low tree species diversity (Plate 3). Appropriate forest rehabilitation techniques for this level of degradation include scattered tree planting, and dense planting using many tree species.

Plate 3. Fraxinus pennsylvanica (foreground) and Acacia melanoxylon (background) invading the edge of natural forest in Kuresoi in Mau West (Photo by J. Amwatta)

3.0 PLANNING FOR FOREST REHABILITATION

3.1 Concepts and requirements for rehabilitation

Several issues should be considered while initiating forest rehabilitation approaches. These include the following:

a) Identifying degraded sites, mapping the extent of degradation, and delineation of areas based on degree of degradation. These will help in effective rehabilitation and monitoring changes.

b) Understanding the underlying causes of forest degradation and whether it is on-going or arrested. Characteristics of the degradation should be carefully evaluated to enable identification of the level of degradation for selection of suitable intervention techniques.

c) Specifying the purpose of carrying out rehabilitation intervention. Rehabilitation may focus on hastening recovery of tree species in degraded areas, ameliorating soil conditions before planting trees, stabilizing soil surface to prevent further erosion, or eradicating invasive species.

d) Selection of appropriate rehabilitation techniques. For instance, it should help to identify whether the site simply requires protection from further disturbance to allow natural regeneration or if it requires re-introduction of certain tree species.

3.2 Conceptual planning in forest rehabilitation

The logical conceptual steps necessary to understand and plan for undertaking rehabilitation of a degraded natural forest include:

i) *Identifying the degraded forest site location and delineating boundaries*. Mapping the forest site is important to make informed reference of the forest site. Use of Global Positioning System (GPS) is useful in mapping.

ii) *Specifying the ecosystem to be restored.* This involves describing the kind of original ecosystem that was degraded, damaged or destroyed.

iii) *Specifying objectives of rehabilitation*. Formulating the objectives is important for monitoring success of the rehabilitation.

iv) *Elaborating restoration goals.* This is an expression of the degree to which recovery can be anticipated to a former state and are more ideal outcomes than immediate outputs. This could be expressed in ecological, structural or in biodiversity terms.

v) *Identifying physical site conditions requiring repair.* This will need expressing and stating clearly what is at stake for physical intervention, e.g. is it soil compaction, species erosion or loss, soil erosion, reproductive species depleted general forest over-exploitation that requires focused action to reverse the situation.

vi) *Identifying and outlining the kinds of biotic interventions required.* This involves specifying which species require removal (unwanted species e.g. invasive non-native species) or introduction (desired species e.g. Nitrogen fixing bacteria or trees, mycorrhizal fungi) to ameliorate impoverished soil conditions.

vii) *Identifying sources of planting materials (seeds, seedlings, propagules, etc).* Sources of planting materials could be own collection, sourcing from existing nurseries or commercial procurement.

viii) *Identifying strategies for short and long-term protection, and management of rehabilitated sites.* This ensures that the site will be protected and properly managed into indefinite future. External threats can be reduced by buffers and building partnership/collaborative commitments from neighboring communities.

3.3 Preliminary tasks in undertaking forest rehabilitation

Once the site targeted for rehabilitation is well understood and objectives are clear, several preliminary activities are necessary in practice before proceeding with the restoration exercise. These tasks include:

i) *Documenting existing site conditions* – This entails quantifying the degree of site degradation or damage. Species composition and abundance should be determined and structure of the component communities described to allow a realistic prediction of the effectiveness of subsequent rehabilitation interventions. It is important also to describe soils, hydrology and other aspects of the physical environment. Photographs of pre-restoration site condition and compass directions should be recorded so that before and post-rehabilitation photos can be compared.

ii) *Document site history* **–** This involves providing a comprehensive site history, recording the years during which degradation occurred and important events associated with degradation that have taken place since then.

iii) *Establish an ecosystem/reference target indicator* – This provides a reference of pre-disturbance site condition based on one or more undisturbed sites of a similar ecosystem. A past documentation describing the same site or a similar ecosystem would suffice as a reference target indicator should an intact reference site be unavailable. A reference indictor later serves as a basis for evaluating rehabilitation success.

iv) *Document ecological information of key species* – This entails indicating recruitment mode, growth, and reproductive strategy of key ecosystem species. Silvicultural requirements of key tree species should be recorded if available.

v) *Document the intended objectives and actions required to achieve restoration goals identified in the conceptual planning* – This entails linking the objectives to clear initiatives for intended results. For example, if the goal is to restore the forest ecosystem after the natural forest was converted to plantation forest, one objective would be to establish tree cover with designated species composition and species abundance.

vi) *Establishing partnership/collaboration with public and interested stakeholders including adjacent communities* – This is necessary since forest rehabilitation is a public concern whether conducted on public or privately owned land. Upon appreciation of tangible and intangible benefits of restoration, restored forests would be accorded protection by a wide range of stakeholders regardless of ownership.

4.0 FOREST REHABILITATION APPROACHES AND METHODS

Forest rehabilitation methods are broadly categorized into; Passive restoration approaches and Active restoration approaches. Choice of restoration approaches depends mainly on; extent of degradation, resources available, and objectives of restoration.

4.1 Passive restoration approaches

Passive restoration approaches refer to techniques that allow natural regeneration and colonization to restore forest diversity and structure. These approaches are best suited to forests where residual forest patches remain or some advanced forest re-growth is already present. The three common techniques used is natural regeneration are; Natural regeneration, Tropical shelterwood regeneration system, and Controlled selection regeneration system.

i) Natural regeneration

Natural regeneration is a rehabilitation technique in which forest restoration is achieved by allowing natural regeneration and successional processes to restore ecosystem biodiversity and structure. This technique is best suited for degraded forest sites where some recovery has already occurred or in recently disturbed sites where disturbance was slight or short-lived because the site has a large pool of residual seedlings, seed in topsoil or live tree stumps. Such sites should be close to patches of intact forest which serves as sources of seeds. The technique works best where degraded sites are protected from human-mediated repeat incidence of disturbance such as grazing, forest fires and illegal tree extraction.

Comparison of relative costs and benefits for various rehabilitation techniques

Natural regeneration is generally less expensive than active restoration techniques (Table 1) and always results in species that are well adapted to the rehabilitation site. The technique is especially advantageous when there are limited financial resources available for forest rehabilitation. This makes it one of the few forest rehabilitation techniques that are suitable across large degraded forest areas.

Table 1: Relative costs and benefits of various forest rehabilitation approaches

Technique	Relative cost	Biodiversity recovery rate	Ecological benefit	Production benefit
Natural regeneration	Low	Slow	High	Low
Enrichment planting	Low-medium	Slow-medium	High	Medium
Direct seeding	Low-medium	Medium	High	Medium
Scattered tree planting	Low	Slow	High	Medium
Close-spaced planting with limited species	Medium	Medium	High	High
Dense planting using many tree species	High	Fast	High	High

Testing of Controlled Natural regeneration in Kakamega, Nandi and Wire forests

Natural regeneration has been applied successfully to rehabilitate degraded natural forest areas in Kakamega, Nandi and Wire forests. Two hectare plots were enclosed using barbed wire fence to protect them from human-mediated disturbances especially grazing. In Kakamega rehabilitation site, the number of woody species increased from 8 at the point of intervention to 57 in four years in the protected area. In the unprotected area (control), the number of woody species increased from 8 to 9 in the same period (Figure 1; Plate 4).

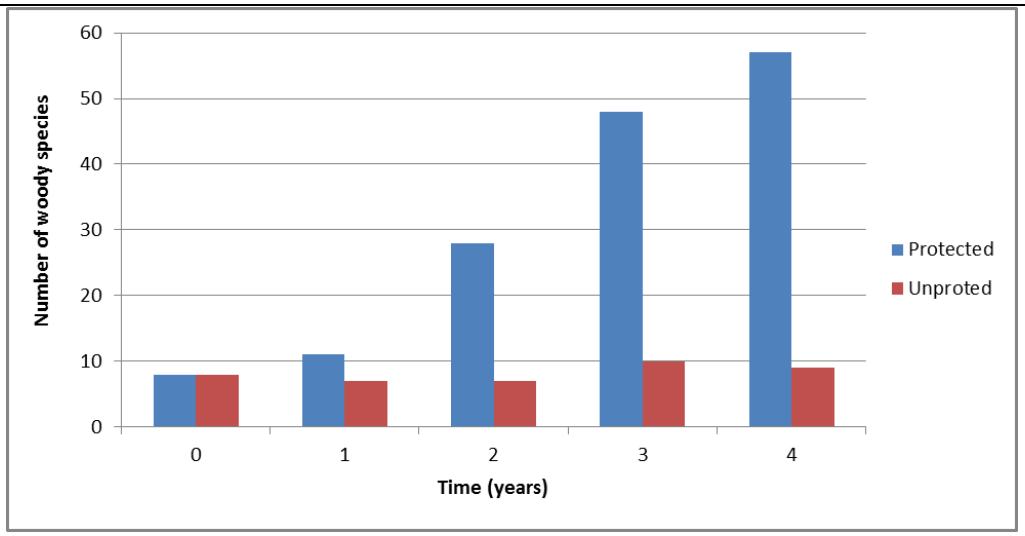


Figure 1: Changes in number of woody species over a four-year period in protected and unprotected plots in Kibiri Block of Kakamega Forest. *Source:* Otuoma *et al*. (2010)

April 2009	April 2013

***Plate 4. Changes in vegetation community structure through natural regeneration in a protected plot over a four-year period at Kibiri rehabilitation site* (*Photos by J. Otuoma*)**

Results from Wire forest showed that the number of woody species increased from 19 at the point of intervention to 34 in six years within the protected area (enclosure). In the unprotected plot (control), the number of woody species increased from 19 to 21 during the same period (Figure 2; Plate 5).

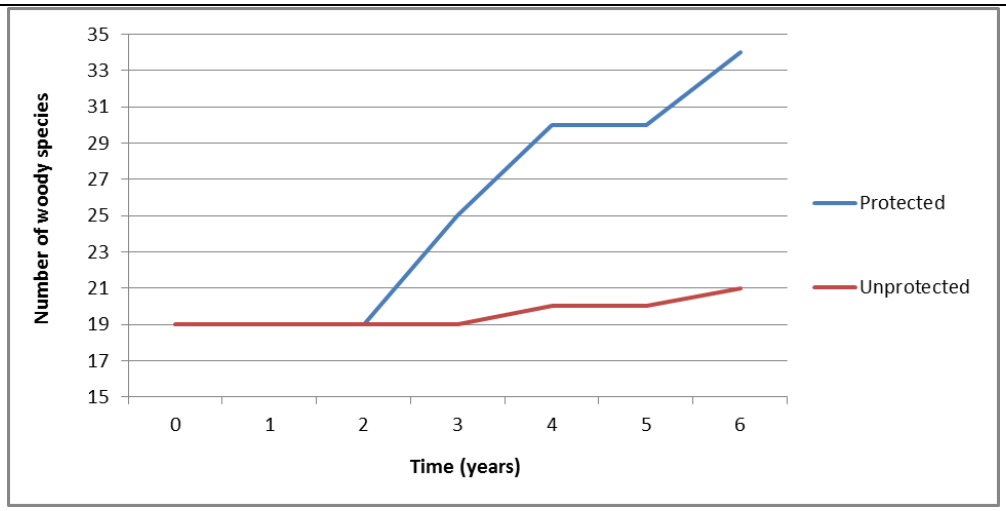


Figure 2: Changes in number of woody species over a six-year period under natural regeneration in protected and unprotected forest rehabilitation plots in Wire Forest. *Source*: Otuoma *et al*. (2010)

Plate 5. Changes in vegetation community structure through natural regeneration over a six-year period at Wire Forest rehabilitation site (Photos by J. Otuoma)

ii) Tropical shelterwood regeneration system

The method is aimed at combining harvesting and regeneration, thus arresting degradation at the earliest opportunity. It is commonly used in West Africa in productive forest system. The method involves dividing the forest area into compartments of about 2.5 km^2. Licensees select the compartments they will exploit after five years. During the five-year interlude before exploitation, the forest authority carries out compartment treatments aimed at securing regeneration. Treatments during the five years include:

- selecting desirable timber species within a compartment
- clearing undergrowths twice in a year
- girdling undesirable middle-storey canopy trees around the desirable trees, and
- gradual climber cutting and canopy opening

It is expected that by the time exploitation commences, the regeneration of the desirable trees will be above 4 m tall. Although, the Kenyan situation does not cater for harvesting of timber in natural forests, tropical shelterwood regeneration system can be adapted to encourage restocking of degraded sites with selected desirable trees.

iii) Controlled selection regeneration system

This method involves carrying out the normal selection cutting method of the remaining desirable species in the forest. In addition to felling these trees, clearing of all undergrowth and undesirable species 5 m around the cut stumps is done to ease regeneration. Regenerating seedlings are weeded during the next five years. Quantity of seedling regenerated using controlled selection system is usually adequate. This regeneration method, as in the case of shelterwood regeneration technique, will depend on close operations necessary to see the regeneration through the critical phases of establishment.

4.2 Active restoration approaches

Active forest rehabilitation approaches involve planting of tree seedlings to reforest degraded forests. Indigenous tree species from the immediate area are the most appropriate. Attributes of candidate species to used in rehabilitation confer different forest rehabilitation benefits (Table 2). Where forests are being rehabilitated by Active restoration approaches the choice of tree species should take into consideration suitability of these trees as well as their potential to become invasive weeds.

Table 2: Desirable tree species attributes for forest rehabilitation

Desirable tree attribute	Forest rehabilitation benefits
Indigenous tree species	Enhance biodiversity conservation
Fast-growing species	Suppression of herbaceous vegetation
Species attractive to fruit-dispersing birds	Seed dispersal
Ecologically beneficial species	Enhance ecological functions
Economically / socially beneficial species	Provision of forest goods and services
Rare / endangered / over-utilized species	Enhance abundance and diversity
Fire tolerant species	Suppression of forest fires
Species tolerant to harsh site conditions	Nurse trees

Intervention techniques in active restoration programmes depend on sizes of degraded forest areas. Some of the common approaches in active restoration include: Enrichment planting; Direct seeding; Scattered tree planting; Close-spaced planting using a limited numbers of species; Dense planting using many tree species; Group planting; and Rehabilitating degraded forests invaded by woody species.

i) Enrichment planting

Enrichment planting is a technique where native species of ecological and economic value are introduced to a degraded forest site to supplement biological diversity and hasten the process of rehabilitation. This intervention is suitable for:

- Forests stands disturbed many times in the past such that only a small number of relatively common species remain.
- Naturally regenerating degraded sites with low species diversity and tree density.
- Situations where exotic monoculture plantations have been established but the management objective has changed to both production and conservation.
- Establishing species that cannot grow in open areas because such trees are intolerant to direct sunlight.

Enrichment planting generally consists of transplanting nursery-grown seedlings or wildlings into natural openings in the forest, lines or strips opened specifically for this purpose. The planting strips are often opened on an east – west orientation to increase light availability for planted seedlings. The planting strips should be spaced at least 5 m apart depending on the nature of the disturbance and canopy openings. The size of the canopy opening should be adjusted to match the tolerance levels of the species being planted. The strips do not have to be in complete straight lines, but can detour round large trees located on their path. Seedlings to be planted should be at least 45 cm tall, while planting holes should measure 45 cm diameter by 45 cm depth. Seedling spacing along a planting strip should be at least 3 m. Species identified for enrichment planting should be fast growing to overcome competition from other regenerating woody species.

The initial plant condition at planting time is a major determinant of success, thus emphasizing the importance of obtaining high-quality planting stock from the nursery. The species planted should be of economic, ecological or social interest (e.g. non-timber species such as fruit or nut trees as well as bamboo/rattans, medicinal plants). Tending involves removal or back cutting of competing and overarching trees from the cut and uncut strips. The limiting factor to survival is shading and suppression from neighbouring faster growing weedy shrubs. Intensive labour is required to keep the strips open to allow light to reach the establishing seedlings.

ii) Direct seeding

Direct seeding is a forest rehabilitation technique in which seed is deliberately sown or broadcasted in a degraded site to accelerate the recruitment of woody species. Usually the seed is sown on bare soil so that it can establish quickly under weed-free conditions. Direct seeding can be used in areas that might be difficult to reach when transporting seedlings. Challenges associated with this technique include; keeping the site weed-free, and requirement for large amounts of seed. In many cases only a small proportion of the seed broadcast is able to germinate and survive due to seed predators and harsh field conditions.

iii) Scattered tree planting

Scattered tree planting is characterized by planting a small number of scattered, single, clumps, or rows of trees in a degraded forest site (Plate 6). The trees are intended to accelerate natural regeneration by acting as perches that attract seed or fruit-dispersing birds. Seedlings germinate from bird droppings below the perch trees enlarging clumps of trees in the process colonizing degraded forest areas. This technique is suitable for abandoned clear-felled forest areas with grasslands or shrubs and sites with few scattered remnant trees. The technique is inexpensive since the trees are widely spaced and large numbers of seedlings are not needed, though closer spacing between trees or clumps leads to faster forest recovery. However, its success is highly dependent on the availability of seed-dispersing birds.

Plate 6. Dombeya torrida and Acacia species used for rehabilitating degraded forest lands in Mau West (Photo by J. Amwatta)

iv) *Close-spaced planting using a limited numbers of species*

Close-spaced planting is a forest rehabilitation technique which involves closely spaced planting of a small number of species able to attract seed-dispersing birds. These early plantings act as "nurse trees". High planting density (1,000 trees per ha, or even more; spacing of 2 m or less between seedlings), of a limited number of tree species is used (Plate 7). At least two tree species should be planted in a mixed formation. Within a group, slow growing species and those with a spreading crown should be planted on the outside. Tree species from early successional stages should be used to create suitable conditions for the later arrival of a more diverse community. Alternatively, tree species which are tolerant to the degraded site conditions or are attractive to fruit dispersing birds should be used to enable fast colonization of the site. The advantage of this technique is that once the trees are established, they soon out-compete grasses and weeds, making it easier for the species brought in by seed-dispersing animals to establish. The approach is especially suited to areas close to intact forest that act as a source of seeds and a refuge for birds, which allows additional species to be recruited quickly.

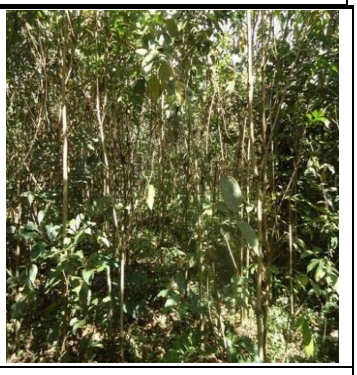
Plate 7. Closely spaced mixed planting used in rehabilitation of a degraded riparian forest at James Finlay Tea Estate (Photo by J. Amwatta)

v) *Dense planting using many tree species*

Dense planting using many tree species, also known as the maximum diversity method, is a forest rehabilitation technique which involves planting a larger number of species (i.e. 10-20) at a higher density (4,000 plants per ha) . The technique uses a large number of indigenous tree species in an attempt to restore as much as possible of the site's original species richness and structural diversity. Suitable tree species include fast-growing species able to exclude weeds, poorly dispersed species, species forming mutually dependent relations with birds, and possibly rare or endangered species that might be present only in small numbers or in small geographic areas. Since the method bypasses the normal successional sequence, the species used should be from late successional stages, rather than early pioneer species.

Dense planting rehabilitation demonstration in Nandi South

A dense planting rehabilitation technique using eleven indigenous tree species was established by KEFRI in Nandi South in 2010. Preliminary results show that the species have managed to suppress the grasses and weeds (Plate 8).



6 months	2 years	3 years

Plate 8. Dense planting demonstration in South Nandi showing progression from six months to three years after establishment (Photos by J. Otuoma)

The method has several challenges. The growth rate of some plant species in dense plantings can be slow because of competition and many of the original species may die. Also, some species may need to be introduced to the succession in a particular sequence e.g ……. give specific examples of such species and the sequence) …….. The disadvantage of this approach is cost (Table 1) as it is expensive to collect seed and raise such a large variety of species in a nursery and plant them out in the field.

vi) Group planting

This method is suitable where canopy openings are medium to large or over 0.5 ha in size. Pure or mixture of species are planted in line at a spacing of 2-3 m between seedlings. Planting holes should be 45 cm diameter and not less than 30 cm deep. Seedlings used should be at least 45 cm tall. Spot weeding of 1-m diameter is done around the planted tree seedlings.

vii) Rehabilitating degraded forests invaded by woody species

Invasion of degraded forest areas by woody species is now considered a major threat to forest recovery and biodiversity. The increasing fragmentation and degradation of natural forests creates better opportunities for continued rise in frequency and severity of woody species invasions that often inhibit the establishment and growth of native species. If the invaded area is left for natural recovery to take place, it may remain under invasion for many years. Consequently, eradication and control of invasive woody species are common practices in most ecological restoration efforts. These include:

- Eliminating invasive species through physical slashing, cutting, or uprooting depending on the species.
- Initiating non-invasive tree species recovery by planting fast-growing tree species to suppress the invasive individuals and improving the environment thus facilitating the establishment of indigenous tree species.
- Accelerating tree seedlings establishment by reducing competition from weedy species such as grasses and vines (within 0.5 m radius), slashing, hand weeding and thinning of clumps of woody seedlings to liberate the desired species.
- Preventing further invasions by removing or carefully managing disturbance agents e.g. fires, grazing, which interrupt succession and recovery of indigenous tree species.
- Monitoring and eradication of woody species invasion as an essential component of forest rehabilitation programme.

5.0 MANAGEMENT OF REHABILITATED FORESTS

Success in forest rehabilitation will greatly depend on management of the restored site. Overall long-term intervention will focus mainly on protection, maintenance and monitoring.

Management interventions for restored sites involves:

i) Protecting rehabilitated sites from human interference and animal damage

Security of the rehabilitated site should be reviewed and appropriate protection measures put in place in consultation with the forest adjacent communities. It is recommended to use organized community groups in protection but such groups must be adequately sensitized and facilitated to participate in forest protection.

Livestock grazing and browsing by wild animals remains the biggest threat to rehabilitation efforts in all the natural forests. Where necessary, barriers should be erected and maintained to keep out the browsers and grazers including livestock.

ii) Site maintenance and protection

Clearing around seedlings, and removal of climbers should be done regularly (Plate 9)**.** Spot weeding should be undertaken by clearing weeds 1-meter diameter around seedlings and to a depth of 10 cm. The weeding should be done twice per year for the first two years. Weeding is better done two months after the main rainy season. In situations where there is an overabundance of saplings or pole-size tree stems, not all of which can possibly survive until maturity, selective thinning to favour the growth of the remaining individuals is necessary. Restored sites should be protected from fire hazards using standard practices e.g. firebreaks, education and awareness on fire risks.

iii) Regular monitoring of restored sites

Restored sites should be inspected frequently especially during the first and second year following rehabilitation intervention. Monitoring ensures that the recommended maintenance is undertaken on time. Monitoring should also be carried out periodically to assess; stand characteristics, species composition, and invasion incidences, to facilitate taking the necessary and timely corrective measures to achieve objectives of the rehabilitation.

Plate 9. Promoting growth of desired tree species through cleaning and clearing of unwanted bushes and shrubs (Photo by J. Amwatta)

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