Kenya's Water Towers Protection and Climate Change Mitigation and Adaptation (WaTER) Programme

GUIDELINES FOR REHABILITATING DEGRADED WATER TOWER ECOSYTEMS IN KENYA

Component 4: Science to Inform Design of Community-Level Actions and Policy Decisions

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February 2018

This programme is funded
By the European Union

Kenya Forestry Research Institute
(KEFRI)

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FOR

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December 2017

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Captions for cover photographs
Top: A forest restoration demonstration plot in Sinen in Embobut Block in Cherangany Hills Forest Ecosystem. *Photo by J. Amwatta.*

Published by:
Kenya Forestry Research Institute under the Water Towers Programme
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1.0 INTRODUCTION

The water towers of Mt Elgon and Cherangany provide important environmental goods and services, such as watershed protection, biodiversity conservation, carbon storage, provision of fuel wood, construction materials and non-wood forest products. Over the past 3 decades, increase in demand for these environmental goods and services, coupled with competing land use, has led to their overexploitation leading to deforestation and forest degradation. Forest degradation has largely been intensified by indiscriminate extraction of high value old-growth tree species and commercialized non-wood products thereby compromising the capacity of these water towers to sustainably supply ecosystem goods and services. Ordinarily, natural forests are expected to recover after initial disturbance events, but this has been hampered by repeat anthropogenic disturbances. This, as a result, adversely affects the capacity of forests to provide the needed ecosystem, ecological, biodiversity and environmental functions on a sustainable basis. The situation calls for human intervention to accelerate forest recovery to their near original forms.

KEFRI with support from the European Union has demonstrated suitable rehabilitation techniques from the two ecosystems critically drawing strategic lessons from past successful rehabilitation interventions in Maragoli Hills, Gwasi Hills, Wire and Mau Forests. This guidelines are expected to serve as reference material for field level forest managers, researchers, conservationists, community forest associations, landowners, non-governmental organizations, private timber companyies, and county government planning officers in the restoration of degraded forests and forest lands at the site level. The guidelines provide a set of rehabilitation technologies for different levels of forest degradation, selection criteria for restoration species, restoration species mix, and involvement of local communities in management of rehabilitated areas as a component of sustainable participatory forest for social and economic development.

The scope of the guidelines is to:

a) Provide a framework and implementation procedures for suitable rehabilitation techniques for degraded water tower forests,

b) Stimulate the adoption of appropriate rehabilitation woody species to enhance the success of rehabilitation interventions, and

c) Involvement of local communities in the site selection, species selection, establishment and protection of the rehabilitation sites.

1.1. Biophysical characteristics which affect the restoration of Water Towers

Due to climate changes at specific altitudes, vegetation in the water towers is divided into altitudinal zones which lead to a vertical sequence in various agro climatic areas. Consequently, restoration of the water tower is limited to zones between altitude 1300 and 2400 m. At extreme altitudes, over 2400 m above sea level, satisfactory restoration is not possible according to the current state of technical awareness. Widespread deforestation, which occurred in the upper zones of water towers has created wide openings, which currently serve as grazing areas. Large areas used for grazing suffer from multiplicity of damage (trampling, browsing etc) which have aggravated the degradation process.

The loss of indigenous tree species, on the other hand, has also led to the removal of topsoil creating conditions under which ecologically adapted grasses can no longer thrive. Further degradation of the forest area has led to loss of most species including natural seed banks. At altitudes between 1800 and 2400m, a minimum vegetation cover of 70-80% is required to avoid erosion. Forest restoration interventions in water towers should therefore target this minimum cover to restore the catchments functions. A sufficient combination of suitable techniques and adapted restoration tree species must be the main target for restoration of different altitudinal zones of the water towers.

2.0 Approaches for sustainable restoration of the water towers

Our general approach to restoring the water towers ecosystems is based on the need to repair, rehabilitate and restore ecosystem health and ecosystem services. The overall aim is to ensure greater attention is given to the interrelated environmental and economic issues of biodiversity on one hand and climate change and sustainability on the other. This approach can be defended on purely economic grounds, but also finds ample justification on social, cultural and ecological grounds. Given the history of anthropogenic disturbances, we target the restoration of damaged, degraded or destroyed areas of the ecosystem. As human demands on these water towers increase, conservation and restoration responses need to become increasingly creative and collaborative.

In addition, we focus on restoration of vegetation, and especially woody species and leave the restoration and re-introduction of animals aside in our discussion. Large woody plants and trees are the main structural component in the water towers ecosystems, and they play an important role in the functioning of these ecosystems. Further, in all areas long modified by humans, trees and large shrubs can play an important role as bio-indicators and should be used for determining the best options, goals and procedures for ecological conservation and restoration.

The basic objectives of restoration actions in the water tower ecosystems should be as follows:

i. To stop degradation affecting the most sensitive or hotspots in the water towers,
ii. To assist secondary succession through stimulating natural regeneration by fully exploiting the potential of indigenous species , ecotypes and provenances, and
iii. To increase water tower ecosystem resilience, especially in relation to the most threatening disturbances, such as grazing, wildfires and climate change.

Degradation process, either recent or relic, may not be reversed spontaneously, once one or more ecological thresholds have been crossed. Such degradation can only be reversed by human intervention in the form of restoration actions. In the next section, we review some of the restoration approaches currently demonstrated in the two water towers and discuss how we can go further towards improving their efficiency in our situation.

2.1. Restoration Priorities in Water Towers Conditions

We focus on restoration of large–scale ecosystems, degraded most often by long-term over-exploitation and grazing. The specific objectives of restoration differ widely, although the general and priority objective is soil and water conservation. Specific objectives vary depending on the degree of degradation, and climatic, biotic and socio-economic constraints as shown in Table 1. In the case of water towers ecosystems, we consider the following priorities.

i. Soil and water conservation as the main priority, for reducing or preventing soil losses and for regulating water and nutrients
ii. Improving the resistance, and especially the resilience, of ecosystems with respect to human and non-human disturbance to ensure sustainability of the restored lands, we aim to promote plant, animal and microbial communities resilient to current and future disturbance regimes
iii. Increase mature woody formations, both forests and shrub lands, depending on the environmental conditions of the site, in order to improve ecosystem and landscape quality and to increase carbon storage under scenarios of global warming and Carbon dioxide build up
iv. Promote biodiversity and foster the re-introduction of key species that have disappeared because of past land uses.

Table 1. Framework for restoration of the Kenya water tower ecosystems. Drivers of restoration are identified, as well as actions that can be undertaken to manage them, and available techniques to implement these actions. Each driver can be offset to ensure successful restoration.

Driver	Action	Technique
Persistent stress (disturbances, invasive species)	Release stress	Limited access to people, herbivores, etc Fire prevention, windbreaks Species control (fires, clearing)
Low propagule availability	Artificial introduction	Seeding, planting
	Promote dispersion	Bird–mediated restoration, frugivory–mediated restoration(artificial perches, catches, habitat amelioration)
Adverse environmental conditions	Reduce soil losses	Emergency seeding, mulching, sediment traps
	Ameliorate soil properties	Amendments, nutrients, soil preparation
	Improve microclimate	Shelters, mulching, micro site selection

3. 0 FOREST REHABILITATION METHODS

Several approaches can be used to rehabilitate degraded forests. The specific approaches described below were selected as the most suitable and have successfully been demonstrated in different sites in the project area. Several factors should be considered while initiating these forest rehabilitation approaches, irrespective of the technique used. The first consideration is a full understanding of how the intervened area will be integrated within the broader ecosystem, especially in terms of those components of the ecosystem that may affect the long-term functions of the restored site. The second consideration is the participation of the local communities in the following conceptual planning as stipulated below.

i) *Identifying the location of the degraded forest site and delineating boundaries*. Members of the communities should be involved in mapping the forest site to make informed reference of the forest site. Global Positioning System (GPS) should be used to mark positions of the identified areas.

ii) *Specifying the objectives of rehabilitation*. The community members should provide the history of the degradation of the site and what is desired from the restoration

iii) *Identifying physical site conditions requiring repair.* This involves a clear definition of the real physical condition 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?

iv) *Identify and outline the kinds of biotic interventions required.* Together with community members we need to specify what plant life need removing (unwanted species e.g. invasive non-native species) or need introduction (desired species e.g. medicinal, indigenous fruit trees, nitrogen fixing bacteria or trees, mycorrhizal fungi) to ameliorate impoverished soil conditions and provide desired products

v) *Identify sources of planting materials (seeds, seedlings, propagules, etc).* This will mean planning and identifying sources of planting materials in terms of collection, sourcing from existing community tree nurseries or commercial procurement, and

vi) *Identifying strategies for short and long-term protection and management of rehabilitated sites.* Community members and local leaders should provide commitment and assurance that the site will be protected and properly managed into indefinite future. External threats can be minimized by building partnership/collaborative commitments from neighboring communities, KFS, CFAs and County Governments in advance of the project initiation.

Plate 1.Comparing notes with the Kapcherop Community leaders on suitability of selected site for rehabilitation (Photo. J. Amwatta)

3.1 Preliminary tasks towards implementation of rehabilitation

Once the site targeted for rehabilitation is well understood and objectives are clear, several preliminary activities should be undertaken with the communities and partners before proceeding with the restoration exercise. The practical tasks include:

i) *Documenting existing site conditions* – this entails quantifying the degree of degradation or damage of the site. Species composition and abundance should be determined and the structure of the component communities described to allow a realistic prediction of the effectiveness of subsequent rehabilitation interventions. Photos of pre-restoration condition and compass directions should be recorded so that prior and post-rehabilitation photos can be compared.

ii) *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 recover a former forest ecosystem that was converted to plantation forest, one objective would be to establish tree cover with designated suitable tree species combination.

iii) *Establishing partnership/collaboration with public and interested local stakeholders* – this is necessary since water tower forest rehabilitation is a public concern. Upon recognition of the benefits of restoration, tangible and intangible, such restored forests would be accorded protection regardless of ownership and funding by a wide range of local stakeholders.

4.0 SUITABLE REHABILITATION TECHNOLOGIES FOR WATER TOWERS

4.1 Passive restoration technologies

Passive restoration technologies refers to techniques involving simply protecting degraded areas from further disturbances and allowing natural regeneration and colonization to restore forest diversity and structure. These technologies are recommended for forests areas where residual forest patches remain or some advanced forest re-growth is already present. The techniques are especially advantageous when there are limited financial resources available for forest rehabilitation. Natural regeneration is generally less expensive than active restoration techniques and always results in species that are well adapted to the rehabilitation site. This makes it one of the few forest rehabilitation techniques that are suitable across large degraded forest areas in the water towers.

Selection of the tree species/areas to be protected should be based on a combination of factors namely, geographic range, species spatial distribution, and local species abundance as a shown in Table 2.

Table 2. A classification of species based on abundance and distribution to guide selection of species and habitat to be considered for enclosure.

Habitat	Natural Range			
	Large		Small	
Habitat specificity	Wide	Narrow	Wide	Narrow
Population size				
Large dominant	Locally abundant over a large range in several habitats.	Locally abundant over a large range in a specific habitat.	Locally abundant in several habitats but restricted.	Locally abundant in a specific but restricted.
Small Non-dominant	Constantly	Constantly	Constantly	Constantly

	sparse over a large range in several habitats.	sparse in a specific habitat but over a large range.	sparse and restricted in several habitats.	sparse and restricted in a specific habitat.

i) Community managed enclosure management system

This a rehabilitation effort aimed at assisting natural regeneration through enclosures to protect the area from grazing and other interferences, which enhances regeneration and recovery of the browsed saplings and stumps. It should target indigenous tree species which are facing natural regeneration challenges due lack of mother seeds and continued disturbances through livestock grazing. An area of about 2 ha of a degraded area with scattered stunted saplings and mature trees of key indigenous tree species can be enclosed with dead fences or barbed wire to enhance natural regeneration. The presence of a pool of residual saplings, seed in topsoil and live tree stumps in the enclosure will allow natural regeneration and successional processes to restore the targeted species and general forest structure. The enclosure should also be sited close to patches of forest area which would be sources of dispersed seeds of other species into the enclosure. The enclosure should be under the management of the local communities through the CFAs or WRUAS who should benefit from products such as grass 'cut and carry,' collection of dried wood, and erecting beehives. Two key species namely *Juniperus procera* and *Syzygium guineense* have been placed under this management in Kapcherop and Sinen areas of Cherangany Forest Ecosystem.

Plate 2. Enclosed area for assisting natural regeneration and recovery of *J. procera* saplings in Kapcherop

ii) Liberation thinning in Mt Elgon ecosystem

This refers to the clearing a degraded forest site of herbs and shrubs that inhibit natural forest regeneration. The understanding behind this forest restoration technique is to create space for light capture by tree seedlings and saplings and lessen competition from shrubby and herbaceous life-forms. It is often applied when the growth and development of seedlings or saplings of desired woody species are inhibited by overtopping shrubby and herbaceous competitors in a naturally regenerating degraded forest. The restoration technique was employed in Kongit in Kaboywo Forest Block in Mt Elgon Forest Ecosystem in August 2016.

4.2 Active restoration technologies

Active forest rehabilitation approaches involve planting of tree seedlings to reforest degraded areas. Extensive testing may be required before determining which tree species or tree species mix to use. However, indigenous tree species from the immediate area are the most appropriate and their selection can be based on some of the characteristics in Table 2. A range of suitable techniques demonstrated in the water towers are discussed below.

Table 2: Species with desirable attributes for forest rehabilitation

Species type	Forest rehabilitation purpose
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

i) Enrichment planting using 4 by 4 m in Mt. Elgon Ecosystem

This forest restoration technique is also referred to as aided forest regeneration. Planting is carried out at wide spacing in order to introduce framework species to accelerate natural forest regrowth. The planted tree species often constitute fast growing late successional pioneers (light demanding) and early intermediate species (shade tolerant) e.g., *Harungana madagascariensis, Bridelia micrantha, Blighia unijugata, Bersama abyssinica, Cordia africana, Measa lanceolata,* etc. The restoration technique was employed at Kongit and Kaberua degraded sites in Mt. Elgon Forest Ecosystem in August 2016. Previously, KEFRI successfully applied this forest rehabilitation method in Gwassi hills to rehabilitate a degraded forest land between 2009 and 2017 (Plate 4).

Plate 3: Changes in vegetation cover from farmland to closed canopy forest in Kisaku in Gwassi hills between 2009 and 2017 as a result of enrichment planting by KEFRI (*Photo*: John Otuoma)

ii) *Group close-spaced planting using limited numbers of species*

Close-spaced planting is a forest rehabilitation technique which involves more closely spaced planting of a small number of species able to facilitate the establishment and growth of other species and also to attract seed-dispersing birds. Over time, the unplanted spaces are occupied by recruits arising from the soil seed bank and / or dispersed seed, while planted trees spread their crowns to cover the natural recruits. It results in a forest stand comprising trees of different age, size, stem-form and crown shape. This forest restoration technique creates an artificially planted forest that closely resembles a natural stand. The selection of restoration tree species should be appropriate for site conditions, and should incorporate fast-growing tree species to provide rapid vertical structure. This is an innovative restoration technique that provides more rapid vertical development and greater species richness on sites restored with a series of systematically distributed clusters of fast-growing trees. Within a group, slow growing or late successional species and those with a spreading crown should be planted on the outside with one fast growing early successional or nitrogen fixer species at the centre. Tree species from early successional stages should be used to create suitable conditions for facilitation of neighbors and also the later arrival of a more diverse community.

We have used ten suitable restoration tree species in two sites in Cherangany Ecosystem to demonstrate this technology for the water towers at Lomuge I, Lomuge II, Sinen I, Sinen II, Kaplomen and Kapelot. The ten tree species were classified into fast growers, medium and slow growers to guide the mixing or combination as shown in Table 3. The restoration tree species were planted at a spacing of 2 by 2 meters in groups of five in random mixed formation as shown in Plate 4. The fast growing or nitrogen fixing trees (*Polyscias kikuyuensis or Albizia gummifera)* surrounded by four trees of medium or slow growth.

Table 3. List of tree species used in rehabilitation demonstration plots and their growth characteristics.

Species	**Fast**	**Mediun**	**Slow**	**Site**
Juniperus procera		✓		Sinen I
Dombeya torrida			#	Sinen I& II
Syzygium guineense		✓		Sinen I& II, Lomuge I &II
Podorcarpus gracillior			#	Sinen I& II
Hagenia abyssinica			#	Sinen I& II
Albizia gummifera	×			Lomuge I &II
Polyscias kikuyuensis	×			Lomuge I &II
Markhamia lutea		✓		Lomuge I &II
Prunus africana		✓		Lomuge I &II
Croton megalocarpus			#	Lomuge I &II

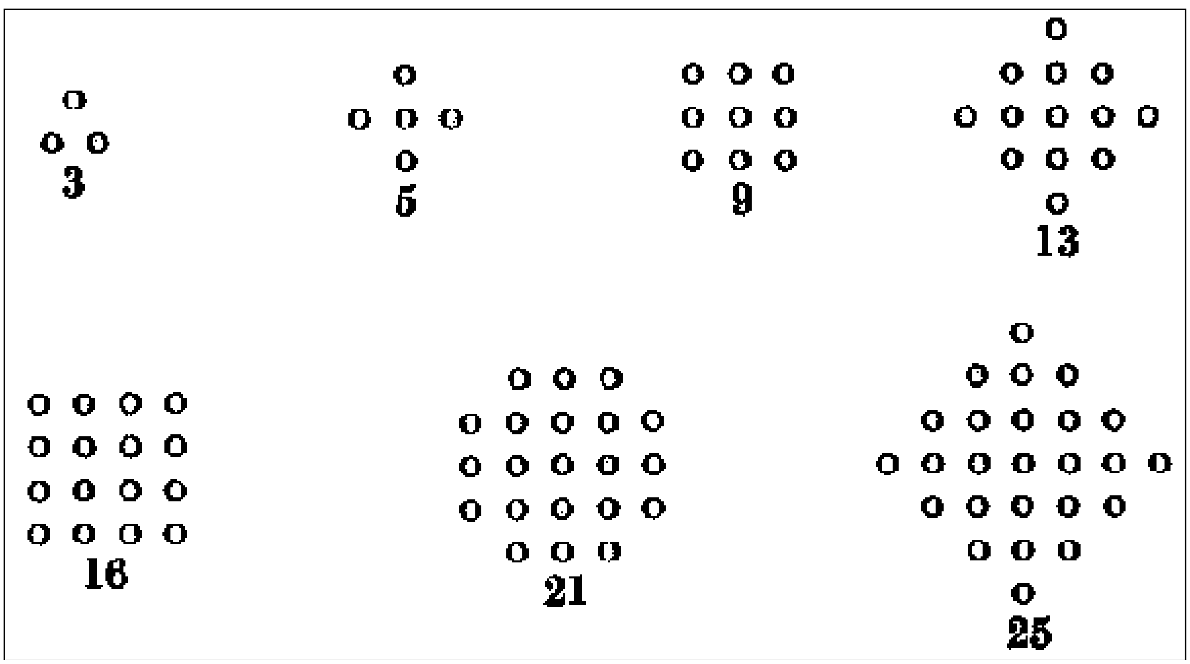

Plate 4: Different tree mix and formations of group planting in natural forest restoration

Plate 4: Different tree mix and formations of group planting in natural forest restoration

Plate 5. *Demonstration of closely spaced mixed planting used in Lomuge I (Photo J Amwatta)*

iii) Demonstration of dense planting using 1by 1 m, 2 by 2 m in Mt. Elgon Ecosystem

This forest restoration technique involves planting many tree species at dense spacing, such as 2m, 1m or 0.5m spacing. The purpose is to restore vegetation cover to the degraded forest site at a much faster rate. It employs a mix of light-demanding and shade-tolerant woody species. It is applicable in degraded forest sites with very low potential for natural regeneration, which makes planting inevitable. The restoration technique was employed at Kongit and Kaberua degraded sites in Mt. Elgon Forest Ecosystem in August 2016. Previously, KEFRI had successfully applied this restoration technique in South Nandi Forest using a mix of light-demanding and shade-tolerant woody species at varying spaces of 0.3 and 1m (Plate 6).


Plate 6: Dense planting_South Nandi_2010 South Nandi _ 2015 (*Photo*: John Otuoma)

iv) Strip planting in Mt Elgon

This forest restoration technique involves clearing of shrubby and herbaceous vegetation in a degraded forest site to create strips, which are then planted with the desired tree species. Strip planting is a form of enrichment planting because the planted trees serve as framework tree species that nurture naturally growing seedlings and saplings by growing above the weed canopy to suppress their growth and accelerate natural forest recovery. The size of a strip should be adjusted to conform to the requirements of the tree species being planted. The restoration technique was employed at Kongit degraded site in Mt. Elgon Forest Ecosystem in August 2016

v) Rehabilitating degraded riparian areas through enclosure and use of bamboo species

Riparian corridors covering 10-30 metres in width on both stream banks on many rivers, streams and tributaries have been degraded on a large scale in most water systems. In many areas, catchment-scale vegetation modifications caused by livestock grazing and invasive alien plants are among the most influential agents of degradation. The first step is to fence off the area using either dead fencing materials or barbed wire to exclude livestock to allow designated riparian areas to revegetate and stabilize. Once secured, riparian suitable tree species including bamboo should be planted at a spacing of 2 m by 2m. Any restoration of riparian areas should not only target watercourses, but also focus on the perception of the local communities hence their involvement in the whole process is key.

Plate 7: Rehabilitation of upper section of River Nzoia through enclosure and planting with bamboo species in Cherangany Forest Ecosystem (*Photo*: J. Amwatta)