### **Dryland Forestry Research and Development in Kenya**

# Achievements and Lessons of Four Decades of Kenya/Japan Cooperation in Forestry





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#### **KEFRI/JICA 2023**

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#### Citation

KEFRI/JICA 2023: Dryland Forestry Research and Development in Kenya: Achievements and Lessons of Four Decades of Kenya/Japan Cooperation in Forestry. KEFRI, Kenya.

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#### ISBN: 978-9914-723-46-5

Published by: Kenya Forestry Research Institute (KEFRI) P. O. Box 20412-00200, Nairobi, Kenya Tel: +254-724 259 781/2, +254-722-157 414 E-mail: director@kefri.org Website: www.kefri.org

This publication was supported by **JICA through SFS-CORECC Project** 



**Printed by: Coregra Concepts** P. O. Box 52963-00200, Nairobi, Kenya Tel: +254 20 204 2994, +254 711 476 080, +254 738 487 520 E-mail: info@coregra.co.ke

#### FOREWORD



Japan International Cooperation Agency (JICA) is an official agency of the Government of Japan, responsible for administering the bulk of Japan's Official Development Assistance (ODA). As a signatory to the Paris Agreement, Japan is strongly committed to addressing climate change and is demonstrated in Kenya by forestry being one of JICA's priority sectors.

With a forest cover of 67% including pristine forests, and long-established robust forestry sector institutions, Japan

has had opportunities to share with Kenya technologies and techniques for sustainable forest conservation and management contributing towards enhancing Kenya's forest cover. This is exemplified by JICA's continuous collaboration with relevant forestry sector institutions over the years.

From a historical perspective, JICA's support to the forestry sector began in 1984 with a request from Government of Kenya (GOK) to develop social forestry in Kenya through seedling production. This was against a backdrop of a closed canopy forest cover in gazetted forests standing at less than 2%. Forest cover was further threatened by the high demand for, but unsustainable use of wood products in the country. Shortly afterwards, the Kenya Forestry Research Institute (KEFRI) was established in 1986 sparking a timely relationship with JICA, oftentimes described as a marriage of sorts, that has blossomed and successfully weathered the test of time.

Soon after establishment, KEFRI was incorporated into a preparatory phase of technical cooperation in the field of tree-nursery training that was implemented from 1985 to 1987. This paved the way for strong collaboration between JICA and KEFRI in a series of 6 projects implemented for a period of 5 years each, over a total span of 30 years. The ongoing Project for Strengthening Forestry Sector Development and Community Resilience to Climate Change through Sustainable Forest Management and Landscape Restoration that commenced in 2022 is the seventh one and it is scheduled to continue up to the year 2027.

Running concurrently with the projects, JICA's support included the Third Country Training Programme (TCTP) that was continuously implemented in 5 phases over a period of 24 years from 1995 – 2018, benefitting over 500 participants from 21 countries in East, Central and Southern Africa. TCTP is a South-South/Triangular cooperation JICA scheme under which participants from

developing countries are trained by a JICA partner institution whose capacity has been highly developed through collaboration, for the purpose of transfer or sharing of development experiences, knowledge and technology. The value of this partnership was internationally acclaimed in 2013 when KEFRI and JICA received awards from the United Nations Office for South-South Cooperation in recognition of special contribution to South-South and Triangular Cooperation, during the United Nations Global South-South Development Expo that was held in Nairobi.

KEFRI capacity in terms of research and dissemination of findings has therefore been strengthened over the years through partnership with JICA in implementing projects and training programmes, organizing and hosting workshops at both national and international levels. Many KEFRI scientists have also been trained in Japan. Clearly, KEFRI has been instrumental in progressively building individual and institutional capacity across the board. In Kenya, the Social Forestry Training Project (SFTP) - Phase I & II), Social Forestry Extension Model Project (SOFEM) and the Intensified Social Forestry Project (ISFP) targeting researchers, forestry extension officers, farmers, and farmers groups have been implemented. Further afield, the capacity of sector institutions and organizations' staff in Kenva and other countries in Eastern, Central and Southern Africa has been developed through TCTP, and under the African Initiative for Combating Desertification to Strengthen Resilience to Climate Change in the Sahel and Horn of Africa (AI-CD. Consequently, KEFRI is now firmly positioned not only as a highly respected forestry research institution in the region but also as an authority on drylands species research, especially drought tolerant tree species such as Melia volkensii and Acacia tortilis. This status was recognized by JICA at the highest level in 2017, when KEFRI received the prestigious JICA President Award, for outstanding contribution to the forestry sector through a strong and long-term partnership with JICA.

In line with the forestry research profession and as a forestry research institution, it is incumbent upon KEFRI to live up to its Mission, Vision and Mandate, and add to the body of knowledge in the field of forestry. As JICA's key partner in implementing so many continuous interventions in the forestry sector on the one hand, and as a beneficiary of the same on the other, best placed to record the story and showcase the achievements of this strong collaboration.

This book therefore documents the long and rich history of collaborative efforts by JICA and KEFRI in terms of research and development including dissemination both in Kenya and regionally. The book captures the chronology and nature of the

collaboration, highlighting its contribution to the forestry sector in this country and beyond by including case studies and the key lessons learnt.

JICA highly appreciates not only the long-standing and solid relationship with KEFRI but more importantly the fruits of that collaboration. For JICA, this is an excellent example of an outstanding cooperation and partnership in institutional development. The writing of this book is therefore a great initiative to acknowledge and record JICA's contribution towards building KEFRI's solid foundation and an affirmation of KEFRI's strong ownership. It also serves as good reference material for posterity, underscoring KEFRI's contribution to the forestry sector through collaboration with JICA.

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**Mr. Hajime Iwama** Chief Representative JICA Kenya Office

#### PREFACE



The Arid and Semi-Arid Lands (ASALs) of Kenya are estimated to occupy about 89% of the total land area. The ASALs are endowed with many natural resources that include trees and other vegetation types. The vegetation in ASALs plays a critical role in economic, ecological and livelihood needs of inhabitants of the drylands. Despite their importance, the ASALs face serious threats from land degradation, deforestation, biodiversity loss, invasive

plant species and desertification. The adverse impacts are attributed to effects of climate change that include; frequent and prolonged droughts that alternate with severe flooding, increased human and livestock population and intensified human activities. For improved livelihood of ASAL communities, there is need for sustainable management, utilization and conservation of drylands natural resources.

The Government of Kenya (GoK) has continued to prioritize ASALs development through promulgation of targeted policies, strategies and focus on research and development in various sectors, since 1960s. However, landscape degradation and deforestation of woodlands in dryland ecosystems still exists mainly due to: inadequate scientific information and technical knowledge on; tree species-site matching and establishment methods leading to low tree survival rates; tree management techniques to ensure high tree productivity; and impactful extension approaches to enhance adoption of good practices.

Over the last four decades, Kenya Forestry Research Institute (KEFRI) in collaboration with Japan International Cooperation Agency (JICA) has undertaken research and development work in dryland forestry and major milestones achieved. The Grant Aid Assistance from JICA enabled KEFRI to acquire ultramodern research and training facilities as well as equipment and machinery, which have been instrumental for consistent research and development. The support through Technical Cooperation Projects and Third Country Training Programme has enabled Kenya to be a leader in dryland forestry research and capacity building within Sub-Saharan Africa. Major achievements have been made in selection and breeding of *Melia volkensii* (Mukau), an indigenous tree species with great potential for dryland plantation development. Melia breeding is a pioneering research in the region of an indigenous tree species. The adoption of Mukau by small-scale farmers, commercial-scale private companies, community-based and non-governmental organizations in Kenya, indicates that through research and innovation, indigenous species of Africa have great potential as commercial crops.

This book is a synthesis of four decades of forestry research and development work undertaken by KEFRI in collaboration with JICA from 1985 to 2023, with a twoyear formulation phase from 1982 to 1984. The book gives details on: chronology of research and development projects under KEFRI/JICA collaboration; research outcome on tree seed sources identification, processing and handling, tree nursery development for ASAL species; techniques and practices for tree establishment and management in drylands; on-farm tree planting verification and promotion; and *Melia volkensii* development and improvement. The book also provides information on strategies for knowledge sharing through piloted extension approaches, and capacity building for technical officers, extension agents and farmers in Kenya and Sub-Sahara Africa countries.

It is anticipated that the book will; inform, provide research and development approaches, share knowledge on nature-based solutions for restoration of degraded drylands, woodlands, and farmlands in ASALs of Africa.

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Jane W. Njuguna (PhD) Ag. Director, Kenya Forestry Research Institute

#### ACKNOWLEDGEMENT

Kenya Forestry Research Institute (KEFRI) extends special gratitude to the People and Government of Japan, through Japan International Cooperation Agency (JICA) for consistency and unwavering support to the people and Government of Kenya through the Ministry of Environment, Climate Change and Forestry since 1984 to date. The Grant Aid and Technical Cooperation support extended to KEFRI by JICA enabled the Institute to build research and training facilities, as well enhance human resource capacity. The facilities and human resource capacity has strategically enabled KEFRI to deliver its mandate in forestry research and development not only in Kenya, but also to the Institute and stakeholders beyond Kenya.

The JICA Kenya Office and the Embassy of Japan in Kenya are also acknowledged for continued technical, financial and logistical support to KEFRI, which greatly contributed to achieving objectives of various integrated JICA supported projects for the benefit of relevant institutions and communities in our collective aspiration to ensure environmental resilience and improved quality of life through appropriate nature-based solutions. JICA Kenya Office support in production of this book is highly appreciated.

KEFRI extends its appreciation to the Government of Kenya through the Ministry of Environment, Climate Change and Forestry for financial support and for providing an enabling environment that has ensured successful implementation of JICA supported projects over the years.

Special thanks go to KEFRI Board of Directors and Directorate for prudent financial, technical and logistical support availed during the various JICA supported projects and during compilation of this book.

Acknowledgement is also extended to staff of various institutions and agencies who include; JICA long- and short-term experts, officers from KEFRI and Kenya Forest Service (KFS) who worked tirelessly to ensure objectives of the various projects, namely; Social Forestry Training Project (SFTP). Social Forestry Model Extension Project (SOFEM), Intensified Social Forestry Project in Semi-Arid Areas of Kenya (ISFP), Development of Drought Tolerant Trees for Adaptation to Climate Change in Drylands of Kenya, Capacity Development Project for Sustainable Forest Management in the Republic of Kenya (CADEP-SFM) and the Third Country Training Programme were achieved according to Plan of Operations. The JICA experts from Forest Tree Breeding Centre (FTBC) Japan, are acknowledged for their technical support in breeding of *Melia volkensii* and

*Acacia tortilis*, particularly Melia, which is a pioneering tree breeding research of an indigenous tree species in Kenya.

Special acknowledgement goes to the Heads of participating Third Country Training Programme (TCTP) institutions in Sub-Saharan Africa (SSA) for identifying and nominating technical officers to participate in the various Regional Training Courses, hence strengthening the new paradigm on knowledge sharing.

Appreciation also goes to participating farmers, learning institutions (schools and colleges) and other stakeholders in the project sites and beyond, who availed their land for various on-farm trials and acted as trainers especially during the TCTP Regional training courses, when participants visited their farms.

The model and core farmers who participated in the various projects are once more appreciated for availing information used in development of case studies included in this book. These model farmers continue to implement, scale-up and encourage adoption of the technologies promoted during the various projects, which is a show of positive impacts of the projects that were implemented over the years.

To those who supported and contributed to the success of the various JICA supported projects for forestry development in Kenya, but are not mentioned directly or indirectly, their support is equally appreciated.

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#### ABBREVIATIONS AND ACRONYMS

ACE	After-Course Evaluation
ACIAR	Australian Centre for International Agricultural Research
AESA	Agro Eco-System Analysis
AI-CD	African Initiative for Combating Desertification to Strengthen Resilience to Climate Change in the Sahel and Horn of Africa
ASALs	Arid and Semi-Arid Lands
CADEP-SFM	Capacity Development Project for Sustainable Forest Management
CBO	Community-Based Organization
СОР	Conference of Parties
CPTs	Candidate Plus Trees
СТР	Commemorative Tree Planting
dbh	Diameter at Breast Height
DGL	Diameter at Ground Level
E-E	Extra Evaluation
FD	Forest Department
F-F	Farmer-to-Farmer
FFE	Farmer-to-Farmer Extension
FFS	Farmer Field Schools
FINNIDA	Finnish Agency for International Development
FRL	Forest Reference Level
FTBC	Forest Tree Breeding Centre
FUV	Follow-up Visit
GCA	General Combining Ability
GoJ	Government of Japan
GoK	Government of Kenya
На	Hectare(s)
HoA	Horn of Africa
IDRC	International Development Research Centre, Canada
IGAs	Income Generation Activities
IKS	Indigenous Knowledge System
IPA	Inter-Participant Assessment

IPCC	Intergovernmental Panel on Climate Change
ISCO	International Soil Conservation Organization
ISFP	Intensified Social Forestry Project
JICA	Japan International Cooperation Agency
KEFRI	Kenya Forestry Research Institute
KENGO	Kenya Energy Non-Governmental Organisation
KFS	Kenya Forest Service
KNBS	Kenya National Bureau of Statistics
KRSFTC	Kitui Regional Social Forestry Training Courses
M/M	Minutes of Meeting
MoA	Ministry of Agriculture
MoA	Memorandum of Agreement
MoU	Memorandum of Understanding
NDCs	National Determined Contributions
NGO	Non-Governmental Organization
NORAD	Norwegian Agency for International Development
NRM	Natural Resource Management
NSFTC	National Social Forestry Training Courses
PTD	Participatory Technology Development
R&D	Research and Development
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RoD	Record of Discussion
RoK	Republic of Kenya
RTC	Regional Training Courses
RTP	Roadside Tree Planting
SDGs	Sustainable Development Goals
SFTC	Social Forestry Training Centre
SFTP	Social Forestry Training Project
SFS-CORECC	Strengthening Forestry Sector Development and Community Resilience to Climate Change through Sustainable Forest Management and Landscape Restoration
SOFEM	Social Forestry Extension Model
SOFONA	Social Forestry Network for Africa

SSA	Sub-Saharan Africa
TC	Technical Committee
ТСТР	Third Country Training Programme
TICAD	Tokyo International Conference on African Development
ToR	Terms of Reference
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

### **CHAPTER 1**

#### **OVERVIEW OF DRYLANDS OF KENYA**

Robert Nyambati, Josephine Wanjiku, Paul Tuwei, Dorothy Ochieng and Musingo T.E. Mbuvi

#### **1.1 Biophysical Conditions**

Kenya's total land area is 580,364 km<sup>2</sup> of which dryland areas also referred to as arid and Semi-arid lands (ASALs) are estimated to cover 89% of the total land area (Figure 1.1). The ASALs are home to about 14 million people (KNBS, 2010), support 70% of the national livestock and 90% of the wildlife (GoK, 2015a; Gerwen *et al.*, 2018; Nganga *et al.*, 2021). The ASALs of Kenya are found in agro-climatic zones (ACZs) IV to VII (Table 1.1). These areas are characterized by erratic low rainfall ranging from 150 mm and 550 mm per year in the very arid to arid zones, and 550 mm to 850 mm per year in semi-arid zones (GoK, 2015a). The ASALs have high seasonality and annual variability in climatic parameters especially rainfall and temperatures. Temperatures are high throughout the year and may rise up to 38°C during the day. These high temperatures expose the areas to high rates of evapotranspiration, which exceeds precipitation. The soils are generally shallow and of low fertility, and are highly erodible. Soil fragility combined with high intensity storms, creates conditions for excessive runoff and soil erosion by both rainwater and wind.

Vegetation dynamics in the ASALs vary and are determined by different variables, including; climatic conditions especially rainfall amount, distribution, altitude, degree of aridity, soil moisture, and local topography. Consequently, the vegetation varies widely both in space and time (Jaetzold and Schmidt, 1983). The vegetation in ASALs consists mainly of woodland, wooded grassland, grassland, bushland, and shrubland. In the very arid areas, desert scrub is the main vegetation. In some ASALs areas, forests are found mainly along mountain ranges, rivers, ravines, and hilltops. The mountains and hilltops forests, form low montane forests with some of the dominant species being: Juniperus procera, Podocarpus gracilior, Olea africana, Olea hochstetteri, Lawsonia inermis, Combretum molle, Cassipourea malosana, Diospyros abyssinica, and Teclea simplicifolia. Except in the Chalbi Desert, the ground vegetation in ASALs is dominated by forbs (non-grassy herbaceous plants), C4 grasses, and a woody layer of shrubs and trees, which vary from being sparsely scattered to a dense canopy depending on; dominant species, rainfall, and livestock population. The predominant tree and grass species in the more arid areas are Acacia and Themeda species, respectively.

In the semi-arid areas, deciduous thicket and bushland and Acacia-Commiphora associations, are common at 800m - 1,200m elevation. In the driest areas below 900m, Commiphora-Sanseveria thorn bush are common, changing gradually to semi-desert vegetation (Ojany and Ogendo, 1973). However, much of arid lands are covered by deciduous and evergreen thorn bush. In this vegetation type, the dominant tree species include; *Acacia reficiens, A. senegal, A. mellifera, Pappea capensis* and Combretum species.



Figure 1.1: Arid and Semi-Arid Areas of Kenya (Source: GoK, 2015a)

Zone	R/E <sub>o</sub> (Ratio of rainfall to potential evaporation) (%)	Classification	Average annual rainfall (mm)	E <sub>o</sub> (Annual potential evaporation (mm)	Vegetation
Ι	>80	Humid	1100-2700	1200-2000	Moist forest
II	65-80	Sub-humid	1000-1600	1300-2100	Moist and dry forest
III	50-65	Semi-humid	800-1400	1450-2200	Dry forest and moist woodland
IV	40-50	Semi-humid to semi-arid	600-1100	1550-2200	Dry woodland and bush land
V	25-40	Semi-arid	450-900	1650-2300	Bush land
VI	15-25	Arid	300-550	1900-2400	Bush land and scrubland
VII	<15	Very arid	150-350	2100-2500	Desert scrub

Table 1.1: Agro-climatic zones classification

Source: Sombroek et al., (1982)

#### **1.2** Socio-economic Environment

Vegetation of the ASALs is of great importance to livelihood of communities living in the drylands as it provides food for people, forage resources for livestock and wildlife, protection against desertification, as well as providing many other products for livelihood needs and ecosystem services (KEFRI, 1992). Woodlands meet a range of subsistence and industrial needs through provision of wood and non-wood forest products that include fuelwood, charcoal, poles, timber, fodder, fibre, raw materials for industry such as gums and resins, food, medicine, and honey. Due to their importance, there is need to conserve, manage and utilize ASALs resources sustainably.

The ASALs have over time, undergone resource degradation leading to changes in vegetation composition, structure, and densities. The degradation

has substantially reduced ability of the ecosystem to support livelihood and economic development. The most prevalent manifestation of land degradation in the drylands include increased bare ground and decreased vegetation cover through loss of shrubs and grasses leading to biodiversity loss. The main driving forces for environmental and land degradation in the ASALs of Kenva include; increasing human population due to natural causes or immigration and settlement, over-exploitation of woodlands, overgrazing, land use changes, unsustainable agricultural practices, pests and diseases, wildfires, climate change, and erosion of traditional natural resource management systems. In the past, informal traditional management systems and practices were used to conserve much of the woodlands resource rich areas such as hilltops. However, such Indigenous Knowledge Systems (IKS) and practices are gradually being abandoned as they are in conflict with legislative and policies instruments and the collapse of indigenous institutions (Stave et al., 2001). Challenges within the ASALs, which are further exacerbated by climate change include; water scarcity, low land productivity, food insecurity, limited diversity of livelihood sources, low economic development and unchecked access to markets.

#### 1.3 Policies and Legislations Towards Development of ASALs

The ASALs have great potential and enormous resources that can be harnessed not only to sustain the drylands but also contribute to national development. Woodlands provide ecosystem services, ecological biodiversity, and environmental functions. Some major services from dryland forests and woodlands include; provision of wildlife habitat, conservation of water sources, and carbon sequestration. Sustainable development of the ASALs relies on rational use of its natural resources, which entails recognizing and developing potential that exists in the vegetation resources for production of economically valuable products and services.

The Government of Kenya recognizes that the country will not achieve sustained growth in the economy and progress as a nation, if the ASALs are not appropriately factored into national planning and development. The Government also recognizes that Kenya will not achieve its development goals as stipulated in the Economic Blue Print, Kenya Vision 2030 or meet international commitments such as the UN Sustainable Development Goals (SDGs) if regional inequalities are not addressed (GoK, 2015b). The Kenya Vision 2030, articulates and demonstrates the need to mainstream ASALs into national development with interventions in various sectors that include, water and sanitation as well as environment. The Constitution of Kenya 2010 (GoK, 2010) also provides for ASALs development.

To successfully promote sustainable conservation, management and utilization of the ASALs resources, relevant policies and legislation, strategies and plans need to be developed, reviewed, and implemented. The Constitution of Kenya 2010, provides ground for the enactment of relevant policies, legislation, and strategies that guarantee the rights of citizens to a clean and healthy environment (GoK, 2010). The Government has developed several policy documents to operationalize this right.

Initially, a government policy paper entitled; "A framework for implementation, programme planning and evaluation of the Arid and Semi-Arid lands of Kenya" of 1979 was the first major framework towards development of the drylands (GoK, 1997). The document provided an enabling environment and an opportunity for participation of various development partners in funding projects in the ASALs.

A policy on drylands was developed in 1989 when the government came up with the National Development Plan of 1989-1993. The Development Plan emphasized issues such as; creation of an environment suitable for exploiting the potential of dryland resources, sustainable management and generation of opportunities for improving the living conditions of the ASALs inhabitants.

Since 2003, the Government of Kenya has renewed its commitment to ASALs through development of relevant policies and strategies to reverse historical marginalization and under-development of the drylands. One of the strategy is the Economic Recovery Strategy for Wealth and Employment Creation 2003-2007 (GoK, 2003), which was key in recognizing 'the important contribution ASALs can make to national development through; agriculture mainly livestock production and fishing, mining, tourism development, trade, and industry. The strategy also identified challenges to be addressed in order to realize the full potential of ASALs. The strategy led to creation of the Ministry of State for Development of Northern Kenya and other Arid Lands, which aimed to promote targeted service delivery to the drylands. The Ministry also focused on reducing levels of inequality with the rest of Kenya (Mortimore, 2009).

Development of "The ASAL Policy of Kenya 2013", was also instrumental to realization of ASAL development (Odhiambo, 2013). The policy sought to strengthen resilience of ASAL communities to drought and other climate-related disasters, with interventions targeting; drought management and climate change, land and natural-resource management, livestock production and marketing, dryland farming, livelihood diversification, and poverty and inequality.

In 2018, the Government of Kenya (GoK) established the Ministry of Devolution and Arid and Semi-Arid Lands whose functions included;

- Development of laws, policies and guidelines for management of devolution and ASALs.
- Capacity building and technical assistance to counties in the ASALs.
- Implementation of policy interventions.
- Promoting socio-economic development.
- Implementation of special programmes for the development of Northern Kenya and other arid lands.

Other key policy documents targeting development of ASALs in Kenya include;

- Kenya National Agroforestry Strategy; 2021 2030.
- Strategic plan of the ASALs 2018 2022 which was meant to ensure that the over 80% of Kenya's land mass comprising the ASALs, realises its full development potential and contribute to national development.
- Sessional Paper No. 12 of 2012, on National Policy for Development of ASALs, which provides a framework to close the developmental gap between Northern Kenya and the rest of the country, strengthen national cohesion; protect and promote mobility and institutional arrangements, which are so essential to productive pastoralism, and ensure food and nutrition security across the ASALs.

## 1.4 Historical and Present Perspective in Forestry Research in Drylands of Kenya

In the dryland ecosystems, the tree component was identified as the main pillar to environmental and land productivity. Research was therefore, necessary to generate technologies in forestry and allied natural resources to ensure conservation, sustainable management and utilization of wood and non-wood forest products in the ASALs.

Forestry research at sectoral level started in the early 1970s, following a prolonged and severe drought. The drought caused great suffering to inhabitants of the ASALs through loss of; livestock, vegetation, and crops, as well as increased land degradation. Consequently, the Government of Kenya began to re-orient its policies and research priorities towards addressing these challenges. Within the forestry sub-sector, initiatives in research also commenced in 1970s with establishment of research stations at Ramogi in western Kenya, Hola in the coast, and Kibwezi in eastern region. Objectives of the research initiatives

were to: identify suitable trees and provenances for production of firewood and poles; develop appropriate tree nursery techniques and effective methods for tree establishment.

The arid and semi-arid lands of Kenya Framework for Implementation, Programme Planning and Evaluation of 1979, provided an enabling environment and an opportunity for participation of various development partners to provide financial support for projects in the drylands. Some of the donors in the forestry sub-sector include the; Norwegian Agency for International Development (NORAD) in 1982, FAO/Australian Project in 1982, British Overseas Development Administration (ODA) in 1983, International Development Research Centre Canada (IDRC) in 1983, Finnish Agency for International Development (FINNIDA) in 1984, Japan International Cooperation Agency (JICA) in 1985 and Australian Centre for International Agricultural Research (ACIAR) in 1987.

The KEFRI/JICA collaborative research and development activities were initiated in 1985 to promote effective management of woodlands, wooded grasslands and bushlands as well as to improve on-farm tree growing. The collaboration was through Grant Aid, Technical Cooperation Projects, and Third Country Training Programme.

Most of the field activities were undertaken in Kitui County under various KEFRI/JICA Technical Cooperation Projects. It was anticipated that results from the research under the projects would be extrapolated to other areas with similar conditions both within Kenya and beyond.

The KEFRI/JICA collaboration is the longest continuous partnership supporting research and development for tree growing and livelihood improvement in drylands of Kenya. The projects under this collaboration have resulted in several systematic information and incremental products, which has informed the partnership investment over the period. The partnership predictability has built trust, therefore strengthening the collaboration. The partnership has also provided learning experience at community, national and continental level with global effects in countries with similar socio-ecological conditions.

This book provides a summary of the various aspects of dryland forestry research and development covered during the long-term collaboration between KEFRI and JICA from 1982 to 2022. The book provides information on: Overview of Drylands of Kenya; Research and Development Projects under KEFRI/JICA Collaboration from 1985 to 2022; Tree Seed Collection and

Handling for Dryland Species; Tree Nursery Technologies for Drylands of Kenya On-Station Development of Technologies for Tree Establishment and Management in Drylands; On-Farm Verification of Dryland Tree Establishment and Management Technologies; Bringing *Melia volkensii* an Indigenous Drylands Tree Species into Cultivation; Breeding *Melia volkensii* for Improved Productivity and Drought Tolerance; Extension Approaches in Social Forestry; Building Capacity for Social Forestry Development and Sustainable Forest Management in Africa; and Social Forestry Success Stories of Model Farmers from Drylands of Eastern Kenya.

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## **CHAPTER 2**

#### **RESEARCH AND DEVELOPMENT PROJECTS UNDER KEFRI/JICA COLLABORATION FROM 1985 TO 2022**

Joshua K. Cheboiwo, Josephine Wanjiku, Michael Mukolwe and Musingo T. E. Mbuvi

#### 2.1 Introduction

The cooperation between the Government of Kenya (GoK) and Government of Japan (GoJ), in forestry sector development has been consistent since the 1980s, making Kenya a major recipient of Japanese Technical Cooperation in Sub-Saharan Africa. The collaboration is implemented through Japan International Cooperation Agency (JICA), which is a governmental agency that delivers the bulk of Official Development Assistance (ODA) for GoJ. The Agency is charged with assisting economic and social growth in developing countries, and promotion of international cooperation. In Kenya, JICA supports various sectors including environmental conservation. Under the environment programme, Japan has supported Kenya in dryland forestry development since 1985.

Selection of drylands for research and development in Kenya was based on the fact that the drylands constitute more than 80% of the country's land area, with enormous natural resources, which are not fully tapped. Despite their importance, the drylands face serious threats from; degradation, deforestation, biodiversity loss, invasive plant species and desertification. High population growth, expansion of agriculture and settlements, over-exploitation of woodlands, as well as over-grazing have been cited as major causes of environmental degradation and deforestation in drylands of Kenya. Following this realization, there was an urgent need to promote landscape restoration through environmental conservation strategies and tree planting by local communities in order to reverse the negative environmental effects. By late 1960s, GoK had developed a strategy focusing on integrated rural development, and subsequently intensified development of farm forestry, focusing on production of seedlings for use in reforestation and onfarm tree planting. However, tree cover remained low due to inadequate technical knowledge and scientific information on tree establishment such as tree speciessite matching and appropriate planting methods.

To address forestry development challenges in the drylands, the Nursery Training Project for Social Forestry Development, a cooperation between Kenya and Japan was formulated at the request of Government of Kenya (GoK) in 1982. The project title later renamed in 1985 to Social Forestry Training Project (SFTP) which was subsequently developed as a cooperation project between KEFRI and JICA. The main aim of the project was to enable GoK achieve its afforestation goals. The project was actualized in 1985, with a Preparatory Phase of two (2) years, from 1985 to 1987 as a Grant Aid for construction of research and training facilities at Muguga and Kitui Centres and installation of machinery and equipment for implementation of the project.

#### 2.2 Japan Grant Aid Assistance to KEFRI

The Grant Aid assistance to KEFRI was mainly in two phases. The first phase from 1985 to 1987 was a preparatory phase while the second phase from 1994 to 1995 was an expansion phase. Research and development facilities put up through the Japan Grant Aid included; offices, laboratories, green houses, and training facilities such as conference and meeting rooms, hostels and catering facilities. Vehicles, laboratory equipment and machinery, were also provided. The ultimate objective of the Grant Aid was to avail and improve facilities in KEFRI in order to enable the Institute develop, improve and disseminate technologies for Social forestry. The facilities provide a conducive working environment for KEFRI staff, which contribute to improved implementation of research, development and dissemination activities. The training facilities at KEFRI Headquarters in Muguga and KEFRI Kitui have enabled the Institute to conduct and host numerous national, regional and international meetings, seminars, workshops and other environmental related fora, hence contributing to KEFRI's achievements of its mandate on dissemination of research findings and building capacity of stakeholders.

In 1994/1995, an expansion phase provided; Research Block B, Social Forestry Training Centre (SFTC), additional glass houses, and modernization of initial infrastructure and equipment in Muguga and Kitui.

The facilities and equipment acquired through Grant Aid Assistance are outlined in Table 2.1 for those at Muguga, and Table 2.2 for those in Kitui.

Facilities/Equipment	Purpose/Use			
Dormitories/Hostels	Accommodate Social forestry training participants			
Guest House	Accommodate Social forestry training resource persons			
Dining Hall/Kitchen	Catering services for staff and Social forestry participants			
Research Block "A"	<ul><li>Offices for scientists</li><li>Dryland laboratories</li><li>Board Room</li></ul>			
Research Block "B"	Offices for scientists and laboratories			
Old Library Block	Now offices for Accounts staff			
Administration Block	<ul><li>Office for Director</li><li>Office for Deputy Director (R&amp;D)</li><li>Main Registry</li></ul>			
Old Social Forestry Training Wing	<ul> <li>Office for Chief Advisor/ JICA Experts</li> <li>Now Personnel and Administration Office</li> </ul>			
New Training Wing "B" – Social Forestry Training Centre (SFTC)	<ul> <li>Auditorium</li> <li>Library</li> <li>JICA Counterparts</li> <li>Training Officers</li> <li>Meeting Rooms</li> <li>Lecture Rooms</li> <li>Printing Rooms</li> <li>KEFRI Clinic</li> </ul>			
Garage	Motor vehicle repairs			
Glass houses	Undertake research activities			
Assorted laboratory equipment	Undertake research activities			
Assorted training equipment such as video camera, video editing system, in-built communication and printing press	Audio visual and printing			

Table 2.1: Facilities provided at KEFRI Headquarters - Muguga

Facilities/Equipment	Purpose/Use		
Dormitory/Hostels A, B and C	Accommodate Social forestry training participants		
Dining Hall/Kitchen	Catering for Social forestry training participants		
Guest House	Accommodate Social forestry training resource persons/instructors		
Japanese Dormitory/Hostel	Accommodate Japanese Experts		
Training Wing 'A'	Offices of the Centre Director, Team Leader, Administrative staff and Pilot Forest Manager		
Training Wing 'B'	Offices for Training and Pilot Forest officers and staff, conference room, storage and library		
Training Nursery facilities	Store tools and equipment weather studies		
Soils and Silvicultural laboratories	Undertake research activities		
Green Houses/ Glass houses	Undertake research activities		
Garage	Minor repair and service of project vehicles and storage of vehicles		
Store	Store tools and weather equipment		
Field Offices	For the forester and nursery officers		
Tiva Pilot Forest Site	Dryland research demonstration/ research plots		
Watch Tower	For management/overseeing the entire Tiva Pilot Forest		

Table 2.2: Facilities provided at KEFRI Kitui Centre
Some of the facilities and equipment provided through Japan Grant Aid are shown in Figure 2.1.



Aerial view of KEFRI Headquarters, Muguga



Aerial view of KEFRI-Kitui Regional Centre



Hot air oven (incubator)



Technical officer loading samples on electrophoresis tank



Genetic Analyzer



Tissue culture cabinet





Tissue culture equipment



Autoclave

Bulldozer at Tiva Pilot Forest in land preparation and ground ripping



Frontage of Melia volkensii seed orchard in Kitui

Watch tower at Tiva Pilot Forest, Kitui

Figure 2.1: Pictorials of KEFRI headquarters, Kitui Regional Centre, research equipment and field site at Tiva Pilot Forest

### 2.3 Technical Cooperation in Social Forestry and Forestry Research

Implementation of the Technical Cooperation in Social forestry development commenced in 1986 in Muguga and 1987 in Kitui, with initial phases ending in 1997. During the various Technical Cooperation period, KEFRI benefited through; technology development, building staff capacity in Social forestry, which was undertaken in Kenya and Japan, Expert dispatch, technical assistance and provision of equipment. Collaborative research between KEFRI and JICA continues to evolve and address emerging challenges in forestry. The projects implemented during the four (4) decades of KEFRI/JICA collaboration are as outlined in Table 2.3.

No.	Name	Period	Implementing Agency
1	Preparatory phase (Pilot phase of development).	1985- 1987	KEFRI/JICA
2	Social Forestry Training Project Phase I	1987 - 1992	KEFRI/JICA
3	Social Forestry Training Project Phase II	1992 - 1997	KEFRI/JICA
4	Social Forestry Extension Model Development Project (SOFEM)	1997 - 2000	KEFRI/JICA/KFS
5	Intensified Social Forestry Project in Semi-Arid Areas of Kenya (ISFP)	2004 - 2009	KFS/KEFRI/JICA
6	Project on Development of Drought Tolerant Trees for Adaptation to Climate Change in Drylands of Kenya	2012 - 2017	KEFRI/JICA
7	Capacity Development Project for Sustainable Forest Management in the Republic of Kenya (CADEP-SFM)	2016 - 2021	KEFRI/KFS/ MECCF/JICA
8	Strengthening Forestry Sector Development and Community Resilience to Climate Change through Sustainable Forest Management and Landscape Restoration (SFS- CORECC)	2022 - 2027	KEFRI/KFS/ MECCF/JICA
9	Third Country Training Programme (TCTP)	1995 - 2018	KEFRI/MECCF/ JICA

Table 2.3: Chronology of KEFRI/JICA Technical Cooperation Projects

# 2.3.1 Social Forestry Training Project Phase I and II

Due to increasing land degradation in the Arid and Semi-Arid lands (ASALs), there was an urgent need to promote tree planting by the local communities to rehabilitate lands and provide environmental goods and services. To address land degradation, Social Forestry Training Project (SFTP) was started with an objective of developing and disseminating technologies in Social forestry through training and extension in order to improve the living standard of the people in semi-arid areas of Kenya by providing forest products and services.

The SFTP was implemented for a period of 10 years, in two 5-year phases from 1987 to 1997. The project was executed through two (2) Sub-projects namely; Training and Pilot forest sub-projects. Pilot Forest Sub-project consisted of three (3) sections, namely; nursery, silviculture and extension. Several activities were conducted through the three (3) sections with the aim of developing appropriate technologies for tree planting in semi-arid areas. Activities under Nursery Section included; tree seed germination studies, tree phenology studies, mother tree identification for seed collection, seedling production and seed orchard establishment. The activities under Silviculture Section included; tree establishment trials, species screening, natural succession studies, tree physiology studies, tree management trials, tree protection and soil studies. Activities conducted under Extension Section included; promotion of community planting, private planting, small scale nursery development, model farmers approach, seedling distribution, demonstration plots, field seminars and prize days.

### Main achievements of SFTP Phases I and II

Several technologies were developed in the Pilot forest area through activities that included screening suitable species and appropriate establishment techniques. The technologies were further screened and refined to suit farmers conditions. Several extension approaches were tested. Success and challenges, which were of socio-economic and biophysical nature were noted. Success cases were also noted for adaptation while solutions for challenges were sought to enhance tree planting activities in the semi-arid areas.

### Tree nursery achievements

- Identified tree species that were suitable for the semi- arid regions of Kitui.
- Identified suitable seed collection and processing techniques, pre-germination treatment of some difficult to propagate species.
- Identified nursery establishment and management techniques that were biologically sound, socially acceptable and economically feasible in the semi-arid regions. These achievements included use of farm yard manure as part of soil potting mixture to enhance soil fertility.
- Built capacity of farmers on tree nursery establishment and management suitable for dry areas.
- Enhanced production of suitable tree species for dryland planting. Most of the seedlings raised by farmers were planted in their own farms.

# Silvicultural trials and achievements

### Hole size

Three (3) hole size ranging from 25cm x 25cm; 45cm x 45cm; and 65cm x 65cm were tested. Hole size 45cm x 45cm was found to be most appropriate as it was cost effective and improved tree survival.

### Water catchment trials

Five different types of water catchment techniques namely; contour bands, circular bands, ground division, V- and W-shaped micro-catchments were tried. The results showed that V- and W- types of micro-catchments were more effective and were adopted for tree planting within the pilot forest area.

### Species screening

Over 74 species and 12 provenances were screened and a total of 24 species/ provenances recommended for use in the project area within Kitui region.

### Weeding trials

Different weeding methods that included; spot weeding, complete weeding using human labour, slashing and tractor plough were tested. Results indicated that complete weeding was better than spot weeding and slashing.

### Pruning

The experiment aimed at determining optimum pruning height. Two pruning heights  $(\frac{1}{3} \text{ and } \frac{1}{2})$  were tried. Results showed that higher pruning height reduced die-back of *Senna siamea* caused by drought, and also improved the growth rate in terms of diameter and height.

### Thinning trials

The aim of the trial was to determine the optimum thinning intensity. Three thinning intensities namely, 0%, 50% and 75%, were tried on *Senna siamea*. Results showed that higher thinning intensity (75%) resulted in higher height and diameter growth.

### Spacing trials

The experiment showed that wider spacing resulted in higher growth performance. Spacing of 4 m x 4 m was found to be the optimum spacing for Kitui area.

### Natural regeneration studies

A 9 ha plot was fenced off to allow natural regeneration and equivalent area set without fencing for comparison. *Commiphora africana* was the most dominant which was attributed to the fact that the species was not used for firewood or timber. Only a few trees of Acacia species remained as many were selectively harvested for various uses.

### Termite control methods

Among the local materials tested on *Grevillea robusta*, tobacco offered the best protection against termites.

# Extension and training achievements

# Extension

- Farmers acquired skills in tree planting and management. Model farmers working with the Project positively influenced neighbouring farmers who in turn started planting trees on their farms.
- Demonstrations such as homestead management through establishment of small scale tree nursery, kitchen garden and rain water harvesting, showcased at the Pilot forest site, influenced farmers to adopt the practices demonstrated.
- Woodfuel conservation through use of *Enzaro jiko*, an improved cook stove was introduced and promoted by Population Education Promotion Project (PEPP) and thereafter widely adopted.

# Training

- National and regional level courses targeting extension officers and teachers were held.
- Promoted tree nursery establishment in schools through training of teachers and environmental club members.
- Conducted grassroots level courses and field seminars for farmers.
- Developed, produced and distributed diverse training materials including; manuals, leaflets, guidelines, pamphlets and videos.

Some of the activities undertaken during this project phase are as shown in Figure 2.2.



Map of Tiva Pilot forest site



Pilot forest site before project commencement



A farmer's tree nursery



Trees planted by model farmers during SFTP



Tree nursery booklet

Guide on various demonstrations in Tiva Forest

#### Figure 2.2: On-station and on-farm sites at Kitui and extension materials

### 2.3.2 Social Forestry Extension Model Development Project

Social Forestry Extension Model Development Project (SOFEM) was implemented from November 1997 to November 2002. The Project emphasized on enhancing tree planting knowledge and skills at national level where the target recipients were government and Non- governmental (NGO) technical staff. At local level, SOFEM trained farmers, community groups, teachers and grassroots/ frontline extension staff.

# **Objectives of the project**

The objectives of SOFEM were to equip the inhabitants of semi-arid areas of Kenya with practical techniques to plant and manage trees through establishment of farm forests. SOFEM's expected outputs were to:

- 1 Provide practical techniques for planting and tending trees for the establishment of farm forests through on-station and on-farm research (Technology development).
- 2. Develop practical methods of farm forestry establishment through training of extension agents and farmers (Farm forestry extension).
- 3. Provide avenues for sharing information with other forestry and allied land use stakeholders through promotional events, seminars and publication/ information materials.

SOFEM activities under Technology development and validation, were divided into On-farm and On-station research. The main activities carried included:

- Seed germination and establishment protocols for Melia volkensii.
- Validation of water harvesting micro-catchments, weeding, spacing, intercropping experiments and coppicing.
- Tree species promotion through establishment of demonstrations of exotic and indigenous utility tree species in arid and semi- arid areas.
- On-farm forestry experiments and extension to verify technologies developed on-station as well as demonstrate technologies to other farmers.

### **Achievements of SOFEM**

- Developed 19 practical techniques for planting and tending trees for establishment of farm forests.
- Held annual Social forestry conferences and seminars to exchange knowledge and skills on dryland forestry with stakeholders.
- Held 28 mobile shows to create awareness on tree planting.
- Produced extension materials and technical reports that included; proceedings, manuals, pamphlets, booklets, leaflets, brochures, videos and newsletters (Figure 2.3). Recipients of these materials included various government and non-governmental organizations.
- Developed and promoted Farmer-to-Farmer Extension (FFE) approach. Encouraged by the high adoption of farm forestry technologies by farmers, the project adopted FFE approach for up-scaling the practices.



Trocceangs of Soft En conferences

DVDs on tree nursery (in Kiswahili) and planting in drylands

Figure 2.3: SOFEM extension materials

# 2.3.3 Intensified Social Forestry Project in Semi-Arid Areas of Kenya

The Intensified Social Forestry Project in Semi-Arid Areas of Kenya (ISFP) was developed based on desire to utilise outputs of past cooperation and need for wider application and intensification of Social forestry activities in the drylands. The ISFP was implemented from March 2004-March 2009 with Kenya Forest Service (KFS) being the lead agency while KEFRI and JICA were collaborators.

# **Overall goal**

Living standards of the people in the semi-arid areas are improved while enhancing sustainable environmental conservation.

# **Project purpose**

Individual farmers, farmer groups and other stakeholders intensify Social forestry practices in semi-arid areas.

### **Project outputs**

- 1. Institutional and technical capacities for Social forestry extension are strengthened.
- 2. Social forestry extension activities among individual farmers and farmer groups are promoted.
- 3. Farmers and other stakeholders obtain enough practical knowledge and techniques.
- 4. Information on Social forestry is shared among the stakeholders.

### Achievements

- Developed, promoted and intensified Farmer Field School (FFS) extension approach in the drylands.
- Built technical capacity of KFS staff on forestry extension and information sharing.
- Built capacity of farmer facilitators and farmers for farm forestry development.

### 2.3.4 Third Country Training Programme

Commitment by the Governments of Kenya through KEFRI and Japan through JICA presented an opportunity to improve Kenya's capacity to undertake Social forestry development. The Social Forestry Training Project (SFTP) Phases I and II, had a strong component on capacity building where technical officers from KFS (formerly Forest Department), other government departments, Non-Governmental Organizations (NGOs), local leaders and farmers were trained at the National and Regional (Grassroots) level. It was through SFTP that KEFRI developed expertise and capacity to conduct Regional Training Courses (RTC) in Social forestry. It was prudent that such knowledge developed through the projects be shared with countries of similar socio-economic and biophysical conditions in Africa through a South-to-South Cooperation, under the Third Country Training Programme (TCTP). The TCTP was therefore, formulated and implemented by KEFRI in collaboration with JICA, through a Scheme, where support is extended to developing countries to conduct training programmes in order to build capacities of other developing countries based on common characteristics

A total of five (5) phases, consisting of 24 Regional Training Courses (RTC) were held between 1995 and 2018 for technical staff from participating countries in Sub-Saharan Africa (SSA). The RTCs were entitled: Regional Training Course for Promotion of Social Forestry in Africa (Phases 1 and 2), Enhancing Adopting of Social Forestry in Africa (Phase 3), Mitigating Climate Change in Africa through Social Forestry (Phase 4) and Adaptation to Climate Change in Africa through Social Forestry (Phase 5).

The first phase (1) of the training entitled; Regional Training Course for Promotion of Social Forestry in Africa, started in 1995. The main purpose of the training was to enable specialist in extension, trainers and resource managers from central, eastern and southern African countries, to learn Kenya's experience in Social forestry, and provide a forum for participants to exchange knowledge, skills and innovations. The TCTP Phase 1, was conducted for 5 years from 1995 to 1999. Due to the success of Phase 1, and the large number of officers who still required to be trained, support to the training programme was extended into a second phase of another five years, from 2000-2004. However, with this critical mass of trained personnel, it was realized that Africa's forest sector challenges and opportunities were changing rapidly, continuing to create additional demand for capacity development and a need to work through strategic partnerships. The demand gave rise to Phase 3 of the Technical cooperation through TCTP entitled "Enhancing Adoption of Social Forestry in Africa", which was implemented for 4 years from 2005 to 2008. The main purpose of this training programme was to reverse the low adoption of Social forestry innovations.

Despite the critical mass of trained personnel from Africa during the 14 years period, new and complex challenges continued to emerge as witnessed by the challenges brought about by climate change. The new challenges created additional demand for capacity development and need to work through comprehensive and relevant partnership in Social forestry. A new training Phase (4) entitled; "Mitigating Climate Change in Africa through Social Forestry" was developed for implementation from 2009 to 2013. The training was to contribute to building capacity to ensure that urgent measures are put in place to cushion farmers against adverse effects of climate change and avoid further degradation of forests.

Challenges of climate change continued to emerge, therefore requiring natural resource managers to endlessly develop nature-based innovations and solutions to counter the new challenges. Though many African countries continued to develop and implement strategies aimed at mitigating climate change effects, it was realized that even the most effective mitigation measures would not prevent further climate change impacts as the consequences were already being felt, making it necessary to promote climate change adaptation measures. This led to development and implementation of TCTP Phase (5) entitled; "Adaptation to Climate Change in Africa through Social Forestry" implemented from 2014 to 2018. Information gathered and developed during the various training phases and

events was recorded in Regional Training Course (RTC) proceedings.

### 2.3.5 Development of Drought Tolerant Trees for Adaptation to Climate Change in Drylands of Kenya

The Project was implemented for a period of 5 years, from 2012 to 2017. It was a pioneer multidisciplinary project whose overall goal was to establish and expand quality plantations of indigenous species in the ASALs through incremental capacity building for: breeding drought tolerant trees; development of quality seed/seedlings supply system; and creating awareness of drylands forestry, using improved drought tolerant germplasm of *Melia volkensii* (Figure 2.4) and *Acacia tortilis* (Figure 2.5). The Project was structured into synergetic discipline-oriented components, namely:

- 1. Molecular/DNA component whose major objective was to study inter- and intra-population genetic variation of *M. volkensii* and *A. tortilis*
- 2. Tree breeding component responsible for selecting Candidate Plus Trees (CPTs) of *M. volkensii* and *A. tortilis*, establishing seedling seed orchard/ progeny trial of *A. tortilis*; and clonal seed orchard and progeny trials of *M. volkensii* for continuous improvement of breeding stock.
- 3. Drought tolerance/physiology component whose objective was to develop drought tolerance index for *M. volkensii*.

The strategy outlined processes of; selection of Candidate Plus Trees (CPTs), collection of scions from the CPTs, and establishment of seed orchards using the selected material. The breeding objective was to develop fast growing and healthy trees for timber production that will be drought tolerant and adaptable to *M. volkensii* growing areas.

Breeding of *A. tortilis* for fodder and firewood production was developed based on Melia breeding programme experiences. The improved Acacia was expected to provide high quality fodder for livestock in the ASALs.



Fruiting Melia tree

Improved Melia seed orchard



Unimproved Melia tree growing on-farm with great growth variation



Improved Melia trees with straight boles

Figure 2.4: Melia volkensii trees



Seeding Acacia tortilis (Vachellia tortilis)

Figure 2.5: Acacia tortilis (Vachellia tortilis) tree

### 2.3.6 Capacity Development Project for Sustainable Forest Management in the Republic of Kenya

Kenya is a low tree cover country, therefore, the Government of Kenya, developed various policies, strategies and plans to achieve and attain 10% tree cover by 2030. These legislative instruments include the Kenya Constitution 2010, the Vision 2030, The National Strategy for Achieving and Maintaining Over 10% Tree Cover by 2022.

Integrating JICA's past and on-going cooperation in Forestry sub-sector, the Government of Kenya (GoK) officially requested Government of Japan for a technical cooperation support to promote sustainable forest management in the country. This request gave rise to the project entitled "Capacity Development Project for Sustainable Forest Management in the Republic of Kenya (CADEP-SFM)" implemented from 2016 to 2021. The implementing agencies were; Ministry of Environment, Climate Change and Forestry, KFS and KEFRI. The Project purpose was to enhance capacity at the national and county level for sustainable forest management. CADEP-SFM goal was achieved through five (5) components presented in Table 2.4.

Component	Objective	Achievement
Component 1 (Policy Support)	Implementing and monitoring capacities of forest-related policies/ strategies at the national level are enhanced.	<ul> <li>Forest-related policies /strategies reviewed</li> <li>Draft "Forest products export and import rules, 2021" prepared.</li> <li>A report on analysis County Governments' forestry legislations developed.</li> </ul>
Component 2 (Tree Growing Extension in ASALS)	Capacities of selected County governments, private sector, NGOs, and CBOs (Community - based Organization) are enhanced through implementing Pilot Forest management activities.	<ul> <li>Conducted Farmer Field Schools and formulated Participatory Forest Management Plans in two (2) pilot counties, namely Embu and Taita Taveta Counties formulated.</li> <li>Memorandum of Agreement (MoA) for collaboration in research and development on <i>Melia volkensii</i> was signed by KEFRI, a private company and CADEP-SFM.</li> <li>Growth curve of <i>Melia volkensii</i> was prepared.</li> <li>Published Melia growing guidelines.</li> </ul>
Component 3 (REDD+ Readiness)	Technical capacities for REDD+ readiness activities in KFS are strengthened.	<ul> <li>Forest Reference Level (FRL) developed and evaluated.</li> <li>National Forest Monitoring System (NFMS) developed.</li> <li>Forest Information Platform (FIP), developed.</li> <li>The first Forest Reference Level (FRL) to UNFCCC in January 2020 and modified FRL in August 2020, submitted.</li> </ul>

28 | Table 2.4: CADEP-SFM outputs, objectives and achievements

Component U	bjective	Achievement
Component 4 T	he Capacity of breeding	• A draft Plus Tree Traits Tables, developed.
(Tree Breeding) th	comiques for arought toterant ees in KEFRI is improved	• On-site further selection of 400 individuals of 2 <sup>nd</sup> generation Melia undertaken.
		• Capacity for pollen collection and artificial crossing technique through technology transfer strengthened.
Component 5 C (Regional cc	apacity of regional ooperation in KEFRI is	• 5 Regional fora for Horn of Africa (HoA) countries to share knowledge and experiences on combating desertification held.
Cooperation) In kr	nensined by promoting nowledge sharing and ansfer of technologies for	• Tools to systematically collect, document and share good practices in Natural Resource Management (NRM) developed.
Si Cl	rengthening the resilience to limate change and drought in ub-Sahara Africa	• Knowledge materials that include; book, guideline and brochures on combating desertification developed, published and shared.

### 2.3.7 Strengthening Forestry Sector Development and Community Resilience to Climate Change through Sustainable Forest Management and Landscape Restoration

Forests in Kenya are important for economic, environmental and social benefits as they provide many wood and non-wood forest products as well as ecological services that include; soil stabilization, biodiversity conservation, water catchments protection and carbon sink. Dryland forests play a fundamental role in the lives and livelihoods of many rural forest adjacent communities as they provide important products such as firewood, wood for building and dry season grazing lands. Loss of forest cover and land degradation is particularly severe in the arid and semi-arid lands (ASALs).

Preventing further deforestation and degradation of Kenya's forests and woodlands by investing in their restoration and sustainable use, is considered as an efficient and cost-effective natural capital investment. Health forests will in turn lead to jobs and wealth creation, water and food security, as well contribute to addressing climate change challenges.

To meet Kenya's national and global commitments in natural conservation, the Government of Kenya requested the Government of Japan to support Kenya's efforts to address challenges in sustainable forest management, landscape restoration and climate change mitigation and adaptation, to accelerate on-going processes. This gave rise to a 5-year project entitled, "Strengthening Forestry Sector Development and Community Resilience to Climate Change through Sustainable Forest Management and Landscape Restoration (SFS-CORECC)", to be implemented from 2022 to 2027 by; the Ministry of Environment, Climate Change and Forestry, KFS, and KEFRI.

### **Overall Goal**

Sustainable forest management and landscape restoration are promoted for achieving and maintaining over 10% tree cover in line with the aspirations of the Constitution of Kenya 2010, Vision 2030 and Nationally Determined Contributions (NDCs).

### **Project purpose**

The capacity of relevant institutions in Kenya is strengthened for promoting sustainable forest management, landscape restoration and climate change mitigation and adaptation in the country and in the region.

# **Project Outputs**

- 1. Policy-planning processes for sustainable forest management and landscape restoration are strengthened.
- 2. Enabling environment to support the promotion of commercial forestry with public-private partnerships and community participation is strengthened.
- 3. *Melia volkensii* and *Acacia tortilis* productivity and drought tolerance are improved and their production capacity for promoting their commercial use is enhanced.
- 4. Kenya and KEFRI's capacity and roles in regional cooperation to contribute to the Sub-Sahara African region in promoting sustainable forest management, landscape restoration and climate change mitigation and adaptation is enhanced.

# 2.4 Human Resource Capacity

The technical corporation projects implementation was undertaken by both Kenya officers and experts from Japan as indicated in Table 2.5.

# Table 2.5: Number of JICA Experts and Counterpart staff engaged in various project activities

Project	Japanese experts (long and short- term)	Counterparts (Officers engaged)	Counterparts trained in Japan
SFTP I	36	21	24
SFTP II	26	14	7
SOFEM	18	30	15
ISFP	9	40	12
Drought tolerant Project	26	38	35
CADEP- SFM	34	66	18
Total	149	209	111

# 2.5 Lessons Learnt and Recommendations

- The long-term collaboration between the Governments of Kenya and Japan through a series of Grant Aid and Technical Cooperation Projects continue to be successful and reference point for Social forestry and forestry development in Kenya, Sub-Saharan Africa and beyond. A graphical presentation of the chronology of KEFRI/JICA Projects from 1985 is presented in Figure 2.6.
- Natural resources management challenges continue to emerge.
- Partnerships and collaborative are crucial to providing timely solutions through joint research innovations and capacity building.
- Environmental challenges transit geographical boundaries, sharing existing information and knowledge and experiences is important for sub-Saharan Africa regional development to ensure effective use of existing resources and continued building on existing knowledge.



*Figure 2.6: Chronology of KEFRI/JICA collaboration projects since 1985* (*Illustration by M. Mukolwe and Y. Honjo, 2022*)

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# **CHAPTER 3**

# TREE SEED COLLECTION AND HANDLING FOR DRYLAND SPECIES

Robert Nyambati, Bernard Kamondo, Paul Tuwei, Rebeccah Nenkai and Dorothy Ochieng

# 3.1 Introduction

Trees are important resources in the drylands as they provide various products and services for inhabitants of these regions. To meet domestic requirements and market needs of wood products many farmers are now planting trees on farms. A constraint faced by farmers in tree planting is inadequate or lack of readily available, desired, quality tree seedlings. Quality tree seed is a key input that determines success of any tree planting programme. Quality seed are characterized by: genetic attributes based on the target product; physical quality that include purity and physiological attributes such as high viability and vigour. Quality tree seed is not readily available mainly due to low genetic quality of trees on farms and in woodlands, which are often degraded through selective harvesting of quality trees. Quality seed depends on good seed source identification for genetic quality and proper planning and appropriate seed collection and handling for physical and physiological quality (KEFRI, 2004).

# 3.2 Seed Collection

### 3.2.1 Seed sources

A seed source is a group of trees growing in a defined site used for seed collection often referred to as seed provenance. A good provenance will consist of a stand of several healthy and vigorous growing trees of same species referred to as mother trees. It is advisable to collect seed from trees that are growing on similar sites to those where the seed will be sown, as those trees will fully adapt to the particular environmental conditions including rainfall, temperature and soils.

### 3.2.2 Planning for seed collection

Planning for seed collection involves undertaking surveys on phenology of the tree which includes: budding, flowering, fruiting and seed maturity. Planning also involves determining; quantities of seed to collect, resources required, and timing for collection.

### 3.2.2.1 Flowering

Flowering in a seed source should be monitored to determine occurrence, abundance and extent of flowering to make informed decision on anticipated size of seed crop, and expected genetic quality. High genetic quality is correlated with high abundance and extensive flowering. Seed of low genetic quality can be as a result of a flowering that is restricted to only a few individual trees or only part of the seed source.

### 3.2.2.2 Fruit development and seed maturity

Seed maturity, quantity, and quality of the seed crop should be monitored through regular observation in the potential collection sites to indicate when collection of seed is likely to be worthwhile and to provide information on the quality and quantity of a season's crop. Signs of maturity depend on types of fruits. Fleshy fruits, generally turns from green to yellow, red, brown or black and the pulp softens. Pods, capsules, and cones turn brown or black. Normally, the inside of the seed (endosperm and cotyledons) become firm. This is confirmed through cutting test.

Seed maturity is indicated by change of colour or texture. Fleshy fruits change their taste from acid and stringent to sweet. But tasting as a method of monitoring maturity should be restricted only to edible fruits. The fruits should be opened to observe the texture of the seeds. Collection should only be of mature and ripe fruits, pods, cones, capsules or nuts. Some fruits, pods, cones, capsules and nuts open and dispense their seeds immediately when they ripen. The species, which disperse their seeds immediately after maturity should be collected before the dispersal.

The ripe capsules, cones and nuts can slowly be cut without damaging the seed and observe the seed coat colour, which is normally dark coloured and have a firm flesh. Unripe or immature seeds have whitish seed coats and soft or milky contents. Some species retain mature seeds in the tree for a longer period. Experience on fruit ripening characteristic is the best guide to seed collection. Some of the fruit and seed types of some dryland species are as shown in Figure 3.1.



a) Melia fruit



b) Melia nuts



c) Senna siamea pods



d) Neem seed

Figure 3.1: Fruit and seed types of some dryland species

### **3.2.3** Seed collection methods

Seed collection involves choosing healthy mother trees in the entire seed source. The mother trees should preferably be from at least 30 trees and sufficiently distanced from each other to minimize the danger of narrowing the genetic variation available within the seed source. The collection should be of the same amount of seed per tree to ensure genetic information of each tree is equally represented within the seed lot. Maturity of the seeds should be confirmed by a cutting test before collection.

Seeds should be collected in hessian sacks, nets and ventilated bags to avoid over-heating. Collected seed should be documented by recording information on the seed source and date of collection. The methods to be used for seed collection depends on; the species and the nature of its fruits and seeds, the stand, the tree, and characteristics of the site. There are two main methods of seed collection; crown collection, and ground collection (Figure 3.2).

### 3.2.3.1 Crown collection

This method applies to species whose fruits do not fall when they mature. It also applies to species whose seeds are difficult to pick when they fall to the ground. The third categories of species are those that when ripe, the pods open and seeds are dispersed far by wind. The seeds can be detached from the tree by hands, shaking using hooks, or can be gently knocked from the tree. Small branches with seeds can be cut using shears. Climbing trees without thorns is recommended, but those with thorns require protective clothing. During crown collection the following should be available; a collecting bag and a net sheeting or tarpaulin, and a big bag for mass gathering. The net sheeting or tarpaulin is spread on a clear ground before harvesting starts (Figure 3.2). Ladders are most convenient for climbing into the crown. Climbing spurs, full body harness and safety ropes should be used to collect seed from canopies of tall trees.



Figure 3.2: Collection of seed from the crown using net spread under tree and looping shears to shake branches

### 3.2.3.2 Ground collection

This method applies to large seeded species after natural fall of mature fruits. Ground collection has risk of collecting immature, empty, or seeds destroyed by insects or other pests. Some of the species that are ideal for ground collection include; *Croton megalocarpus, Melia volkensii, Balanites aegyptiaca, Terminalia mantaly* and *Terminalia brownii*.

### 3.2.3.3 Other seed collection methods used by farmers

Methods used by farmers include collecting seeds after they pass through the alimentary canal of livestock and birds without getting damaged. Some of the species are either extracted by birds whereby the bird consumes the juice and drops off the seed such as *Cordia monoica, Azadirachta indica* and *Phyllogeiton discolor*. Examples of those that pass through elementary canal of livestock without damage are; *Melia volkensii* and *Balanites aegyptiaca*.

# 3.2.4 Special consideration for seed collection in the drylands

Crown and ground collection methods depend on; tree height, thorniness and behaviour of pods once mature, which dictates the approach used to collect seed from respective category of trees.

# 3.2.4.1 Thornless trees whose pods do not burst

Seed collection in this case is done by either climbing up the tree, from natural seed fall or after shaking the tree. Tree species in this category include; *Acrocarpus fraxinifolia, Senna spectabilis, Croton megalocarpus, Delonix regia, Ficus natalensis, Grevillea robusta, Jacaranda mimosifolia, Terminalia brownii, Terminalia mantaly, Terminalia pruinoides, Tamarindus indica* and Sesbania grandiflora.

### 3.2.4.2 Thornless trees whose pods burst

For the trees in this category, seeds must be collected before pods burst and release seeds. In this case, seed collection is done by either climbing the tree or by shaking the tree and collecting fallen seeds. Tree species in this category include; *Albizia anthelmintica, Senna siamea, Leucaena leucocephala* and *Newtonia hilderbrandtii*.

# 3.2.4.3 Thorny trees whose pods do not burst

Seed collection is done in several ways, seed from natural fall or those that fall after shaking the tree can be collected. Seed can also be collected with the help of a pole or by use of a ladder. The trees in this category include; *Acacia albida (Vachellia tortuosa), A. gerrardii (Vachellia gerrardii), A. nilotica (Vachellia nilotica), A. polyacantha (Vachellia polyacantha), A. tortilis (Vachellia tortilis), Balanites aegyptiaca, Parkinsonia aculeata and Prosopis juliflora.* 

### 3.2.4.4 Thorny trees whose pods burst

The seed in this category must be collected before the pods burst. This entails climbing the tree and shaking the branches for the seed to fall or use of a ladder and or a pole. The species in this category include; *Acacia mellifera (Senegallia mellifera) A. senegal (Senegallia senegal)* and *Caesalpinia decapetala*.

### 3.2.5 Transportation and temporary storage

Seeds are sensitive living organisms and careful handling is essential for maintenance of their viability. In some cases, temporary storage is necessary especially; where there is labour and time shortage, long distance from seed sources, and where after-ripening is required. The temporary storage should ensure the following: ventilation, ambient temperature and free from pest and diseases. In case of pulpy fruits, it is necessary to spread them thinly to avoid over-heating, moisture content build-up, and fungal infection.

# 3.3 Seed Processing

The collected seeds should be protected from rain, excessive heat, and animal and insect damage, e.g. rodents. The main seed processing activities are seed extraction, cleaning and sorting, and drying.

### 3.3.1 Seed extraction

Most seeds are collected when in fruits which could be pods, cones, capsules or in fleshy or dry pulpy fruits. The seeds must therefore, be extracted out from their fruits. Extraction of seed after collection should be as soon as possible. For pulpy fruits, the extraction should be done immediately. The extraction methods used include; de-pulping, drying and threshing (Figure 3.3 and Table 3.1).



Figure 3.3: Seed extraction methods

<b>Table 3.1:</b>	Seed extraction methods for various tree species as used by
	KEFRI/JICA SFTP project in Kitui

No.	Species	Seed extraction methods	
1.	Acacia abyssinica (Vachellia abyssinica) A. hoiosericea A. mellifera (Senegallia mellifera A. polyacantha (Vachellia polyacantha) A. senegal (Senegallia senegal) A. santhophloea (Vachellia xanthophloea) Albizia anthelmintica A. amara A. lebbeck Faidherbia albida (Vachellia tortuosa) Senna siamea	<ul> <li>Pods are sun dried to open and release is seeds.</li> <li>Duration of drying depends on species a the weather.</li> <li>The husks are removed by hand and sm pieces removed using a winnower. A remaining parts should be picked by hand obtain clean seeds.</li> <li>The seeds are dried further to a low moist content.</li> <li>Ripe mature pods are sun dried to open a seed of the seed</li></ul>	
2.	Acacia nilotica (Vachellia nilotica) A. tortilis (Vachellia tortilis)	Ripe mature pods are sun dried to open and release the seeds. Duration of drying depends on the amount of moisture in the pods (it may range from 1-4 days). The pods are put in a mortar pounded with a pestle to release the seed. The seeds are separated from the chaff using a winnower. Any remaining parts of pods stalk and bad seeds should be picked by hand.	
3	Caesalpinea decapetala Lawsonia internis	Fruits are collected sun dried and seeds removed by hand.	
4	Acacia gerrardii (Vachellia gerrardii) Acrocarpus fraxinifolius Leucaena leucocephala Parkinsonia aculeata Sesbania sesban	The ripe pods are sun dried sufficiently according to species; put in a bag and threshed with a stick. The chaff is separated using a winnower.	
5	Tecoma stans Spathodea nilotica (Spathodea campanulata) Jacaranda mimosifolia Grevillea robusta Callitris robusta (Callitris preissii) Eucalyptus spp. Casuarina equisetifolia	Capsules or pods are sun dried according to species until pods/capsules open. Sun drying should be under light cover. Vigorous shaking is done to release any remaining seeds. The pods are separated from the seeds by hands.	

No.	Species	Seed extraction methods
6	Bauhinia thonningii	Most of the pods dry properly in the tree before collection. The pods are sun dried, put in a mortar and pounded using a pestle. The chaff is separated from the seeds using a winnower.
7	Bombax rhodognaphalon	Pods are dried until a mixture like cotton wool and seeds start to appear. Cotton wool and seeds are put in water. The seeds are separated from cotton wool by hand. The seeds are then sun dried for 2 to 3 days before storage.
8	Tamarindus indica	The fragile outer covering is removed by hand. Seeds are put in a drum of water then de-pulped. Seeds are then sun dried for 3 days.
9.	Balanites aegyptiaca Melia volkensii	Nuts are pounded in a mortar using pestle. The nuts are separated from the pulp using water. Nuts are sun dried for $3 - 4$ days. The nuts are eaten and pass through the alimentary canal of goats. The nuts can also be collected from goats sheds.
10.	Delonix regia Kigelia africana	Fruits are put in water for 1-3 days. The fruit is cut using a knife to release the seeds. The seeds are sun dried for 1-2 days.
11	Gmelina arborea	Fruits are put in water for 4 days before de-pulping. Sufficiently ripe fruits can be de-pulped without putting in water but the mixture is washed to separate seeds from the pulp. The seeds are dried for 2 days.
12	Dovyalis caffra Maesopsis eminii Phoenix reclinata Psidium guajava	Fruits are put in water for 3 days. The fruits are then pounded either in a drum or mortar. Water is used to separate seeds from the pulp. Seeds are sun dried and re-squeezed to remove the remaining material. A winnower is used to separate the seeds from the chaff.
13	Azadirachta indica	The dry collected fruits should be soaked in water before cleaning. The pulp and the seed are separated in water easily. The seeds are sun dried for 2 days.

No.	Species	Seed extraction methods
14	Dalbergia melanoxylon	Pods are separated from leaves and other debris by hand. No more cleaning is required as the seeds are very light and difficult to separate with the pods.
15	Newtonia hilderbrandtii	The pods are dried in the sun. They are either stirred or slightly threshed in a bag. Pods open to release the seeds.
16	Sesbania grandiflora	The pods are sun dried. The pods open and are threshed in a bag to remove seeds. A winnower is used to separate the chaff from the seeds.
17	Terminalia catappa	A knife is used to cut every side of the fruit to remove the covering in order to release the seeds.
18	Terminalia brownii Terminalia spinosa Terminalia pruinioides	Secateurs shears or a pair of scissors is used to remove the wing like appendages.
19	Adenium obesum Croton megalocarpus	Fruits are sun dried for 2 -4 days. The seeds are removed from the nut by using two hard surfaces to crack the nut.
20	Trema orientalis	Pods are put in a bag and threshed with a stick to release the seeds. The seeds are then sun dried.
21	Senna spectabilis	A knife is used to slit the pod open and release the seeds. The seeds are then sun-dried.
22	Terminalia mantaly	Seeds readily germinate without extraction. Sun drying is a good way for seed processing.
23	Thevetia peruviana (Cascabela thevetia)	The skin and the litter pulp can be removed using a mortar and pestle. The nut is crushed between two hard surfaces to release the seed. The seed is then dried for 2 days if the nut was still green.
24	Ziziphus mauritiana	The fruits are put in water and the nut separated from the fleshy pulp using hands. The nut is then sun dried.
25	Carica papaya	The fruit is slit open with a knife and the seeds removed. The seeds are sun dried for 2 days.

No.	Species	Seed extraction methods
26	Berchemia discolour (Phyllogeiton discolour)	Fruits are pounded in a mortar with a pestle. The seeds are separated from the pulp by rubbing with water and sand because seeds are gummy. They are sun dried for 3 days.
27	Cordia ovalis (Cordia monoica)	The fruit are put in dry sand to remove the seed from the pulp. The seeds are then washed and sun dried for 2 days.
28	Schinus molle	Fruits are sun dried for 3 days. The seeds are rubbed with the hand to remove the thin skin. A winnower is used to separate the seed from the chaff.

# 3.3.2 Cleaning and sorting

Cleaning and sorting are necessary for good germination and protection against pests and diseases. Dirt, immature light seeds and seeds that are rotten, broken, damaged by insects or infested by diseases should be removed. The damaged seed should be removed by hand sorting, use of a fan sorting machine.

# 3.3.3 Drying

The aim of seed drying is to reduce seed moisture content and hence reduce deterioration of seed especially if seed is to be stored. Although there are several methods of seed drying, sun drying is the most common. The drying process should be gradual over several days and the seed should be turned every few hours. The seed is spread in a thin layer in the open sun either on a fine wire mesh tarpaulin, polythene sheeting or net sheeting. Where seeds are light winged and can be blown by wind like *Grevillea robusta*, light sheet covering should be applied. When the seed is dry, it may be packed in clean, air and moisture tight containers such as polythene bags.

# 3.4 Seed Quality Assurance and Pre-sowing Treatment

# 3.4.1 Seed testing

Seed tests are very important to verify the seed quality, vigour and monitoring seed condition from collection through handling to storage. Seed is tested for purity percentage, seed weight, moisture content, and germination capacity.

### 3.4.2 Seed purity analysis

Generally, tree seed samples contain impurities such as detached seed structure, leaf particles and other objects. Purity analysis is conducted to determine the

composition by weight of the pure seed as a percentage of the total weight of the sample.

# 3.4.3 Seed weight

Seed weight is the weight of a 1,000 seeds in a seed lot. It can also be reported as the number of seeds in a kilogramme of seeds. This can help the manager determine the approximate weight of a seedlot in case a weighing machine is not available. The weight of the seeds depends on provenances, the collection period, and the size of the seeds per parent tree. Seed weight information for some tree species is as shown in Table 3.2.

No	Species	Project Estimates (seeds per kg)	Other Estimates (seeds per kg)	Information source for other estimates
1	Acacia gerardii (Vachellia gerrardii)	7,700	1,000-15,000	(2)
2	A. holosericea	71,400	70,000	(2)
4	A. mellifera (Senegallia mellifera)	16,900	20,000	(2)
5	A. nilotica (Vachellia nilotica)	7,200	700-1,100	(1)
6	A. polyacantha (Vachellia polyacantha)	10,500	15,000	(3)
7	A. senegal (Senegallia senegal)	8,100	8,000-18,000	(1)
8	A. seyal (Vachellia seyal)	2,400	20,000	(3)
9	A. tortilis (Vachellia tortilis)	17,200	12,000-31,000	(1)
10	Acrocarpus fraxinifolius	28,400	24,000-29,000	(2)
11	Albizia amara	10,100		
12	A. anthelmintica	8,500		
13	A. lebbeck	11,600	8,000-10,000	(1)
14	Azadirachta indica	5,000	16,000-17,000	(1)
15	Balanites aegyptiaca	350	500-1,500	(1)
18	Cassia siamea	39,000	35,400-45,400	(2)
19	Cassia spectabilis	36,200	25,000-45,000	(2)

 Table 3.2: Seed weight information as obtained in the Kitui KEFRI/JICA project

No	Species	Project Estimates (seeds per kg)	Other Estimates (seeds per kg)	Information source for other estimates
20	Casuarina equisetifolia	269,600	735,000	(3)
21	Cordia ovalis (Cordia monoica)	4,100		
22	Croton megalocarpus	2,000	1,000	(1)
23	Dalbergia melanoxylon	16,000	6,000-16,000	(2)
25	Delonix regia	2,500	2,000	(2)
26	Dovyalis caffra	27,000	20,000-100,000	(1)
27	Eucalyptus camaldulensis	100,000	100,000- 200,000	(2)
28	E. maculata	100,000	160,000	(3)
29	Eucalyptus tereticornis	100,000	2,900,000	(3)
30	Faidherbia albida (Vachellia tortuosa)	72,600	75,000-100,000	(2)
31	Gmelina arborea	1,400	1,400	(3)
32	Grevillea robusta	70,000		(1)
33	Jacaranda mimosifolia	77,950	63,000-80,000	(1)
34	Leucaena leucocephala	178,000	13,000-34,000	(2)
36	Melia azedarach	2,000	2,100	(3)
37	M. volkensii	4,200	200	(3)
39	Parkinsonia aculeate	12,200	12,000	(1)
40	Prosopis juliflora	40,800	8,000-35,000	(1)
41	Tamarindus indica	1,300	1,400-2,500	(2)
42	Terminalia brownii	1,900	3,000-3,200	(2)
43	Terminalia mantaly	2,000		

#### **Key: Source of information**

- (1) H. V. Maydell (1990). Trees and Shrubs of the Sahel: Their Characteristics and Uses
- (2) Maundu, P. and Tengnäs, B. (ed). (2005). A Selection of Useful Trees of Kenya. Technical Handbook No. 35. World Agroforestry Centre, Nairobi.
- (3) W.O. Omondi, J.O. Maua and F.N. Gachathi (eds) 2004). Tree seed handbook of Kenya. 2nd Edition , KEFRI, Muguga, 284 pp.

# 3.5 Seed Germination

# 3.5.1 Germination capacity and quality testing

The potential germination of seeds is the most important factor of measuring seed quality. Germination test is used to estimate the number of seeds, which can germinate at a given time.

The average days that different species take to germinate depends on provenances and the storage period. Some species germinate readily if sown after collection but when stored for some time the period may change. Germination capacity is determined by sowing a given number of seeds, normally a hundred (100) per seed-lot and counting the number of seeds that germinated. The germination capacity is reported in percentage.

# 3.5.2 Pre-germination treatments

Seeds of many tree species germinate readily when subjected to favourable conditions of moisture and temperature. However, some species tend to remain dormant even after being subjected to the right conditions for germination. Where persistent dormancy is a problem, pre-sowing treatment increases the percentage of seeds that germinate. The other benefit of pre-sowing treatment can be faster and uniform germination. The major pre-sowing treatment methods are as follows:

# 3.5.2.1 Nipping

Nipping involves cutting the seed coat to allow moisture to enter inside the seed. This treatment can be done with a nail clipper, fine pliers, knives or needles. Care should be taken when nipping, not to injure the radical.

# 3.5.2.2 Soaking in boiling water

This is the most frequent used technique whereby the seeds are immersed in boiling water 4-10 times their volume. The heat source is immediately removed to avoid cooking the seeds. The seeds are left in water which is let to cool gradually for 12-24 hours. The technique can however, give erratic results. The optimum soaking time varies with species. This technique is suitable mainly for Acacia species. Hot water softens the seed coat increasing water permeability.

# 3.5.2.3 Soaking in hot water

Soaking the seeds in hot water within a temperature range of  $60^{\circ}$ C -  $90^{\circ}$ C is as effective as soaking in boiling water ( $100^{\circ}$ C). This method is applicable to the hard-coated seeds. The water temperature depends on species.

### 3.5.2.4 Soaking in warm or cold water

Some seeds tend to develop seed coat impermeability as they over mature or due to prolonged storage. Soaking of seeds in cold or warm water within the temperature range of 40°C or below helps to increase permeability and accelerate germination.

The pre-sowing treatments and germination percentage for various tree species as undertaken by the KEFRI-JICA project in Kitui are as shown in Table 3.3.

No.	Species	Pre-treatment	<b>Temp</b>	Germination
1	Acacia mearnsii	Boiling for 7 minutes	80	69
2	A. abyssinica (Vachellia abyssinica)	Boiling for 15 minutes	80	98
3	A. aulacocarpa	Boiling water for 7 minutes	80	55
4	A. auriculiformis	Boiling for 15 minutes	80	76
5	A. crassicarpa	Boiling water for 7 minutes	80	62
6	A. gerrardii (Vachellia gerrardii)	Nipping then soaking in cold water		98
7	A. holoicilica	Boiling water for 7 minutes	80	92
8	A. holosericea	Boiling for 2 minutes	80	86
9	A. hypophylla	Boiling for 3 minutes	80	52
10	A. mellifera (Senegallia mellifera)	Soaking in cold water for 12 hours		80
11	A. nilotica (Vachellia nilotica)	Nipping then soak in cold water overnight		92
12	A. pendula	Boiling for 1 minute	80	51
13	A. polyacantha (Vachellia polyacantha)	Boiling water then left to cool overnight		93
14	A. saligna	Boiling for 3 minutes	80	50
15	A. senegal (Senegallia senegal)	Soaking for 12 hours		82
16	A. stenophylla	Boiling for 3 minutes		51
17	A. tortilis (Vachellia tortilis)	Nipping then soak in cold water		90

 Table 3.3: Pre-sowing treatment and germination percentage of ASALs tree species as done under KEFRI/JICA Project

No.	Species	Pre-treatment	Temp (°C)	Germination (%)
18	A xanthophloea (Vachellia xanthophloea)	Boiling water for 15 minutes	60	72
19	Acrocarpus flaxinifolius	Nipping		60
20	A. amara	Soaking for 12 hours		18
21	A. anthelmintica	Soaking in cold water for 12 hours		92
22	A. lebbeck	Nipping then soaking in cold water overnight		72
23	Azadirachta indica	None	-	97
24	Azanza garckeana (Thespesia garckeana)	None		49
25	Balanites aegyptiaca	None		72
26	Berchermia discolour (Phyllogeiton discolour)	Soaking in cold water for 48 hours		80
27	Bombax rhodognaphalon	None	80	65
28	Caesalpinia decapetala	Boiling for 2 minutes		85
29	Callitris robusta (Callitris preissii)	None		45
30	Carica papaya	None		58
31	Senna siamea	Boiling for 20 minutes	60	95
32	S. spectabilis	Boiling for 15 minutes	80	95
33	Casuarina equisetifolia	None		92
34	Cordia ovalis (Cordia monoica)	None		70
35	Croton megalocarpus	None		99
36	C. ovalis	None		89
37	Dalbergia melanoxylon	None	İ	90
38	Delonix regia	Boiling water for 2 minutes	80	74
39	Dovyalis caffra	None		92
40	Erythrina abyssinica	None		23
41	Eucalyptus camaldulensis	None		99
42	Eucalyptus citriodora	None		89

No.	Species	Pre-treatment	Temp (°C)	Germination (%)
43	E. globulus	None		50
44	E. grandis	None		52
45	E. nitens	None		61
46	E paniculata	None		70
47	E. pellita	None		64
48	E. terticornis	None		65
49	Faidherbia albida (Vachellia tortuosa)	Nipping then soak in cold water overnight		76
50	Ficus natalensis	None or soak 24 hours.		40
51	Gmelina arborea	None	ĺ	71
52	Grevillea robusta	None or soak 24 hours.		88
53	Jacaranda mimosifolia	None		88
54	Kigelia africana	None		39
55	Lawsonia inermis	None	İ	84
56	Leucaena leucocephala	Boiling for 15 minutes	60	96
57	Markhamia lutea	None		60
58	Melia azedarach	None	ĺ	97
59	Melia volkensii	Nipping and soaking in cold water overnight		50
60	Melia volkensii	None		65
61	Moringa oleifera	None		70
62	M. stenopetala	None		69
63	Newtonia hilderbrandtii	Boiling for 3 minutes		52
64	Parkinsonia aculeata	Boiling for 3 minutes	80	86
65	Phoenix reclinata	Boiling for 15 minutes	60	18
66	Piliostigma thonningii	Soaking in hot water	-	11
67	Prosopis juliflora	Boiling water for 15 minutes	80	98
68	Psidium guajava	None		85
69	Schinus molle	None	-	98
70	Sesbania grandifllora	Soaking for 12 hours.	60	80
71	Sesbania sesban	Boiling for 20 minutes	60	90
72	Tamarindus indica	Boiling for 3 minutes		98
73	Tecoma stans	None		21
No.	Species	Pre-treatment	Temp (°C)	Germination (%)
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74	Terminalia prunioides	Nipping then soak in cold water overnight		72
75	T. brownii	Nipping then soak in cold water overnight		74
76	T. catappa	Boiling for 3 minutes	60	98
77	T. mentalis (T. mantaly)	Nipping, soak in cold water overnight		70
78	T. spinosa	Nipping then soak in cold water overnight		55
79	Thevetia peruviana (Cascabela thevetia)	None		91
80	Tipuana tipu	Soaking in cold water overnight		45
81	Trichilia roka (Trichilia emetica)	None		15
82	Ziziphus mauritiana	Soaking in water, crack nut		10
83	Syzygium cuminii	None	1	97

*Note:* Seed boiling was initially used as a treatment for experimental purpose. However, it is not currently advisable to boil seed as this could lead to seed damage.

# 3.6 Seed Storage

The main reason for storing seeds is to enable production of seedlings whenever they are required. Storage is necessary especially for species that do not produce seed continuously. However, in few species such as *Parkinsonia aculeate*, which seeds throughout the year, there is less need for storage unless the seeds are required in large quantities. Some species have a pattern of producing seeds i.e. they may produce seeds after every two or four years, thus need for seed of such species to be stored to have regular production of seedlings.

The storage conditions should ensure the seed retain viability. The storage period may range from 1 day to many years depending on the species. Tree species such as acacias may be stored for 3-15 years. Most species in ASALs can be stored at room temperature for a long period of time, provided they are sufficiently dried, protected from insects and rodents attack and are loosely stacked. Such species include; Acacia, Albizia, Eucalypts, and Terminalia. Acacia spp., Albizia spp, *Melia volkensii* and *Tamarindus indica* should be treated with chemicals to

protect them from rodents and insect attack. Some seeds including; *Grevillea robusta, Dovyalis caffra, Azadirachta indica, Ficus benjamina* and *F. natalensis* are killed by excessive drying. Where cold storage is affordable many species can be stored for long periods of time.

All types of seeds are hygroscopic that is; they pick up moisture from the air when their moisture contents are below that of the surrounding air. This mostly happens during the rainy periods. Rehydration of dried seed increase respiration and metabolic activities in the seed and significantly lower the germination capacity overtime. To prevent such conditions to occur, the seeds should be sufficiently dried and stored in moisture proof containers. Air tight containers such as sealed polythene bags, jars and tins are preferred. The storage containers should contain properly recorded labels with details of; date of collection, provenance, and date of extraction, purity and the weight at packing.

When using sealed containers, the following must be considered:

- Moist (wet) seeds must not be sealed.
- Air-tight containers should be used for storage.
- The container should be clean and dry.
- The container should not be opened except when necessary.
- It is advisable to keep the container full of seed.
- A label on which the name of the species, collection date and place or mother trees, are written should be attached to the container.

Not all seeds can withstand long storage. Some species including *Carica papaya*, *Dovyalis caffra* and *Azadirachta indica* lose viability within a short time. Such seed should be sown within two months from the time of collection.

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# **CHAPTER 4**

# TREE NURSERY TECHNOLOGIES FOR DRYLANDS OF KENYA

Robert Nyambati, Rebeccah Nenkai and Paul Tuwei

#### 4.1 Introduction

Tree nurseries play a critical role in seedling production for afforestation programmes in arid and semi-arid lands (ASALs). The success of these programmes depends on the quality of seedlings raised as it contributes to their survival and growth in the field. The Kenya Forestry Research Institute (KEFRI) and Japan International Cooperation Agency (JICA) have worked in partnership for over 30 years to develop forestry technologies with the aim of enhancing tree establishment and survival in the drylands. A total of 20 tree nursery experiments were set with an aim of refining techniques that were being applied in ASALs. A total of 90 different tree species were tried. Some of the technologies developed include; soil media, sowing schedule, pot colour, pot size, watering intensities, root pruning and hardening up, pest and disease management, and use of stump seedling.

#### 4.2 Justification

The ASALs are characterized by high seasonality and annual variability in climatic parameters especially rainfall and temperatures. These characteristics and the high rate of evapotranspiration affect implementation of various activities including tree planting. The success of forestry programmes (afforestation and reforestation) in the ASALs depend mainly on quality and adaptability of tree seedlings. Seedling production for ASALs is faced with numerous challenges mainly due to inadequate research on nursery techniques.

## 4.3 Dryland Nursery Technologies

Nursery experiments examined various parameters including: soil media, pot size, pot colour, root pruning, use of stump seedling and hardening. Results of the respective trials are as presented in Table 4.1.

Conclusion and recommendations	In mixing soils for potting, soil physical and chemical characteristics should be taken into consideration. Given the sandy nature of soils in many ASAL places, a ratio of 2:0:8, soil mixture was recommended.
Discussion	Performance of the seedlings varied among the different soil media. Seedlings grown with manure as one of the components grew faster. This would be attributed to improved nutrient supply especially nitrogen that is critical for plant growth. Soil media composition has an influence on seedling performance.
Results	Soil mixture ratio 2:0:8 had the best overall seedling performance in terms of height growth followed by 2:4:4 and 2:2:6. With the exception of <i>S</i> . <i>spectabilis</i> , which had generally low growth in all the treatments, all other species showed good height growth with minimal variance among the species. Soil mixture ratios 0:0:10 and 0:5:5 had the lowest performance.
Materials and methods	Five soil media were used, namely: (0:0:10); (0:5:5); (2:2:6); (2:4:4), and (2:0:8). The parts used were cow manure, sand and forest top soil respectively. Five different species were used, namely; <i>Acacia</i> <i>polyacantha (Vachellia</i> <i>polyacantha), Sema</i> <i>spectabilis, Croton</i> <i>megalocarpus, Prosopis</i> <i>juliflora</i> and <i>Tamarindus</i> <i>indica</i> . A completely randomized design was used and 25 seedlings were used for each treatment for each species. Survival and height parameters were assessed on monthly basis. A pot size 4" by 7" was used.
Objective	To determine the optimum proportions of top soil, sand and manure for tree seedling production in ASALs.
Trial	1. Soil media trials

Table 4.1: Results of nursery trials

Conclusion and recommendations	Slow growing species such as <i>Melia volkensii</i> , <i>Tamarindus indica</i> , <i>Osyris lanceolata</i> , <i>Terminalia brownii</i> , requiring longer time in the nursery to attain planting size should be planted in medium size pots (4"x7"). Fast growing species do grow well in small potting bags (4"x6"). Larger pots may be used for slow growing species and those that are larger in size such as mangoes and bamboo.
Discussion	The results indicated a direct proportionality between height growths and size of the pot, i.e. large size pots had better growth in terms of height. Large pot sizes have advantages of larger volume of water, nutrients and root growth space compared to small size pots. The volumes of the respective pot sizes were: $3^{n} \times 7^{n}$ (9,810 cm <sup>3</sup> ), $4^{n} \times 5^{n}$ (1,029 cm <sup>3</sup> ), $4^{n} \times 7^{n}$ (1,440.75 cm <sup>3</sup> ) and $4^{n} \times 9^{n}$ (1,852 cm <sup>3</sup> ). These varying volumes have various implications on seedling growth and development. Smaller pots have the limitation of space and nutrient provision especially at the later stages of seedling growth. Larger pots, may be used for slow growing species and those seedlings that are larger in size, e.g. mangoes and bamboo. This may however, be disadvantageous in terms of cost of production (purchasing, filling pots as well as transportation).
Results	Pot size of 4" x 9" inches had the best overall performance followed by 4" x 5", 4" x 7" and 3" x 7".
Materials and methods	Five different pot sizes were used, namely; 3" x 7", 4" x 5", 4" x 7" and 4" x 9". Five different species were used, namely; <i>Acacia polyacantha</i> , <i>Sema spectabilis, Croton</i> <i>megalocarpus, Prosopis</i> <i>juliflora and Tamarindus</i> <i>indica</i> . A uniform soil media (2:0:8) was used in all the pots. A completely randomized design was used with the following layout. For each treatment 50 seedling were used. Height and root collar diameter were measured on monthly basis.
Objective	To determine the optimum pot size for seedling production in ASALs.
Trial	2. Pot size trials

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conclusion and recommendations	in respective Seedlings raised species were in clear pots nowever, noted had (better	bjected to the higher average	ces were raised in black	difference was may therefore, and or armus be recommended	ular experiments for seedling	had performed   ASAL afforestation	ed in the clear programmes.		od that black	ot that black e growing at le inner walls	a that black e growing at he inner walls ects of these	e growing at the inner walls ects of these seedling is not	in that black e growing at the inner walls ects of these seedling is not it is suspected	cd that black e growing at le inner walls ects of these seedling is not it is suspected idered proper	cd that black e growing at le inner walls ects of these seedling is not it is suspected idered proper ings. Mukolwe	a that black e growing at le inner walls acts of these seedling is not it is suspected idered proper ings. Mukolwe ommunication)	ot that black e growing at le inner walls acts of these seedling is not it is suspected idered proper ings. Mukolwe ommunication)	ot that black e growing at te inner walls acts of these seedling is not it is suspected indered proper ings. Mukolwe ommunication) preenish black to pand sides	or that black e growing at te inner walls acts of these seedling is not it is suspected indered proper ings. Mukolwe ommunication) greenish black te top and sides ptation to the	a that black e growing at le inner walls ects of these seedling is not it is suspected it is suspected ings. Mukolwe ommunication) greenish black he top and sides ptation to the characteristics of
Discuss	The means attained treatments for each quite close. It was h	that different specie differently when sul	two treatments. Significant differenc	<i>P. juliflora</i> . A small observed for <i>C</i> mee	where previous simi	raised in black pots	better than that raise	Mote It was abcarva	purs. IL was upsur	pots had green algae the ton as well as th	pot scuo are unactively pots had green algae the top as well as th of the pots. The effe	pots the way been algae pots had green algae the top as well as th of the pots. The effe algae on growth of :	pots had green algae pots had green algae the top as well as th of the pots. The effe algae on growth of : well known though	pots had green algae pots had green algae the top as well as the of the pots. The effe algae on growth of ' well known though that it may have hin	pots. It was ouse up to the pots had green algae the top as well as the of the pots. The effe algae on growth of ' well known though that it may have him growth of the seedli	pots. It was occovered pots had green algae the top as well as the of the pots. The effe algae on growth of f well known though that it may have hin growth of the seedli (1993), (personal cc	pous. It was occovered pots had green algae the top as well as the of the pots. The effe algae on growth of s well known though that it may have hin growth of the seedli (1993), (personal cc reported that such g	pots. It was occover pots had green algae the top as well as the of the pots. The effe algae on growth of s well known though that it may have hin growth of the seedli (1993), (personal cc reported that such g algae growing on th	pots. It was occover pots had green algae the top as well as the of the pots. The effe algae on growth of s well known though that it may have hin growth of the seedli (1993), (personal cc reported that such g algae growing on th of tubes was an ada	pots. It was ouse up the pots had green algae the top as well as the of the pots. The effe algae on growth of ' well known though that it may have him growth of the seedli (1993), (personal cc reported that such g algae growing on th of tubes was an ada high temperatures c
Results	Seedlings raised in clear pots had higher average height than those raised	in black pots.																		
Materials and methods	Two types of pots i.e. Clear and Black pots were used.	All the pots were of size	4 x / and open at the bottom. Five species i.e. Acacia polyacantha	(Vachellia polyacantha), Senna spectabilis, Croton	megalocarpus, Prosopis juliflora and Tamarindus	<i>indica</i> were used. All	pots had a unitorm soil media i e. 2.0.8		(manure: sand: forest	(manure: sand: forest soil) respectively. A	(manure: sand: forest soil) respectively. A completely randomized	(manure: sand: forest soil) respectively. A completely randomized block design was used.	(manure: sand: forest soil) respectively. A completely randomized block design was used. 40 seedlings were	(manure: sand: forest soil) respectively. A completely randomized block design was used. 40 seedlings were used in each sub plot.	(manure: sand: forest soil) respectively. A completely randomized block design was used. 40 seedlings were used in each sub plot. Height and root collar	(manure: sand: forest soil) respectively. A completely randomized block design was used. 40 seedlings were used in each sub plot. Height and root collar diameters were measured	(manure: sand: forest soil) respectively. A completely randomized block design was used. 40 seedlings were used in each sub plot. Height and root collar diameters were measured on monthly basis and	(manure: sand: forest soil) respectively. A completely randomized block design was used. 40 seedlings were used in each sub plot. Height and root collar diameters were measured on monthly basis and analyzed for significant	(manure: sand: forest soil) respectively. A completely randomized block design was used. 40 seedlings were used in each sub plot. Height and root collar diameters were measured on monthly basis and analyzed for significant difference by use of t-test	(manure: sand: forest soil) respectively. A completely randomized block design was used. 40 seedlings were used in each sub plot. Height and root collar diameters were measured on monthly basis and analyzed for significant difference by use of t-test at 0.10 level.
Objective	To determine the	performance of seedlings	clear pots compared to	those raised in black	pots under	conditions.														
Trial	3. Pot colour trials			<u> </u>		<u> </u>														

Trial	Objective	Materials and methods	Results	Discussion	Conclusion and recommendations
4. Root pruning trials	To compare the performance of seedlings raised in open pots to those raised in closed pots	Seedlings were raised in two types of pots: open at the bottom and closed at the bottom. Five species were used, namely; <i>Acacia polyacantha</i> ), <i>Senna spectabilis</i> , <i>Prosopis juliflora</i> , <i>Crotom</i> <i>megalocarpus and</i> <i>Tamarindus indica</i> . For all the treatments soil media of 2:0:8 (manure: sand: forest soil) was used Completely randomized design was used. The seedlings were watered using 30 litres/1000 seedlings twice daily. Height growth and root collar diameters were assessed on monthly basis and analyzed for any differences. Their means were compared a few days before out planting by t-test (comparison of paired observations at 0.1 level).	Open end pots performed better than closed end pots. Significant differences were only observed for <i>Tamarindus indica</i> .	Significant differences were only observed for <i>T. indica.</i> Though other species did not show significant differences (height/ growth), seedlings raised in open end pots had a higher average height. Open end pots seedlings also performed better in the field. This may be attributed to the extra environment (ground) the roots come into contact with and are able to tap moisture and nutrients as opposed to those raised in closed end pots. The lower performance for the closed end pots could be due to water logging conditions in the root zone of the seedlings, which may have not been conducive for the uptake of nutrients and moisture. It was also observed that in closed end pots, the seedlings had coiling and twisting roots, which is a major disadvantage in areas where moisture is scarce or fast receding into lower horizons.	Open end pots are recommended for raising seedling in the ASALs as they encourage the development of straight fibrous roots, a major factor that influences tree establishment and survival in arid areas.

Conclusion and recommendations	t ofSpecies that growynaturally in highspotential areassuch as <i>Croton</i> atnt.megalocarpus mayareexposure tohardening off thanthose that grownaturally in ASALs.evapotranspiration,hadpoor soils and highed toof 5oweriesnes.
Discussion	Wilting of seedlings as a result reduced watering intensity may be attributed to specific species ability to withstand moisture stress in its natural environmer Species such as <i>A. polyacanth</i> predominantly found in riverin or areas with high water table. It was therefore, possible that they may wilt when subjected to drastic or sudden moisture reductions. <i>Tamarindus indica</i> the highest mortality rate, whil <i>C. megalocarpus</i> had the least. <i>Tamarindus indica</i> may probal require to be gradually subject hardening off process. It was also observed that 4 out species had 100% survival at lo watering intensities. Such spec can be candidates to be used in dryland afforestation programr
Results	There were variations in the performance of different treatments. It was observed that reduction in watering intensity led to general wilting in all the species. There were however, variations wilting among species. This was mainly evident in <i>A</i> . <i>polyacantha</i> ( <i>Vachellia</i> <i>polyacantha</i> , <i>Senna</i> <i>spectabilis</i> , and <i>T</i> indica while <i>C</i> . megalocarpus, <i>P</i> juliflora showed relatively uniform behaviour at all watering intensities. It was also observed that it was not necessary to reduce watering intensity as it led to seedling mortality.
Materials and methods	Seedlings of five tree species namely Acacia polyacantha (Vachellia polyacantha), Senna spectabilis, Croton megalocarpus, Prosopis juliflora and Tamarindus indica were subjected to 30 litres/1,000 seedlings twice daily. One month to out planting, the watering intensity was changed to 40, 30, 20 and 10 litres of water once daily. Survival and height growth were observed and recorded.
Objective	To determine the effect of gradual reduction of watering intensity on the seedlings prior to out planting and performance in the field
Trial	5. Hardening off trial

Conclusion and recommendations	Reduction of water close to the normal is recommended as the seedlings are able to adapt fast. Intense water reductions (10 litres) will mainly lead to wilting, stunted growth and sometimes death of seedlings, while high moisture levels will lead to luxuriant growth leading to high mortality in the field because of the harsh field conditions (high evapotranspiration, poor soils and high temperatures).
Discussion	It is important to note that before hardening off procedures are initiated, it would be necessary to understand specific species moisture requirements especially in respect to tolerance to drought. Species that grow naturally in high potential areas require gradual exposure to hardening off conditions compared to those that grow naturally in ASAL conditions. For treatments, i.e. 10, 20 and 40 litres, respectively, 20 litres had the best performance in all the species, while 10 litres had the lowest. This implies that improving the moisture conditions may lead to slow growth as this saturates the soil leading to water logging conditions, hence the slow growth or even death of seedlings.
Results	Different species responded differently to different watering intensities. It was noted that at 30 litres watering level, <i>C. megalocarpus,</i> <i>P. juliflora and S.</i> <i>spectabilis,</i> had significantly large height increments. <i>A.</i> <i>polyacantha</i> ( <i>Vachellia</i> <i>polyacantha</i> ) and <i>T.</i> <i>indica</i> had very low height increments. 30 litres once daily had the highest height increment.
Materials and methods	
Objective	
Trial	

Conclusion and recommendations	Paper pots may be recommended for fast growing seedlings for high potential areas where termite attack is low. The paper pots have the advantage of being cheap and light.
Discussion	The poor performance paper pots may be attributed to their smaller sizes (294 cm <sup>3</sup> ). Small sized tubes have the disadvantage smaller space for seedling growth (root) moisture and nutrients, over a short time food reserves in the pots get exhausted. In polythene tubes (large-sized), growing space was not restricting seedling growth. Previous studies have shown that large-sized seedlings have higher chances of survival than small-sized seedlings. This therefore, calls for the use of large-sized pots.
Results	Results showed that seedlings raised in paper pots performed poorly. Other observations revealed that paper pots were prone to termite attack, which lead to serious damages on the seedlings.
Materials and methods	Seedlings of six tree species namely; Acacia polyacantha (Yachellia polyacantha), Senna siamea, Senna spectabilis, Croton megalocarpus, Prosopis juliflora and Tamarindus indica were raised in both paper pots (5 cm x15 cm) and polythene tubes (10 cm x 17.5 cm), all in soil mixture 2:0:8 (manure, sand and forest soil), respectively. Paired observations were made on monthly basis and comparison of survival, and height made accordingly.
Objective	To compare the performance of seedlings raised in paper pots and polythene pots
Trial	6. Paper pot trial

Conclusion and recommendations	Large diameter seedlings 1 - 1.5 cm have better survival and sprout formation.
Discussion	Variation in growth rates could be attributed to a tree's inherent ability to perform. The time taken for various seedlings to attain the 0.7 cm diameter mark was varied. Growth of seedling in the nursery and especially height and diameter is to a large extent influenced by species, soil media, moisture in the soil and density. For seedlings to attain a specified diameter class, it will be necessary to evaluate the growth rates of individual species and this will be a good guidance as to when sowing can be down. Previous studies in the same project showed that the performance of seedlings in the field (survival and sprout formation) were influenced by diameter. High diameter 1 - 1.5 cm were reported to have better survival and sprout formation.
Results	The results showed that growth rates of tree species subjected to similar conditions were different.
Materials and methods	Seedlings of 14 different tree species, namely; Acacia crassicarpa, A. mellifera (Senegallia mellifera), A. mearnsii, A. tortilis (Vachellia gerrardii), A. polyacantha (Vachellia gerrardii), A. polyacantha (Vachellia polyacantha), Azadirachta indica, Bombax rhodognaphalon, Dalbergia melanoxylon, Tamarindus indica, Senna speatabilis and Eucalyptus camaldulensis were raised in specially prepared beds. The seedlings were at the at the nursery for 6.3 - 8.1 months for slow and fast growing species, respectively. Height, mean diameter, density, and percentage of seedlings with >0.7 cm diameter were recorded.
Objective	To determine performance of stumps as an alternative planting stock in ASALs
Trial	7. Stump seedling trial

Conclusion and recommendations		It is important to develop hardening off strategies that will ensure adaptation, establishment, survival, and subsequent growth of seedlings in the field.
Discussion		The low weight loss in <i>P. juliflora</i> may be attributed to special adaptation to minimizing moisture loss by nature of its leaves (small in size) or that its anatomy is hardy while other species, e.g. <i>C.</i> <i>megalocarpus</i> , and <i>S. spectabilis</i> had large reduction in weight. This may be attributed to their large leaves, therefore the surface areas available for moisture loss are large and their replenishing capacity was greatly reduced as it had no access to the moisture. This has an implication during planting out. Such seedlings require a gradual hardening up process or they may wilt and die off after planting if there no rains.
Results		There were variations in the performance of different species at different moisture levels. On overall, <i>P.</i> <i>juliflora</i> lost the least weight followed by <i>C. megalocarpus, A.</i> <i>polyacantha (Vachellia</i> <i>polyacantha), S.</i> <i>spectabilis</i> , and <i>T.</i> <i>indica.</i> Seedlings with large leaves such as <i>C.</i> <i>megalocarpus, S.</i> <i>spectabilis</i> showed large reduction in weight.
Materials and methods	One to two days before field planting, the seedlings were dug and trimmed at 20 cm root, and 5 cm top. The seedlings meant for field trials were trimmed at different levels 20 cm and 40 cm for Acacia polyacantha, and 15 cm for <i>Senna spectabilis</i> .	Seedlings of five tree species namely; <i>Acacia</i> <i>polyacantha (Vachellia</i> <i>polyacantha), Senna</i> <i>spectabilis, Croton</i> <i>megalocarpus, Prosopis</i> <i>juliflora</i> and <i>Tamarindus</i> <i>indica</i> were subjected to different watering intensities i.e. 10, 20, 30 and 40 litres. Their shots were then cut and weight loss monitored over a period of 20 hours (5 pm, 7 pm, 9 pm, 11 pm, 7 am, and 1 pm) of the next day respectively. Temperature variation was also recorded.
Objective		To compare shoot weight loss of various species after being cut from the main stem
Trial		8. Reduction of shoot weight on lopping

Conclusion and recommendations	
Discussion	Given the conditions prevailing in ASALs, nursery it is advisable to critically check the leaf structure (size and morphology) of the various tree species and device hardening off strategies that will ensure adaptation, establishment, survival and subsequent growth in the field. It was observed that seedlings that received very low moisture in the nursery lost very little weight. This may be explained by the fact that such seedlings may have adapted to conserving moisture (morphological adaptation). Seedlings receiving a lot of water are usually very succulent and a break in moisture supply from the tap roots will usually affect them. This was most conspicuous in the 40 litre watering intensity.
Results	
Materials and methods	
Objective	
Trial	

Conclusion and recommendations	Various tree species have the ability to produce planting materials from cuttings if only the right conditions are provided. Some of the conditions that favour root and sprout formation are; adequate moisture, right diameter (age of parent tree), soil media, and temperature.
Discussion	Ability of the cuttings to survive depends on diameter class and type of species. It was observed that the two species formed callus but did not root. This led to death of the cuttings, the bark of <i>M. volkensii</i> easily rot and could be detached, hence causing disease attack and death. Death of the shoots may also be attributed to the soil media used, the watering regime, age of stock and placement. It is important to note that root- ability and sprout-ability is mainly influenced by the soil media, moisture provision, presence of rooting hormone and humidity. A change in soil media showed that the best range in diameter was 9-14 cm for <i>Gmelina arborea</i> . This encouraged the callus occurrence, hence influencing sprouting ability. The ability of various species to sprout at different diameter vould easily form sprouts as opposed to those that and larger diameter.
Results	The results showed that survival of cuttings and callus occurrence was size dependent. The highest survival was recorded in the diameter range of 12-17 cm for <i>M. volkensii</i> , and 9-13 cm for <i>G. arborea</i> . On overall <i>G. arborea</i> . M. volkensii.
Materials and methods	Stem cuttings of <i>Melia</i> <i>volkensii, Gmelina</i> <i>arborea,</i> and <i>Terminalia</i> <i>brownii</i> were cut at 20 cm length. The cuttings were of various diameter classes. The cuttings of <i>Melia volkensii</i> were planted into sand boxes (pure sand) while those of <i>Gmelina arborea</i> were planted into two types of soil media sand to soil ratio of 8:2 and sand to soil ratio of 2:8. Planting was done in July. Observations on survival, sprout formation, root formation were made in September (after 2 months).
Objective	To determine the rootability and sprouting ability of <i>Melia</i> <i>volkensii</i> , <i>Gmelina</i> <i>arborea</i> , and <i>Terminalia</i> plant plant cuttings
Trial	9. Root stock trials

Conclusion and recommendations	Factors influencing vegetative growth from the roots should be investigated.
Discussion	The trial did not result in any vegetative growth. Vegetative growth from root cuttings is dependent on species, moisture and nutrients, air temperature, hormone, rooting media. However, in other trials, some of the species that have shown remarkable performance were Acacia tortilis (Vachellia tortilis), Commiphora, zimmermanii, Commiphora africana, and Erythrina abyssinica.
Results	Roots did not produce any vegetative materials.
Materials and methods	Root cuttings of two species Melia volkensii and Terminalia brownii, 15 cm long of 1.0–1.5 cm diameter were planted in slanting positions in sand boxes and watered twice daily. Observations of survival, sprout and root formation were monitored and recorded on 2-weeks interval.
Objective	To determine if planting materials could be raised from roots directly propagated in the soil in ASALs.
Trial	10. Root planting trialal

#### 4.4 Lessons Learnt

- For proper growth of ASALs species in the nursery, it is advisable to improve soil fertility in order to enhance nutritional value of soil medium as the sand soils have low fertility. Without additional soil amendments such as animal manure, seedling growth will be affected.
- Seedling that take long in the nursery before attaining planting size should be planted in large pots
- Seedling hardening off depends on leaf morphology

# 4.5 Conclusion

A tree nursery provides the optimum conditions through which quality seedlings are raised for any successful tree-planting programme. Observing good nursery practices will ensure good establishment, survival and realisation of seedlings in desired quality and quantity.

## **Bibliography**

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# **CHAPTER 5**

# ON-STATION DEVELOPMENT OF TECHNOLOGIES FOR TREE ESTABLISHMENT AND MANAGEMENT IN DRYLANDS

Robert Nyambati, Paul Tuwei, Josephine Wanjiku and Dorothy Ochieng

#### 5.1. Introduction

The arid and semi-arid lands (ASALs), are characterized by; low, erratic and unreliable rainfall, frequent droughts, high temperatures, and generally, poor and shallow soils that are highly erodible. These factors contribute to low land productivity, including production of crops and trees. Inadequate technical know-how on appropriate techniques for tree conservation, establishment, and management have been identified as major factors contributing to low tree survival and poor growth in the ASALs. Information on tree species characteristics such as drought tolerance, pest and disease resistance, and growth performance are not well understood and nor sufficiently documented, and are also inadequate to enable identification and selection of suitable tree species for planting and management in the drylands.

#### 5.1.2 Justification

The unique climatic and environmental features of ASALs require innovative tree establishment and management technologies to enhance tree planting, survival and growth to ensure vegetation /woodland conservation, rehabilitation, restoration and availability of wood and non-wood products in the drylands (Rocheleau *et al.*, 1988). This chapter highlights the various tree establishment and management techniques applicable to the ASALs, developed on-station. The chapter also provides information on various trees species tested and recommended for promotion in ASALs. The technologies and techniques presented are based on trials conducted under KEFRI/JICA activities in Kitui at Tiva Pilot Forest site.

#### 5.1.3 Objective

The objective of on-station development of technologies was to identify, develop and evaluate innovative technologies for tree establishment and management for drylands.

## 5.1.3.1 Specific objectives

The specific objectives were to;

- 1) Identify suitable tree species for drylands.
- 2) Assess and identify suitable tree establishment and management techniques for drylands.
- 3) Determine performance of different tree species in drylands.

# 5.2 Materials and Methods

Initial site preparation was undertaken through strip clearing and total clearing of small area in the Tiva Pilot Forest. Land preparation involved demarcating boundaries of compartment(s)/sub-compartment(s) and planting blocks. Site preparation was done just before the on set of rains. Pilot Forest research trials undertaken were designed to test; site preparation methods, tree establishment and management practices i.e. spacing, hole size, weeding, mulching, water harvesting, thinning, pruning, and coppicing. The test tree species was *Senna siamea* (Figure 5.1). The species was selected as it was widely planted in Kitui County due to its tolerance to drought, browsing, and termites. The species is useful for fuelwood and timber production. Species and provenance trials were also undertaken.



Senna siamea tree in flower

Senna siamea trees planted along farm boundary



# 5.3 Tree Establishment Technologies: Summary of Key Findings

Using *Senna siamea* as the test crop, five tree establishment technologies were tested to identify the best options for tree planting in the drylands. The technologies, methods applied and key findings are as presented in Table 5.1.

Technology		Objective	Method	Key findings and recommendation
1.	Site clearing and preparation	To assess the effect of site preparation on tree survival and growth	Land preparation methods included; bush clearing (both strip and complete clearing), hand digging, oxen and disc ploughing and ripping using a bulldozer.	<ul> <li>All land preparation methods improved tree survival.</li> <li>Tractor ploughing resulted in the highest tree survival rate.</li> <li>Land preparation must be done early enough before rain onset, to allow time for other activities such as staking and pitting to be undertaken.</li> <li>Least costly and feasible methods such as hand tilling and oxen plough were recommended for farmer use.</li> </ul>
2.	Spacing	To determine the optimal spacing of <i>Senna</i> <i>siamea</i>	The trial was established in November 1997. Different spacing regimes were used i.e. (1m x 1m, 2m x 2m, 3m x 2m, 3m x 2m, 3m x 3.3m, 3.5m x 3.5m, 3m x 4m, 4m x 4m, 5m x 5m, and single line planting at 3m). The following parameters: survival, height, diameter at ground level and dieback were assessed.	<ul> <li>Wider spacing gave better tree performance. The better performance was attributed to the fact that tree crown is more exposed to larger photosynthetic area.</li> <li>Closer spacing induced formation of weak (thin) and long stems.</li> <li>Dieback incidences were higher with closer spacing.</li> <li>Die back incidences were common during dry season.</li> <li>A 4m x 4m spacing was most preferred. This spacing allows use of both animal and small machinery drawn implements during land ploughing and weeding.</li> <li>Single line planting at 3m spacing is recommended for both poles and firewood production.</li> <li>Stocking density is determined by the end use product, density of existing vegetation, soil fertility, silvicultural treatment, rainfall and the available land. Wider spacing e.g. 5m x 5m is recommended in more arid environment. In Tiva, 4 m x 4 m spacing was adopted.</li> </ul>

<b>Table 5.1:</b>	Tree establishment	technologies	tested in	Tiva	Pilot	Forest	and
	key findings						

Techr	nology	Objective	Method	Key findings and recommendation
3. Wa har tecl (mi cato	ter vesting hnology cro- chment)	To compare effectiveness of different water harvesting technologies. To compare tree growth performance under different water micro- catchments.	Three catchment types were tested, i.e. Turkana (square shaped), W and V shaped structures were set up in November 1995 with <i>Senna siamea</i> planted in 1994. Contour and circular bands were also tested.	<ul> <li>Tree growth performance was better under Turkana followed by W-shaped and V-shaped water micro-catchments, respectively.</li> <li>Turkana water micro-catchment perfomed well as it is larger in size. However, it is more labour intensive. The W-shaped was just as effective as theTurkana water micro-catchment and was therefore recommended. Nevertheless, there is need to test effectvinnes of the micro-catchment using other different tree species.</li> </ul>
4. Pla hole	nting e size	To identify optimum hole size for planting tree seedlings in drylands.	Three hole size were tested; namely; 25cm x 25cm, 45cm x 45cm, and 65cm x 65cm.	<ul> <li>Hole size 45cm x 45cm was most appropriate as it is cost effective and improved tree survival, while 25cm x 25cm was small and resulted in poor tree survival.</li> <li>Hole size 65cm x 65cm gave good tree survival but is expensive to construct.</li> </ul>
5. Pla and up o rep	nting l beating or lanting	To determine when to plant tree seedlings in the field To determine when to replace seedling that may have died.	Compare performance of tree seedlings planted out at various times during the rainy season.	<ul> <li>Planting should be carried out at the beginning of rainy season.</li> <li>Avoid planting on hot and sunny day.</li> <li>In Kitui and other similar areas, planting is done during October - December rains.</li> </ul>



a) V-Shaped water micro-catchment

b) W-Shaped water micro-catchment



c) Circular water micro-catchment

d) Rectagular water micro-catchment

Figure 5.2 Types of water micro-catchments

# 5.4 Tree Management Technologies - Summary of Key Findings

Using *Senna siamea* as the test crop, various management technologies were tested to identify suitable techniques for improved tree productivity. The technologies tested and key findings are as outlined in Table 5.2.

Technology	Objective	Method	Key findings and recommendation
Mulching	To determine effect of mulching on growth of <i>Senna</i> <i>siamea</i> and conservation of soil moisture	Murram, sand mulching and control plots (without mulch) were set up on a <i>Senna siamea</i> plot (planted in December 1995). Mulch thickness was 7-10cm. Tree parameters assessed were tree height and root collar diameter.	<ul> <li>During the first year murram mulching gave a better performance. There was no clear difference between murram and sand mulching.</li> <li>The general observation was that where soil surface cover was present, trees had better performance presumably because mulching material reduced soil moisture loss.</li> <li>It is not advisable to use grass mulch in the drylands as it usually attracts termites.</li> </ul>
Weeding	<ul> <li>To determine effect of weeding on tree growth performance</li> <li>To determine the most suitable and cost effective method for weeding</li> </ul>	Treatments included; complete weeding (with trees), slash weeding (with trees), and spot weeding and replicated 4 times. <i>Senna siamea</i> was planted in November 1999. Soil moisture sensors were installed in each of the plots.	<ul> <li>Complete weeding had higher growth performance compared to other treatments. The higher growth rate observed in trees under complete weeding could be attributed to fast establishment due to effective use of ground moisture.</li> <li>Crown cover was well spread in complete weeding</li> <li>In grassland or low bushlands, the planted area should be spot weeded to enhance tree survival and growth. This method may apply in areas where there is labour and/or financial limitation. This technique can be used in combination with other techniques such as slashing to achieve desired results.</li> <li>Slashing is the most cost effective method of weed control. It can effectively be used in combination with spot weeding.</li> <li>Weeding should be done immediately weeds emerge.</li> </ul>

 Table 5.2:
 Tree management technologies

Technology	Objective	Method	Key findings and recommendation
Pruning	To determine the optimal pruning regime for <i>Senna siamea</i>	Three types of pruning regimes, namely; <sup>1</sup> / <sub>2</sub> height, <sup>2</sup> / <sub>3</sub> height, control (no pruning) were set up in 1999. Parameters assessed were survival, height, diameter at ground level, and dieback.	<ul> <li>There was no difference in height growth between ½ height and ¾ height pruning regimes.</li> <li>Pruning height was inversely correlated to diameter growth i.e., the high the intensity of pruning, the smaller the diameter.</li> <li>Trees pruned at ⅔ height were observed to be prone to windfall.</li> <li>Over-pruning reduced the photosynthetic area and caused more bruises to the tree.</li> <li>Pruning at both levels prevented the occurrence of dieback, probable due to more light penetratin into the crown.</li> </ul>
Thinning	To determine effect of thinning on tree growth	The trial was established in 1993. The trees were planted at 2m x 2m in hole- size measuring 45cm x 45cm. Two thinning intensities and a control were set up at 50%, 75%, and 0% (control). Assessment of tree height and root collar diameter was done.	• Tree performance improved with higher thinning intensity with 75% thinning giving the best tree growth results.

Technology	Objective	Method	Key findings and recommendation
Coppicing	To determine optimal coppicing height for <i>Senna siamea</i>	The trial was established in 1999. Coppicing heights of 10cm, 40cm, 70cm, 100cm, and 150cm were administered. Tree parameters assessed were coppicing ability, survival and dieback.	<ul> <li>Initial results indicated that coppicing height of 1.5m had better coppicing ability.</li> <li>Over 70% of the trees coppiced at 1.5m had more than 8 stems as coppices.</li> </ul>

## 5.5 Species and Provenance Trials

## 5.5.1 Introduction

A key objective of the Pilot Forest Sub-project under SFTP Phase I (1987-1992) was to identify, evaluate and recommend suitable tree species for ASALs. Species and provenance trials, commenced during SFTP Phase with the aim of initiating the selection of species suitable for Kitui County. By 1992, 68 tree species had been established through phased planting. However, by October 1993, except for a few species such *Dalbergia melanoxylon, Prosopis juliflora, Tamarindus indica* and *Croton megalocarpus*, which had survival rates of between 49-92%, the other species had very low survival rate of below 1% or had died. Exotic tree species such as Eucalypts, Australian Acacias and *Grevillea robusta*, had the best initial growth performance but due to termite damage, severe drought in 1992, and competition from existing trees and bushes, most of the trees died.

To enhance survival and growth of planted trees, the Project embarked on; complete clearing to reduce competition, water harvesting, and soil preparation to improve water percolation and retention. In total, over 72 tree species were screened from 1987–1994 in an area covering more than 334 ha. The species tested were mainly exotic however, since knowledge and techniques of their establishment was limited, their survival rate was low.

Table 5 highlights the outcome of the species and provenance trials at the Pilot Forest site in Kitui County between 1987 and 1994.

Year	Methodology	Key findings and discussion
1987	Land preparation was manually done through bush clearance of 5-10 m strips with espacements of 2-4m. Planting holes were 45cm x 45cm x	Survival count results after three years showed that with the exception of <i>Acacia polyacantha (Vachellia polyacantha)</i> (59.5%), <i>Croton</i>
	45cm. Twenty four (24) tree species were planted in 1987 covering an area of 59.23ha. Maintenance was by slashing. Survival counts were done in 1988, 1989 and 1990.	<i>megalocarpus</i> (27.5%), <i>Leucaena</i> <i>leucocephala</i> (20%), <i>Prosopis juliflora</i> (39%) and <i>Tamarindus indica</i> (18%), all other tree species had died. In the subsequent count of 1993, survival of these species had dropped considerably except <i>Prosopis juliflora</i> , which recorded at rate of 35.5%. The
	drastic drop was attributed to severe drought that was experienced in 1992.	
1988	Land preparation was done manually, bush clearance of 5-10m strips with espacements of 2-4m. Thirty three (33) species were planted in an area covering 111.56ha. Planting holes were 45cm x 45cm x 45cm. Maintenance was by slashing. Survival count was done in 1989, 1990, 1991 1992 and finally in October 1993.	Results showed that most tree species recorded a survival percentage of below 30%. However, survival percentage of <i>Dalbergia melanoxylon, Acacia nilotica</i> and <i>Terminalia pruniodes</i> was between 49 and 92%. The varying performance of the same species may be attributed to site and species differences. The reduction in survival rates was as a result of low rainfall and drought experienced in 1992 season. The three species <i>D. melanoxylon,</i> <i>A. nilotica (Vachellia nilotica) and T. pruniodes</i> seemed to be well adapted to the site conditions. These trees are predominantly found in the ASALs, and therefore, naturally adapted to dry conditions. The trees have potential and were recommended for planting in dry lands. It was observed that some species were more susceptible to termite attacks notably <i>Eucalyptus spp, Acacia gerrardii (Vachellia gerrardii)</i> and <i>P. juliflora.</i>

 Table 5.3:
 Species and provenance trials

Year	Methodology	Key findings and discussion
1989	Thirty two (32) tree species were planted in an area of 26.56ha. Different technologies were tried during tree establishment to enhance tree survival. The technologies included; pit sizes, water retention structures, mulching and weeding methods. Assessment of survival rates was done in October 1990, 1991, 1992, and finally in October 1993.	Average survival rates for all species reduced drastically by 1993 when the last survival assessment was done. However, <i>Terminalia brownii</i> , <i>Dalbergia melanoxylon</i> , <i>Acacia</i> <i>nilotica (Vachellia nilotica)</i> and <i>Albizia</i> <i>amara</i> maintained fairly consistent survival rates of 91%, 72.2%, 81%, and 64%, respectively, during the last two assessments in 992 and 1993.
1994	The following 8 tree species were planted in a spacing of 3.5m by 3.5m: Acacia cowleana (18515), Acacia cowleana (18524), Eucalyptus camaldulensis (18604), E. urophylla (18094), E. urophylla (18096), Grevillea robusta (18106), Acacia crassicarpa (17601) and A, crassicarpa (17871).	Results showed that the best performing species one year after planting were: <i>Acacia crassicarpa</i> seed batch 17601 (87%), <i>E. camaldulensis</i> batch 18604 (85%) and <i>Acacia</i> <i>crassicarpa</i> seed batch 17871(82%). <i>Grevillea robusta</i> batch 18106 (63%) had the lowest survival. However, survival rates reduced by more than 20% by the end of the second year. The lowest survival rates were observed in <i>G. robusta</i> and <i>E. urophylla</i> , which are known to do well in medium and high potential zones. The best height growth was registered by <i>E. camaldulensis</i> (5.3 m), <i>E. urophylla</i> (3.9 m) and <i>A.</i> <i>crassicarpa</i> (3.8 m).

#### 5.5.2. General discussion/lessons learnt

- One of the most important experiences from the species and provenance trials is that since envornmental conditions in the ASALs are harsh, only well adopted tree species can survive, and have good growth and performance, under natural conditions. The most important challenges to tree planting in the ASALs include; low soil moisture, poor soil conditions and termite damage. Unless these conditions are amended and/or controled, survival and reliability of most species introduced in ASALs is uncertain.
- Selection of species and provenances to be tested should only include species known to do well in ASALs, and should avoid testing species adapted to highlands or medium potential conditions.

- Farmers preferred to plant Eucalypts and *Grevillea robusta* on on their farms. Due to this demand, the Project continued to introduce new species and provenances from Australia and local collections. New introduction that included; *Eucalyptus camaldulensis* and *Eucalyptus tereticornis* showed fairly good performance. *Prosopis juliflora, Jacaranda mimosifolia* and *Acacia crassicarpa* showed promising results under intensive management.
- Land preparation, and good maintenance operations are important for better tree survival and growth in ASALs. The important managment operations include: site preparation by clearing all the vegetation, land ploughing, weeding and water harvesting.
- Apart from Australian species and provenances, other species that showed good performance in terms of survival and growth included; *Melia volkensii, Terminalia brownii, Azadirachta indica,* and *Tamarindus indica.* Though slow growing, the species are considered as promising candidates species for growing in the ASALs due to their high utility value.
- Selection of species for ASALs is a difficult task as there are numerous factors which vary across the region and even within a locality, making it difficult to recommend a species found to perform well in one site for introduction to another site.

#### 5.5.3. Recommendations

- 1. Suitable exotic species recommended for planting in the ASALs included; *Eucalyptus camaldulensis*, *E. tereticornis*, *E. microtheca*, *Senna siamea*, and *Azadirachta indica*.
- 2, Indigenous species recommended for planting in the ASALs were; *Melia* volkensii, Acacia nilotica (Vachellia nilotica), A. polyacantha (Vachellia polyacantha), Terminalia brownii, Dalbergia melanoxylon and Croton megalocarpus.
- 3, More trials to enhance tree survival and growth in the drylands of Kenya should be undertaken.

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# **CHAPTER 6**

# ON-FARM VERIFICATION OF DRYLAND TREE ESTABLISHMENT AND MANAGEMENT TECHNOLOGIES

Robert Nyambati, Paul Tuwei, Dorothy Ochieng and Josephine Wanjiku

#### 6.1 Introduction

The Social Forestry Extension Model Development Project (SOFEM) was implemented jointly by Kenya Forestry Research Institute (KEFRI), Kenya Forest Service (KFS) formerly Forest Department and Japan International Cooperation Agency (JICA) in selected divisions in Kitui County. Under this project, tree planting technologies developed for arid and semi-arid lands (ASALs) through on-station trials at Tiva Pilot Forest were verified on farmers land using farmers resources hence termed as on-farm trials. The on-farm trials were necessary given that the tree establishment and management technologies had been developed at on-station level using heavy machines such as bulldozers to prepare the trial sites, and a lot of human labour were involved. Since heavy machinery and high labour input may not be affordable to most farmers, which may hindering adoption of such technologies. The on-farm verification of the forestry technologies aimed at assessing modification of the technologies by farmers, hereby making them cheaper and easier to adopt as farmers were encouraged to use their own skills and resources (Kyalo and Okamoto, 2002).

Technologies verified in the farms were: site preparation technologies; use of different tree planting hole sizes; water harvesting technologies; weeding regimes/methods which included: complete, spot and slash weeding methods; pruning ratios of half height ratio and two thirds height ratio; termite control using local concoctions; fruit establishment and fodder establishment.

## 6.2 Justification

In the drylands, water scarcity is a key factor affecting tree-growing activities. The tree planting technologies selected for verification were for ensuring adequate moisture availability for plants through reduced competition, enhanced water infiltration into the soil and uptake by plants. Site preparation enhances tree growth and survival in the drylands as it reduces competition for moisture and increase water infiltration into the soil as well as uptake by the plants. Appropriate hole-size contributes to holding adequate moisture for tree growth. Micro-catchment structures trap run off water and conserve it for tree growth.

Weeding reduces competition for the scarce water resource hence ensures it is more available for tree growth.

The objectives of on-farm verification of dryland tree planting technologies developed on-station were to;

- 1. Apply and verify technologies developed on-station under different farmland conditions.
- 2. Demonstrate the technologies to pilot forest adjacent farmers to promote adoption.

#### 6.2.1 Site preparation trial

Tree survival and growth in drylands is determined by site preparation, among other factors. Site preparation is mainly influenced by; soil type characteristics, slope, and available tools. In the drylands, site preparation is primarily aimed at increasing trees access to the limited moisture and nutrients from the soils. Two site preparation technologies that is, oxen ploughing and hand tilling were verified on-farm.

#### 6.2.1.1. *Objective*

To validate site preparation technologies under on-farm conditions.

#### 6.2.1.2. Site description

Four farms were selected from four different sub-counties in Kitui County. The farm characteristics are described in Table 6.1.

Trial site	Area (ha)	Slope	Soil type	Average rainfall (mm)	Pre-site condition
OF-A	0.08	25° (None)	Luvisols	572.6	Grazing land
OF-B	0.11	5°(Exist)	Regosols	669.6	Farm land
OF-C	0.07	4º (Exist)	Cambisols	723	Farm land
OF-2E	0.12	(None)	Ferralsols	782	Grazing land

Table 6.1	: Site	description
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#### 6.2.1.3. Experimental design and management

The trial design had three treatments that is oxen ploughing, hand tilling and a control with two replicates in each farm. The treatments were combined with use of W-shaped water catchments except for trials established in 1998 where V-shaped water micro-catchments were used. *Melia volkensii* was the trial

species which was spaced at 3.5 m by 3.5 m and hole sizes of 45 cm by 45 cm by 45 cm. Tending activities involved complete weeding twice per season and repair of broken micro-catchments. Assessments of survival rate and growth rate were done every three months.

## 6.2.1.4. Results and discussion

Trees planted under oxen ploughing and hand tilling site preparation methods had on average higher survival rate compared to the control across the sites (Table 6.2). There were variations in survival rates among the sites. Sites OF-C and OF-2E had higher survival rates compared to OF-and OF-B, which could be attributed to higher rainfall received in the two sites (Table 6.1).

Site	Survival	% per tr	Avorago Survival %		
treatment	OF A	OF B	OF C	OF 2E	Average Survivar 70
Oxen Plough	40	38	90	90	64.5
Hand tilling	60	22	90	95	66.75
Control	20	0	56	82	39.5

 Table 6.2:
 Survival data for site preparation trial

There were variations in height growth across sites (Table 6.3). Farm OF-C had the highest average height growth, which could be attributed to the good condition of the farm (relatively flat terrain, higher rainfall and sandy soils), which are suitable for Melia growth. Oxen ploughing gave the highest average tree height growth followed by hand tilling.

 Table 6.3:
 Height growth for site preparation trial

Site preparation treatment	Heigł	<b>it growth</b> i			
	OF A	OF B	OF C	OF 2E	Average height (cm)
Oxen plough	460	250	610	610	482.5
Hand tilling	560	110	580	590	460.0
Control	500	0	680	550	432.5
Average	506	120	623	583	

Oxen ploughing gave the highest root collar diameter growth followed by control

(Table 6.4). Site OF-2E had the highest average root collar diameter growth, which could be attributed to flat terrain, higher rainfall and soil type.

Site preparation	Root c	ollar diam (May	Average root collar diameter (cm)		
treatment	OFA	OF B	OF C	OF 2E	
Oxen Plough	9.8	4.8	11	13	9.7
Hand tilling	12	2	8.9	12.8	8.9
Control	12.2	0	14.2	10.2	9.2

 Table 6.4: Root collar diameter growth for site preparation trial

#### 6.2.1.5. Conclusion and recommendations

- Site preparation plays a critical role in survival and growth of trees on-farm.
- Site conditions influences tree survival and growth.
- Site conditions interact with site preparation technologies to influence survival and growth of planted trees.
- Oxen ploughing gave higher performance compared to other treatments.
- Given the natural condition prevailing in ASALs, site preparation is recommended to enhance water capture, infiltration, retention, and root penetration.
- In farmlands, which are flat and the soil is sandy, site preparation in terms of tilling and oxen ploughing may have little effect on tree survival and growth as water percolation is high as opposed to planting on a sloppy ground with clay soils (Kyalo and Okamoto, 2002).

# 6.2.2. Verification of different planting hole sizes

Tree establishment and management in ASALs is constrained by low and unreliable rainfall among other factors. Preparation of planting holes is an important aspect in promoting initial tree establishment and survival in the drylands. The amount of water harvested, retained and initial root development space is influenced by hole size.

# 6.2.2.1. *Objective*

To compare tree performance under different hole size on-farm.

# 6.2.2.2. Trial design

Four farms were selected from four sub-counties of Kitui County. The experiment was conducted between November 1998 and November 2002. The experimental

design used was complete randomized block design with three treatments; 20cm by 20cm, 45cm by 45cm and 60cm by 60cm replicated two times in each farm. The species used for this trial was *Azadirachta indica*. Assessment for growth parameters was done every three months.

# 6.2.2.3. Results and discussion

Survival of planted trees was not significantly affected by the different hole sizes. The survival percentage varied from 80% to 95% for the various planting holes. The results could be attributed to oxen ploughing done in the farm before digging holes.

## 6.2.2.4. Conclusion and recommendations

- There were variations in growth performance of different hole sizes.
- The largest hole size of 60 cm by 60 cm had on average the best performance two years after planting which was attributed to more water collecting in the planting hole and reduced competition from weeds.
- Given the labour constraint in the preparation of the different holes sizes, the 45 cm by 45 cm holes was recommended for tree growing in drylands compared to 60 cm by 60 cm hole size.

# 6.2.3. Water micro-catchment technologies

Water is one of the most limiting factors for afforestation in the ASALs. Innovative water harvesting and retention technologies are critical in the initial stages of tree establishment in drylands. Use of micro-catchments for tree establishment has been found to be successful under on-station conditions. However, the same had not been tried under on-farm conditions hence the need of verification.

# 6.2.3.1. *Objective*

To compare the performance of trees under different water micro-catchment technologies.

# 6.2.3.2. Trial design

This trial was carried out on five farms in Kitui County. The trial comprised of three treatments; two micro-catchments (V-shape, W-shape) and a control (without micro-catchment) replicated twice on each farm. Farm slopes ranged from 4° to 23°. The tree species used in the trials were *Grevillea robusta, Senna siamea* and *Azadirachta indica*. The angle of the constructed micro-catchments was maintained at 150° to reduce damage of oxen plough furrows through pressure caused by collected water at one point. Survival rates and growth (height and root collar diameters) were assessed every three months.

## 6.2.3.3. Results and discussion

Trees under micro-catchments W and V had higher survival rates ranging from 70% to 90% as compared to the control, which had survival rate of less than 60%. However, in farmlands with gentle slopes and well drained soils, the effect of micro-catchments on tree survival and growth was minimal.

#### 6.2.3.4. Conclusion and recommendations

- Micro-catchments are important for tree establishment in the drylands and they are more effective on sloppy areas than on flat sites.
- Weak micro-catchments (with embankment height of 20 cm) are easily washed away by runoff water.
- W-shaped micro-catchments are easily damaged by run off compared to the V-shaped micro-catchments. However, where W-shaped are to be used, they need to be widened and they should be along the contour trenches.
- Where the slope is steep, use of terraces is preferable to use of microcatchments.
- Adoption of micro-catchments has not been very high because they require frequent repairs.
- Micro-catchments are more effective on gentle slopping sites.

## 6.2.4. Weeding trial

Water plays a critical role in tree establishment and survival. However, this resource is scarce in drylands due to low and unreliable rainfall. For successful establishment and growth, trees in ASALs require minimum competition for water and nutrients. Weeding (removal of unwanted vegetation), is recommended as one of the cultural practices to minimize competition.

## 6.2.4.1. Objective

To compare tree performance under different weeding methods on-farm.

## 6.2.4.2. Site description

The trial was established in 1999 and 2000 in two sub-counties, namely: Chuluni (one farmer-OF 4) and Mutomo (two farmers- OF 5 and OF 2F) in Kitui County (Table 6.5).

Trial site	Area (ha)	Slope	Average rainfall (mm)	Soil type	Pre-site condition
OF-4	0.16	10	572.6	Luvisols	Grazing land
OF-5	0.15	none	669.6	Luvisols	Grazing land
OF-2F	0.13	none	723	Luvisols	Farm land

 Table 6.5:
 Site description

## 6.2.4.3. Experimental design

This trial was carried out in three sites in Kitui County. The experiments were set as a complete randomized block design with three treatments (complete weeding, spot weeding and slashing) replicated twice. Survival rate and growth (height and diameter) were assessed every three months. The species used for this trial were *Senna siamea* and *Azadirachta indica*.

#### 6.2.4.4. Results and discussion

• There were variations in survival across sites and weeding methods used 2 years after planting. The survival ranged from 88% to 100% (Table 6.6). Although complete weeding had been observed to give better performance in other trials, in this case, spot weeding was observed to give higher survival compared to complete weeding. This observation was attributed to browsing and physical damage of trees during slashing in the complete weeded area.

Weeding treatment	Surviv	al % per (Ma	Average survival %		
	OF 4	OF 5	OF 2F	per treatment	
Complete weeding	98	95	100	97.7	
Spot weeding	100	100	100	100.0	
Slashing	90	88	100	92.7	

<b>Table 6.6:</b>	Tree	survival	rate	for	weeding	trial
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• Complete weeding gave the highest tree height growth followed by spot weeding (Table 6.7). This can be attributed to reduced competition for moisture and nutrients. Complete weeding treatment, gave the highest root collar diameter followed by the spot weeding treatment across all sites.

Waading treatment	Height	growth in	Arreno za kojakt (am)	
weeding treatment	OF 4	OF 5	OF 2F	Average neight (cm)
Complete weeding	590	450	240	426.7
Spot weeding	580	280	140	333.3
Slashing	500	190	130	273.3
Average height (cm)	556.7	306.7	170.0	

 Table 6.7:
 Height growth for weeding trial

#### 6.2.4.5. Conclusion and recommendations

- Complete weeding gave the best overall performance and therefore, recommended for dryland condition.
- Weeding ensures that trees grow well without competition for moisture and nutrients from weeds
- Intercropping trees and crops maximizes benefits for the farmer in that cost of labour for weeding is reduced while cultivation enhances water infiltration and aeration of the soil.

#### 6.2.5. Pruning trial

Tree pruning is mainly done for timber tree species with the main purpose of producing knot-free timber. In intercropping systems, pruning is also done to reduce the lateral growth of branches, which shade crops from sunlight. Pruning height ratios developed on-station were tested on-farm to identify the most applicable one for farmers.

## 6.2.5.1. *Objective*

To validate pruning technologies developed on-station under on-farm conditions.

## 6.2.5.2. Trial design

The design used was completely randomized block design with three treatments namely; two thirds pruning ratio, half pruning ratio, and control (no pruning). *Melia volkensii* was used as a trial species. The spacing adopted for the trial was 3.5m x 3.5m and the hole size was 45 cm x 45 cm. Tending activities in the trial sites involved complete weeding twice per season and repair of broken microcatchments.
#### 6.2.5.3. Results and discussion

- Survival of planted trees ranged from 80% to 100%. There was no significant difference in survival rates between the different pruning ratios and the different sites at one and half years after planting.
- Different pruning ratio had no significant difference on height at 1.5 years. However trees pruned at high level had lower collar diameter.

#### 6.2.5.4. Conclusion and recommendations

Pruning timber species such as *M. volkensii* is aimed at increasing the usable bole height and ensuring it is straight and smooth to provide knot free timber at harvesting age.

#### 6.2.6. Fruit trees establishment

Fruit trees constitute important biological resources in many agro-ecological systems and forest ecosystems all over the world. The assertion is evident since these tree species have long-term economic benefits and ecological impact in nature. Fruits are rich in essential nutrients, antioxidants and other health benefits for people and other animals without alternation in most cases (Rathore, 2003; Lapeña *et al.*, 2014). Fruit trees traditionally provide rural communities in Sub-Saharan Africa's drylands, with nutritious fruits for consumption and sale. However, farmers lack critical information on characteristics such as; drought resistance, growth performance, and productivity of the different fruit species. There is a need for different species and provenance trials on-farm, in-order to improve fruit production at farm level.

#### 6.2.6.1. *Objective*

To compare performance of various fruit tree species under different farming conditions.

#### 6.2.6.2. Design treatment

On-farm fruit tree trials were carried out in 1998, 1999 and 2000 in 15 farms in four different locations of Kitui County. The key fruit tree species commonly grown in drylands such as *Mangifera indica* (5 varieties), *Citrus sinensis, Psidium guajava*, and other indigenous fruits were established in all the sites. Survival rate and other growth parameters such as height were assessed every three months.

# 6.2.6.3. Method of planting and tending

Site preparation was done by bush clearing and removal of all existing vegetation. This was followed by oxen-ploughing. The seedlings were planted at a spacing of  $7m \ge 7m$  and  $5m \ge 5m$ , and hole sizes of  $60cm \ge 60cm$ . W-shaped microcatchments were constructed but V-shape were used in 1998/1999. Tending activities included repairing of micro-catchments and complete weeding (two times in each rain season). Watering at a rate of 5 litres per week per tree was done during the dry season.

#### 6.2.6.4. Results and discussion

#### (i) Survival rate

The survival rate of *M. indica* ranged between 0% and 75% (average 41%) in the first year and 0% to 55% (average 22%) in the second year. In general, there were high differences in survival rates. However, watering during the dry season improved the survival rate of *Mangifera indica* to 62% in the first year.

The survival rate of *Citrus sinensis* ranged between 0% to 100% (average 74%) in the first year and 0% to 35% (average 35%) in the second year. In general, there was high variability in survival rates. However, watering during the dry season improved the survival rates of *C. sinensis* to 90% in the first year.

Survival rate of indigenous fruit trees ranged from 90% to 100%. However, survival rate of *Tamarindus indica* was low. Generally, survival rate of the indigenous fruit trees did not change much even after two and half years. The indigenous fruit trees grew well without watering, despite browsing by livestock during the dry period.

# (ii) Growth performance

Height of *M. indica* ranged between 10cm and 71cm (average 35cm) by the end of the first year and 22cm to 75cm (average 49cm) by the end of the second year. In general, there were high variability in height growth although slow. Where watering was done, height growth increased by 40cm and 72cm in the first and second year, respectively.

Height of *C. sinensis* ranged between 30cm and 50cm (average 46cm) in the first year and 40cm to 56cm (average 45cm) in the second year. Comparatively, the height growth of *C. sinensis* was slower than that of *M. indica*. Watering improved growth to average of 52cm by the end of first year with minimal increase in the second year.

The following observations were made;

(a) Mangifera indica grew better than Citrus sinensis despite the browsing.

(b) Although watering (4-5 litres/week), improved the growth of *M. indica*, the same was not observed for *C. sinensis*.

Height growth for indigenous fruits ranged from 25cm to 75cm (average 47cm) by the end of the first year and 61cm to 193cm (average 124cm) by the end of the second year. With the exception of *Tamarindus indica* whose growth performance was low, the growth of other fruit trees was higher. It is important to note that indigenous fruit trees grew well without watering and withstood heavy browsing during the dry spell.

In most of the trial sites, the fruits were not watered and the problem of browsing was evident which led to low survival and growth performance. However, the following were observed;

- *Mangifera indica* and *Citrus sinensis* required watering (at least 5 litres/ week) during the dry period.
- Indigenous fruit trees were tolerant to drought, therefore they required minimal water during the dry season.
- Livestock also browsed on indigenous fruit trees, but the recovery rate was high, which contributed to low mortality rate.
- Many farmers were not able to water their fruit trees during the dry season.
- In some sandy soil sites, *Mangifera indica* showed better growth even without watering. This could be attributed to the fact that sandy soils have a good drainage allowing for good root growth during the rainy season; sand soils also allow infiltration of water which is retained in the lower soil layers.

# 6.2.6.5. Conclusion and recommendation

- *Mangifera indica* and *Citrus sinensis* require supplemental watering and protection from browsers in the first two years. Planting of *M. indica* and *C. sinensis* is recommended only to farmers who are able to water, harvest run-off and protect the fruit trees from the browsers.
- Naturalized fruit trees such as *Psidium guajava*, which have a high ability to withstand dry condition, are highly recommended to farmers, as they are less labour intensive, do not require watering and recover fast from browsing.

# 6.2.7. Fodder growing on-farm

In Kenya, the drylands constitute 89% of the land surface, support 14 million people, and 70% of the total country's livestock (RoK, 2012). Pastoral livestock

contributes over 50% of agricultural Gross Domestic Product (GDP) in Kenya (Rodriguez, 2008). Further, the livestock subsector in Kenya employs about 90% of the ASALs population who derive up to 95% of their households income from livestock production (GoK, 2003). Despite the enormous contribution to local and national economies, pastoral and agro-pastoral production system in the country are facing a myriad of problems, among them climatic, environmental, economic, and socio-political challenges. Fodder plays a critical role in livestock production systems in ASALs, more so during the dry season. Fodder shortage in the dry season is a big challenge as it causes livestock losses.

# 6.2.7.1. Objective

To validate suitable tree species for on-farm fodder production in ASALs.

# 6.2.7.2. Trial design

Key fodder species; *Melia volkensii, Calliandra calothyrsus, Leucaena leucocephala Prosopis pallida* and *Prosopis juliflora* were tested. The species were planted on-farm at spacing of 3.5m x 3.5m spacing. Farmers intercropped the trees with food crops such as maize, beans, and cowpeas.

# 6.2.7.3. Results and discussion

#### (i) Survival rate

There were variations between species and across sites. Survival percentage was generally high for *Prosopis pallida, Prosopis juliflora* and *Leucaena leucocephala* ranging between 80% and 100% during the first year. *Calliandra calothyrsus* had the lowest survival percentage at 5% by the end of the first year. The low survival was attributed to severity of drought as well as browsing. Survival of *Melia volkensii* ranged between 10% and 50% during the first year. This was attributed to water logging at the time of planting.

#### (ii) Growth performance

By the end of the first year, *M. volkensii* had the best overall performance ranging between 2m and 2.5m. The other species attained heights ranging between 0.5m and 1.5m. Variations in growth performance could be attributed to adaptability of the species to the environment, repeated browsing as well as natural potential to generate. By the end of the first year, *L. leucocephala* could be harvested while the other species required more time to produce pods to be used as fodder.

Harvesting of *L. leucocephala* at 1 m height gave good coppicing results. The species was responsive to frequent harvesting even during dry periods. However, the performance of *Calliandra calothyrsus* was generally poor. This could be

attributed to the species being more adapted to cooler humid areas, therefore, is not suitable for growing in the drylands.

#### 6.2.7.4. Conclusions and recommendations

- *Leucaena leucocephala* gave the best overall performance and recommended for growing in dry areas such as Kitui County.
- Where livestock is under free range, the species require protection against browsing.
- Although *Calliandra calothyrsus* has high fodder potential, it is not recommended for drylands as it is more suitable for humid sites.
- Most of the species tried have nitrogen-fixing ability and could be intercropped with crops to maximize productivity of the land unit.
- Further research should be undertaken on; frequency of harvesting, competition for nutrients and water, and coppicing ability.
- Though *Prosopis pallida*, and *Prosopis juliflora* had shown good growth performance it is not recommend to introduce the species has it shown great potential of being invasive.

# 6.2.8. Termite control experiment

Termite has been one of the main causes of poor tree establishment in the drylands as they cause mortality of both seedlings in the nursery and saplings planted in the field. Most exotic tree species planted in the drylands, such as *Eucalyptus spp*, *Grevillea robusta*, *Casuarina spp* and *Leucaena spp* are very susceptible to termite attack. Termite attack is higher during the dry season, when the trees are stressed due to limited moisture availability in the soil. During the project period, it was noted that farmers were using both traditional (organic concoctions) and conventional methods (commercial chemicals) for control of termites. The commercial chemicals are considered to be more effective and are able to improve the survival rates of the target species. However, the chemicals are; known to be poisonous if not carefully handled, not environmentally friendly and expensive for most farmers. The traditional methods used by farmers are considered to be; cheap, easily available, safe for human health and friendly to the environment. The effectiveness of the traditional methods in controlling termites have not been scientifically validated hence the need for the study.

# 6.2.8.1. Objective

To determine the effectiveness of different organic concoctions made from local materials for controlling termite damage on *Grevillea robusta*.

# 6.2.8.2. Materials and methods

The experiment was conducted at Tiva Pilot Forest in Kitui County in November 1999. The area receives rainfall of 400mm to 800mm per year with an average temperature of 28°C.

#### 6.2.8.3. Trial design

The experiment was complete randomized block design. It was set up to study the effectiveness of various materials, initially reported to be effective in the control of termite. The material under test included; neem cake, tobacco powder, mixtures of chilli (pepper) + Omo (washing detergent) + tobacco, and control (no concoction). Three replicates were undertaken and each treatment consisted of eight plants. The test species was *Grevillea robusta*. Survival percentage, height and diameter were measured every 3 months.

#### 6.2.8.4. Results and discussion

The results show that most of the treatments were effective in the short-term (lasting upto ten months). Their effectiveness decreased gradually as indicated by the decrease in survival rates. As at the end of the experiment after 21 months, survival ranged between 21% and 29%, (Table 6.8) which was generally low. Tobacco powder had the best overall performance in the first 10 months.

	Survival (%)					
Treatments	After 6 months	After 10 months	After 15 months	After 18 months	After 21 months	
Neem cake	63	58	38	29	25	
Tobacco Powder	88	87	31	21	21	
Chilli + Omo+Tobacco	67	67	38	38	29	
Control	54	54	50	29	21	

 Table 6.8:
 Survival rate for termite control experiment

# 6.2.8.5. Conclusion and recommendations

- The effectiveness of various concoctions varied greatly.
- In the short term, tobacco powder was effective.
- Effectiveness of the concoctions decrease with time.
- Further studies should be undertaken to provide information on; concentration, dosage and frequency of application, duration to reapplication and the residue effects.

- Most of the local materials used, need to validated for their effectiveness and application rates standardized.
- Planting termite resistant tree species such as *Tamarindus indica*, Acacia spp., *Azadirachta indica*, *Dalbergia melanoxylon*, *Terminalia brownii*, *Schinus molle* and *Melia volkensii* is recommended.

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# **CHAPTER 7**

# **BRINGING** *MELIA VOLKENSII* AN INDIGENOUS DRYLANDS TREE SPECIES INTO CULTIVATION

Bernard Kamondo, Josephine Wanjiku, Dorothy Ochieng, Paul Tuwei and Musingo T. E. Mbuvi

# 7.1 Introduction

Due to over-exploitation and forest fragmentation in Kenya, many indigenous trees are under threat of disappearance and there is urgent need to bring them to cultivation through domestication. Tree domestication involves identification, characterisation, selection, multiplication, and cultivation of high-value tree species in managed systems such as plantations or woodlots. The main objective of domestication is to enhance sustainable provision of tree products and services by encouraging cultivation of trees by small- and large-scale farmers while conserving wild populations through reduced pressure on the natural resource base. Cultivated germplasm also serves as useful *circa situ* or *circa situm* conservation also referred to as farm based conservation (Boshier *et al.*, 2004; Maheswarappa *et al.*, 2022), if genetic diversity is taken into consideration in selecting materials to grow on farm (Simons and Leakey, 2004). In Kenya, *Melia volkensii* was identified for domestication in the drylands due to it adaptability in the drylands and the threat of disappearance it faced in the wild from over-exploitation for its high quality timber.

#### 7.1.1 Spread and ecology of Melia volkensii

*Melia volkensii* (Melia) occurs naturally in drylands of eastern Africa, i.e. Eastern and North Eastern Kenya, Southern Somalia, Ethiopia and Northern Tanzania (Dale and Greenway, 1961; Milimo, 1986; Kidundo, 1997). The species is found naturally growing in: dry bushland, woodlands, wooded grassland, and coastal hinterland; areas lying between 80 and 1600 m above sea level; and agro-climatic zones V-VI, where temperature ranges from 26-38°C, and annual rainfall of 300-800 mm. Melia is normally found in well-drained sandy clay and stony soils, although it also occurs on sites classified as imperfectly drained soils (Muok *et al.*, 2001). The species belongs to the Meliaceae family and is locally known as Mukau (Kamba, Embu and Tharaka), which is also its trade name, and Mpenda bure (Swahili).

#### 7.1.2 Tree description

*Melia volkensii* is a deciduous tree (sheds leaves during the dry season). The tree has a light, rounded spreading crown with branches that hang down low. Melia is a fast-growing tree. Mature trees range between 6 to 20 m tall and 40 cm diameter in 10 to 18 years, depending on genotype, site conditions, and management. However, in the wild, trees with clear long boles are increasingly rare due to over-exploitation and selective harvesting. The bark is grey, fairly smooth but furrow with age. The leaves are bright green, compound bi-pinnate with (sub) opposite leaflets. The leaflets are oval, tapering to the apex. Flowers are small, white and fragrant, borne on a dense inflorescence. The fruit is drupe-like and oval, and colour changes from green to yellow as the fruit matures. Fully mature fruits develop brown patches. Fruit size is normally 4 cm long with a very thick, bony endocarp. Different stages of Melia tree development are shown in Figure 7.1.



a) Melia tree with clear bole selected for domestication



b) Fruiting Melia tree



c) Ripe Melia fruits



d) Melia plantation on-farm during wet seasons

Figure 7.1: Melia tree development at different stages

# 7.1.3 Uses of Melia volkensii

*Melia volkensii* is highly preferred in the drylands due to its drought tolerance, and high quality and termite resistant timber used for construction. Other products of Melia include; poles, posts, fodder (fruit and leaves), medicine (bark), firewood, bee forage, mulch and green leaf manure (Luvanda *et al.*, 2015; Kimondo and Kiamba, 2004). The species provides services such as soil improvement and is found in tree-crop mixtures on-farm (Kimondo and Kiamba, 2004; Muok *et al.*, 2001).

#### 7.2 Justification for Bringing M. volkensii into Cultivation

Melia populations in the wild have over the years continued dwindling due to over-exploitation. In natural stands, mature Melia trees of good form, have been heavily exploited for timber leaving trees of poor form. The threat facing Melia populations is exacerbated by clearing of woodlands for conversion into agricultural lands. Frequent droughts also have had adverse effects on the species in the wild, aggravating genetic erosion, which is expected to worsen due to climate change as environmental stresses increase. The lack of *ex-situ* conservation strategies for Melia has unfortunately led to disappearance of many candidate plus trees (CTPs) as well as populations.

Melia is a fast growing species producing quality timber in 10 to 12 years (Mulatya, 2000; Kimondo 2002; Muchiri and Mulatya, 2004). It has been demonstrated that with appropriate silvicultural interventions, Melia can be intercropped with crops or grown in plantations in the drylands. Melia being a high value tree species whose products are highly sought, combined with its inherent silvicultural potential of fast growth, make it a species of high priority for domestication.

To maximize gains from domestication process of Melia, selection of good quality trees, their *ex-situ* conservation and breeding were identified as the most promising intervention towards sustainable development of *M. volkensii* (Kariuki and Muchiri, 2017). The fast growth and tree with better form that were initially found on-farm, compared to those in the wild, suggested tremendous potential gains through domestication.

A survey undertaken in areas of Melia occurrence in drylands of Kenya, indicated that where Melia was intensively managed, merchantable height ranged from 40% to 42% of total tree height. For trees that were growing in the wild without any form of management, merchantable height was from 28% to 30% of total tree height (Muchiri and Mulatya, 2006). This difference suggests that merchantable height of Melia could be improved through management.

# 7.3 Traditional Techniques for Raising M. volkensii Seedlings

Historically, large-scale planting of Melia was constrained by difficulties in germinating seed and lack of technologies for raising seedlings, leading to postgermination losses. However, due to high value of the species, farmers developed indigenous technical skills, which they applied to raise Melia seedlings. The traditional skills included scarification through burning of nuts, and use of nuts regurgitated by goats (Kidundo, 1997), as well as use of sprouts that arise from injured roots. KEFRI undertook a survey to document farmers methods and techniques for raising Melia (Mwamburi *et al.*, 2006). The survey established that seven (7) traditional methods commonly applied by farmers to break seed dormancy and enhance seed germination are as highlighted in Table 7.1.

No.	Method	Procedure	Germination rate
1	Burning of nuts	• Farm residues are uniformly laid on the ground to a thickness of 10cm - 15cm	An approximate germination of 5% - 10% occurs 1 - 3
		• 1 - 3 stacks of either fresh or dry nuts are laid on the residue	weeks after onset of rains.
		• The nuts are then covered with another 10cm - 15cm layer of farm residue and lit	
2	Use of troughs	<ul> <li>Troughs of about 20cm - 30cm deep and 60cm wide are dug 2</li> <li>3 months before onset of rain</li> </ul>	An approximate germination of 10% - 25%, is achieved.
		• The nuts are then sandwiched between two equal layers of fresh manure up to <sup>2</sup> / <sub>3</sub> the depth	
		• The top $\frac{1}{3}$ depth is filled with soil	
		• The trough is then covered with grass and watered thoroughly	

 Table 7.1: Common traditional methods of breaking Melia seed dormancy on farms

No.	Method	Procedure	Germination rate
3 Cracking of nuts		• Current year nuts are collected from goat sheds and cracked using machetes with nuts placed on either wood or stones	Germination occurs in 1 - 3 weeks.
		<ul> <li>The exposed seeds are sown in containers at depths of 2cm - 3cm</li> </ul>	
		• The sown seeds are thoroughly watered once	
		• The container is then covered tightly with polythene sheet	
4	Long- term beds	<ul> <li>Fresh nuts from goat shed are sown in a sunken bed and covered with manure 2 – 3 months before rains</li> </ul>	Germination occurs every rainy season over a period.
		• The bed is watered once	
		<ul> <li>The bed remains in place for 2 – 3 rainy seasons</li> </ul>	
5	Sunken beds	<ul> <li>Fresh nuts from goat shed are sown in sunken beds of 10cm</li> <li>15cm depth and covered with manure</li> </ul>	Germination occurs in about 30 days.
		• The beds are watered once per day	
6 Dire sow seed	Direct sowing of	• Nuts are cracked to remove the seeds	Germination occurs after 1-3 weeks.
	seeds	• 3 - 10 seeds are then sown per hole at depths of 5cm - 10cm just before rains	
7	Sowing of nuts	<ul> <li>Current year nuts were sown in seedbed using forest soil</li> <li>They were watered once a day</li> </ul>	A germination of about 20% was achieved after 8 - 10 weeks in one nursery.

Adapted from Mwamburi et al., 2006.

# 7.4 Melia Seed Collection, Processing and Sowing Techniques

Successful propagation of Melia depends on appropriate; seed collection, processing, germination techniques, and nursery management.

#### Seed collection

- Identify mother trees with desired traits such as height, good branching, straight-bole, healthy trees.
- Collect by picking only mature yellow fruits with brown patches from selected tree.

#### Seed processing

- Use a pestle and mortar to remove the fleshy cover of the fruit leaving a nut, a process known as de-pulping.
- Wash the nut in clean water and then dry under sun for about two days.
- Using a nut cracker, crack the nut to extract the seeds. If cracker is not available, carefully cut the nut using a sharp knife after placing it on a grooved wooden plank. Cut the nut perpendicular to the nut length taking precaution not to slice through the seeds. Any immature nut should be removed by hand sorting.

The various processes of extracting Melia seed are as shown in Figure 7.2.



a) De-pulping of Melia fruits using a mortar and pestle



b) Cracking nut using a grooved wooden plank and a knife



c) Cracking nut using a nut cracker

d) Processed Melia seed

Figure 7.2 (a, b, c, d): Melia seed extraction methods

Experienced extractors can extract 1kg of Melia seed per day, which is about 2500 seeds. Extractors with moderate experience can extra 0.5kg of seed per day.

#### Melia seed extractor (Nut cracker)

Among the factors that hindered mass propagation of Melia was seed extraction from the hard stony nut (endorcarp). Initially, seed extraction was undertaken by cracking the nut using a sharp kitchen knife while placing the nut on a grooved wooden plank (Figure 7.2 b). This method was however, slow, cumbersome and led to seed injuries, consequently resulting to low seed extraction rate.

A more efficient extraction tool nut cracker (Figure 7.2c and 7.3), which was easy to handle, faster and less destructive to the seed was developed in 1993 (Kyalo *et al.*, 1997). The machine increases the rate of seed extraction by increasing precision of breaking the nut. It reduced seed damaged during extraction from 75% using knife to 10% using the machine (Lugadiru, 2006).

To effectively extract seeds using the nut cracker:

- Place and fasten the nut cracker firmly on a table for safe operations.
- Sort nuts into uniform size classes by visual means.
- Place the nut onto the nut rest slot with nuts long axis perpendicular to the knife.
- Raise the knife holder and using optimal force, crack the nut.
- Gently ease out the seeds from the cracked nut.



# Seed pre-treatment and sowing

A Melia seed pre-sowing technology was developed by KEFRI (Milimo, 1989). The technology when correctly applied on mature seeds enhances germination to 80%. The pre-sowing procedure and pre-treatment involves the following steps:

- Nick at the sharp end of seed.
- Soak the seed in cold water for 12 24 hours.
- Sterilize sand (the sowing medium) by use of appropriate chemical fungicide or baking.
- Put the sterilized sand into the sowing bed.
- Using a sharp clean knife, slit soaked seed coat longitudinally.
- Sow seed in the sterilized sand and water once.
- Cover the seeds with transparent polyethylene sheet.
- Ensure that the sowing medium remains moist.
- Seed germination will begin in 3 6 days after sowing and attain maximum germination at about 20 days (Figure 7.4a).



a) Melia seed germinating in a seedbed

b) Melia seedlings

#### Figure 7.4 (a, b): Melia seed germination and seedling growth in the nursery

#### Pricking out and tending of seedlings in the nursery

- Prick out seedlings 1 3 days after germination. Ensure early pricking out to avoid mortalities.
- Prick out seedlings into the pots filled with well-drained potting medium that may consist of soil: sand: manure at a ratio of 3:1:1. Since Melia is sensitive to water logging, only water when the potting media is almost dry.
- Place potted seedling under shade in a green house or under polyethylene sheet.
- Retain the seedlings in the green house before hardening.
- Harden seedlings for 15 days by removing the seedlings out of the shade and reducing watering intensity to expose seedlings to conditions similar to field conditions (Figure 7.4b).

# 7.5 Melia Establishment and Management in the Field

Melia seedlings should be planted out when they are about 30 cm tall.

# 7.5.1 Spacing of Melia

KEFRI has undertaken trials to establish appropriate Melia establishment and management protocols. Before planting, the land was cleared and deep ripped with bulldozer to enhance water infiltration. Trees were planted at a spacing of 2.5 m x 2.5 m, 3.0 m x 3.0 m, 3.5 m x 3.5 m and 4.0 m x 4.0 m. Weeding was first done until the tree canopy closed. The trees were assessed for survival rate, diameter at breast height and height at  $1^{1/2}$  years.

Data after  $1\frac{1}{2}$  years, showed that survival rate ranged from 69.4% for 2.5m x 2.5m spacing to 76.6% for the 3.5m x 3.5m spacing. However, survival was not significantly different among the treatments. The highest mean height of 3.83m was attained in the 3.5m x 3.5m spacing, whereas mean diameter was highest at both 3.5m x 3.5m and 4.0m x 4.0m spacing as presented in Table 7.2 (Kimondo and Ouma, 2006.)

Treatment	% Survival	Height (m)	Diameter (cm)	
(Spacing)		Mean± se		
2.5 x 2.5m	69.4	$3.36 \pm 0.06$	$4.2 \pm 0.1$	
3.0 x 3.0m	71.3	$3.38 \pm 0.08$	$4.4 \pm 0.1$	
3.5 x 3.5m	76.6	$3.83 \pm 0.09$	$5.0 \pm 0.1$	
4.0 x 4.0m	72.8	$3.70 \pm 0.11$	$5.0 \pm 0.2$	

<b>Table 7.2:</b>	Percentage survival, mean height and diameter of trees at
	different spacing treatments of Melia volkensii at 1 <sup>1</sup> / <sub>2</sub> years

A wider spacing experiment was thereafter set to test optimum spacing of Melia. The species was planted at a spacing of  $3m \times 3m$ ,  $4m \times 4m$ ,  $5m \times 5m$  and  $6m \times 6m$ . Data from 8-year old trees, showed that wide spacing of  $6m \times 6m$  favoured height, diameter at breast height and crown diameter which could be attributed to less competition for above- and below-ground resources (Kigwa *et al.*, 2018). The comparative tree densities for the smallest spacing and the widest spacing are 1,111 for  $3m \times 3m$  spacing and 278 stems per ha for the  $6m \times 6m$  spacing, respectively. It is therefore, plausible that competition affected height growth in the closer spacing.

# 7.5.2 Water harvesting techniques for Melia seedling establishment

Water harvesting trials were undertaken in the year 2000 to determine appropriate planting water micro-catchment techniques for Melia. Seedlings were planted at different position in relation to water micro-catchment, i.e. on upper, and lower side of micro-catchment as well as the water collection point of the micro-catchment. Complete weeding was undertaken. Trees planted away from micro-catchment on upper or lower side, showed better survival compared to those in the micro-catchment (Muok *et al.*, 2001). This was an indication that the Melia does not do well in water-logged soils.

# 7.5.3 De-budding and pruning of Melia

Management of the Melia is through; weeding twice per year for the first three years, and pruning, which is carried out through removal of buds or de-budding.

De-budding should begin three months after planting and is carried out up to 2/3of the tree height until a desirable clear bole of about 5m is attained.

Pruning should begin from the second year after planting and should be carried out after considering three factors; 1) trees with double leaders; 2) possession of large branches relative to stem diameter and height, e.g. larger than 1 inch; and 3) presence of whorls (CADEP-SFM/KFS, 2018). If double leaders are observed, it is recommended to remove one of them as early as possible. Selective pruning is encouraged to remove branches of large diameter and those that appear to be competing with the main stem. These branches of large diameter should be pruned irrespective of their location on the tree. Melia de-budding and pruned Melia trees are as shown in Figure 7.5.



b) Well pruned Melia

c) Poorly prunned Melia

Figure 7.5 (a, b, c): Melia de-budding and pruning

#### **Melia Growing Challenges** 7.6

#### 7.6.1 Diseases and Pests

Survey on Melia diseases is routinely carried out in the nursery, on-farm and on-station trials, and in plantations. During the survey, diseased plants were identified, disease symptoms recorded and plant materials sampled for laboratory analysis.

In the nurseries, the common disease symptoms include; wilting, leaf necrosis (yellowing of leaves), and root collar rots (damping off). The commonly encountered symptoms in the field include; wilting, weak seedlings, severe chlorosis, powdery mildews, damage from browsing and water logging, root collar rots, stem cankers, stem breakages, diebacks, and gummosis (production of a yellowish brown resin) (Njuguna et al., 2006).

Melia nursery diseases are caused by fungi mainly *Fusarium* spp (Figure 7.6). The fungi cause seed rot, and therefore, poor germination and root rot.

Pests associated with Melia seedlings include, nematodes and spider mites. Nematodes cause soft rot of roots and root-collar rot while spider mites suck sap from the leaves. Mites are common during hot and dry weather. Nematodes can be controlled through use of nematicides and avoiding over-watering. Spider mites can be controlled by termiticides or acaricides.

To reduce incidence of pests and diseases, the following should be applied;

- Pre-soak Melia seed in fungicide solutions for 12 24 hours before sowing.
- Pre-treat the nipped seeds, first with dilute sodium hypochlorite, e.g. JIK, before sowing and subsequently spray the seedlings every 14 days during the first month.
- Spray with systemic fungicide Ridomil (active ingredient Mancozeb and Metalaxyl) against blights.
- Control mildews by spraying with Copper oxychloride or Agrocop 50 wp (Copper based fungicides) 45g/20 litres of water at intervals of 21 days until the mildew clears.
- Rotate the nursery site to reduce build-up of pests and diseases.
- Use of biological control agent (BCA), e.g. Trichoderma against Fusarium.
- Plant only healthy seedlings and avoid seedlings from areas of infestation.

Few significant pest and diseases in the Melia trees plantations have been reported. However, there are cases of cankers (Figure 7.7), mites and fungal attack on the main stems mainly associated with stress such as extended periods of drought or infertile soils. The best way to prevent heart rot is to keep the tree healthy using proper management techniques such as:

- Pruning trees at an early age so that no major branch will be removed later.
- Removing infected trees early when they still have sound timber that can be utilised (KEFRI/FTBC, 2016).



Figure 7.6: Fusarium spp affecting Melia seedling



Figure 7.7: Stem canker on Melia volkensii

#### 7.6.2 Animal damage

Melia is palatable to livestock and requires protection to avoid animal damage especially goats, which damage leader shoots and debark large trees.

#### 7.7 Summary of Recommendations for Melia Establishment

To establish Melia, site preparation should be carried out through; clearing of land, fencing, ploughing, harrowing, and levelling. Planting holes measuring 45cm deep x 45cm wide x 45cm long, spaced of at least 4m x 4m to 5m x 5m are dug before the onset of rains. The hole is re-filled starting with the top soil, then the sub-soil to top up the pit to the ground level. Where manure is available, it can be mixed with top soil before re-filing the planting hole. Melia seedlings that are about 30 cm tall should be planted at the start of the rainy season.

Melia management practices to be undertaken include; weeding twice per year; pruning from second year after planting: and survey to detect and control any pests and diseases,

#### 7.8 Melia Enterprises

A study to establish the status of Melia based enterprises was undertaken by KEFRI s in 2015 in four Melia growing counties of Kenya, namely; Taita Taveta, Makueni, Kitui and Embu. The aim of the study was to evaluate the socioeconomic importance of Melia based enterprises in the dry lands of eastern Kenya that included timber, round wood seeds and seedlings enterprises (Luvanda *et a*l., 2015).

The study revealed that Melia seed, seedling, round wood, and timber enterprises were important alternative on-farm enterprises. These were as indicated by the high level of Melia planting on-farm, and that *M. volkensii* was a very important drylands species for both domestic and income generation purposes. The adoption of Melia was enhanced by; ready market for its products, drought tolerance, employment opportunities from various enterprises therefore improving income and livelihood of farmers, readily available seeds, fast growth with great potential for timber production, provision of windbreak, shade and for environmental conservation.

A cost-benefit analysis showed that seed, seedlings, round wood and timber enterprises were economically viable at 10%, 15%, and 20% discount rates, respectively (Luvanda *et al.*, 2015). It was, thus recommended that stakeholder awareness creation and training be undertaken to enhance the rate of adoption Melia growing at the farm level as farmers recognized adaptability, fast growth, high quality timber and financial viability of Melia enterprises in the drylands as

compared to other competing tree species.

Melia market chain analysis showed that the market players continued to derive their livelihood from the Melia enterprises. Results of the study showed that it is economically viable for farmers to invest in Melia enterprise based on costbenefit ratios, i.e. Melia seeds (4.25), seedlings (1.87), round wood (1.12) and timber (1.90) calculated at 15% interest rate. (Luvanda *et al.*, 2015).

# 7.9 Achievements in Melia Research and Development

Achievements by KEFRI and its partners on *M. volkensii* research and development include:

- Development of a seed pre-sowing treatment.
- Identification of Melia as a fast growing tree species producing quality timber in 10 to 15 years with potential for domestication.
- Melia tried and recommended for plantation establishment in the drylands.
- Identification of due to its faster growth on farm than in the wild.
- Development of the Melia nut cracker, which enabled fast extraction of seeds to support an expanded tree-planting programme.
- Identification of optimal spacing of 4m x 4m based on Pilot Forest plantation trials at Tiva, Kitui County. At farm level, Melia can be grown at a wider spacing to allow growing of under-storey crop such as fodder grass to maximizing land use.
- *Melia volkensii* growing has been adopted by both small-scale farmers and large companies in Melia growing areas of eastern and coastal Kenya. Large companies have their own plantations and have also recruited farmers to grow Melia through out-grower schemes.
- Farmers have been trained on best practices on; Melia seed collection, processing, seedling production, and tree establishment and management.
- Identified and geo-referenced 100 CTPs (superior trees) from existing populations both wild and on farm and subsequent seed orchard establishment and breeding for drought tolerance and climate change mitigation.
- Published various documents on Melia key among them:
  - A Guideline on Production, Distribution and Use of Improved Melia Seed and Seedlings in the Drylands of Kenya.

- A maintenance manual of Melia seed orchard (KEFRI and FTBC, 2021) that provides details of selection of Plus Trees, establishment of clonal seed orchards, reducing pests and diseases, weeding, and seed production.
- Plus Trees traits table on *Melia volkensii* in the drylands of Kenya.
- Manual for managing Melia seed orchards.
- Guidelines for clone propagation of Melia volkensii.
- Disseminated information of Melia for plantation establishment in SSA and Sahel regions creating interest for species introduction.

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# **CHAPTER 8**

# **BREEDING** *MELIA VOLKENSII* FOR IMPROVED **PRODUCTIVITY AND DROUGHT TOLERANCE**

Jason Kariuki, Musingo T. E. Mbuvi, Josephine Wanjiku, Dorothy Ochieng, Bernard Kamondo and Paul Tuwei

#### 8.1 Introduction

Tree improvement is an approach for production of genetically improved germplasm in order to meet demand of forest products such as high quality timber. Tree improvement involves tree breeding, silvicultural practices and integrated pest and disease management that are simultaneously applied to take advantage of the existing genetic variation in forest tree populations to increase productivity per unit area (KEFRI, 2018). However, considerable variation for many forest trees exists in traits such as growth rate, stem form and wood quality between different populations within a species, and also between individual trees within populations. Opportunities exist to improve economic value of a species by identifying the best wild seed sources, which can be used in developing improved tree varieties. Tree breeding programmes therefore aim to select and breed from the best individuals within the best populations. Improved varieties have potential to produce larger volumes of better quality wood than can be achieved from wild material. To ensure maximum returns from tree improvement, species-site matching is of paramount importance.

*Melia volkensii* is one of the species selected for improvement based on its availability of base population, economic importance, and suitability for the drylands of Kenya. *Melia volkensii* is one of the most important indigenous tree species in the drylands of eastern Kenya, and probably the only timber species that can be grown on commercial scale in these areas. Initial planting revealed that Melia grown on-farm and in plantations, had high diversity in terms of tree form and growth parameters. To address this diversity in Melia, a breeding strategy was developed. This strategy involved initial selection of candidate plus trees (CPTs) in both remnant natural stands and on-farm populations. KEFRI in collaboration with JICA commenced activities for Melia breeding and improvement under the project "Development of Drought Tolerant Trees for Adaption to Climate Change in Drylands of Kenya". This was a pioneer multidisciplinary project whose overall goal was to extend quality plantations of indigenous tree species in the drylands through incremental capacity building for: breeding drought

tolerant trees; development of quality seed/seedlings supply system; and creating awareness of drylands forestry using improved drought tolerant germplasm of M. *volkensii* and *Acacia tortilis*. Under CADEP-SFM (2016–2021), progeny tests of 1<sup>st</sup> generation of M. *volkensii* were undertaken. In the "Project for Strengthening Forestry Sector Development and Community Resilience to Climate Change through Sustainable Forest Management and Landscape Restoration (2022 – 2027)", progeny tests of 2<sup>nd</sup> generation of M. *volkensii* is ongoing (Figure 8.1).



Figure 8.1: Roadmap for breeding Melia volkensii in Kenya (Source: FTBC, 2018)

Due to the economic potential and ability of *M. volkensii* to grow in dryland ecosystems, it has become a flagship species for afforestation in Kenyan arid lands. *Melia volkensii* is being bred for drought tolerance and fast growth. Identification of drought tolerant individuals of the species is a priority to promote large scale planting within the ecosystem. Breeding of the species for drought tolerance is ongoing to provide high value planting materials, which can withstand the harsh climate and at the same time provide valuable products.

Capacity building and a distribution system for improved Melia seed and seedlings was developed. This involved training of Melia distributors and users of improved Melia. KFS in partnership with KEFRI and JICA adopted farm forestry field schools extension approach in disseminating information in comparing performance of Melia trees.

# 8.2 Melia Breeding and Improvement Process

Melia breeding strategy, developed by KEFRI with support from JICA in 2008, included: selection and grading of plus trees in both natural stands and those planted on-farm; collection of scions from the plus trees; and establishment of seed orchards using the selected material. Objective of the breeding programme was to develop fast growing trees for timber production, drought tolerance, and adaptable to Melia growing areas and drier sites.

# 8.2.1 Selection process for Melia Candidate Plus Trees

Sites known to have viable populations of *M. volkensii* within the species natural range were surveyed and location of Candidate Plus Trees (CPT) documented. Selected populations were divided into two categories; on-farm and wild. Many trees were screened during reconnaissance survey and in each transect 2 - 10 trees were selected.

# 8.2.1.1 Criteria for Melia volkensii candidate plus trees selection

*Melia volkensii* CPTs selection was aimed at traits that maximize uses and benefits of the tree as a whole, while maintaining adaptability to dryland conditions. After evaluation of the most common uses of *M. volkensii* and probable future uses, the following were adopted as the selection criteria for individual trees of Melia (Kariuki and Muchiri, 2017):

- The trees are in the dominant or co-dominant crown class (at or above the general tree canopy level) within the immediate tree surrounding.
- Superior in height and diameter growth in comparison to surrounding 5 trees (growth vigour).
- Straightness of stem.
- Light-medium branching, less steep angled branches.
- Free from insect pests and free of any signs of disease.
- Not crooked or twisted stems/branches.
- No spiral grain tendency.
- Survival in very dry sites.

# 8.2.1.2 Selected Melia candidate plus trees

One hundred (100) candidate plus trees (CPTs) were selected between 2010 and 2013. Selected trees displayed superior characteristics to the surrounding trees in terms of stem straightness, and larger volume (Kariuki and Muchiri, 2017). Scions from the 100 selected CPTs, were collected and grafted on Melia rootstock for establishment of an initial clonal seed orchard.

#### 8.2.2 Production of clonal materials

# 8.2.2.1 Root stock preparation

The soil for raising Melia clonal materials was collected 3 months prior and fumigated before potting. Melia seeds to raise the root-stocks for grafting were from general collection. The root stock seedlings were raised for 5 months to a height of about 30cm. Tree nursery management practices were undertaken to ensure a healthy rootstock.

# 8.2.2.2 Collection of scions and grafting

Scions from the 100 selected candidate plus trees were collected and grafted on Melia rootstock for establishment of an initial clonal seed orchard. The rootstock were raised in the nursery for a period of between 4 months to 1 year. The grafted seedlings were then maintained in the nursery by watering, root-pruning, and disease control for 4 to 6 months.

# 8.2.3 Establishment of seed orchards

The seed orchards were established in 3 phases; in December of 2012, 2013 and 2014 in two sites - Tiva in Kitui County and Kibwezi in Makueni County. The phased out establishment was due to inability to have all clones from all the candidate plus trees ready for planting at the same time.

# 8.2.3.1 Site preparation, orchard planting and initial management

An 11-hectare plot was earmarked for planting of orchards in each site. The selected sites have slight slope, and were cleared of all existing natural vegetation using a bulldozer. The sites were then ripped to a depth of 60cm using a heavy duty ripper and thereafter fenced.

Staking was done followed by pitting. Pit size was 30cm x 30cm x 30cm. The pits were then backfilled with top soil mixed with 0.5 kg of charcoal dust to improve water holding capacity. The seedlings were then transported to the sites and planted at a spacing of 6m x 6m. Initial planting involved planting of about 1,800 seedlings in each of the two sites and the rest of the CPTs were planted over a span of 3 planting seasons to the full stocking level of 3,000 seedlings per site. Each orchard is divided into 6 blocks planted with 100 Melia tree families of 5 ramets each.

The planting position of the 100 families was subjected to computer randomization to facilitate cross pollination among the families and avoid planting ramets of the same CPT near each other. It is expected through randomization and cross pollination even more superior germplasm will be obtained. Management of the orchards included weeding and disease control.

#### 8.2.4 Progeny test

After two years of clonal seed orchard establishment, seed was collected from the orchards and seedlings raised for establishment of progeny tests. The progeny test ascertains the genetic worth of individual candidate plus trees. Four (4) main progeny tests and 4 sub-progeny tests were established in 2014 in sites where Melia naturally occurs in Kenya. Objectives of the progeny tests were: to compare the parent trees (CPTs) used as sources of desirable seed; to rank the parent trees according to the performance of their progenies; to estimate heritability of traits assessed and the General Combining Ability (GCA) of the female parent trees for a range of characteristics. Tree height, diameter at breast height (DBH) and diameter at ground level (DGL) and at 50cm above ground (D<sub>50</sub>) were assessed at 6 and 12 months of age. The ranking of the plus parent trees based on their progeny performance and heritability of various traits were used to rogue existing seed orchards. Rogueing involved removing trees that; have an undesirable phenotype, or showed through progeny tests to have a less desirable genotype, from a seed orchard or seed production area.

Results of the progeny tests showed that at 6 and 12 months of age, the progenies were significantly different in height and DBH, and DGL at 6 months with moderate heritability values being realized for these traits. The heritability estimates for *M. volkensii* for traits associated with productivity indicated that the genetic improvement achieved can be transmitted to the next generation of trees. Immediate gain in plantation productivity can be achieved through rogueing the Melia seed orchards. For long-term gain, sufficient seed orchards should be established using the best available material.

#### 8.3 Drought Tolerance

A major objective of Melia breeding was to determine if fast growing clones had superior drought tolerant traits than slow growing clones. From the growth data, it was evident that fast growing clones responded to soil water availability by higher growth rates than slow growing clones. Moreover, chlorophyll fluorescence was higher in fast growing than in slow growing clones during drought. Leaf photosynthesis was also higher in fast than in slow growing clones. Since growth is a result of photosynthesis, whereas chlorophyll fluorescence is surrogate measure of leaf damage in response to stress, the results suggested that variation in drought tolerance manifests in variation of physiological traits such as those investigated in the study. The traits can therefore, be used as initial proxies for determining variation of environmental stress tolerance in *M. volkensii*. The higher photosynthetic rate of fast growing clones could indicate higher carbon dioxide assimilation as manifested by higher diameter growth of fast clones both in Tiva orchard and in the nursery (Muchiri *et al.*, 2017).

# 8.4 Comparing Seed Productivity among Clones

Based on data for weight of extracted and dried Melia nuts for both 2015 and 2016, clones were grouped into high yielding ( $\geq 10$  kg) total weight and low yielding clones (<10 kg). Fourteen (14) clones (23% of clones) were grouped into high yielding clones in orchards, 25 clones (42%) into low yielding clones for both orchards in Tiva and Kibwezi, 13 clones (22%) into high yielding clones in Tiva (Kitui) orchard, and 8 clones (13%) into high yielding clones in Kibwezi orchard. The low yielding clones were disaggregated to reveal clones that had not seeded since the orchards were established. Seven (7) clones in Tiva and 8 clones in Kibwezi had not seeded by 2018.

Seed production and productivity among the seeding clones was on average about 9.7 kg of extracted and dried Melia nuts per tree. Results showed that the number of ramets contributing to seed production among the high seed yielders ranged from 3% of the ramets to 27%.

Experience shared by workers who have been involved in collecting Melia seed over a long period of time indicate that in the wild, trees produce between 30 and 50 kg of extracted dried seed in a year or an average of 40 kg of extracted dried nuts. The current production in the orchard among seeding clones (9.7 kg) is about 24% of the wild productivity from mature trees. In general, trees produce more seeds as they grow older up to a peak, after which production reduces with age.

It is anticipated that seed productivity in the Melia orchards will increase with age. Given that the orchards have been raised using grafts from mature trees, it is also possible to expect that high seed productivity will be achieved in a much shorter time period of time. The physiological quality established for the few clones is strongly indicative that the clones will produce seeds of high physiological quality (Kamondo *et al.*, 2017).

# 8.5 Melia Wood Density

Melia produces high quality, termite resistant and durable timber within a period of 15 to 20 years (Mulatya, 2000). The rotation age is relatively shorter than for most common indigenous timber tree species. Its timber characteristics compare favourably with that of *Ocotea usambarensis* and *Vitex keniensis* (Blomley, 1994; Kidundo, 1997; Mulatya and Misenya, 2004). Melia wood is suitable for making assorted furniture, acoustic drums, containers, mortars, door and window frames, and door shutter rafters.

The main objective of this study was to determine variation in wood density within and between trees of *M. volkensii* at three different ages. Specific objectives were to determine: (i) relationship between stand age and wood basic density in Melia; (ii) variation in basic density between sapwood and heartwood and at different tree heights; (iii) percentage heartwood ratio, roundness and decentering as an index of wood quality; and (iv) basic density of a standing tree using a non-destructive method – the Pilodyn.

The experimental design in the two sites was randomized complete block design (RCBD) with six blocks and 5 trees of each clone per block. Tree stem height and tree diameter at 1.2m was measured at 5 and 12 months after planting. Tree volume was determined from the tree DBH and height using a tree volume function, which assumes that the tree is conical in shape.

Wood density using pilodyn penetration was determined at 12 months after planting. Pilodyn penetration (PP) was measured using a 6 - J Forest pilodyn with 2.5mm diameter and 60mm length steel needle, over the bark at 1.2m and taking pilodyn shots on two opposite sides of the pole.

Preliminary results showed that there was significant variation in growth and wood density of different selected clones. The variation was attributed to reaction of clone based on geographical area where the clones were collected. At an early stage, it was possible to identify Melia clones/families combining the following characteristics: fast growth and high wood density, slow growth and high wood density, fast growth and low wood density, and slow growth and low wood density. Clones of high wood density and fast growth from the Melia plus trees were recommended for further improvement of varieties by tree breeding. Average basic density across the grains indicated a gradual increase from the pith to the bark along the height of the tree from the bottom to the top of the tree.

Results from previously planted Melia trees showed that basic density between trees of three ages of 10, 12 and 14 years was not significant. However, the volume of the wood increases with age. It is therefore recommended that harvesting of the Melia tree is done at age 14 years as the heartwood ratio is acceptable at about 75% (Oduor and Miyashita, 2017).

# 8.6 Tree Breeding activities Implemented under the Capacity Development Project for Sustainable Forest Management (CADEP-SFM)

The tree breeding activities continued under the Capacity Development Project for Sustainable Forest Management (CADEP-SFM) project implemented in 2017-2021. Activities undertaken included; evaluation of progeny tests and selection of second generation trees for promoting current breeding population and genetic resources of *M. volkensii*.

The main activity in this phase was establishing second generation seed orchards of Melia towards selection of 3<sup>rd</sup> generation. This activity builds on results and techniques developed by the previous tree breeding project.

# 8.7 Dissemination and use of Improved Melia Seed and Seedlings

Dissemination of improved Melia was undertaken through; establishing a demonstration forest of improved Melia, examining breeding gains in terms of carbon fixation, and testing viability of improved Melia in drier regions of Kenya. Production and distribution system of improved Melia seeds was promoted by; supporting communities and enterprises to establish/manage seed production orchards, providing breeding information in seed production, and forming a reliable seed distribution system. These activities were developed to enhance commercial use of improved Melia to increase forest cover and contribute towards adaptation to climate change.

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# **CHAPTER 9**

# **EXTENSION APPROACHES IN SOCIAL FORESTRY**

Musingo T. E. Mbuvi, Josephine Wanjiku, Michael Mukolwe and Sylvia Mwalewa

# 9.1 Introduction

Due to rapid population increase in Kitui County of Kenya, trees were clear-felled to give way for settlement, agricultural activities and for provision of woodfuel, particularly charcoal. Tree exploitation targeted species, which were valuable for construction, woodfuel and carving (Sola *et al.*, 2020; County Government of Kitui, 2013). Effects of the changing land use patterns in the County became severe in the 1980s, resulting in rapid environmental degradation and biodiversity loss. There was need to rehabilitate degraded landscapes by growing trees for provision of various goods and services. To successful involve the community in tree growing, new participatory extension approaches and methods were embraced.

The main objective of exploring various extension approaches was to identify and invest in suitable methods for transferring tree growing technologies to, and among farmers in semi-arid areas of Kenya.

# 9.2 Extension Approaches Applied during Social Forestry Projects

Extension approaches are avenues for productive involvement and engagement of rural communities, extension agents, teachers and policy makers in the restoration of degraded landscapes and biodiversity. Most of the extension approaches applied in forestry have evolved from those applied in agriculture. These approaches included; Training and Visit, Catchment Approach, Focal Area Approach, Participatory Forest Management, Farmer-to-Farmer Extension Approach, and Farmer Field Schools. The success of each approach has been demonstrated in enhanced adoption and sustainability of various technologies. The main extension approaches subjected to assessment within Kitui County by the KEFRI/JICA Social Forestry Training Project (SFTP) between 1988 and 1997, the SOFEM project from 1997 to 2000, and ISFP from 2004 to 2009 included;

- Small-scale tree nurseries approach.
- Model farmers approach.
- Demonstration approach.
- Seedlings distribution approach.

- The People's plantations approach/*Mwethya* group approach.
- Private plantations approach.
- Prize giving days approach.
- Farmer-to-Farmer Extension (FFE).
- Farmer Field School (FFS).

The extension approaches aimed at developing and promoting tree planting by communities through technical guidance, as well as to enhanced knowledge and skills. The extension approaches are discussed in details in the subsequent sections.

#### 9.2.1 Small-Scale Tree Nurseries Approach

Small-scale tree nurseries approach aimed at training voluntary organized groups such as; women groups and schools, individual farmers using simple, local and adoptable nursery establishment and management techniques. This extension approach was to ensure self-sufficiency in seedling production and sustainability of the project. Project support was provided in form of; nursery tools, seeds, potting tubes, water storage drums, and advisory services. Advisory services offered included; information on collections of locally available tree seed, seed storage, seed pre-treatment methods and technical information on nursery management.

#### Achievements

- Within a period of about 8 years (1988 to 1997), the groups participating in tree nursery activities increased in number from 14 to 88, while schools increased from 4 to 18.
- The annual targets of seedlings production were surpassed by 5% where each farmer group was expected to produce 2,000 seedlings while schools had a target of 3,000 seedlings.
- Groups participating in nursery activities increased from 29% to 91% by 1996, which was a reflection of increased awareness on usefulness of tree planting.
- Group members acquired knowledge and skills needed in nursery establishment and management through participating in tree planting activities. Enhanced capacity was evidenced by the quality and number of seedlings produced in the nurseries.
- Success in tree seedlings distribution was attained as presented in Table 9.1. Most of the seedlings raised by farmers were planted on their own farms, which translated to increased tree cover on-farm.
| Beneficiaries    | Ratio (%) |
|------------------|-----------|
| Members (self)   | 79        |
| Non-members      | 10        |
| Sold             | 6         |
| Carry-over stock | 5         |
| Total            | 100       |

Table 9.1: Success in tree seedlings distribution

## 9.2.2 Model Farmers Approach

The purpose of model farmers approach was to promote tree farming by individual farmers who were expected to sensitize and build capacity of neighbouring farmers. The Project provided support to the model farmers in form of farm implements, seedlings, water storage drums and technical advice.

The Project selected 22 model farmers through discussion with local communities and organized by local leadership (*baraza*), where interested farmers volunteered to take part. In-depth awareness on planned activities was created for interested farmers. Selected farmers underwent a residential training at KEFRI Kitui Regional Social Forestry Training Centre to enhance their knowledge and skills on tree growing and communication.

#### Achievements

- Model farmer approach contributed to high survival rate (average 50%) of planted trees.
- The farms acted as demonstration points to several visitors and trainees of the Project.
- Famers surrounding model farmers were positively influenced and adopted tree planting activities on their farms.
- Model farmers acquired skills for tree planting and were willing to expand tree planting to on their farms to ensure sustainability.

## Challenges

- Competition for labour with other farm activities especially for women who constituted 60% of the labour.
- Dependency syndrome as seedlings were issued free of charge by the Project. Only two (2) out of the 22 (9.1%), model farmers started own nurseries.

## 9.2.3 Demonstration Plot Approach

The aim of this approach was to demonstrate tree farming and soil management techniques to the local community, and hold project organized courses for trainees, as well as other interested stakeholders. Two on-station demonstration plots averaging about 2.5 ha each were set. Practices, that included land rehabilitation using terraces, cut-off drains and water micro-catchments, woodlot establishment for various uses such as; fuelwood, poles and fodder, alley cropping using nitrogen fixing trees such as *Gliricidia sepium*, homestead management (small scale nursery, kitchen garden and rain water harvesting) as a model farm layout were demonstrated.

#### Achievements

- Demonstration plots acted as a learning site for participants at the KEFRI Kitui Regional Training Centre.
- The plots attracted many visitors to the Project site and therefore serving the intended purpose of show-casing various environmental management techniques.

#### 9.2.4 Seedling Distribution Approach

The aim of the approach was to avail seedlings to interested farmers and institutions in the project areas. Distributions were done during the rainy seasons from local administration offices. A calendar of seedling distribution was drawn by project staff and respective local administration (chiefs) and posted in market centres, churches, government offices and schools to enable as many farmers as possible to be aware of the tree seedling distribution day in their areas. Demonstration of planting techniques by project staff was carried out and pamphlets on tree planting methods issued before distribution of the seedlings. Records of farmers who received the seedlings was captured by name, location and villages to facilitate follow-up.

#### Challenges

Sustainability of the approach beyond project period included;

- Expensive and required efficient logistical support.
- Discouraged seedling production by farmers.
- Lacked nursery management skills.
- Encouraged dependency by the recipients.

## 9.2.5 The People's Plantations Approach/Mwethya Group Approach

Communal land ownership is common in the drylands of Kenya. However, due

to competition for resources which leads to tragedy of the commons, most of the drylands are normally over-exploited through overgrazing and indiscriminate felling of trees, which result into land degradation. Therefore, there was need to sensitize farmers and community on importance of tree planting in communal lands in drylands of Kitui County. Communal tree planting was introduced within the Pilot Forest Site in 1987 to create what was referred to as People's Plantation. The Pilot Forest site was characterized by natural bushland, woody vegetation with Commiphora being the dominant natural tree species. The objective of People's Plantation Approach was to involve and build capacity of the local farmers in tree planting, to enhance transfer of developed tree farming technologies such as water harvesting, land preparation and tree tending.

The People's Plantation Approach involved mobilization of farmer groups to voluntarily participate in tree planting on Pilot Forest Site owned by KEFRI. The approach disseminated forestry techniques through tree planting activities in the Pilot Forest Site by voluntary self-help groups called "*Mwethya*". *Mwethya* are self-help organizations consisting of individuals, mainly women, coming together in order to solve specific challenges.

Selection of groups was done in collaboration with the local leaders. The criteria used for group selection was that the group should;

- Be active.
- Have interest in tree planting.
- Have reasonable number of members involved in hands-on group activities.
- Be within walking distance to the Project site.
- Be non-political in nature.
- Be willing to participate in tree planting activities.

Eighteen (18) groups were selected and allocated a portion of land within the Pilot Forest Site. About 70 ha were allocated for the activity. Groups were required to sign a Memorandum of Understanding (MoU) and have it renewed each year to allow them to work in the people's plantation (Kute *et al.*, 1997).

The main articles of agreement included;

- The Project leases a portion of land to groups for a period of 10 years, which was renewable.
- The group utilizes the land for the purpose of tree planting.
- The group plants, tends and care for the planted trees.
- The Project provides technical guidance and other assistance as necessary.

## Incentives

To boost the morale of the groups, the Project provided incentives, which included;

- *Working tools:* jembes (hoes), shovels, pangas (machetes), mattocks, slashers to each working group member.
- *Technical advice:* Through the Project technical officers and extension agents.
- *Seedlings*: The Project provided high quality seedlings of various species for planting every season.
- *Prizes:* Groups were awarded according to their performance. However, in order not to discourage lower achievers, such groups were awarded prizes of participation.
- *Firewood:* The group members were allowed to collect dry wood from the Pilot forest during the working days.
- *Transport:* This was provided during working days for group members who had to cover an average of 4-5 km to their plots.
- *Animal feed:* During the dry season, members were allowed to cut grass for their livestock from the forest.

#### Achievements

- A total of 87,198 seedlings of 18 different species which included; *Senna siamea, Tamarindus indica, Senna spectabilis, Psidium guajava,* and *Terminalia brownii* were planted by the groups, between 1987 and 1996.
- Members acquired skills in tree planting and tending and accessed products such as firewood, thatching grass and fodder.

## Challenges

- Time management and sharing of products and incentives.
- Low survival rates of trees due to low rainfall, damage by termite and animals.
- Socio-cultural issues due to competing individual means of livelihoods.
- Communal ownership concept not well embraced by members.
- Expectations not met as benefits took long time to be realized.
- Low motivation to participate in communal activities at the time, since most farmers had sizable land holdings.

## Lesson learnt

Although the activity of the "Mwethya" groups in People's Plantations was

a promising approach for promoting communal tree planting in communal lands, such as catchment areas and grazing lands, however the activity at the Pilot Forest Site was not very successful. The performance of trees planted and survival was very low. Due to low success from People's Plantation experience, it was considered appropriate to promote Private plantations on individual farmer's land.

## 9.2.6 Private Plantations Approach

In Private Plantations Approach, farmers were encouraged to start their own plantations/woodlots. The Project provided tools, seedlings and technical advice, to encourage farmers to plant more trees.

The survival rate of tree planted was high. The reasons that motivated farmers to start private plantations included the following benefits; provision of firewood (83%), construction poles (17%), soil conservation (33%), and ornamentals purpose (17%) (Kute and Yaguchi, 1997). Problems experienced by farmers in the private plantations and proposed solutions are as presented in Table 9.2.

Problem	Proposed solution
Water	Dig borehole and wells, or buy a donkey to ferry water
Termites	Use of chemicals and local materials of controlling termites
Inadequate tools	Purchase tools
Manure	Make compost
Potting tubes	Use local materials

Table 9.2: Problems and proposed solutions

The solutions proposed by farmers, was an indicator that farmers were ready to seek solutions to their problems. To ensure sustainability of private plantations, farmers proposed the following actions; establish own tree nurseries (66%), utilize the knowledge acquired (17%), buy seedlings/tools and (17%) and hire labour (17%).

## Lesson learnt

The Private Plantation Approach created awareness in tree planting and had a good potential for promoting self-initiative and sustainability in tree planting.

## 9.2.7 Farmer-to-Farmer Extension

Farmer-to-Farmer Extension (FFE) approach was introduced in the drylands of Kenya in the forestry sector during the SOFEM Project, which was implemented between 1997 and 2002. It was envisaged that through introduction and promotion of this approach, there would be continuity of activities beyond the Project period. The approach involves information and technology transfer by core/lead farmers to other farmers. Scarborough *et al.*, (1997), defined farmer-to-farmer extension as "provision of training by farmers to farmers, often through creation of a structure of farmer promoters and farmer trainers". The FFE approach emphasizes farmer interactions and recognizes that though farmers may be aware about a technology, however, farmer interactions and exchange of experiences is an important stimulus to adoption.

Adoption of FFE approach was therefore, expected to fill in the gap of the few extension personnel in the drylands as well as provide farmers with technical knowledge and skills in Social forestry. The advantage of using core farmers as technology promoters is that they are aware of the farm problems that their neighbours face, the solutions that have been tried and failed before and the realities of individual farmer incomes and abilities.

## 9.2.7.1 Implementation process of Farmer-to-Farmer Extension Approach

Implementation of FFE involved several steps, which included:

- *Selection of core farmer using a criteria developed by the Project*: The criteria included; farmer being from the target community, approachable and accessible by other farmers, available, have good communication skills, and have basic literacy.
- *Training of selected core farmers:* Selected farmers underwent a 2-day residential training to enhance their technical skills in seedling production, marketing, and communication skills.
- **Profile survey which involved characterization of core farmers:** The survey involved collection of data including; education status, age, socio-economic status, and leadership in other organizations.
- Agreeing on the duties and responsibilities of core farmers: This entailed; training other farmers, monitoring and evaluating established technologies, and mobilizing community for various activities such as field days.
- **Developing farmer-to-farmer extension guideline for extension agents:** The guideline was to help extension agents familiarize with the procedures and steps to take when undertaking the tree planting activities assisted by the Core farmers.

- **Designing farm forests:** The farmers establish their own farm forests, which act as demonstration and information sources.
- *Trained farmers preparing their own training materials and inviting other farmers to field seminars on their farms*: During these field exercises, the trained Core farmer takes the leading role to explain and demonstrate the technologies implemented on their farm and those learnt from the project.
- *Evaluation of field seminars:* Each farmer attending the field seminar organised by the Project gave an evaluation feedback by filling a questionnaire. Aspects captured in the questionnaire included, participant's opinion about the field seminar, technology preference and recommendation for future improvement.
- *Monitoring established farm forests:* This was to enable farmers collect relevant data on general performance of trees in the farm. Data collected included; survival of the tree undertaken through survival count, and observation and recording of pest and diseases attacks. Monitoring promoted backstopping of technical support to the farmers.

## 9.2.7.2 Technologies demonstrated

Technologies demonstrated on-farm as presented in Table 9.3, varied from farm to farm depending on:

- Technologies already on the farm.
- Availability of demonstration materials.
- Farmers understanding on the technologies.

#### Table 9.3: Technologies demonstrated on-farm

No.	Technologies demonstrated
1	Tree planting and management
2	Agroforestry
3	Woodlot development
4	Fruit tree improvement (grafting and budding)
5	Boundary planting
6	Tree nursery techniques
7	Soil and water conservation
8	Fuelwood conservation measures
9	Bee keeping
10	Basket composting

## 9.2.7.3 Role of technical extension agent in FFE approach

- Building capacity of core/lead farmers.
- Packaging of technical messages.
- Establishing trials with lead farmers before scaling-up and scaling out.
- Follow-up and working with core farmers.
- Quality inspection (work of core/lead farmers, e.g., demonstration plots).
- Field backstopping and on-the-job training.

# 9.2.7.4 Sustainability of Farmer-to-Farmer Extension through Cluster Farmer Approach

Target farmers who had participated in Farmer-to-Farmer Extension Approach formed clusters (Figure 9.1). Target farmers involved in FFE were the Cluster leaders whose role involved;

- Selection of interested neighbouring farmers to be cluster member.
- Giving technical advice to cluster farmers in absence of technical assistants.



• Acting as extension agents to the surrounding community.

Figure 9.1: Cluster farmer formations

After acquiring adequate knowledge, the cluster farmers developed their own clusters. The clusters helped to enhance sustainability of the Farmer-to-Farmer Extension. Cluster leaders offered services to clusters such as grafting and budding, carried out at a fee, hence enhancing cluster leader's income and social

status. The cluster leaders also became important by helping other community development projects to have a good entry point into their communities.

## 9.2.7.5 Motivation of farmers to be a lead farmer

- Early access to technology.
- Concern for the well-being of others.
- Increase in social networking.
- Social status is enhanced due to increased knowledge and skills among the community.
- Job benefits.
- Income from associated activities such as grafting.

#### 9.2.7.6 Advantages of FFE approach

- Increased coverage of farming knowledge.
- Increased efficiency in management
- Enhanced productivity.
- Sustainability of programmes.
- Increase adoption of innovations by farmers.
- Increased farmer ownership of practices.
- Enhanced capacity building for the local community
- Increase feedback from farmers.
- Less costly by use of lead farmers and less extension agents.
- Improved interaction between farmers.

#### 9.2.7.7 Achievements of Farmer-to-Farmer Extension Approach

- Farmers continued with Farmer-to-Farmer Extension strategy, creating farmer clusters after the project ended. Some of these clusters evolved into large farmer cooperatives encompassing other farm activities, such as cotton farming.
- Farmers adopted other technologies not promoted by SOFEM project.
- Employment creation through SOFEM farmers being contracted by other farmers for specialized farm forestry skills such as grafting and landscaping. Some farmers became suppliers of tree seeds and seedlings.
- Farmers continued promoting farm forestry technologies through on-farm field seminars and field days organized by KEFRI and other organizations as they had the technical know-how.

- Improved communication skills for the core farmers.
- Transfer of practical techniques of establishing farm forest.
- Publicising established farm forest through on-farm field seminars.
- Created Cluster Farmer Approach.
- Participating farmers acquired knowledge on tree growing and planted more trees per year.

#### 9.2.7.8 Lessons learnt

- Farmer-to-Farmer Extension Approach was an effective methodology for sustainable establishment of on-farm forests and dissemination of tree planting technologies.
- Core farmers can simplify technical information and communicate effectively to other farmers.
- The approach is a cheaper method of technology transfer.
- The approach can reduce the extension cost and workload of extension workers in areas where extension worker: farmer ratio is low.
- The approach requires collaboration of local communities and government support for sustainability and scaling-up to larger areas.

#### 9.2.8 Farmer Field Schools Extension Approach

Through collaborative testing of various extension approaches by KFS, KEFRI and JICA, Farmer Field Schools (FFS) approach was identified as one of the most promising methodologies for disseminating forestry technologies. The methodology was prioritized since it has advantages, which include: reaching out to many farmers at a time, given that it is a group approach; empowering and building farmers capacity through discovery-based learning process that emphasizes; observation, discussion, analysis, and collective decision making.

A FFS is a school without walls, where farmers learn in the field through observations and experimentations. The school is composed of a group of 20-30 farmers who are selected among interested farmers. The group agree to attend weekly sessions for a certain period during which a wide range of topics are discussed. The extension approach was selected as other approaches did not sufficiently involve farmers in identifying problems or in selecting, testing and evaluating possible solutions.

## 9.2.8.1 Objectives of FFS

The objectives of FFS were to:

- Empower farmers with knowledge and skills to make them experts in their own farms.
- Enhance farmers capacity to make informed decisions, which consequently made their farming profitable and sustainable.
- Sensitise farmers on new ways of thinking and problem solving.
- Support farmers learn how to organise themselves and their communities.
- Enhance linkages between farmers, extension and researchers.

## 9.2.8.2 Key characteristics of FFS extension approach

#### Farmers as experts

Farmers 'learn-by-doing' and are therefore, experts conducting their own field studies. Training is based on comparisons that farmers conduct and are therefore, continually learning.

## The field is the learning place

All learning is based in the field where the Participatory Comparative Experiment (PCE) is established on a host's farm. Farmers working in small groups collect data, analyse and make decisions based on their analyses then present the decisions to other farmers for refinement.

#### Extension workers as facilitators not teachers

The role of the extension worker is that of a facilitator rather than a conventional teacher, and only offering guidance to farmers when there is need. Facilitators encourage FFS members to think, observe, analyse and discover answers by themselves.

#### Subject matter specialists work with rather than lecture farmers

The role of subject matter specialists is to provide backstopping support to members of the FFS and in so doing, to learn to work in a consultative capacity with farmers.

## The curriculum is integrated

The curriculum is integrated where relevant fields in agriculture, environment, health, food and nutritional security are part of the programme. Topics must be related to what is important to the group members, therefore, filling a given knowledge gap.

## Training follows the seasonal cycle

Training is related to the seasonal cycle of the practice being investigated.

For tree nursery, training starts from seed collection, seed sowing and nursery management up to transplanting in the field.

#### **Regular group meetings**

Farmers meet at agreed regular intervals. With the guidance of facilitators, the group meets regularly throughout the season to:

- Identify Participatory Technology Development (PTDs).
- Carryout experiments and field trials related to the selected technology.
- Implement PTDs (Test and validate).
- Conduct Agro-Eco System Analysis (AESA), which is comprehensive on-farm monitoring and evaluation as well as data collection. AESA, therefore, involves observation, data analysis and presentation for discussion.
- Process and present the data.
- NB: PTD is a process of collective analysis with the aim of initiating community action on solving local problems. The process empowers farmers with analytical skills of their farm challenges (Sustainet, 2010).

#### Learning materials are learner generated

Farmers generate their own learning materials, including drawings of what they observe in the field trials.

## Group dynamics and team building

Training include; communication skills building, problem solving, as well as leadership skills and discussion methods. Group dynamics is usually done through song, dance and drama to refresh participants and enhance group coherence and solidarity with fun. Learnt messages can be converted to song and dance, therefore, promoting better understanding.

## 9.2.8.3 Steps in conducting FFS

The phases in conducting FFS are mainly preparation, implementation and postgraduation. Each phase has several steps as shown in Figure 9.2.



Figure 9.2: Steps in formation and implementation of FFS Adapted from Ndeti (2019)

#### **FFS establishment**

The establishment process involved several steps, which include;

## FFS promotion

- Organize a FFS promotion meeting.
- Introduce FFS to community members during promotion meeting.
- Select FFS participants.
- Organize FFS group and structure.

## Qualification of participants

The following are some of the qualifications for FFS members in forestry;

- Practicing farmers.
- Available to attend weekly session for 52 weeks.

## Organize FFS group and structure

This is done by electing FFS officials such as;

- Chairperson and Vice Chairperson.
- Secretary and Vice Secretary.
- Treasurer.

## Agreeing on meeting day and starting time

Members agree on convenient day and time to start the meeting on a weekly basis.

#### Setting of learning norms

Members discuss and agree on the rules and regulations during entire FFS period.

#### Examples of learning norms

- Absentees pay fines.
- No smoking during the session.
- Respect other peoples' opinions.
- Conflicts to be resolved democratically.
- Every participant and facilitator to keep time.
- A late comer should perform a dynamics.

## Sub-group formation

Sub-group, are formed from the main group. The objective of sub-group formation is to have small groups to maximize on each member's participation and increase effectiveness of the activities. Criteria for sub-group formation include; gender, age distribution and profession. The sub-group selects a name and slogan as well as elect the sub-group officials, i.e. the chairperson, secretary and time keeper. An example of a slogan in tree farming included: "cut a tree, plant trees".

Once the sub-groups are formed, the host team is selected. Duties and responsibilities are then explained to the host team.

#### **FFS** preparation

The activities involved in FFS preparation include:

- FFS orientation.
- Signing of an Agreement between FFS and co-ordinating office.
- Delivery of stationery.
- Setting up of learning enterprise in the wet season.
  - Planning of farm experiment.
  - Discussion on learning plan.
  - Learning preference selected through a participatory approach.
- Planning of Host Farm design.
- Host Farm selection and Host Farm Agreement.
- Host Farm establishment.
- Learning site preparation.

- Time table preparation.
- Training of facilitators.

#### FFS timetable

- FFS meet on a specific day.
- Usually they conduct  $3^{1/2}$  to 4 hours session.
- Just like regular schools, FFS has its own schedule or timetable (an example is shown in Table 9.4).
- The activities which are allocated more time are:
  - Agro Ecological System Analysis (AESA), which involves field data collection, data analysis and results presentation by farmers.
  - Today's/Special topic related to specific village level conditions or problems. This can be about an activity that is expected to be undertaken in subsequent week.

Time	Activity	Objectives	Materials	Responsible
9.00 - 9.05 am	Prayer	To commit the day's activities to the Lord	Bible	Host
9.05 - 9.10 am	Roll call and recap	Who is present to remind ourselves of our previous activities	Books, pens, pencils, rulers, tape measures	All participants
9.10 - 9.40 am	AESA taking processing and presentation	To synthesize, analyse data, and present it to the larger groups for collective decision in what management action to take	Flip charts, books, felt pens, board, crayon, ruler, masking tape	All subgroups Facilitator
9.40 - 10.30 am	Group dynamics	<ul> <li>To energize / revitalize the group</li> <li>To enhance participation</li> <li>To educate on group activities</li> </ul>	Tea, music, instruments	Host grower All participants

Table 9.4: An example of Farmer Field School timetable

Time	Activity	Objectives	Materials	Responsible
10.30 -10.40 am	Special topic	To input on special topic, which will widen their scope of knowledge / skills	Books, pens, pencils, rulers, tape measures	Facilitator
10.40-10.45 am	Review of the day's activities	To evaluate our achievements	AESA materials	Host team Facilitator
11.45-11.50 am	Planning for next session	To prepare adequately	Flip chart, felt pen	All
11.45-11.50 am	Roll call announcement	To note the late comers, absent, fine collection	Register	Host team
	Prayer	Thank God for the day	Bible	Host team

During discussions a "*talk ball*" is used. The ball is thrown to the member who should speak. Only person with the ball speaks. To appreciate the speakers various claps are given. These include:

• The FFS clap

• The generator

The lightning clapThe chicken clap

The mosquito clap

- The high 5 clap
- The Coca-Cola/Pepsi clap
- The 5 factorial clap
- The rain clap
- The Tokyo/Osaka clap

## **Group dynamics**

•

These include: clapping, songs, dances, poems, drama, refreshments such as tea/ coffee.

## FFS field days

This is organized at the FFS site and the objectives are to:

- Provide the FFS members with an opportunity to display and share their experiences, such as the experimentation results and learning activities, including group dynamics.
- Reinforce the FFS cohesion and raise awareness among the community.

Farmers are facilitators during these field days.

## **Exchange visits**

Exchange visit is an educational tour by one FFS group to another FFS.

- Both visiting and visited groups can share and exchange ideas, tested technologies, challenges and unique innovations.
- Visits are also useful for farmers to compare their level of empowerment and facilitators performance with another group.

## **FFS graduations**

- This activity marks the end of FFS sessions.
- It is usually organised by farmers, facilitators and the co-ordinating office.
- It is also a forum to pass on the lessons learnt at the FFS to the public, and non-FFS members.
- The harvest results of PTD are displayed.
- FFS participants dramatize (using folk media), all lessons learnt at the FFS.
- Participants are awarded certificates by the supporting office/programme.

## 9.2.8.4 Follow-up FFS activities

Core facilitators backstop on going FFS.

## Farmer facilitator and farmer-run field schools

In some FFS programmes, a few farmers will be identified from FFS and trained as farmer facilitators so they can facilitate other groups/community members.

## FFS network

Several FFS groups organize their own FFS network for challenging activities such as, income generating activities (IGAs), marketing of farm products and seeking external funding through proposal writing.

## 9.2.8.5 Lessons learnt

- Farmers can collect their own data and analyze it.
- FFS brings group together to unite with common objectives.
- Accepted technologies by group members are adopted by members on their farms.
- FFS enhances participatory planning.
- Communication, presentation and listening skills are enhanced.
- Through this experiential learning process, farmers learn together as they

collectively analyze their production systems, identify problems, test possible solutions and eventually adopt practices most suitable to their farming systems.

• Farmer empowerment is crucial for programme success.

#### Farmers benefits from FFS

- Strengthening observation capability and increasing knowledge ownership through discovery based learning.
- Building self-confidence and enhancing decision-making capacity.
- Minimizing risks in experimenting with new practices.
- Changing deep-rooted beliefs and practices.
- Developing problem-solving capabilities.

## **FFS** Achievements

Farmer Field School achievements during the ISFP include the following;

- Developed Farm Forestry Field Schools (FFS) extension management system
- Formed networks among graduated FFS groups
- Developed extension management tools that included; DVDs, FFS manuals, study guide, special topics
- Built capacity of County Forest Conservators and foresters on FFS methodology
- Trained farmer facilitators who conducted grassroots extension work
- Developed enterprise catalogue for selected enterprises
- Tree planting increased significantly among FFS members and surrounding farmers
- Increased seedling production
- Improved capacity of farmers for self-determination and decision making
- Built capacity on FFS to other countries such as Oromia Regional Government, Ethiopia
- Some Sub-Saharan Africa countries are promoting and adapting the approach through officers trained in FFS in Kenya during TCTP.

## 9.2.9 Prize Giving Days Approach

The success of any tree planting and conservation initiative is expressed as adoption of best practices promoted by different stakeholders. Farmers and other interest groups are the ultimate beneficiaries of successful tree planting, which is a function of knowledge and skills, enabling environment and motivation or incentives. To motivate farmers, the Kenya /Japan Social Forestry Training Project (SFTP) adopted as one of its activities, holding of an annual national competition, popularly referred to as Social Forestry Prize Day. The objective of the competition was to promote nation-wide awareness of Social forestry and to enhance rural tree planting and management by recognizing outstanding activities of the people at "grassroots" level. The promotional activities organized, comprised of two components, namely; National Social Forestry Prize Day, and Secondary Schools Prize Day. The event was sponsored by JICA in collaboration with KEFRI and KFS.

#### 9.2.9.1 Purpose

The National Social Forestry Prize Day served three purposes, namely; i) enhancing tree planting and management activities at the grassroots level by recognizing and motivating farmers, ii) strengthening Research-Extension Farmer linkages in on-farm development, and iii) providing a stakeholder's forum. The Secondary Schools Prize Day served two purposes, namely; i) generating awareness about Social forestry in Secondary Schools in Kenya, and ii) documenting the Social forestry initiative and engagement of the youth. The Prize Day event competitors were drawn from arid and semi-arid Counties (formerly Districts) of Kenya.

## 9.2.9.2 How it was organized

A Joint Prize Day Technical Committee (TC) of SFTP organized the event. The responsibilities of the committee included:

- i) Overall planning of the event.
- ii) Setting selection criteria at County (formerly district) level.
- iii) Identifying participating Counties.
- iv) Liaising with the County officers who were in-charge of Forestry and Agriculture to identify at least six (6) outstanding farmers or interest group(s) in on-farm tree planting and environmental conservation activities based on prevailing environmental, socio-economic conditions and administrative arrangement.
- v) Deliberating on information provided by the identified County Officers to identify at least three (3) outstanding farmer(s) or interest group(s) for a site validation by a Sub-team of the TC.
- vi) Undertaking validation visits, which involved discussion with the stakeholder, taking notes, photography and videography as evidential resources.

- vii) Deliberating to identify at least a winner from participating Counties based on visit and evidential resources.
- viii) Determining types and number of awards in order of priority.
- ix) Determining amount of refunds to invited competitors and accompanying team members.
- x) Determining the day and venue of event.
- xi) Setting award winning criteria.
- xii) Determining and inviting Prize Day Panel of judges.
- xiii) Identifying and inviting guests from relevant institutions and individuals from Social forestry extension, research and tertiary education.
- xiv) Compiling event report.

## 9.2.9.3 National Social Forestry Prize Day

Selected stakeholders were invited to make presentations and displays during the Prize Day. Presentations by the competitors were judged by a Panel of judges with a wide experience in Social forestry. The judgments were based on the superiority of activities, effectiveness of presentation and handling of questions. The presentations highlighted challenges and opportunities among competitors, which included: appropriate species-site matching; availability of inputs such as tree seeds/seedlings and tubes at the right time; water and prolonged droughts; managing insect pests; labour and socio-cultural constraints to tree planting. Enhancing communication and capacity building were observed as drivers of successful Social forestry extension programmes.

## Prizes awarded

Prizes awarded included; bicycles, wheel-barrows, fork-jembes, jembes, watering cans, shovels machetes and rakes. The awards were presented in diminishing quantities, with the top winner being awarded all items. The rational was to enhance mobility, on-farm agricultural operations using the tools provided and use the forum to share experiences from the farmer(s) or interest group(s). A total of nine (9) National Prize Days were held, and attended by over 40 Counties and 1,090 participants.

## 9.2.9.4 Secondary Schools Social Forestry Prize Days

Schools play a major role in forestry activities, a school-focused approach, was therefore, adopted for Secondary Schools in Kenya. The organizing team relied on the Ministry of Education and relevant County Education Officers to reach out to eligible schools in semi-arid areas of Kenya. Two (2) events were held involving participation of 18 schools from three (3) Counties during which 540 Environmental club members attended. Schools were presented with assorted textbooks and notebooks, in addition to the National Prize Day Awards.

## 9.2.9.5 Lessons learnt

- Social Forestry Prize Days are an important approach to enhancing adoption of forestry innovations.
- Despite its resource demands, Prize days blend and contribute well to addressing resource needs and performance of the beneficiaries for sustainable on-farm conservation.

## 9.2.10 Roadside Tree Planting in urban and peri-urban landscapes

Trees, shrubs and associated plants are an important part of the rural and urban landscapes. The plants are either planted or of natural occurrence. Plants along the roads form a linear rural and urban green space resource, which, enhance visual impact, act as windbreak and support biodiversity conservation along the roadsides or paths. Establishment and management of trees in such linear green spaces in Kenya was for a long time the domain of local government authorities as part of their plan to manage a healthy urban and rural-urban environment. However, in 1987, the Kenya/Japan Social Forestry Training Project (SFTP) requested the Nairobi and Kitui County authorities to be enjoined as support tree planting along Mombasa Road in Nairobi and Machakos-Tiva in Kitui. The Nairobi site, also known as the Commemorative Tree Planting (CTP) site, is a linear stretch covering a distance of about 4 km. The Kitui County site is along Machakos-Tiva Kitui Road, also known as Roadside Tree Planting (RTP) covers a distance of about 12.6 km. These activities were to promote and intensify tree planting and management initiatives within or close to the urban and rural-urban environment. The CTP and RTP in Nairobi and Kitui counties were implemented between 1987 and 1994. However, a section of CTP is now occupied by the new Nairobi Expressway with remnants of the trees on its left and right flanks.

## 9.2.10.1 Commemorative Tree Planting

The CTP was initiated as a symbolic gesture to mark the beginning of cooperation between the people of Kenya and Japan in Social forestry development in Kenya. The specific objectives of CPT were to: enhance the natural landscape; provide urban outdoor recreation opportunities; and foster conservation ethics on the part of urban inhabitants, visitors and relevant groups. The site is situated along Nairobi-Mombasa Road between the Syokimau Station Railway Bridge and the junction bridge to Jomo Kenyatta International Airport (JKIA). The site was selected due to its strategic location as a gateway to and from Nairobi. Residents and visitors, travelling by road would notice the presence of different indigenous and exotic tree species planted in pure or mixed stands. Notable groups that planted trees at CTP site included visiting Japanese Parties, popularly known as "Green Kenya" and the International Soil Conservation Organisation (ISCO). The CTP site was also selected for National Tree Planting activities in 1988, which was an annual event marking the climax of tree planting week in Kenya.

## 9.2.10.2 Roadside Tree Planting

The RTP commenced in 1994 in Kitui. Its objectives were to promote SFTP's efforts based on successes, attributed to: i) selection of adaptable and fast growing tree species; developed tree planting and tending techniques; promising early establishment and better survival trees; and ii) provision of services such as: aesthetics; windbreak; shade for pedestrians, local roadside vendors and animals; and wood products resulting from appropriate tree management practices. The site covers a linear green space along Machakos-Kitui Road from Syongila to Kwa Vonza (Figure 9.3), featuring a striking visual impact. The key tree species planted are presented in Table 9.5.

Table 9.5:	Kev tree	species for	commemorative	and ro	adside tree	<b>blanting</b>
14010 7.5.	itey tite	precies ior	commentor acree	anaio	ausiac tice	pranting

CTP tree species	RTP key species
Kigelia africana	Spathodea campanulata
Acacia xanthophloea (Vachellia	Senna spectabilis
xanthophloea)	Delonix regia
Senna spectabilis	Jacaranda mimosifolia
Warbugia ugandensis	
Casuarina equisetifolia	
Terminalia brownii	
Ficus benjamina	



Figure 9.3: Roadside tree planting in Kitui

# 9.2.10.3 Basic establishment and management experiences that ensured success of CTP and RTP

The success of establishing and managing roadside trees are dependent on ownership, management objectives, nature of landscape and available resources. The values and operations that ensured survival of 60-90% to desired mature trees involved a range of activities. The key operations included:

- Paying special attention to planning and designing the desired linear greenspaces given that each site has its own unique set of characteristics.
- Consideration of ecological requirements for tree species to ensure and enhanced growth and performance.
- Sensitivity to species site matching, hence the need to select appropriate tree species.
- Quality of the planting stock, in terms of health, appropriate size and hardened off.
- Preparing the ground well by digging or pitting/ planting holes that measure at least 1 m wide x 1 m long x 1 m deep. As a rule of thumb, the larger and deeper the hole size, the better.
- Backfilling the pits with soil ratio of 3:1:1:1 (3 parts humus rich red soil; 1 part farm yard manure: 1 part small stones 2-3 cm diameter and 1 part peat which were obtained from other sites).
- Planting hardened up planting stock when there is adequate soil moisture build up.
- Ensuring that the roots go downwards but well spread out to avoid "J" shaping when planting or transplanting.
- Constructing and maintaining appropriate water harvesting structures to enhance soil moisture retention and maximize the use of rain water to the planted stock.
- Watering seedlings at establishment phase, particularly first year of growth and during the long dry season.
- Topping-up the planting holes in the second year of establishment.
- Mulching to conserve soil moisture if possible but at the same time keeping a constant check for termites in termite prone areas.
- Staking, tying or guying the planted stock to support or stabilize it.
- Controlling grass and other weeds by spot weeding.
- Fencing was not necessary for CTP because of constant project staff patrol but for RTP because of livestock movement at night and unattended livestock during the day the site was fenced.
- Protection done on an individual tree basis against human, unattended livestock, pests (spraying to control defoliators, sap suckers and termites), diseases and fires.

• Pruning as a regular maintenance measure ensured that the planted stock achieve desired impact as it encouraged compactness, good healthy, vigour and balance between the crown and root system.

## 9.2.10.4 Challenges

- Both CTP and RTP site are located in very dry environment characterized by long dry spells and black cotton soils which are prone to cracking deeply into the soil profile. The soils are also subjected to moisture stress in the dry season and waterlogged in the rainy season making tree establishment a challenges.
- Site-specific limitations, which limit the selected tree species from providing the desired effects.
- Due to preference of choice, the same species were planted repeatedly, hence low species diversity along the roadsides.
- Limited awareness of characteristics of the tree species at maturity in terms of root and crown structure, which often impacts negatively on infrastructure.
- Loss due to fire damage by motorists or passengers who threw away lighted cigarette butts and mock fire exercises, hence the need to replace the affected tree species.
- Loss of land and planted trees to a rapidly expanding industrial and road infrastructure.
- Resource constrains to sustain the activities.

## 9.2.10.5 Achievements

- A total of 2,519 different indigenous and exotic tree were successfully planted and managed in the two different sites.
- Under CTP 2,171 trees were planted with the highest species diversity comprising 16 indigenous and 15 exotic tree species.
- Under RTP 418 trees were planted comprising four (4) different indigenous species.
- The trees have gradually provided a great aesthetic value as a linear greenspace especially in Kitui.
- The success of the activities drew positive response from the inhabitants, visitors, local authorities and other organisations to take similar steps to enhance the quality of the urban and rural-urban landscapes.

## 9.2.10.6 Lessons learnt

The lessons learnt include;

• The promise of the benefits of roadside tree planting makes the practice appealing.

- The success of establishing and managing roadside trees are dependent on ownership, management objectives, nature of landscape and available resources.
- Planning and designing the desired linear greenspaces requires special attention given that each site has its own unique set of characteristics.
- The first year of tree establishment and management is important to ensure tree survival.
- Public education, sensitization and involvement are important protection measures.
- There is need to sensitize and encourage the industrial/business community on the importance of trees and related plants within the urban and rural urban green spaces in maintaining a viable and healthy environment.
- Incremental survival rate of 60% 90% was realised with improvement in management practices.

## 9.2.10.7 Conclusion

The shift in attitude and need for a viable and healthy environment through planning, establishment, managing and benefitting from trees and related plants as linear green spaces within or close to urban and rural-urban areas are reasons for its appeal. Emerging challenges in promoting the activities are of environmental, technical, social and economic nature. However, these are readily addressed by observing and being sensitive to planning, designing, establishment and management requirements as well as sensitizing the public on the need to embrace and protect the linear green spaces.

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## **CHAPTER 10**

## BUILDING CAPACITY FOR SOCIAL FORESTRY DEVELOPMENT AND SUSTAINABLE FOREST MANAGEMENT IN AFRICA

Michael Mukolwe, Josephine Wanjiku and Honjo Yuki

#### **10.1.** Introduction

Human induced and natural causes continue to impact negatively on natural resources, compromising the ability of these resources to sustain livelihoods, socioeconomic activities, and ecological services that depend on trees. The negative impacts are mainly reflected in continued landscape degradation, deforestation, loss of biodiversity, declining soil fertility, and low crop productivity, among other challenges. These challenges continue to create additional demand for technology development, promotion and adoption of practices that ensure sustainable management, conservation and utilization of natural resources, strategic capacity building and need to work through comprehensive partnerships within and beyond country boundaries.

The Government of Kenya (GoK) through Kenya Forestry Research Institute (KEFRI) and Government of Japan (GoJ) through Japan International Cooperation Agency (JICA) have continued to play a leading role in sustainable natural resource management within Africa, particularly through Social forestry technology development and capacity building.

Since 1986, , JICA and GoK through KEFRI have collaborated to build capacity of Kenyan counterparts, farmers and other relevant government officers from Sub-Saharan Africa countries through various training programmes and projects. These programmes include the: In-country National and Grassroots Social Forestry Training Courses; Third Country Training Programme (TCTP) on Social Forestry and through the Capacity Development Project for Sustainable Forest Management in the Republic of Kenya (CADEP-SFM) - Regional Cooperation Component. This section, documents the processes and achievements of KEFRI and JICA in building capacity for Social forestry development and sustainable forest management in Kenya and Africa.

## **10.2** National and Grassroots Social Forestry Training Courses

#### Introduction

The sustainability of Social forestry development process depends on among other factors, stakeholders and beneficiaries whose knowledge and skills are continuously enhanced through training. The stakeholders include; staff of relevant government agencies, non-governmental organizations (NGOs), and communities. In its endeavour to enhance knowledge and skills, KEFRI/JICA Social Forestry Training Project (SFTP), organised two categories of capacity building activities to support Social forestry development at the national and regional or "grassroots" level, from 1986 to 1997. These training categories were the National Social Forestry Training Courses (NSFTC) and Regional Social Forestry Training Courses (KRSFTC) carried out in Muguga and Kitui, respectively.

The main objective of the National Social Forestry Training Courses was to improve knowledge and skills of government and non-governmental organisations (NGOs) staff involved in promoting Social forestry and Agroforestry. A total of six (6) different courses were planned and implemented, with a duration of 3-5 days and 1 - 2 weeks per year. The courses included; District Level Course, Divisional Level Course, Orientation Course, Extension Officers Course, Teachers Social Forestry Course, and Training of Trainers Course. The maximum number of participants per course was 30, while the frequency was 1-2 courses per year, for each category of courses. However, the frequency was increased for some courses due to increasing demand and as a result of positive impact from performance of ex-participants and the beneficiary communities.

The main objective of the Kitui Regional Social Forestry Training Courses (KRSFTC) at grassroots level was to ensure that farmers, community group leaders, teachers, and frontline extension staff in semi-arid counties in the former Eastern Province of Kenya, acquired knowledge and skills on Social forestry.

#### How the training was done

- The training decisions and processes were articulated by a Training Sub-Committee, while the day-to-day operations were administered by the Training Manager and Training Officers.
- The curriculum was consultatively designed to cover issues under introductory concepts on social forestry and agroforestry policy, technology development, technology application, extension and field visits (Kaudia *et al.*, 1992). The training methods included; presentations,

discussions, demonstrations and practice. On average, a 2-week course consisted of 25 topics, while a 1-week course consisted of 15 topics. Resource persons were drawn from KEFRI (60%) and other relevant institutions (40%).

• The nominators were encouraged to select women, to ensure gender balance.

A summary of National Social Forestry Training Courses (NSFTC) and Kitui Regional Social Forestry Training Courses (KRSFTC) title, target group and objectives are as presented in Tables 10.1 and 10.2, respectively.

Course title	Target group	Objective(s)
District Level Course	District level officers from forestry, agriculture, livestock, energy, social services, provincial administration, physical planning and education	To impart current knowledge and skills in Social forestry and agroforestry in order to improve their management and extension skills
Divisional Level Course	Divisional level officers from forestry, agriculture, livestock, energy, social services, provincial administration, physical planning and education	To update the officers on agroforestry technologies and dissemination techniques
Orientation Course	Newly recruited natural resource management, forestry and other serving officers at District and Divisional levels	To provide officers in forestry and other related sectors of natural resource management with knowledge on Social forestry/ agroforestry development and promotion
Extension Officers Course	Extension officers at Divisional and Divisional level	To enhance knowledge and operational skills in Social forestry and Agroforestry so as to improve extension skills for rapid adoption of technologies

 Table 10.1:
 Summary of National Level Social Forestry Courses

Course title	Target group	Objective(s)
Teachers Social Forestry Course	Teachers and Trainers coordinating environmental clubs' activities from Secondary schools, Teachers Training Colleges, Institutes of Technology, Forestry and Agricultural Colleges	Impart teachers with basic knowledge and operational skills on Social forestry to improve their capacity to coordinate environmental youth club and other afforestation activities
Training of Trainers Course	Individuals from government agencies and NGOs who have participated as resources persons in the planned Social forestry and agroforestry courses at national and grassroots level	To develop and enhance the training ability of resource persons in order to enhance their teaching/ training skills

Course title	Target group	Objective(s)	Remarks
Farmers Course	Farmers from semi-arid areas	To train participants on practical knowledge and skills on tree planting and associated activities and to extend the recommended practices to the neighbours	Nominated by relevant governmental agencies and non- governmental organisations
Women Leaders Course	Women leaders from semi-arid areas	To train participants on practical knowledge and skills on tree planting and associated activities in semi-arid lands	Nominated by relevant governmental agencies and non- governmental organisations
Community Leaders Course	Local Community leaders from semi-arid areas	To expose leaders to issues in tree planting and related activities in order to enhance their ability to sensitize and mobilize the rural communities to plant, tend and conserve trees	Nominated by District Commissioners, NGOs in the dryland Eastern counties (formerly Eastern Province) of Kenya

Course title	Target group	Objective(s)	Remarks
Teachers Course	Primary school teachers from semi-arid areas	To create awareness on the need for tree planting and related activities among teachers and to enable them play a role in motivating the youth and community to plant, tend and conserve trees in their semi-arid areas	Nominated by District Education Officers in in the dryland Eastern counties (formerly Eastern Province) of Kenya
Frontline Extension Course	Frontline Extension staff from semi-arid areas	To train participants on practical knowledge and techniques in tree planting and associated activities, extension techniques, so as to improve their capability to promote Social forestry in semi-arid areas	Nominated by relevant governmental agencies and non- governmental organisations
Field Technical Assistants Agroforestry Course	Frontline extension staff who had previously attended a 2-week course at Kitui Centre	To train the participants on integrated land use activities emphasizing various kinds of Agroforestry techniques and to motivate them to further Social forestry activities by way of carrying out follow-ups	Nominated by KRSFTC Training Officers
On-farm Tree Nursery Course	Farmers from Social Forestry Extension	To train participants on practical knowledge and skills on tree planting and to extend recommended techniques to the rural areas so as to promote Social forestry activities in semi-arid areas	

Course title	Target group	Objective(s)	Remarks
Teachers' Course in the Extension area	Primary School teachers	To create awareness on the need for tree planting and related activities among teachers and to enable them play a role to motivate youth and community to plant, tend, and conserve trees in semi-arid areas	Nominated from the Extension area by Extension Section of the Pilot Forest Sub- Project
Field Seminars	Interest groups in semi-arid locations of the Extension area	To reach more people in a cheaper and faster way, particularly in remote locations	5 Field seminars held in 5 locations 4,100 participants attended

#### What was achieved

- A successful 10 years of implementation of National and Grassroots level courses.
- A total of 33 planned courses were held and 842 participants were trained in Muguga.
- A total of 47 planned courses were held and 1,212 participants were trained in Kitui.
- Developed a training curriculum and course programmes to guide the implementation of the planned courses in Muguga and Kitui.
- The discussion topics were reviewed over the years to emphasize on relevance, current issues, impact, efficient and effectiveness of training methods, preparation of lessons, development of quality training materials, and to address new information.
- In Kitui, 4,100 persons were reached in five (5) locations through organized field seminars.
- The success of NSFTC provided the skills and expertise to develop Third Country Training Programme (TCTP) in Kenya. The results culminated in the formulation of the Regional Training Course for the Promotion of Social Forestry in Africa with support from the Government of Japan through Japan International Cooperation Agency (JICA) TCTP Scheme rather than the normal Technical Cooperation Project.

## Lessons learnt

The lessons learnt include:

• Feedback from a combination of post-training impact surveys, followup workshops and seminars at the national and regional levels, provided positive responses across the various indicators influencing the success of Social forestry at institutional and community level. The responses included; enhanced awareness (motivation and positive attitude), understanding (equipped with practical knowledge and skills) and action (adoption of good practices from increased number of seedlings/trees in nurseries and on-farm).

- Training is a driver of sustainable Social forestry and socio-economic development.
- Training has the potential to help in identifying research issues and providing feedback to institutions and communities, for example, potential semi-arid trees for up-scaling and drought resistance, pest management, and cost-sharing.
- Training is imperative for sustainable development at institutional and community levels. Training is useful in bringing out abilities and ingenuity to address the various challenges in sustainable management and conservation of forests and allied natural resources. Therefore, investing consistently in relevant impact-oriented training events is a necessity.

#### 10.3 Third Country Training Programme on Social Forestry in Kenya

Japan International Cooperation Agency (JICA) and the Government of Kenya through Kenya Forestry Research Institute (KEFRI), successfully collaborated to build capacity in Social forestry development in 21 Sub-Saharan Africa (SSA) countries. Capacity was built through a series of phased Grant Aid and Technical Cooperation Projects, under the Third Country Training Programme (TCTP) Scheme from 1995 to 2018. Lessons from the Technical Cooperation projects that consisted of Social forestry technology development and capacity building of Kenya counterparts, enabled Kenya to acquire prerequisite capability to share knowledge and skills with other countries within SSA region. In addition, TCTP benefitted from receiving a number of equipment, vehicles and long-term JICA experts dispatched based on need to support both the In-country and Regional Training Courses (RTC) held under TCTP.

This section shares experiences and insights on TCTP development process in Kenya, RTC implementation experiences, achievements and future collaboration prospects with JICA in Kenya and SSA countries. The TCTP programme comprised of five (5) Phases consisting of 24 Regional Training courses (RTCs), which initially covered 13 countries in SSA. Based on demand, the number of participating countries was expanded to 21. Records of Discussion (RoD) signed between the collaborating agencies effected and articulated the partnership and implementation procedures of RTC.

#### 10.3.1 Third Country Training Programme development process in Kenya

Third Country Training Programme (TCTP) is a fundamental human development programme within the framework of JICA's support through the South-South Cooperation. Support is extended to developing countries to conduct training programmes to build capacities of other developing countries based on common characteristics such as socio-economic and biophysical factors. Unlike conventional type of JICA training programmes, under TCTP, participants are not sent to Japan but are trained within the host country. The respective TCTP phases, titles, purpose/objectives and expected outputs are outlined in Table 10.3.

Phases	Title	Purpose/ Objectives	Expected outputs
			At the end of the training course participants were expected to have:
Phase I: 1995 - 1999 Phase II: 2000 - 2004 (10 years)	Promotion of Social Forestry in Africa	Contribute to development and conservation of forest resources, mitigating the adverse effects of desertification in the region and facilitate regional collaboration through Social forestry	<ol> <li>Fully understood the concept of Social forestry and its usefulness in enhancing forest conservation and mitigating desertification in the region.</li> <li>Developed their abilities in policy formulation to promote Social forestry, which enable the application of Social forestry strategy to various local conditions of participating countries.</li> <li>Learnt effective measures to disseminate the practice and related techniques of Social forestry to farmers and other beneficiaries.</li> <li>Redeveloped their abilities to resolve problems in Social forestry by expanding their knowledge and techniques and by exchanging experiences among participants from other countries.</li> </ol>

 Table 10.3: TCTP Phases, title, purpose and expected outputs

Phases	Title	Purpose/ Objectives	Expected outputs
Phase III 2005 - 2008: (4 years)	Enhancing Adoption of Social Forestry in Africa	Provide an opportunity to enhance capacity in adoption of Social forestry, which would contribute to environmental conservation, poverty reduction, food security and sustainable rural development	<ol> <li>Enhanced knowledge for technical development and adoption of social forestry.</li> <li>Acquired facilitation skills to work with farmers and other resource stakeholders.</li> <li>Be able to apply institutional strategies and develop guidelines.</li> <li>Understood the process of linkages and information sharing with stakeholders.</li> </ol>
Phase IV 2009 – 2013 (5 years)	Mitigating Climate Change in Africa through Social Forestry	Capacities of participating countries to practically mitigate climate change are enhanced through implementation of participatory Social forestry extension methodologies	<ol> <li>Enhanced knowledge on climate change and participatory social forestry extension methodologies.</li> <li>Acquired facilitation skills to mobilize and work with farmers and other resource stakeholders.</li> <li>Able to utilize knowledge and skills acquired to develop, review and apply institutional strategies and guidelines for practical implementation of environmental conservation activities and improvement of livelihoods.</li> <li>Able to practically network with stakeholders to share information and ideas on mitigation of climate change.</li> </ol>

Phases	Title	Purpose/ Objectives	Expected outputs
Phase IV 2011	1 <sup>st</sup> Regional Policy Level Workshop on Mitigating Climate Change in Africa through Social forestry	Capacities of participating countries to practically mitigate climate change are enhanced through implementation of participatory Social forestry extension methodologies	<ol> <li>Enhanced knowledge on what would be attained by participating in the course and how it would fit into their institutional strategies and objectives on mitigating climate change.</li> <li>Improve on the content, scope and content delivery.</li> <li>Be able to ensure that ex- participants are fully engaged and to act on the action plans developed during the course.</li> <li>Be able to encourage creativity and to share information on mitigating climate change through practical networks.</li> </ol>
Phase V 2014	2 <sup>nd</sup> Regional Policy Level Seminar on Mitigating Climate in Africa through Social Forestry	The capacities of participating countries to practically mitigate climate change are enhanced through implementation of participatory social forestry extension methodologies at policy level	<ol> <li>How the capacity developed through the TCTP is being managed for impact on mitigating climate change within their institutional strategies and objectives</li> <li>Gains made by the improving on the course content, scope and content delivery process</li> <li>Challenges to effective implementation of action plans developed by course participants and recommend further measures for TCTP</li> <li>Lessons drawn from the TCTP Terminal Report</li> <li>Recommendations for moving forward – next Phase (2014 - 2018)</li> </ol>
PhasesTitlePurpose/ ObjectivesExpected outputs			
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Phase V 2014 – 2018Adaptation to Climate Change in Africa through Social ForestryCapacities of participating countries to implement adaptation measures to climate change are enhanced through Grield School (FFFS) extension methodology and livelihoodModule 1: I. Fully acquired knowledge skills to practice forestry field school social forestr extension methodologiesI. Adaptation to Climate Change and livelihoodCapacities of implement adaptation methodologiesI. Fully acquired knowledge ability to promote practice ability to promote practice activities.II. Adaptation to Climate Change and livelihoodSocial forestry social forestry social forestry social forestry social forestry social forestry extension methodologies3. Enhanced their knowledge and skills to promote practical actio plans including monitorir and evaluation based on to country and institutional policies, strategies and plModule 2: 1. Enhanced their knowledge and to select, promote, cultiva support conservation of d to select, promote, cultiva support conservation did to learnt trees.1<	ge and farmer ry ge and cal ge mers on in vation n local on ng their lans. ge on lopment +) at l level. l skills ate and drought to rough stry s. to oractical d to vities.		

#### **10.3.2** Preparation and implementation of TCTP

Adequate consultative preparation and implementation measures are key to achieving objects of any capacity building initiative. The measures consist of three interdependent processes, namely; pre-training preparation, implementation (during training) and post-training.

#### Pre-training preparation for RTC under TCTP

Preparation and implementation of RTCs were as articulated by the signed Minutes of Meeting (M/M) and Records of Discussion (RoD) between JICA and Government of Kenya. Relevant institutions and organizations in six participating countries were initially visited for the purpose of creating awareness and establishing the training needs. Policy level workshops and seminars were then held for heads of organisations from participating countries to validate training needs, familiarize with training contents, scope and delivery process and chart a way forward on how capacity developed through TCTP would be utilized and managed for impact within receipient country. Lessons learnt from the policy level events were incorporated into the training programme.

Guidelines of Application were based on modified JICA Guidelines of Application Form for JICA Training and Dialogue Program - Form A2A3 - (https://www. $jica.go.jp>activity 06_04_03-01)$ . The information was adapted to develop the General Information (GI) Booklets. The GI outlined the course title, purpose, modules, outputs, duration, curriculum, participating countries, number of participants, qualification of applicants, implementing agency, procedure for application, measures to be taken by the GoK, measures to be taken by JICA, sponsorship, measures to be taken by participating country or organisation, information on arrival requirements, contacts of KEFRI and JICA Kenya Office. The Booklets were dispatched annually to relevant institutions/organisations in participating countries to facilitate nomination of eligible technical staff to facilitate the training process. Nomination criteria included:

- Having a working experience of three years in forestry or other related fields.
- Having B.Sc. or Diploma or equivalent in forestry or other related fields.
- Having a good command of spoken and written English.
- Being less than forty-five (45) years of age.
- Being presently engaged in forest-related extension planning, implementation or monitoring as administrators, managers, trainers and extension officers within Government or NGOs.
- Being a citizen of the nominating country
- Be nominated by their respective government/organization

The call for nominations was done using both diplomatic and direct channels of communication to eligible countries and institutions. Selection of participants was undertaken jointly by KEFRI and JICA based on a 10-point selection criteria, in addition to gender balance and distribution by country as provided in the GI. During each training event, 20-23 eligible applicants, were selected and invited. High profile officials from Diplomatic Mission of participating countries resident in Kenya, were informed and invited for official ceremonies, which comprised of opening and closing ceremonies.

Preparation and articulation of the course curriculum and structure, which embraced such thematic areas as introductory concepts based on the theme of each phase, technical development of technologies and practices, application/ facilitation skills of best practices, supporting topics, delivery processes and course evaluation was done. Other measures included, identification of partner institutions and resource persons/facilitators as well as their invitations. Themed field sites were identified through pre-field visits to relevant institutions, organizations and farmers.

Preparation of concrete procurement plans and appropriate budget estimates for relevant training materials and services was key to securing funds from JICA Kenya Office. The successful arrival and accommodation of participants at KEFRI concluded the pre-training arrangements.

#### Course implementation and delivery process

The Regional Training Courses (RTCs), lasted for a duration of five weeks each, during the 23 years of implementation. The only exception was the last course in 24<sup>th</sup> year (2018-2019), which lasted four weeks. The Training programme was triangulated in its implementation. Regional Training Courses, embraced as its integral component, interactive and practical-oriented learning methodologies including: presentations on demand-driven issues by various resource persons; country reports presentation by participants; demonstrations; hands-on skills; group work; discussion; field visits to selected farmers or groups sites or institutions; field report writing; and development of implementation action plan. The actions was an imperative output, which could be easily integrated or mainstreamed into exiting institutional frameworks and work plans. A workshop/ seminar-discussion approach was emphasized to facilitate better understanding of concepts, issues and application of Social forestry and climate change mitigation and adaptation strategies as well as ways of solving environmental challenges of each participating country. Most of the field visit sites were maintained, though new sites were identified to address the dynamic training needs and challenges

pointed out during the previous training courses. At commencement of each training, participant's requirements were identified by enlisting expectations.

#### Collaborating/facilitating institutions and resource persons

Over the years, Regional Training Course drew different competent and experienced resource persons from about 100 relevant organizations that included; government ministries and agencies (15), academic institutions (15), international agencies (13), private sector (9), civil society (32), selected farmers (17) and interest groups based on the course content details. The diversity of facilitating agencies gave the training a multidisciplinary approach, which exposed participants to cross-cutting issues in social forestry. About 55% – 60% of technical sessions were facilitated by KEFRI scientists and technical staff and the rest by KEFRI's partners. The training embraced a 3 sessions per day x 6 days x 5 weeks matrix course programme, constituting about 60-65 sessions of which 55% were in-house and 45% field interactions.

#### **Course evaluation**

The RTC adopted and applied three different evaluation strategies to meet it objectives given that there were no written exams but a need for practical output. The strategies included: An After-Course Evaluation (ACE); Extra-Evaluation (EE); and Inter-participant Assessment (IPA) as presented in Table 10.4. The approach, presented a feedback of analysis on overall perception of the course delivery process and interactions from participants, the capacity of the course to enable participants to apply lessons learnt after the training in their respective countries and an opportunity for future course of action. The different evaluation strategies ensured the RTCs remained self-evaluating throughout the training period, and for each training phase. At the end of each training, participants were issued with a certificate of participation, which served as great motivation.

Tool	Objective	Remark
After-Course Evaluation (ACE)	To access logistical and immediate impact of the course (course objectives, course curriculum, application of techniques and knowledge acquired and administration and management)	Average assessment score of 82% achieved

Tool	Objective	Remark
Extra- Evaluation (EE)	To give a feedback on performance of content delivery and interaction of each resource person(s)	An average assessment score of 84% achieved
Inter- participant Assessment (IPA)	To gauge leadership, analytical, communication, facilitation, initiative, participation and technical skills of participants	Average rating of 3.4 out of 5 achieved

Other assessments constituted the participants field report on case studies and techniques observed; preparation and presentation of implementation action plans; and assessing each participant's ability to contribute in teams and individually during in-house and field sessions.

In addition, TCTP Phases 1, 2 and 3, were subjected to terminal evaluations to at least eight (8) participating countries. During these phases, Policy level workshops/ seminars for Heads of institutions/organisations from participating countries and a Follow-up Visit (FUV) to five (5) sample countries in SSA to access and establish how the lessons learnt were being implemented were also undertaken. The FUV gauged the relevance, impact, sustainability, future perspectives and challenges encountered during after the training. The FUV established that RTCs: were consistent with participating countries national policies, strategies, and needs; ex-participants were using knowledge, skills and training materials provided to training interest groups; attempts were made to mainstream action plans into institutional work plan; and that FFS was an applicable extension methodology for most farming communities. However, FFS implementation was constrained by limited resources, hence modified to suit country needs.

#### Sponsorship

The annual sponsorship from JICA and KEFRI was at the proportion of about 88% and 12% respectively. Participating countries contribution was through incountry expenses and Visa payment. The funding was consistently disbursed annually for a period of 24 years. The TCTP also benefited from additional ondemand training equipment and vehicles to support efficient implementation of training activities.

#### Implementation opportunities and challenges

Implementation of RTCs presented opportunities and challenges, which were addressed by putting efficient implementation measures in place.

#### **Opportunities**

- Mainstreaming and implementation of developed action plans into institutional work plans.
- KEFRI seeking to expand mutual collaboration due to increasing demand to share knowledge and nature based solutions.
- Need for more support to a new approach to TCTP whose benefits and outputs extend beyond Kenya and within the context of South-South Cooperation.
- Ensuring careful identification and selection of themed field visits to maximize opportunity to learn from farmers and other field sites.
- Conduct the courses during the dry seasons for ease of accessibility during field visits.

#### Challenges

- Impact assessment was not always done to identify specific issues.
- An increasing demand of over 45 eligible applicants compared to available space for a maximum of 22 23 participants.
- Minimal time allocation for group and individual tasks to fully accomplish assignments.
- FFS extension methodology was applicable for most farming communities but implementation was constrained by limited resources and therefore, a need to modify to suit country needs.
- Ensuring gender balance.
- Receiving applications from Angola, Djibouti, Mozambique and South Africa due to organisational administrative challenges and language barrier among some participants.
- Ensuring that TCTP remains relevant in terms of content diversity, interactive and effective.
- Managing time by participants, resource persons and facilitators, especially during discussion sessions and field visits.

#### Achievements of TCTP

RTC was relevant, impactful on policies and featuring increased demand for training opportunities across participating countries in SSA. These characteristics contributed to its consistent support from JICA and its implementation by KEFRI for a period of 24 years.

The achievements of TCTP are as outlined:

- Five (5) Phases of TCTP each lasting 4 5 years were successfully implemented in a period of 24 years.
- A total of 20 23 participants including Kenyans were invited each year.

- A total of 511 (98.3%) out of 520 expected participants from 21 participating countries in SSA were trained from 1995 to 2018 (Table 10.5).
- KEFRI has developed expertise, acquired and enhanced capacity to implement TCTP.
- A paradigm shift in increasing demand from participating countries to share knowledge in environmental conservation using emerging digital platforms.
- The TCTP in Kenya evolved in scope over the years from Promotion to Adoption, Climate change Mitigation and Adaptation to meet emerging challenges and requirements of Social forestry.
- Positive relationship, reception and a reference with participating countries and within the region.
- KEFRI's capacity to organise and implement training has been enhanced and used in packaging national and international courses, workshops and conferences.
- Policy Level workshops and seminars successfully held for Heads of organisations from participating countries.
- A joint (KEFRI/KFS/JICA) Follow-up Visits (FUV) to five (5) TCTP participating countries successfully assessed activities undertaken by exparticipants to make an impact, commitment and challenges related to RTC lessons.
- Benefitted from assorted equipments, vehicles, photocopiers, computers and training facilities provided under SFTP I and II to facilitate implementation of the TCTP Phases.
- KEFRI benefited from counterpart training in Japan during the various project phases, which further enhanced capacity of KEFRI in technology development and information sharing.
- Experience gained in implementing the regional courses used in packaging and implementing special courses such as seven (7) Special tailor-made training courses attended by 95 technical Counterpart officers of JICA supported projects in Ethiopia, Malawi, Madagascar, Namibia, Tanzania and Ghana.
- Trained 60 Government officials from Federal Republic of Somalia in 2015 2016 on Policy and Practices for Climate Change Adaptation, supported by UNDP based on TCTP experiences.
- Field visits to selected Social forestry projects and activities continued to motivate farmers to apply new innovations learnt from participants as well as maintain/improve their activities.

- Course evaluation was important for refining, modifying and improving course content and structure.
- Social forestry study tours for Japanese university students and professors initiated and successfully implemented between 2002 and 2014.
- Social forestry intern students from Japanese universities accepted and supported by KEFRI Social Forestry Training Centre (SFTC) for 5 months each.
- KEFRI offered 16 training opportunities to relevant County government officials in Kenya on participatory natural resources management (PNRM) at Technical and Policy level, and lessons learnt, were used to strengthen implementation of TCTP.
- Case studies and good practices from participating TCTP countries were integrated into Capacity Development Project for Sustainable Forest Management in the Republic of Kenya (CADEP-SFM) objective of knowledge sharing for Sahel and Horn of Africa regions.

Table 10.5: Regional Training Course attendance by country from 1995 to 2018

E	lotal		32	23	19	42	36	28	32	-	14	28	16	6	14	6	25	25	52	39	31	34	511
	2018			-		-	7				ı	-	-	5		5	7	-	7	-			20
	2017	ı	5	1		-	2	-	-			2	-	-	1	-	7	2	2	-	-	-	22
	2016					-	с,		5		-	5	-	-				-	5	5			21
	2015		7			-	5	-				5		-		-	-	7	5	-			20
	2014	ı	7	-		7	3	5				5	-		1	-			5	-			21
	2013		7				3					7	-	-			7			7			24
	2012		7	-	5	-	3	-	-			ε				-		-	5	5	-	7	23
	2011	ı		-	5	-	3		5		-			5		2		-	-	-	5	-	22
	2010	ı			2	-	5	-	2			-					4	-	2	-	2	5	22
	2009	ı	7	-	-	7	e		2				-				e		2	-		5	22
rse	2008			2		-	3		-				-		-		4	2	2	3	2	-	24
e Cou	2007	ı		2	-	Э	2		-		-	2			2		7	-	2	-		-	24
of th	2006	ı	2		2	2	5		-	-		-					7	2	2	-		-	22
Year	2005	ı		-	-	Э	5	5	2		-		e		1		7		3	-		1	22
	2004			7	-	-		7	-		2	-	7					2	7	-		7	21
	2003	ı	2	-	-	2		2	-						5			3	2	2	-	2	21
	2002		7		-	-		-	-			-	-					2	2	2	7	7	20
	2001			2	7	-			-	1		-	-					-	-	e	-	7	18
	2000	1	7	5	5	5		-	5		-	-			-				5	5			19
	1999	ı		ı	1	5		5	2	ı		2							5	3			24
	1998		-			5		5	-		5								5	5	ε	5	20
	1997					e		5				5			e				3	-	e	e	21
	1996	1		ı		-			2			5			12			-	5		2	12	18
	1995	ı	ε	ı		ε			2						10			-	5	3	2	10	20
	Country	Angola	Botswana	Burundi	Eritrea	Ethiopia	Kenya	Lesotho	Malawi	Madagascar	Mozambique	Namibia	Rwanda	Somalia	South Africa	South Sudan	Sudan	Swaziland	Tanzania	Uganda	Zambia	Zimbabwe	Total

166

#### Lessons learnt

Lessons learnt from TCTP include:

- Anthropogenic and non-anthropogenic causes on environmental degradation continue to create additional demands for capacity development and need to work through comprehensive collaborations in Africa.
- Adverse impacts of climate change and environmental degradation are evolving fast, necessitating a need for innovations that address emerging challenges.
- Capacity building is key as a multi-dimensional approach to provide communities in Africa with measures and motivation to invest in their environment and improved livelihood.
- TCTP is a fundamental development programme to build capacity of developing countries in the region.
- Kenya having a similar socio-economic environment and biophysical conditions with many SSA countries, offers a good learning ground by showcasing success case studies and processes for addressing challenges presented by climate change and need for improved livelihood.
- Follow-up Visits (FUV) provides an important avenue for enhancing interest and commitment to meaningfully engage in implementing action plans by ex-participants and participating institutions.
- Successful implementation and sustainability is better achieved when an implementing agency works with relevant public and non-governmental agencies in participating countries ensures a sustained institutional technical staff capacity, a strengthened networking, and sharing of knowledge.
- Though FFS has great potential to contribute to extension service delivery, there is need for modification for it to suit social, cultural and economic status of participating communities.

#### Recommendations

- Hold a regional workshop/seminar for heads of participating TCTP countries to enhance participation and commitment, as well as mainstream lessons learnt and shared for sustainability.
- Follow-up visits should be undertaken to enhance synergies and partnerships.
- Establish a Regional Social Forestry Network for Africa (SOFONA) to enhance sharing of experiences and challenges on key nature based solution(s) and needs.
- Adopt a training-of-trainers (ToT) model on country or group of countries basis to ensure a critical mass of officers are trained in a country and region.

Figure 10.1: Pictorials of selected RTC process in Kenya and participating countries



TCTP official opening ceremony at KEFRI Headquarters



Group photo of Ambassadors, High Commissioners, Participants and KEFRI Staff during TCTP official opening ceremony at KEFRI Headquarters



Regional Policy Level Seminar on Mitigating Climate Change in Africa through Social Forestry



Group photo after official opening session of the TCTP regional training course



An in-house session during RTC at KEFRI Headquarters, Muguga



A resource person Mr. C. Sunguti (KSG) facilitates group work during discussions



Participants in a group work session on action plan



A participant making a presentation during a group discussion session on action plan





Participants growing through an outdoor FFS session

Participants being exposed on-farm on natural pasture in Makindu, Kenya



Sharing information of construction and performance of the charcoal kilns in Marigat, Kenya



Participants learn about preparation of organic pesticide in Rakwaro, Kenya



JICA Kenya Office hands over a vehicle to Director KEFRI to support TCTP activities



The (former) Cabinet Secretary, MEWNR Prof. J. Wakhungu (centre) presents a South-South Cooperation Award for the annual Global South-South Cooperation Expo 2013 to KEFRI Director (left)



Sample Regional Training Course certificate



**Regional Training Course Report** 



Mr. Mohamed from Sudan happily receives TCTP Certificate flanked by JICA Chief Representaive Ms. Keiko Sano (right) and Director KEFRI (left)



Group photo of TCTP graduands at KEFRI Headquarters in Muguga, Kenya

#### **10.4** Capacity Development Project for Sustainable Forest Management in the Republic of Kenya: Regional Cooperation Component

#### **10.4.1 Introduction**

A Technical Cooperation Project implemented between the Government of Kenya (GoK), through the Ministry of Environment, Climate Change and Forestry (MoECC&F), and Government of Japan (GoJ), through JICA entitled; "Capacity Development Project for Sustainable Forest Management in the Republic of Kenya (CADEP-SFM)" was developed for implementation from 2016 to 2021. The overall goal of the Project was to ensure sustainable forest management is promoted in Kenya towards the national forest cover target of 10%, as envisaged in Kenya's development blue print, the Vision 2030 and Kenya Constitution 2010. The project was implemented through five (5) Components, namely: Policy Support spearheaded by MoECC&F; Forestry Extension in ASALs and REDD+ Readiness both undertaken by Kenya Forest Service-KFS; Tree Breeding, and Regional Cooperation, both undertaken by KEFRI.

Activities of the Regional Cooperation Component were integrated and harmonized with those of a regional initiative entitled; "African Initiative for Combating Desertification to Strengthen Resilience to Climate Change in the Sahel and Horn of Africa" (AI-CD). The AI-CD aim was to enhance knowledge and experience sharing in natural resource management, and to facilitate technology transfer among African countries in order for the continent to collectively combat desertification.

#### 10.4.2 Regional Cooperation activities in Horn of Africa

#### **AI-CD** launch and objectives

The AI-CD was launched on 27<sup>th</sup> August 2016 during the Sixth Tokyo International Conference on African Development (TICAD VI) Side Event held in Nairobi, Kenya. This was the first time TICAD was held outside Japan. During the launch of AI-CD, a Statement was signed by the Cabinet Secretary Ministry of Environment and Natural Resources (MENR)-Kenya, Ministry of Environment and Sustainable Development-Senegal, JICA and United Nations Convention to Combat Desertification (UNCCD). The Statement was a commitment to accelerate efforts to combat desertification.

The objectives of AI-CD were achieved through three (3) outputs, namely; Building networks, Knowledge sharing, and Improving access to finance. The Initiative was implemented in six (6) Horn of Africa (HoA) countries, namely; Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan and Sudan, and in eight (8) Sahel Region countries, namely; Burkina Faso, Cameroon, Chad, Mali, Mauritania, Niger, Nigeria and Senegal. Collectively, there were a total of 15 member countries of AI-CD. Kenya was the lead country for Horn of Africa under the leadership of the Ministry of Environment, Climate Change and Forestry and Kenya Forestry Research Institute (KEFRI).

#### Regional forums and contribution to the international arena

Activities of AI-CD included holding and participating in; regional forums, technical workshops, high level events such as TICAD and UNCCD COPs. The aim of holding the regional forums was to share knowledge and experiences on combating desertification within and among Horn of Africa countries. By utilizing knowledge and experiences shared during the forums, AI-CD therefore, created platform for dialogue and supported the process for each member country to address its own challenges. The forums emphasized on the need to address environmental challenges using local solutions, which can be found within each country. The forums for Horn of Africa were successfully implemented. Some comments from the participants from HoA included those highlighted in Box 10.1

#### Text box 10.1: Participant's quotes

- It was my first time to participate in such a forum, I learnt a lot from the experiences of the partciapting countries on methods/practices for combating desertification. I also gained knowledge on how to change my attitude and that of communities in my country in order to give attention and prioritize combating desertification.
- We had a better understanding of what the different countries experience as a result of desertification and climate change challenges.
- The forum provided a platform for HoA to collectively evaluate where, exchange ideas and experiences, as well as chart a way forward towards climate change mitigation and adaptation as well as combating desertification.

The TICAD and UNCCD COPs forums provided opportunities to disseminate information and share progress by Kenya and participating Horn of Africa countries on combating desertification. Activities undertaken by AI-CD through Regional Cooperation from 2015 to 2022 are as shown in Table 10.6.

Date /Year	Activity	Venue	Outcome
October 2015	Launch of AI-CD during UNCCD COP12 Side Event	Ankara, Turkey	Formation of AI-CD
July 2016	TICAD VI Preparatory Meeting	KEFRI, Nairobi	AI-CD launch documents developed
August 2016	Official Launch of the AI-CD during TICAD VI High-Level Side Event	Nairobi, Kenya	Statement on commitment to combat desertification developed and signed
February 2017	1 <sup>st</sup> Regional Forum for Horn of Africa	KEFRI, Nairobi	Road map to implement AI- CD through development of Terms of Reference (ToRs)
June 2017	Ministerial Forum for Horn of Africa (2 <sup>nd</sup> Regional Forum for Horn of Africa	Nairobi, Kenya	<ul> <li>Promotion of AI-CD at political level</li> <li>Nairobi Declaration commitment to combat desertification</li> </ul>
September 2017	UNCCD COP 13 Side Event	Ordos, China	Side event and follow-up meeting with the Focal Points
May 2019	3 <sup>rd</sup> Regional Forum for Horn of Africa	Nairobi, Kenya	Resource mobilization strategy through Project Concept Note (PCN) development
September 2019	AI-CD Guideline and Book launched during UNCCD COP14 Side Event	New Delhi, India	<ul> <li>Promotion of AI-CD publications</li> <li>AI-CD Side Event and Follow up meeting for Focal Points</li> </ul>
December 2020	4 <sup>th</sup> Regional Forum for Horn of Africa	Held virtually	Progress of AI-CD in Horn of Africa
August 2021	Conference for Horn of Africa (5 <sup>th</sup> Regional Forum)	Held virtually	Shared progress, achievements, challenges encountered and opportunities presented by AI-CD

 Table 10.6 Activities undertaken from 2015 to 2022 by Regional Cooperation

Date /Year	Activity	Venue	Outcome
May 2022	UNCCD COP15 Side Event	Abidjan, Cote d'Ivore	Side event and follow-up meeting with the AI-CD Focal points

Figure 10.2: Pictorials of AI-CD regional fora in Kenya



1<sup>st</sup> Regional Forum participants during a field visit at Mr. Kituku's farm in Kibwezi, Makueni County, Kenya.



2<sup>nd</sup> Region Forum Delegates to Ministerial Forum for Horn of Africa held on 9th June 2017, Nairobi, Kenya.



3<sup>rd</sup> Regional Forum for Horn of Africa held at KEFRI Muguga, Nairobi, Kenya.



AI-CD Guideline and Book launched during AI-CD Side Event at UNCCD COP14 in New Delhi, India.

#### Technical training workshops at regional and national levels

The purpose of technical training workshops was to build capacity of participants on collecting, documenting and sharing good practices in natural resources management (NRM) for combating desertification and land rehabilitation using tools developed by KEFRI. The training also provided an opportunity for participants from HoA to; accelerate knowledge sharing, develop capacity for repackaging good practices into various extension materials, such as brochures, guidelines and manuals to promote adoption of existing good practices. Two (2) Technical Regional Workshops for Horn of Africa (HoA) and four (4) National workshops were held.

#### Figure 10.3: Pictorials of Regional Technical workshops in Kenya



1<sup>st</sup> Regional Technical Training Workshop participants learn about grass seed from Mr. Jeremiah Ngaya.



2<sup>nd</sup> Regional Technical Training Workshop with participants in the group discussion.

#### 10.4.3. Achievements of the Regional Cooperation/AI-CD in HoA

- Developed tools for collecting good practices
- Tools to ensure systematic collection and documentation of good practices in HoA countries were developed. These tools included: how to identify good practice, questionnaire for collecting information on good practice; and documentation guidance on how to write good practices. The good practices documented were then disseminated through internet-based tools and non-internet-based methods through printed materials.
- Improve capacity to access finance through proposal writing
- Improving access to finance was one of the major pillars of AI-CD. To contribute to this pillar, the Regional Cooperation Component identified the need to strengthen capacity of AI-CD participating HoA countries on proposal development. To build the capacity of institutions in HoA, a resource mobilization workshop was held in 2019. It was envisaged that successful proposals that translated into donor funds, would accelerate the activities on combating desertification at the ground level.
- Built networks among and within HoA countries.
- Built capacity of partners in HoA.
- Developed internet Web portal to intensify knowledge sharing through internet based platform.
- Produced and shared various knowledge products/materials such books, brochures, guidelines as non-internet methods. Some materials are as presented in Figure 10.4.

• Shared lessons from HoA on combating desertification.

#### Lessons learnt

- Need to have a common understanding of ownership of an initiative, e.g. through development of Terms of Reference (ToR).
- Involvement of policy makers to mainstream an initiative is paramount.
- Be creative and innovative in case of emerging challenges, e.g. due to COVID-19 containment measures where fora were held virtually.

#### 10.4.4 Opportunities and challenges

#### **Opportunities**

- Created networks and knowledge platforms, which can be used for continued knowledge sharing.
- The pool of trained personnel within HoA will successfully engage in further activities within the country.
- Leverage on prospects created by development partners.

#### Challenges

- Inadequate strategies to promote adoption of good practices in HoA.
- Lack of capacity on resource mobilization from partners to enable promotion of envisaged activities.

#### Recommendations

There is need to:

- Promote knowledge and good practices at ground/community level to collectively combat desertification in Africa.
- Continue working together within and among HoA countries to address current and emerging environmental challenges.



#### Figure 10.4: Knowledge products and aspiration

#### **10.5** Cooperation Awards

#### 10.5.1 The Joint and Individual United Nations Global South-South Cooperation Awards

Third Country Training Programme (TCTP) in Kenya, entailed JICA providing participants from Sub-Saharan Africa countries with a technical training programme in collaboration with Kenya as the third country for the purpose of transferring or sharing Social forestry development experiences, knowledge and technology. Over the 24 years of collaboration in TCTP, the process evolved within the context and objects of South-South and Triangular Cooperation. The success of TCTP in Kenya jointly earned KEFRI and JICA the United Nations Global South-South Cooperation Award in 2013, in recognition of special contribution to the South – South and Triangular initiative. Dr. Michael Mukolwe of KEFRI was equally awarded at the Individual category. The recognition and happy moments are as displayed in Figure 10.5.

#### Figure 10.5: South-South and Triangular Cooperation Awards



The joint United Nations Global South-South Development Award to KEFRI and JICA in recognition of special contribution to South-South and Triangular Cooperation in 2013.



Dr. Michael Mukolwe, Training Manager, KEFRI displaying the Individual United Nations Global South-South Development Award 2013 in recognition of the special contribution to South-South and Triangular Cooperation in 2013.

#### 10.5.2 JICA President Award

The Japan International Cooperation Agency (JICA) annually presents the JICA President Award to commend individuals and organisations with outstanding achievements of the socio-economic development in developing countries through JICA's international cooperation activities.

KEFRI was among five (5) organisations, nine (9) JICA Technical cooperation projects and 26 individuals from all over the world feted with The 13<sup>th</sup> JICA President Award as recognition of over three decades of outstanding international cooperation and contribution to socio-economic development not only in Kenya, but also Sub-Saharan African countries through Social forestry development processes. It is noted with appreciation, that KEFRI and the Ministry of Roads in Nicaragua were the only institutions outside Japan selected for the Award. Figure 10.6 displays a pictorial representation of the recognition and happy moments.

#### Figure 10.6: Pictorial of JICA President Award



KEFRI feted with 13<sup>th</sup> JICA President Award in 2017 from Ms. Keiko Sano, JICA Chief Representative (right) to Dr. Ben Chikamai, Director KEFRI (left) as a recognition of outstanding achievements for over three decades of Technical Cooperation in Social forestry.



Certificate of the 13<sup>th</sup> JICA President Award presented to KEFRI in October 2017.

#### 10.5.3 Embassy of Japan's Commendation to KEFRI

The year 2023 marked the 60th anniversary of the establishment of diplomatic relations between Japan and Kenya. In celebration of this important milestone, the Embassy of Japan honoured various Kenyan organizations who have contributed to the bilateral relations and supported the Embassy's activities these past years. KEFRI was among the institutes honoured and was consequently presented with a Certificate of Commendation on 14 November 2023 at the KEFRI Headquarters. The Institute merited the commendation due to its close to four decades of collaboration with Japan in research and development undertaken through various Technical Cooperations. The Certificate was presented by the Ambassador of Japan in Kenya H. E. Mr. OKANIWA Ken (Figure 10.7).

#### Figure 10.7. Pictorial of Embassy of Japan's Commendation



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### **CHAPTER 11**

#### SOCIAL FORESTRY SUCCESS STORIES OF MODEL FARMERS FROM DRYLANDS OF EASTERN KENYA

Musingo T.E. Mbuvi, Sylvia Mwalewa, Rebeccah Nenkai, Honjo Yuki, Josephine Wanjiku, Michael Mukolwe and Paul Tuwei

#### **11.1 Introduction**

Model farmer approach was one of the extension methodologies adopted for dryland forestry promotion under the Social Forestry Extension Model Development Project (SOFEM) implementation from 1997 to 2002. The purpose of this approach was to determine if selected model farmers could effectively play the role of an extension agent mainly information sharing and training other farmers. Selection criteria for the model farmers included; i) interest in tree planting and agroforestry practices, ii) experience in tree planting, iii) innovative and participatory attitude of the farmers, and iv) accessibility to the farm. Support given to model farmers included; technical advice on farming and tree growing, tools, as well as tree and fruit seedlings. Over the years, the approach was observed to be among the most successful extension methodologies in the drylands of Kenya. The selected farmers continue to disseminate knowledge and skills to other farmers, which is attributed to the effective and rigorous training implemented during the SOFEM project period. The technologies adopted by model farmers were beneficial in various ways including; improving living standards through sale of products such as seedlings, fruits, hay, timber and firewood. As a result of tree planting on-farm, farmers also benefited from improved environment such as, enhanced ecological services that included soil fertility improvement and soil and water conservation, biodiversity improvement, and aesthetic value.

#### 11.2 Case Studies of Model Farmers

An impact survey was undertaken in 2022 to gauge sustainability, adoptability and scalability of technologies promoted during SOFEM project period in Kitui County. Social forestry activities had a spill over effect to neighbouring County of Makueni, where other farmers adopted similar farm forestry technologies. This section highlights some of the success case study stories of model farmers.

#### 11.2.1 Case Study 1

<b>Farmer Information</b>	
Name of model famer	Mr. David Ngonde
2 <sup>nd</sup> generation adopter	Mr. Gideon Kinyamaso Kilunda (Son to Model farmer and also practicing farmer)
Famer home location	Kitui County, (Kisingo Village, Nzangathi Division, Zambani Sub - County)
Land size	6.0 ha
Year of nomination as model farmer	1998

## Technologies adopted on-farm by Mr. Ngonde and Mr. Kilunda

Mr. Ngonde was exposed to various Social forestry technologies through onfarm trials that included, researcher designed-farmer managed trials and farmer designed-farmer managed trials introduced through SOFEM project. Major trees introduced during the project period were; *Melia volkensii, Grevillea robusta, Senna siamea* and Mango. Working with his father, Mr. Kilunda gained interest, knowledge and skills on tree and fruit farming. Using this expertise, Mr. Kilunda adopted tree and fruit farming by sustaining the initial woodlot and fruit orchard established by his father and later expanded to other farm areas. Other farm activities by Mr. Kilunda include; seedling production by establishing a tree nursery, crop farming, and livestock rearing. Overtime, Mr. Kilunda has expanded are under trees and introduced oranges and various mango varieties that include, Apple, Maya, Boribo, Kent, Ngoe and Dodo.

#### Benefits from the adopted on-farm technologies

The on-farm technologies have been a source of livelihood for the farmer. For instance, trees are harvested for provision of timber, poles and firewood for both domestic and commercial purposes. Major income is usually accrued from sale of trees and fruits. At the farm gate, *Melia volkensii* sell at about Ksh. 20,000 (~US\$ 200) per tree, while mango sell at ksh10 per pierce and farmer can fetch over Ksh. 200,000 (~US\$ 2,000) per year. Income generated from farm products has enabled the farmer meet his domestic financial requirements that include; family daily provisions, paying school fees for his children, purchase of additional land, construction of a family house, and source of capital for start-up of other businesses.

#### Knowledge sharing of the technologies

Mr. Kilunda continuously shares knowledge of on farm tree technologies through discussion and advice to community members as well through formal training of organized groups such as tree growers group. The technologies have also been shared with immediate and extended family members who are also adopting the technologies. The technologies have increased the farmer's visibility and social standing, which has enabled him to partner with forestry and agricultural projects supported by County government and Non-governmental Organizations within his area.

#### Sustainability of the technologies

The farmer continues to acquire additional technical knowledge from KEFRI and Ministry of Agriculture as well as from field visits, attending relevant field days and training, and undertaking own field trials. As a result of the knowledge acquired, the farmer has been able to expand and improve farm activities, hence sustain and enhance productivity of technologies implemented on-farm. Though Mr. Kilunda was not the initial model farmer, his ability to continue implementation of introduced technologies is an example of technology transfer from father to son through the family working together on the farm. Involvement of family members in farming is therefore necessary to promote sustainability as adoption transcends from one generation to another.



Harvested Melia volkensii

Orange fruit orchard

Tree nursery

Figure 11.1: Tree technologies on Mr. Gideon Kilunda's farm

Farmer information	
Name of model famer	Mr. Joseph Mutua Kivelenge
Famer home location	Kitui County, Makolongo Village, Kisasi Sub-County
Land size	5.3 ha
Year of nomination as model farmer	1999

#### 11.2.2 Case Study 2

#### Technologies adopted on-farm by Mr. Kivelenge

Mr. Kivelenge was trained on various farm forestry technologies through SOFEM project between 1999 and 2002. During this period the farmers was trained by a multi-disciplinary team that comprised; KEFRI, Ministry of Agriculture (MoA) and JICA. Training entailed knowledge and skills on; tree nursery establishment and management, tree and fruits farming, and pasture growing. During the initial SOFEM project period, the farmer was issued with 20 *Melia volkensii* and seven (7) mango seedlings. With the increased knowledge gained from various training, Mr. Kivelenge later expanded by planting 70 Melia and 300 mango trees. Mango growing is the most preferred technology as it contributes a higher percentage of the farmer's income. The farmer targets to plant 600 mango trees more and expand area under Melia to enhance income generation. The mango varieties currently grown by the farmer are; Apple, Kent and Ngoe, a selection based on market preference.

#### Benefits from adopted technologies

Tree growing and other agroforestry related activities have benefited Mr. Kivelenge economically, ecologically and socially. Through sale of mango fruits, the farmer earns an average of Ksh. 325,000 (~US\$ 325) per year. He also produces hay that is sold at Ksh. 200 - 300 (~US\$ 20-30) per bale. Income generated from the farm has enabled the farmer to meet his financial obligations that include; paying school fees, construction of a family house, and support family day-to-day living requirements.

#### Knowledge sharing of the technologies

With knowledge and skills gained as Trainer of Trainers, practicing the technologies and exposure, the farmer has been able to facilitate various training activities nationally and regionally, specifically on Mango grafting technology. The farmer conducts private training for individual farmers or farmer groups on request, undertakes landscaping and extension services at a fee, therefore, enhancing his income. Mr. Kivelenge has also been able to effectively transfer information and technologies to other farmers and family members by working closely with his family members including his wife and sons, an approach that will ensure continuity and sustainability of technologies on the farm.

#### Sustainability of the technologies

The farmer acquired additional knowledge even after conclusion of SOFEM project, which has enabled him to address emerging challenges such as water shortage, pest and diseases attack, and marketing. The International Centre of Insect Physiology and Ecology (ICIPE) trained Mr. Kivelenge on Integrated Pest

Management (IPM), while Action Aid trained him on marketing mango fruit and value addition. Currently, Mr. Kivelenge is mainly implementing tree, fruit, crop and pasture farming technologies on his farm. Through the various technologies practiced, the farmer has had an opportunity to partner with various forestry and agricultural projects in his area. The farmer has also continued to build his knowledge based through; field visits, participation in Farmer Field School, farmer exchange visits, field days and organized training courses. The farmer has demonstrated that continuous acquisition of technical knowledge, adoption of new innovations, and meeting market demands are key in sustaining on-farm technologies.



Melia volkensii woodlot

Mango fruit orchard

Figure 11.2: 1	<b>Free technologies on</b>	Mr. Joseph	Kivelenge's farm
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#### 11.2.3 Case Study 3

Farmer information						
Name of model famer	Ms. Christine Kitema					
Famer home location	Kitui County, Mosa Location, Kisasi Sub-County					
Land size	3.2 ha					
Year of nomination as model farmer	1999					

#### Technologies adopted on-farm by Ms. Christine Kitema

Ms. Kitema was trained on tree nursery establishment and management and tree planting during SOFEM project period. She received *Melia volkensii, Senna siamea* and mango seedlings for planting from the project. By participating in various training events and farmer exchange visits, Ms. Kitema acquired knowledge on other on-farm activities such as fruit and vegetable farming

and nursery establishment and management, livestock keeping and pasture management. For mango growing, the farmer modified the technology to adopt a spacing of 12m x 12m as opposed to the 8m x 8m initially recommended. The wider spacing was adopted to give enough space for canopy expansion. The farmer also uses traditional methods of eradicating mango pests, which involves burning cow dung to smoke out the pests.

#### Benefits from the technologies adopted on-farm

The farmer earns an average of Ksh 100,000 (~US\$ 100) per year from the sale of mango fruits. The grass pasture provides feed for farmer's livestock and is also sold for income generation. The hay from pasture farming is sold at an average of Ksh. 300 (~US\$ 3) per bale. Livestock keeping and crop farming are undertaken mainly for domestic use. Income from sale of various farm products supports the family's daily needs, and capital for expansion of crop farming specifically vegetable farming. Pasture farming has been useful in control of soil erosion and river bank protection. The returns from farming have motivated Ms. Kitema to maintain and expand on-farm activities despite challenges posed by the harsh climatic conditions and livestock damage on young trees.

#### Knowledge sharing of the technologies

By participating in various training and farmer exchange visits, Ms. Kitema acquired knowledge and skills on various technologies. She shares the information with family members who are actively involved in tree growing, fruit and vegetable farming, seedling production through tree nursery establishment and management, livestock keeping, pasture management, tree and crop farming. Being a retired local Assistant Chief, the farmer has used her administrative skills to mobilize and influence local community members to take up tree planting, an activity being embraced by many households in Kisasi sub-county.



Mature Melia volkensii trees

Harvested senna siamea (front) and hay (back)

Mango fruit orchard

#### Figure 11.3: Technologies on Ms. Christine Kitema's farm

# Farmer information Name of model famer Ms. Teresia Musango Ndetei 2<sup>nd</sup> generation adopter Mr. Ambrose Musango Famer home location Kitui County, (Siukuni village, Kiangwa Sublocation, Ikanga Location, Mutomo Sub-County) Land size 7.0 ha Year of nomination as model farmer 1999

#### 11.2.4 Case Study 4

#### Technologies adopted on-farm by Ms. Ndetei

Ms. Ndetei received *Melia volkensii*, mangoes, *Senna siamea, Azadirachta indica* (neem) and *Terminalia brownii* seedlings from SOFEM project. She later expanded tree planting by establishing 150 *M. volkensii* in a woodlot. The farmer undertakes these activities in collaboration with the family members including her husband, sons and daughters. Naturally, growing *T. brownii* is left as pure stand on-farm. The farmer has a tree nursery for production of own seedlings to plant in the farm. She undertakes: crop farming where maize and legumes are the main crops grown, and livestock farming where mainly cattle, goats, sheep, donkeys and poultry are kept. Food crop farming and livestock keeping are mainly undertaken for domestic use.

#### Benefits from adopted technologies

The farmer generates income from sale of Melia trees. The income accrued supported household requirements such as payment of school fees, medical care, family daily needs and capital to support livestock farming. Timber harvested from trees on-farm was used for family home construction.

#### Knowledge sharing of the technologies

Ms. Ndetei together with the son are involved in knowledge sharing to local communities, farmer groups and self-help groups to promote tree farming. They also worked closely with Ministry of Agriculture especially in promoting adoption of water conservation structures and terraces. The farmer is very grateful to SOFEM project, which was an eye opener in forestry activities and she is keen to work with other projects, which support forestry in drylands.

#### Sustainability of the technologies

Tree planting activities motivated Ms. Ndetei's sons to take up forestry courses

at college level that enabled one son to secure a job in the forestry sector while the other is engaged in tree growing and farming activities on the family land. The sons involvement in tree and crop farming will ensure sustainability farming activities as Ms. Ndetei ages. The sons are determined to enhance forestry activities in the area where most locals prioritize crop farming as opposed to tree planting.



Tree nursery

Neem trees growing on farmMelia volkensii treesFigure 11.4: Tree technologies on Ms. Teresia Ndetei's farm

#### 11.2.5 Case Study 5

Farmer information	
Name of model famer	Mr. Jonathan Mung'ala Kituku
2 <sup>nd</sup> generation adopter	
Famer home location	Makueni County, Nyayo village, Ngulu Sub- location; Kikumbulyu Location; Kibwezi Sub-County
Land size	>17.2 ha under Melia volkensii
Year of nomination as model farmer	2005

#### Technologies adopted on farm by Jonathan Kituku

#### Farmer background

Mr. Jonathan Kituku is a model farmer based in Ngulu Sub-location, Kibwezi Subcounty of Makueni County. Upon early retirement from government services, Mr. Kituku embarked on crop farming, where he mainly grew maize, green grams and beans, an activity he undertook for 14 years. However, due to declining rainfall experienced in Kibwezi area, crop farming became uneconomical, prompting the farmer to shift to alternative investments that included tree farming, Mango growing and livestock keeping. Over the years, with training and advice from KEFRI, KFS and MoA, the farmer has managed to turn his low productive land to one of high productivity through application of the various technologies and adoption of good practices acquired over time.

#### On-farm technologies adopted by Mr. Kituku

#### Melia volkensii woodlot development

Mr. Kituku identified *Melia volkensii*, an indigenous tree in the drylands of Kenya for woodlot development. The species selection was based on its tolerance to low rainfall conditions, fast growth and production of high quality timber. The farmer has established over 16,000 Melia trees since his first planting of about 100 seedlings in 2005. The farmer has developed a tree planting culture and made a commitment to plant additional Melia trees every year to ensure sustainability of Melia growing.

Under the Melia trees, natural grass is left to grow, which is harvested for hay and grass seeds. A bale of hay is sold at Ksh 300 (~US\$ 3). The farmer also sells Melia and selected grass seeds, seedlings, firewood from pruning, and timber.

As an outstanding model commercial Melia farmer, Mr. Kituku received Presidential recognition award of Head of State Commendation (HSC).



On-farm Melia volkensii nursery

Melia volkensii woodlot and firewood from prunings



Hay harvesting and baling from Melia woodlot

Mr. Kituku (right) a prominent Mukau farmer displaying Head of State Commendation (HSC) award

Figure 11.5: Technologies on Mr. Jonathan Kituku's farm

#### Mango orchard development

Mr. Kituku works closely with MoA in orchard development, especially on management practices such as IPM, pruning, pollarding and orchard maintenance procedures, harvesting and post-harvest handling. The farmer has adopted intensified pruning to achieve an inverted funnel crown in order to promote light canopy that allows sunlight penetration for high fruit production. In a good season, production of at least 40 good fruit pieces per tree can be achieved. At the farm-gate, price of a fruit is at Ksh 25 (~US\$ 0.25) per piece. Mr. Kituku plants different Mango varieties on-farm, the main one being Apple, a variety favoured for export market.



Apple mango variety

A funnel shape canopy of mango tree

Figure 11.6: Mango technologies on Mr. Jonathan Kituku's farm

#### Livelihood sources diversification

Other farming activities by Mr. Kituku include; livestock farming and crop growing. The main crops grown constitute maize and green gram, which form short-term enterprise for the farmer. Mango farming form medium-term while tree farming constitutes the long-term enterprise.

#### Sustainability

Mr. Kituku continues to gain knowledge from various ministries, institutions, groups as well as persons who visit his farm. The knowledge and skills gained, have distinguished him as a trainer for other farmers and students on attachment. Mr. Kituku is currently working closely with his son who has studied sustainable agriculture course at College level.

#### 11.3 Lessons Learnt from Model Farmers

- Attributes of model farmers that include; active involvement in on-farm activities, willingness to interact and share with other stakeholders and farmers, enthusiastic, innovative and being a leader are important in developing a farmer trainer, through whom scaling-out of technologies is achieved.
- For a technology to be widely adopted and scaled up, it should be of economic value to meet basic household needs and livelihood improvement.
- Though tree farming is important in sustainable natural resource management, farmers need to create a balance between socio-economic and conservation needs to avoid "Green Hunger" where farmers could face a risk of a green environment surrounding but lack adequate food.
- Integrated farming appeals to farmers as this ensures food security and income generation for the farm families. This model ensures a plan that encompasses various time bound enterprises such as:
  - \* Short-term enterprises growing of drought tolerant crops such as legumes and cereals.
  - \* Medium-term plan enterprises growing of perennial crops such as Mangoes and livestock keeping.
  - \* Long-term enterprises tree growing.
- Inclusion of family members in tree farming activities empowers its members, therefore, promoting sustainability of farm enterprises long after the vision bearer.
- Continuous learning from different institutions as well as other farmers, offering farm as learning ground provides a model farmer an opportunity to learn new technologies and techniques as well as approaches to address current and emerging environmental challenges.

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