



KENYA FORESTRY RESEARCH INSTITUTE



Annual Report and Record of Research 2018 - 2019

KEFRI is ISO 14001:2015 and 9001:2015 IMS Certified



KENYA FORESTRY RESEARCH INSTITUTE

**Annual Report
and
Record of Research
2018 - 2019**

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ASALs	Arid and Semi-arid Lands
ASR	After Storage Ripening
CBO	Community Based Organization
CCF	Chief Conservator of Forests
CERP	Coast Eco-region Research Programme
CHERP	Central Highlands Eco-region Research Programme
CITES	Convention on International Trade in Endangered Species (Flora & Fauna)
DERP	Drylands Eco-region Research Programme
DG	Director General
EMS	Environmental Management System
IMS	Integrated Management System
FY	Fiscal Year
GDP	Gross Domestic Production
ha	Hectare
ISO	International Standard Organization
ISTA	International Seed Testing Association
JICA	Japan International Cooperation Agency
KEFRI	Kenya Forestry Research Institute
KFS	Kenya Forest Service
KFSC	Kenya Forest Seed Center
Kg	Kilogram
Kshs	Kenya shilling
KTDA	Kenya Tea Development Authority
LVBERP	Lake Victoria Basin Eco-region Research Programme
MDAs	Ministry Departments and Agencies
MoAs	Memorandum of Agreements
MoEnv& F	Ministry of Environment and Forestry
MoUs	Memorandum of Understanding
NACOST	National Council for Science and Technologies
NGO	Non-Governmental Organization
OSHA	Occupational Safety Health Act
PC	Performance Contract
PhD	Doctorate of Philosophy
QMS	Quality Management System
RVERP	Rift Valley Eco-region Research Programme
SFTC	Social Forestry Training Centre
STI	Science, Technology and Innovation

Service Delivery Charter

No.	Service/Good	Requirement	Cost	Time line
1.	Develop forest technologies	Research based stakeholder needs	Depends on the technology	Depends on reporting period
2.	Disseminate forest technologies	Communication to stakeholders	Depends on format or channel of communication	Continuous on daily basis
3.	Supply of high quality ree seed	By order	As per Tree Seed Catalogue	<ul style="list-style-type: none"> • On order • Depends on seasonal availability
4.	Supply of high quality tree seedlings	By order	As per Tree Seedlings Catalogue	Depends on seasonal availability
5.	Training in forestry	On request	Nature of training	Quarterly
6.	Analysis of wood, plant and soil	On request	As per Analytical Catalogue	After contractual agreement
7.	Provision of timber and non-timber products	By order	As per Catalogue	Immediate (Depends on number of items)
8.	Advice on landscaping, tree establishment and management	On request	Depends on nature and duration of course	Immediate
9.	Provision of training and conference facilities	On request	Depends on nature and duration of course	Response within 4 working days
10.	Attachment of students	Application plus cover letter from the Institutions	Personal insurance cover	Response within 4 working days
11.	Picnic sites for recreation and video	On request	As per catalogue	Immediate (After booking)
12.	Consultancy in forestry	Call for consultancy	Depends on the nature of consultancy	Immediate (After contractual committee)
13.	Resolution	Launch of specific complaint	After verification	One week

**We value and welcome feedback and comments to enable us serve you better.
Complaints, compliments and Suggestions should be sent to:**

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HUDUMA BORA NI HAKI YAKO

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KEFRI is a state agency established in 1986 and operates under the Science and Technology Act (Chapter 250) of the Laws of Kenya, which was repealed by the Science, Technology and Innovation (STI) Act No. 28 of 2013. The Institute plays a significant role in development of national and international agendas, through research and development of technologies, as well as sharing information for sustainable management, conservation and development of forests.

KEFRI is a state agency established in 1986 and operates under the Science and Technology Act (Chapter 250) of the Laws of Kenya, which was repealed by the Science, Technology and Innovation (STI) Act No. 28 of 2013. The Institute plays a significant role in development of national and international agendas, through research and development of technologies, as well as sharing information for sustainable management, conservation and development of forests.

In the Fiscal Year (FY) 2018-2019, KEFRI continued to enhance outreach to stakeholders in the delineated six geographical eco-regions namely; Coast Eco-region Research Programme, Dryland Eco-region Research Programme, Central Highlands Eco-region Research Programme, Rift Valley Eco-region Research Programme, Lake Victoria Basin Eco-region Research Programme, and the National Forestry Products Development Research Programme. Each programme takes cognizance of the uniqueness in natural resources, forestry development challenges, as well as socio-economic and livelihood status of local communities based on national forestry issues of concern stated in KEFRI Strategic Plan [2018-2022].

In the year under review, KEFRI Board of Directors continued to provide leadership in designing suitable strategies and supporting national and international policies through approval of perquisite budgets as per the agreed performance target in the thematic research approach namely: Forest Products Development; Biodiversity and Environment Management; Socio-economics, Policy and Governance; Forest Productivity and Improvement; and Technical Support Services. Similarly, the Board provided for resources to support infrastructural development at the six Eco-regional programmes and sub-centres namely; Taita Taveta, Migori, Rumuruti and Lamu.

On behalf of the Board of Directors and myself, I pledge for continued support to KEFRI development agenda in human capacity improvement, facilities and implementation of research projects. Special thanks to the Government of Kenya, Development Partners, entire KEFRI staff and many more stakeholders for the support which enabled successful achievement of the research and development agenda in the Fiscal Year 2018-2019.

A handwritten signature in blue ink, appearing to read 'Sammy Letema', written in a cursive style.

Dr. Sammy Letema
Chairman, KEFRI Board of Directors



KEFRI implemented research and development planned activities for Fiscal Year [July 2018 – June 2019]. The planned research activities on forestry development were geared towards realization of Vision 2030 and the Big 4 agenda in forestry sector through enhancing tree productivity, efficient use of forestry resources as well as supporting forestry based climate change adaptation and mitigation initiatives. Notable activities undertaken include: tree improvement, tree products development, validation of propagation protocol for Sandalwood, *Melia*, and indigenous bamboo; screening of

commercial plantation tree for seed and germplasm production; evaluation of tree species for preferred products, silvicultural management for both exotic and indigenous species such as Pines, Eucalypts, *Melia volkensii*, *Gmelina arborea*, *Terminalia brownii*, *Acacia spp* among others and assessment of the performance of natural forest rehabilitation.

During the reporting period, the donor funded projects included: VLIR *Melia* propagation project; KEFRI/JICA project on Development of Drought Tolerant Trees for Adaptation to Climate Change; ASAL Forest Landscape Restoration in Kenya, Biofuel4 Kenya Project, Dutch-Sino-East Africa Bamboo Development Project, DIVERSify, SUNRISE and OPenNESS Projects, Support to Commercial Forestry Development and Integrated Programme to Build Resilience to Climate Change and Adaptive Capacity of Vulnerable Communities in Kenya were funded and became operational.

Major achievements of key flagship projects realized during the reporting period included: tree seed development and production totaling 16,000 Kg, establishment of about 26 ha of seed stands and seed orchards of various commercial species, establishment of progeny trials of *Melia volkensii* and *Acacia tortilis*, raising of 55,000 of difficult to propagate species and superior genetic materials, and 650,000 seedlings of assorted tree species raised in nurseries across the eco-regions and sub-centres.

The Institute carried out outreach activities through scientific for and exhibition in 12 Agricultural Society of Kenya shows countrywide. Copies from 43 diverse KEFRI publications authored within the year were distributed. Mass media, internet and social media were some of the tools used for marketing products and services, transfer technologies, network and share information with stakeholders.

During the reporting period, the Institute launched its 6th Strategic Plan 2018-2022, signed 5 new Memorandum of Understanding (MoUs) and Memorandum of Agreements (MoAs) with various partners for collaborators in research and information dissemination endeavors. Such included, CBO and NGOs, County governments, MDAs and registered youth and university groups/entities. The institute continued building capacity for; scientists, students from universities and tertiary colleges.

On behalf of the entire KEFRI staff and myself, I thank the Board of Directors for guiding and providing enabling environment for the institute to implement its research agenda that has made significant impact to forest sector development and improved livelihood of our citizens.

A handwritten signature in blue ink, appearing to read 'Joshua Cheboiwo', written in a cursive style.

Joshua Cheboiwo (PhD)
Director-KEFRI

Kenya Forestry Research Institute (KEFRI) is a State Corporation established in 1986 under the Science and Technology Act (Cap 250) which has since been replaced by the Science, Technology and Innovation Act No. 28 of 2013 to undertake research in forestry and allied natural resources, generate and promote improve technologies for sustainable development.

Vision

A world class Centre of excellence in forestry and allied natural resources research for sustainable development

Mission

To conduct research and provide information and technologies for sustainable development of forests and allied natural resources for socio-economic development

Mandate

- Conduct research in forestry and allied natural resources
- Disseminate research findings to stakeholders
- Building capacity of stakeholders and
- Establish partnerships and cooperate with other research organization and institutions of higher learning in joint research and training

Core Values

- Teamwork
- Healthy environment
- Professionalism
- Partnership
- Innovation
- Creativity
- Customer focus

1.0 Tree Seed Development and Production

Forestry contributes about 3% to Kenya's GDP and 10% of the non-monetary economy. It is estimated that the formal forest sector employs about 50,000 people directly and about 600,000 indirectly, making it an important source of employment particularly in the rural areas. Forests and trees supply over 90% of the rural and peri-urban energy needs. Forests and trees also provide important ecosystem services that include; conservation of water catchment areas, soil protection and carbon sequestration. The forests also are home to many organisms. Forestry therefore plays a key role in the socio-economic development of Kenya.

Provision of high quality germplasm, which is one of the key areas of forestry research and development, plays a major role in forestry development in meeting the demand for forest products and services. Development, production and conservation of tree germplasm in KEFRI is continuous and involves establishment of seed stands and seed orchards of highly demanded tree species. Seed production activities are undertaken within five eco-regional programmes i.e. CERP, DERP, CHERP, RVERP and LVBERP. The activities aim to meet the Government target of at least 10% tree and forest cover as well as requirements of numerous tree planting programmes within the country and beyond.

1.1 Establishment of tree seed sources

During the fiscal year 2018-19, KEFRI continued to undertake establishment of tree seed sources ie seed orchards and seed stands in order to achieve adequate production of high quality seed in line with its mandate.

1.1.1 Establishment of seed orchards

The institute established five (5) seed orchards comprising different tree species including; *Cupressus lusitanica*, *Gmelina arborea*, *Grevillea robusta*, *Moringa stenopetala*, among other species. These orchards were established in the various eco-regions as shown in Table 1.1.

Table 1.1: Seed orchards established in different Centres / sites

Species	Centre	Centre / Location	Hectares (ha)
<i>Gmelina arborea</i>	CERP		2.0
<i>Melia volkensii</i>			1.0
<i>Cupressus lusitanica</i>	CHERP	KEFRI estate next to Kikuyu Boys Secondary School	2.0
<i>Grevillea robusta</i>		St Georges Secondary School	0.81
<i>P.patula</i>	RVERP		3.0
<i>C. lusitanica</i>			4.0
<i>E.grandis</i>			3.0
<i>Gmelina arborea</i>	LVERP	Migori ASK Showground	4.0
<i>Others assorted</i>			2.0
Total			22

1.1.2 Establishment of seed stands

Within the same period, the Institute established a total of 26 ha of seed stands of various species including; *Bambusa vulgaris*, *Casuarina equisetifolia*, *Eucalyptus camaldulensis*, *Eucalyptus citriodora*, *Eucalyptus maculata*, *Eucalyptus urophylla*, *Gmelina arborea*, *Grevillea robusta*, *Melia volkensii*, *Milicia excelsa*, *Moringa oleifera*, *Osyris lanceolata*, *Tectona grandis*, *Terminalia spinosa*, among other species. The seed stands were established in the different eco-regions as shown in Table 1.2.

Table 1.2: Tree seed stands established in different Centres in 2018 - 2019

Species	Centre	Location	Hectares (ha)
<i>Bambusa vulgaris</i>	CERP	Malindi GK Prison	1.0
<i>Casuarina equisetifolia</i>			1.0
<i>Gmelina arborea</i>			1.0
<i>Tectona grandis</i>			1.0
<i>Grevillea robusta</i>		Taita	1.0
<i>Melia volkensii</i>			1.0
<i>Melia volkensii</i>		Gede	3.0
<i>Terminalia spinosa</i>			1.0
<i>Milicia excelsa</i>			1.0
<i>Tectona grandis</i>		Lamu	1.0
<i>Melia volkensii</i>			1.0
<i>Eucalyptus urophylla</i>	CHERP	Muguga next to Pine View School	1.0
<i>Osyris lanceolata</i>		Farmers field in Tigania, Laikipia County	1.0
<i>Moringa oleifera</i>		University of Nairobi (UoN)	1.0
<i>Eucalyptus camaldulensis</i>	DERP	Gwakaithi Primary School at Ishiara Embu	1.0
<i>Eucalyptus camaldulensis</i>		Kathwana Youth Polytechnic, Tharaka-nithi County	1.0
<i>Gmelina arborea</i>		Muthwani Secondary School, Makueni County	1.5
		Gwakaithi Primary School at Ishiara Embu	1.5
<i>G. robusta</i>	RVERP	Soini ADC	3.0
<i>M. stenopetala</i>			2.0
<i>Eucalyptus camaldulensis</i>	LVERP	Nyagera Primary School	2.0
<i>E. maculata</i>		Mago School in Yimbo, Bondo County	2.0
<i>E. urophyra</i>		Malindi GK Prison	1.0
<i>E. citriodora</i>		Malindi GK Prison	1.0
<i>Moringa oleifera</i>		Ramogi Primary School	1.0
<i>Others assorted</i>			2.9
Total			26.0

1.2 Seed collection, processing and distribution

KEFRI through the Kenya Forestry Seed Centre (KFSC) is the major supplier of high quality tree seed both nationally and within the region to meet the demand for forest products and services. It has a capacity to supply adequate quantities of tree seeds to raise 200 – 400 million seedlings annually.

The Seed Centre collects tree seed from selected and established seed sources and seed orchards. Production of high quality tree seed involves several activities that include: identification of seed sources; seed survey to determine the timing of collection in a particular seed source; actual seed collection; seed processing that entails seed extraction, drying and cleaning; quality testing before storage, and finally distribution to the end users.

1.2.1 Seed collection

The seed activities were undertaken under five KEFRI Eco-regional research programmes and expanded to sub-centres thus covering all the ecological regions of Kenya.

The Central Highlands Eco-Region Research Programme (CHERP) has 2 seed collection stations of Muguga and Nyeri. Drylands Eco-region Research Programme (DERP) has 3 stations of Kitui, Kibwezi and Garissa, Coast Eco-region Research Programme (CERP) has 3 stations of Gede, Lamu and Taita Taveta, Rift Valley Eco-region Research Programme (RVERP) has 2 stations of Londiani and Turbo, and Lake Victoria Basin Eco-region Research Programme (LVBERP) with 3 stations of Maseno, Kakamega and Migori.

All the seed collected was processed and subjected to quality tests before any distribution to clients. The seed testing was done following International Seed Testing Association (ISTA) rules that require determination of; moisture content, purity, germination and seed weight (number of seed per kg) for every seedlot. Seed testing was done for fresh seed as well as retrials for seed that had been in storage for more than 6 months.

In the fiscal year 2018 - 19, KEFRI collected 16,961.50 kg of seed from a range of 103 species (Table 1.3). The Institute also distributed various species to stakeholders including; Kenya Forest Service, individual farmers, schools, NGOs, and private companies.

Table 1.3: Summary of tree seed production and distribution in 2018-2019

Station	Amount (kg)	No. of Spps	Remarks
KFSC, Muguga	1,619.15	23	The seeds are sent to Muguga for the above mentioned preparation
Nyeri	1,544.80	23	
Londiani	1,302.35	16	
Turbo	1,168.40	20	
Maseno	925.30	9	
Kakamega	3,264.50	25	
Kitui	2,789.10	15	
Kibwezi	1,869.50	24	
Garissa	280.10	6	
Gede	1,470.90	21	
Lamu	410.10	11	
Taita taveta	258.00	9	
Suppliers	59.25	2	
Grand Total	16,961.50		

1.2.2 Improvement of Seed Production Facilities

During the year under review, seed production, processing and storage facilities within various eco-region centres were improved as follows:

- Repairing the seed processing unit at Muguga (painting of buildings and seed drying beds).
- Construction and repair of seed stores in Nyeri and Meru
- Construction of a seed drying bed in Garissa
- Construction of a new drying bed and repair the existing ones in Maseno.



Figure 1.1: Renovated Seed extraction unit at CHERP, Muguga

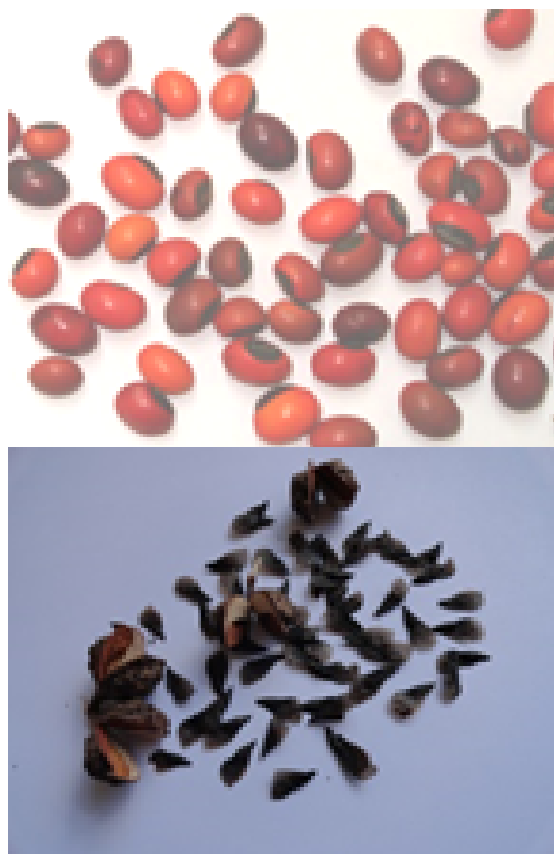


Figure 1.2: Processed seeds of various species



Figure 1.3: Tree seed packed for dispatch to clients

2.0 Production of Planting Materials

KEFRI supports afforestation and conservation of tree genetic resources through production of planting materials for various categories of tree species. In the year 2018 - 2019, the Institute continued to raise seedlings for: species that are difficult to propagate (Table 2.1); superior genetic quality planting materials some of which KEFRI uses in raising high quality seed sources (Table 2.2); and assorted tree species to meet demand from various stakeholders or programmes (Table 2.3).

Table 2.1: Seedlings raised in FY 2018 - 19 for species that are difficult to propagate

Species	Site	No. of seedlings
Bamboo spp.	CERP	6,000
<i>Gmelina arborea</i> grafts		1,000
<i>Melia volkensii</i>		1,957
<i>Terminalia spinosa</i>		1,140
<i>Melia volkensii</i>	DERP	44,921
Bamboo spp.		7,412
<i>Osyris lanceolata</i>		6,188
<i>Vitex payos</i>		1,000
<i>Melia volkensii</i>	CHERP	409
<i>Ocotea usambarensis</i>		135
<i>Bambusa vulgaris</i> var. <i>striata</i> (yellow bamboo) and <i>Dendrocalamus asper</i> (Giant bamboo)	RVERP	3,000
	Londiani	2,000
	Marigat Turbo	1,000

Table 2.2: Some of superior genetic quality planting material raised in year 2018 - 19

Species	Site	Number
<i>Gmelina arborea</i> grafts	Gede	1,000
<i>Gmelina arborea</i> {progeny}	Maseno	1,060
<i>Cupressus lusitanica</i> grafts of improved material	Londiani	2,000
<i>Grevillea robusta</i> grafts	Muguga	500
<i>Cupressus lusitanica</i> grafts		2,000



Figure 2.2: Grafted seedlings under incubation at Londiani centre

KEFRI raised more than 400,000 seedlings of various species in its nurseries countrywide. These seedlings were intended for establishing experimental sites and plantation within the Institute, sales, and free issues to institutions and the public. Seedlings of species raised in the nurseries for the high rainfall areas during the year included: *Azalia quanzensis*, various Bamboo spp including *Bambusa vulgaris*, *Casuarina equisetifolia*, *Croton megalocarpas*, *Dovyalis caffra*, *Eucalyptus spp* (various), *Grevillea robusta*, *Gmelina arborea*, *Kigelia africana*, *Maerua decumbens*, *Milicia excels*, *Octotea usambarensis*, *Senna spectabilis*, *Tectona grandis*, *Terminalia kilimandscharica*. Seedlings raised for the drylands included: *Acacia spp* (various), *Aloe spp*, *Azadirachta indica*, *Bamboo spp* various including *Oxtenanthera abyssinica*, *Carica papaya*, *Dalbergia melanoxylon*, *Delonix regia*, *Eucalyptus camadulensis*, *Mangifera indica*, *Melia volkensii*, *Moringa oleifera*, *Polyacantha longifolia*, *Senna siamea*, *Sclerocarya birrea*, *Syzygium cuminii*, *Tamarindus indica*, *Terminalia mentalis*, *Terminalia spinosa* and *Vitex payos*.

The production include 40,159 from CERP comprising Gede and Lamu; 65,695 at DERP comprising Kitui, Kibwezi and Garissa. Other are CHERP production from Muguga and Nyeri; RVERP production which included Londiani, Turbo Marigat, Turkana and total production for LVBERP which covers Maseno, Kakamega, Ramogi, Kuja River and Migori.



Figure 2.3: Tree seedlings being raised at the nursery and greenhouse in DERP, Kitui

3.0 Development of Forestry Technologies

KEFRI conducts research to develop technologies in forestry and allied natural resources for socio-economic development of Kenya. These technologies therefore play a crucial role in improving forest productivity, increasing forest cover, rehabilitation of degraded forests and woodlands, supply for wood for domestic and industrial use, and development of forest products for improved livelihoods. In the financial year 2018 - 2019, KEFRI developed various technologies that include: propagation of difficult to propagate tree species; breeding tree species for improved yields; and silvicultural management of tree species, as well as developed wood and non-wood forest products.

3.1 Propagation of Difficult to Propagate Tree Species

3.1.1 Propagation of *Osyris lanceolata* (East African Sandalwood)

In the fiscal year 2018-19 KEFRI pricked out 6,200 seedlings of *Osyris lanceolata* commonly known as East African Sandalwood. The seedlings were hosted with plants namely; *Dovyalis abyssinica*, *Pitosporum viridiflorum*, *Indigofera erecta*, *Acokanthera schimperi*, and *Rhamnus staddo*. Sandalwood is a shrub or a small tree growing to a height of six meters. In Kenya, the species occurs naturally mainly in sporadic patches in margins of dry forests, evergreen humid bush-lands, grasslands and thickets. It grows at an altitude of between 800-2550m above the sea level. The species is important for cosmetics, red dye, smoking milk containers, while the bark powder to heal wounds, treating stomachache, tonsils, diarrhoea, ulcers, snakebites and rashes. Due to the species multiple uses, the demand has outstripped supply leading to over exploitation, whereas domestication has been constrained by inadequate seeds and seedlings.

To ensure sustainable availability of Sandalwood products, KEFRI is undertaking research to address domestication and other challenges associated with sandalwood propagation. Several seed collection sources have been identified whereas seed collection, handling and germination protocol has been developed. A seedlings propagation method namely Marcotting has been developed as an alternative to seed propagation methods. Moreover, nursery experiment have been undertaken to ease seedling production.



Figure 3.1.1: Assorted plants being used to host *Osyris lanceolata* plantlets

3.1.2 Propagation of *Vitex payos*

Vitex payos (black plum) is one of the priority dryland fruit species belonging to *Verbenacea* family. It is a small deciduous tree growing up to a height of 10 m high with a low, sparsely branched and rounded crown with square branchlets. The species grows naturally from altitude of 0-1600 m above sea level, in areas receiving mean annual rainfall of 650-850 mm. *Vitex payos* is a source of popular fruits for both domestic consumption and income generation. Fruits are edible and can also be made into jam and juice.



Figure 3.1.2: *Vitex payos* seedlings

The fruit is rich in carbohydrates, macronutrients (K, Na, Ca, Mg,) and micronutrients (Fe, Mn, Zn) and Vitamin C and D. KEFRI embarked on propagating *V. payos* for domestication because of its benefits. About, 1,000 seedlings of *V. payos* were raised at DERP in the financial year 2018/19.

3.1.3 Propagation of *Zysygium cuminii*

Zysygium cuminii is a large tree, native to Burma, India, the Philippines, Sri Lanka and the Malay peninsula. The species has been introduced to many tropical countries. In Kenya, the evergreen ornamental tree is grown in Mombasa and western region where it has been naturalized. The tree is used for; fuelwood, timber, poles, tool handles, edible fruits, bee forage, shade, ornamental, dune fixation, windbreak, and tannin production. However, the tree habitats are continuously lost mainly to widespread deforestation and its indiscriminate cutting for firewood or charcoal production.

KEFRI has identified several seeds collection sources and seed collection, handling and germination protocol developed. Research to develop suitable propagation techniques tried three grafting methods namely; top grafting, wedge grafting and side grafting that proved suitable for mass propagation as it increases plant growth rate and reduces the time, production and reproductive maturity leading to earlier fruit production. A comparison between juvenile and mature scions was also undertaken and success rate of 70.5% was achieved.



Figure 3.1.3: Training community group members on grafting seedlings

3.1.4 Propagation of Bamboo

In Kenya, there is an increase in demand for forest resources which lead to deforestation and forest degradation. Following the Ministry of Environment and Forestry ban on forest logging to allow forest recovery and meet 10% forest cover, KEFRI has broadened bamboo propagation and promotion to supplement the tree based resources in all its regions.

Bamboo belongs to the grass family and has been identified as the second largest sustainable forest resource; convertible into durable material for construction and cottage industries. The species is vital in soil erosion control, water resources protection - catchment areas and riverbank. Bamboo matures fast within 3-5 years and the clump can be harvested up to 40 years.

The Bamboo species propagated during the reporting period include; *Bambusa vulgaris*, giant bamboo and *Oxtenanthera abyssinica* (solid bamboo).



Figure 3.1.4: Transplanted bamboo seedlings being managed at Marigat Tree nursery, Baringo County

3.2 Technologies for Breeding Tree Species for Improved Yields

3.2.1 Grafting *Cupressus lusitanica* for seed orchards development

In Kenya, *Cupressus lusitanica* (Cypress) is the most dominant industrial and plantation crop since its introduction in 1905 and Intensive genetic improvement that commenced in early 1960s. Genetic improvement involved systematic searches and selection of plus trees (superior individuals) in all over ten years old cypresses plantations in Kenya. The plus trees were cloned and planted at Muguga tree bank/seed orchard. Results from other genetic improvement program have shown that substantial gains were achieved through selection of superior (plus) trees for improved productivity of plantations and products.

Demand for cypress planting materials (seeds and seedlings) has been increasing hence the need for more seed orchards. Furthermore, the orchards that were established in 1960s have aged, others wind thrown and the remaining individuals produce insufficient seeds. Vegetative propagation is therefore needed to increase seed output and to conserve clonal materials.

Cupressus lusitanica seedlings were therefore raised in Muguga and Londiani as rootstocks in readiness for grafting. Scions were collected from 30 plus trees at Muguga seed orchard and established in an orchard. One hundred (100) scions were collected from each mother tree. Side cleft grafting method was used. Grafts were kept inside a glasshouse under 80% shade and moved out of the glasshouse under a shade for further hardening off.



Figure 3.2.1: Grafted Cypress seedlings covered with polythene sleeve (left). Grafted Cypress being hardened readiness for planting (right)

The orchard was established using the standard spacing of 6mx 6m. The planting holes were 30cm by 30cm. The families were completely randomized within the orchard to reduce the incidences of inbreeding and also to improve the quality of the orchard. To ensure high survival rate, routine silvicultural practices were effected.

3.2.2 *Grevillea robusta* for seed orchard development

Grevillea robusta, commonly known as Silky Oak or Silver Oak, is an erect single-stemmed tree typically reaching height of 20–30 m and a diameter of 80 cm in its natural range. The species has gained widespread popularity in Kenya highlands as an agroforestry tree in small-holder farms. The species provides economically valuable products including timber, poles, and firewood. It is easy to propagate and establish and is relatively free of pests and diseases. Its proteoid roots help it grow in low-fertility soils, does not compete strongly with adjacent crops and tolerates heavy pruning of its roots and branches.

Farmers usually source planting materials from local tree nurseries within their proximity regardless of the seed sources. Some of these nurseries source their seeds from certified seed dealers such as KEFRI while others undertake general seed collection from own farms regardless of seed quality. However, there is need to safeguard farmers from establishing trees from poor quality seeds or planting materials. Seeds of *G. robusta* were acquired from Kenya Forest Seed Center Muguga to raise rootstocks for grafting. Twenty-three (23) mother trees (families) from Muguga *G. robusta* gene bank were used to raise the grafts. Grafting was undertaken using top cleft grafting method.



Figure 3.2.2: *Grevillea robusta* grafted seedlings in greenhouse. Left. Grafted *G. robusta* seedlings hardening-off in readiness for planting in the field

Land preparation for planting site involved removal of the stumps using a bulldozer, slashing of any shrubs, ploughing and harrowing. Trees were established at a spacing of 6 m x 6 m in planting holes measuring 30 cm by 30 cm. The families were completely randomized within the orchard to reduce incidences of inbreeding and also to improve quality of the orchard.

3.2.3 *Gmelina arborea* Seed Orchard and Progeny Trials

Gmelina arborea is native to Pakistan, Sri Lanka, Myanmar, Thailand, Vietnam and southern China. The species which is normally propagated by seed is extensively being planted in coastal and western regions of Kenya due to its fast-growing lightweight hardwood timber. It can grow to a height of 18m and suitable for farm forestry development. KEFRI current research on *G. arborea* is geared towards improving the quality of the species in terms of fast growth and enhanced straightness of the tree trunk.

During the 2018 /2019 financial year KEFRI continued working on *G. arborea* tree improvement through progeny trials at the coastal region. The goal of the trial is to assess parental components based on the values found in the progeny. The method entailed examining the relationships among progeny tests (correlations, heritability, components of additive and genetic variances) is of great importance in determining which of the progeny is the most suitable (effective) for various sites for purposes of breeding and developing superior germplasm with fast growth and straight trunk. The LVBERP raised 2,500 *Gmelina arborea* seedlings through grafting. To establish the seed orchard land was ploughed, and the grafts planted at a spacing of 4 m x 4 m in planting holes measuring 45 cm x 45 cm.

3.3 Management Technologies for Selected Tree Species

3.3.1 Development of silvicultural practices for raising *Osyris lanceolata* plantation

Sandalwood (*Osyris lanceolata*) has been overexploited in Kenya for its essential oil traded in Asia. The populations of the species in Eastern African region are protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II. The protection of the natural populations will be helped by on farm cultivation. However, little is known about *Osyris* silvicultural treatments that is required to manage the species for optimal production. Consequently, KEFRI established a trial plot (demonstration plot) at Muguga, as the first step of developing silvicultural practices for the species. The planted seedling are raised from seeds and marcots and hosted by: *Acacia senegal*, *Calliandra calothyrsus*, *Carissa spinarum*, *Rhus natalensis* and *Casuarina* species. Silvicultural treatments is imposed overtime. Additionally, the institute is currently in the process of raising seedlings that will be used for raising trial plantations including detailed silvicultural research. The demo plot is mainly used as a seed source and areas for setting marcots. However, singling of stems will be done to compare biomass and oil yield increment monitored at the beginning of the experiment and 4 years afterwards. The following treatments will be applied in 5 replicates at random.

- Individuals with 3 stems
- Individuals with 2 stems
- Individuals with 1 stem

The chosen individuals will not be used for marcoting although seed collection will be allowed. Parameters assessed include; Survival, Health (to be categorized as robust, fair or poor), Height, Number of stems, Number of branches, Leave colour and Diameter at ground level.

Table 3.1: Performance of *Osyris* seedlings planted in Muguga

Host species	Av. no. of branches	Av. root collar diameter (cm)	Av. height (cm)
<i>Calliandra calothyrsus</i>	2.9	0.7	56.0
<i>Acacia melanoxylon</i>	1.7	0.5	51.3
<i>Acacia sp</i>	2.8	0.6	59.0
<i>Croton megalocarpus</i>	2.2	0.6	50.2
<i>Unknown</i>	1.0	0.3	48.0

Initial demonstrations indicated that in harsh environments, survival of seedlings is low if drought is experienced. However, plants that survive may be good at seed productivity but there is need to choose host plant give a chance of survival of Sandalwood trees.



Figure 3.3.1: Assessment of Sandalwood seedlings and seed

3.3.2 Viability of *Melia volkensii* seeds stored as extracted seed or as nuts

The experiment was carried out to determine viability of *Melia* seeds stored as nuts over time. The storage and supply of *Melia* seed is currently based on handling of extracted nuts rather than seed. A *Melia* nut is bulky compared to the enclosed seeds. One Kilogramme of *Melia* nuts yields about 200 seeds. One Kilogram of extracted seeds range from 4,000 to 4,500 requiring the handling and storage of about 20 Kilograms of nuts. Storage and handling of extracted *Melia* seed is not practiced due to lack of information on storability of extracted seeds.

High quality mature *Melia volkensii* fruits were collected, de-pulped and extracted nuts. The nuts were divided into 2 lots with seeds being extracted from 1 lot and the other seed remaining in nuts. Moisture of both extracted seeds and nuts was determined according to International Seed Testing Association (ISTA) rules.

KEFRI undertook to test the following:

Seed storage conditions

- Dried extracted seed
- Seed in dried nuts

Seed storage containers

- Open containers
- Closed containers

Seed storage environment

- Ambient room temperature
- Cold storage -20⁰ C

Seed testing period

- Germination of fresh seeds immediately after collection and extraction
- Germination of seeds after drying of nuts before storage commences (zero months)
- Germination of seeds after storage for 2, 4, and 6 months

Results indicated that *Melia volkensii* stored as seed and nuts whether at cold or in room temp in both open and closed containers maintained viability up to 6 months. The finding suggest after storage ripening (ASR) phenomena had probably improved *M. volkensii* viability. After storage ripening can be defined as an increased sensitivity of perception of seeds to surrounding conditions and this favors germination. On the other hand, ASR can be defined as a decrease in sensitivity of perception of conditions inhibiting germination. There is need to establish viability of *Melia* seeds and nuts after 12 and 24 months.



Figure 3.3.2: Contrasting volume of *M. volkensii* seed production from nuts

3.3.3 Refining propagation Protocol of *Melia volkensii* through tissue culture

Large-scale cultivation of Mukau (*Melia volkensii*) is hindered by difficulties in propagation through seed. The constraints include difficulties in seed extraction due to entrapped seeds within the woody endocarps. Many seeds are damaged during extraction that involve either the use of a hammer or fabricated sharp objects. Mukauseeds germinate poorly due to the inherent mechanical and physiological dormancy. The species is susceptible to fungal attack that causes high post-germination mortalities of seedlings in nurseries. The species also have difficulties in propagation using stem cuttings. In view of these challenges KEFRI is establishing and refining tissue culture protocols to enhance in vitro mass propagation of the species.



Figure 3.3.3: (a&b) Mukau plantlets growing in MacCown woody plant media containing IBA (c) Mukau plantlets habituated in a growth chamber, (d) Mukau habituated plantlets ready in the glasshouse

3.4 Management of woody invasive species

Cestrum aurantiacum is one of the invasive woody species posing a great threat to resilience of forested landscapes in Kenya. The plant, native to South America was introduced in Kenya in 1921 as an ornamental plant, invades disturbed areas and quickly forms dense thickets that compete with native plant species thus limiting natural regeneration and displacement. The evergreen, shrub grows to a height of up to 180 cm tall, with brilliant tubular orange flowers that have a powerful citrus like smell.



Figure 3.4: *Cestrum aurantiacum*

The species is also poisonous to human and livestock. In Cherangany hills for instance, *Cestrum aurantiacum* has invaded most parts of the forest causing social, economic and/or environmental harm, and can spread rapidly to new areas and completely out-compete native vegetation.

The Institute held a farmer's field day to sensitize and demonstrate management of *Cestrum aurantiacum* species to the community at Kapcherop in Elgeyo Marakwet County. Informing them of the following:

To reduce re-sprouting *Cestrum* can be controlled mechanically through continuous uprooting of both seedlings and mature trees, then burning them or leaving them on site to rot. The species stems should not be used to reinforce fences since they can easily re-sprout. The cleared sites should be replanted with alternative fast growing species to prevent *centrum* regrowth.

Biological control involves suppression by vigorous competition from other plants. On farmlands, vigorous pasture species such as Napier grass could be planted to out-compete young *centrum* plants. In the forest, fast growing tree species such as *Dombeya*, *Croton megalocarpus*, *Neubotonia macrocaylx* among others could be planted on cleared sites to suppress *centrum* growth.

3.5 Suitable tree species for charcoal making: A case study of Rarieda, Siaya County

Siaya forest cover is estimated at 0.44% far below the recommended 10%. The increasing human activities e.g. land clearing for agriculture/settlements, livestock grazing, charcoal production, firewood collection, mining, quarries and burning in the hilltops forest, woodland and riparian woodlands in the County are causing substantial deforestation and degradation in the landscape. Open fields where the trees have been lost through clear felling causing damage to the soil and vegetation to a degree that inhibits or severely delays the recruitment and growth of woody species. These activities are mainly common in Rarieda, Bondo among other areas bordering Lake Victoria.

In 2009 KEFRI partnered with Rarieda Agroforestry Development Initiative Programme (CBO) and farmers to promote two *Acacia* species namely; *Acacia polyacantha* (Falcon claw acacia) and *Acacia xanthophloea* (Naivasha thorn tree). Both species are fast growing and produce high quality fuelwood. The trees were planted to promote sustainable charcoal production, intensify tree on the farms to attain the 10% cover, and for income generation in the area and to rehabilitate degraded riparian areas. KEFRI also introduced technologies for efficient charcoal production. Some farmers have adopted annual planting cycle to ensure sustainable charcoal production.

Acacia polyacantha and *Acacia xanthophloea* were identified as key species for charcoal production in the area due to:

- Fast growth of up to 1.5m per year, high yield and minimal management requirements
- High wood density with low moisture content
- Good growth between 600 and 2100 m above sea level
- Soil fertility improvement through nitrogen fixation
- Efficient use of water

At a spacing of 2 m by 2 m, farmers grow 2500 trees/ha which are ready for harvesting at age of 6 years. At a conversion rate of 14%, it is possible to obtain charcoal yield of 290 bags (11.6 tons) per ha. Using efficient kilns that has a 30.5% charcoal recovery, 620 bags (24.8 tons) per ha can be expected. The expected gross income from charcoal production therefore would range between Kshs 174,000 and Kshs 372,000 per ha at Kshs 600 per bag depending on the charcoal recovery level. Charcoal farming can therefore offer continuous income to a farmer who adopts an annual planting cycle of one hectare.

3.6 Economic Contribution of Baobab Fruit *Adansonia digitata* to Household Incomes and Livelihoods in Eastern and Coast region

KEFRI undertook research to determine the economic contribution of baobab (*Adansoniadigitata*) products to food security, income and employment, as well as to determine the socio-economic factors influencing participation in baobab fruit enterprises and markets.

Baobab is a tree that occurs naturally throughout the drier parts of sub-Saharan Africa. In Kenya, the species occurs in large densities in lower eastern and coastal region. The baobab fruit is being recognized globally as a nutrient-rich, raw material for consumer products such as smoothies, biscuits, fruit juices and cereal bars. Despite its high potential to provide additional income to farmers, the fruits is majorly traded raw or with limited value addition. This study was carried out in Kitui and Makueni Counties in the eastern region through interviewing farmers who had baobab trees on their farms, and baobab marketers.

The survey indicated farming household's heads were middle aged at 36-55 years. Majority of the farmers (62.2%) were males probably due to the labour intensity - harvesting of fruits. On average, majority of the respondents farm sizes ranges between 4-7 acres of which majority (73.2%) had title deeds. Other indigenous and exotic trees most popular grown on farm included *Melia volkensii*, *Mangifera indica*, *Senna siamea*, *Berchemia discolor*, *Terminalia brownii*, *Tamarindus indica*.

The study revealed 33.2% of the respondents participated in baobab fruit enterprises and marketing, majority of them (66.8%) sell whole fruit to middlemen with no value addition. The marketing pathways for baobab are not yet firmly developed and the majority of the produce is currently sold only when fruit is available.

The production of baobab fruits is almost entirely based on trees growing naturally on farms, in forests and woodlands. Baobab farming is a supplemental practice less attractive due to low market values determined by brokers.

Baobab fruits are harvested during the dry seasons and healthy fruits can be stored for up to one year. Fruits are sold to middlemen at a prices of Kshs 13-19 per Kg.

None of the farmers interviewed had planted trees on farms in the last decade, discouraged by long duration the tree takes to mature, high water consumption, lack of planting materials, none productive, market mostly determined by middlemen and other traders, un-marketable products, inadequate land, high mortality rate, and lack of knowledge.



Figure 3.6: Baobab farmers drying fruits in Makueni County

It is crucial to train farmers on the importance of forming association/groups that would enable them trade the fruits as blocks, which will give them more negotiating power.

3.7 *Prosopis juliflora* products Market Chain Analysis in Garissa County, Kenya

Prosopis juliflora, a species that survive harsh environments and tolerates drought, was introduced in Kenya to rehabilitate parts of the drylands. However, the species became invasive due to lack of management options leading to; loss of grazing land, pasture production and availability, and loss of plant biodiversity.



Figure 3.7.1: Invasive *Prosopis juliflora* maturing pods



Figure 3.7.2: Trading of *Prosopis juliflora* charcoal and poles in Garissa township

Garissa County to identify *Prosopis* products, status of utilization, and market value chains. The main *Prosopis* products identified were poles/posts, charcoal, pods and honey. Production and marketing of *Prosopis juliflora* charcoal was organized under one umbrella body - Garissa Environment Users and Conservancy Association. The average selling price of charcoal (50 kg bag) was at Kshs 250. The main charcoal markets were Garissa and Nairobi where the product sold at an average price of Kshs 1100 per 90 kg bag and Kshs 350 (50kg bag) in the local markets. Honey and pods were also sold in the market at an average price of Kshs 700 and pods (fodder) at Kshs 50 per Kilogram. Poles/posts prices varied with factors such as size and markets. The small sized pole/posts were sold at average price of Kshs 25 and 150 for the big sized in the market.

Only 57% of charcoal producers were trained on production and environment conservation skills.

Challenges identified in production and marketing of charcoal and pole/posts included:

- High transport costs for persons who do not own donkey carts
- Lack of protective gear
- Poor markets, inadequate entrepreneurial skills and knowledge
- Poor networking and cooperation from stakeholders
- Lack of training in management and utilization of *Prosopis juliflora*
- Harassment, arrests the County government due to current ban on charcoal production and marketing resulted into decline in the supply
- Low production due to insecurity

3.8 Monitoring Tree Products Markets and Price Trends for Key Tradable Products in Kenya

Kenya is a wood deficit country and a major importer of wood from the East and Central African region and information on demand, supply and price regimes for various tree products is unavailable in the country. KEFRI therefore undertook a study aimed at providing information on sources of tree products as well as the supply and demand of tree products, their selling and buying prices at both retail and wholesale sections and the challenges encountered during these businesses. The study was also to ensure that quality information is available for farmers, investors and policy makers for them to make informed decisions on forestry sector development and promotion.

3.8.1 Poles

The study noted a decline in supply of forest products and rapid market prices of sawn wood timber occurred following the Ministry of Environment and Forestry ban on logging in February 2018. The demand for poles and prices of both treated fencing poles and transmission poles increased slightly: small diameter poles increased by 24.4%, medium poles; 14.7%, large; 16.6% and transmission poles by 5.5%. Eucalyptus poles and few cypress thinning were the most available in many urban markets. The prices of various sizes of eucalyptus poles rose from an average of 42.8% to 61.5%.

In the Coastal region *Casuarina equisetifolia* poles were the most available and highly demanded for construction of tourist resorts, scaffolding in high-rise buildings and construction of low-cost houses and kiosks. Investors in the hotel industry indicated paying double the price for the alternatives to mangrove timber needed to maintain their structures. Mangrove pole prices used to be between Kshs 100 and 150 before the ban, currently the prices of alternative poles trade at Kshs 400.

3.8.2 Charcoal and firewood

The charcoal prices went up by 40% from Kshs 1,020 to Kshs 1,430 per bag. Most of the charcoal sold within the coastal market is imported from Uganda and Tanzania with price increased from Kshs 1,800 to Kshs 2,400. On average, the prices of fuel wood used by 68 KTDA affiliated tea processing factories increased by 25.5% from an average of Kshs 1,857 to Kshs 2,330 per M³ as a result of the ban.

3.8.3 Sawn wood timber

Cypress had the highest rise in prices at 36.1%, *Grevillea* was the least affected by the ban with an increase in prices at 11.1% while pine rose by 28.7%. On average the prices of eucalyptus timber rose by 14.7 % nationally. Eucalypts timber due to its preference among consumers and its availability in the market in Kenya had least affected the prices following the imposition of the logging ban.

Timber imports from Tanzania and Malawi have increased drastically as compared to previous years. Most of the timber originating from Iringa large-scale commercial growers. There was over fiftyfold increase in the importation of pine from Tanzania and Uganda timber imports rose from a low of 3,231.38 M³ in 2017 to a high of 29,355.39 M³ in 2018 leading to a loss of Kshs 783 million.

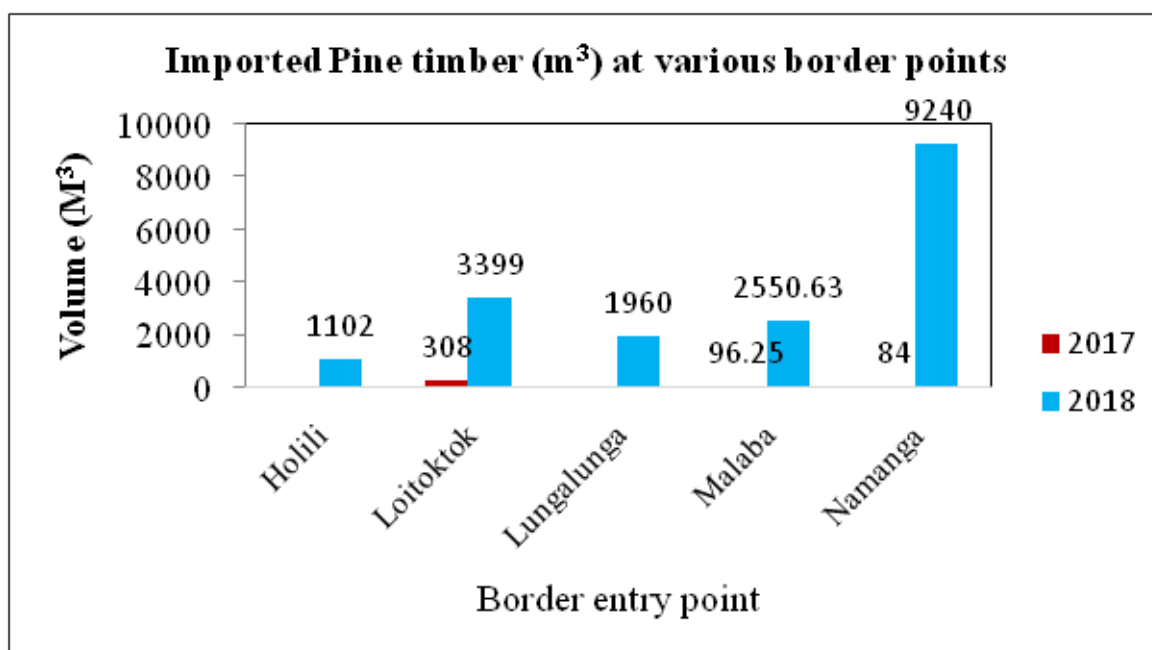


Figure 3.8.1: Imported Pine timber (M³) at various border points

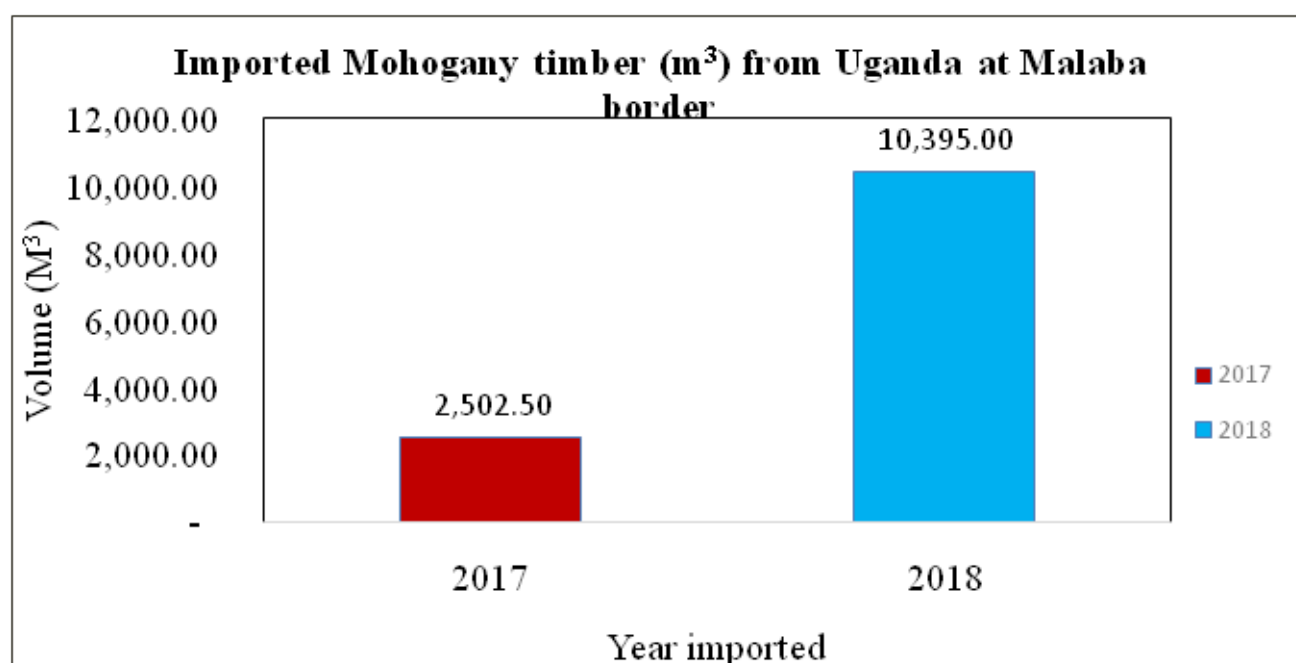


Figure 3.8.2: Imported Mahogany timber (M³) from Uganda at Malaba border point

As a result of imposition of the ban on harvesting in public plantations, the forest markets in Kenya were affected in: scarcity of raw materials; increase in prices; and increased imports.

Most of the sawmills visited were scaling down on selling of timber and undertaking diversification and scaling up of value additionsuch as making doors and other timber products as a strategy to increase incomes.



Figure 3.8.3: A sawmill in Meru specializing in wood pallets from eucalyptus timber



Figure 3.8.4: New pine saw millers in Nyeri specializing in panel and flush doors

Challenges faced by buyers and sellers of tree products include:

- Much of the timber sourced from farms is of small size and immature,
- Majority of the sawmills and timber yards have closed down while others scaled down production due to scarcity of raw materials.

4.0 Development, Refinement, Protocol Development and Linking Tree Products to Markets

KEFRI recognizes that commercialization of tree based products is an important activity for improvement of communities livelihood, creation of employment and a motivation for conservation of trees and plant species with potential for product development. Development, refinement, and protocol development of tree-based products also contribute to the government Big 4 Agenda on food and nutritional security, health and manufacturing. During the financial year 2018-2019 KEFRI developed animal feed (salt lick) from *Opuntia ficus* pads, refined Marula (*Sclerocarya birrea*) fruit jam and animal feed from baobab seed cake; developed processing protocols for *Opuntia ficus* juice concentrate; and linked framed chainsaw technology to users.

4.1 Development of New Tree Products

4.1.1 Development of animal feed (salt lick) from opuntiaficus pads

Opuntia species commonly so-called Cactus are plants adapted to arid and semi-arid zones. *Opuntia* fruit contains lots of iron, calcium, potassium, sodium, magnesium, minerals, vitamin C, has low saturated fat and cholesterol and is a good source of dietary fiber. The species were introduced drylands of Kenya in the 1950's. Until recently, Cactus has not been a problem in the country however due lack of proper management the species is becoming invasive. Cactus pear meets all requirements for processing animal mineral lick, but no attempt has been made so far to exploit this potential. Mineral feed blocks are high energy feed blocks which contain essential mineral supplements for livestock. They are made from affordable and readily available materials. Feed blocks provide supplementary nitrogen and energy to the animals. This is particularly important in times of prolonged drought especially in the ASAL areas of Kenya.

The aim of this study was to develop cattle salt (mineral) lick from *Opuntia ficus* pads.

4.1.2 Procedure for Making Salt Lick

4.1.2.1 Materials required

- Molasses,
- Urea (fertilizer grade),
- Mineral premix
- Maize germ (or other bulking agent)
- Cement
- Common table salt
- *Opuntia* pads ash
- Water

4.2.1.2 Steps of making Salt Lick

- Collect fresh *Opuntiaficus* pads, cut into small pieces, dry and then grind into powder
- Pour 5 litres of water in a concrete mixer and add 10 Kg of urea and run the mixer until all the urea is dissolved
- Add 40% equivalent of weight of *Opuntia* pad ash
- Slowly mix 12 kg of cement in 3 litres of water until a homogeneous paste is attained. Poured this paste into the running mixer
- Add 3 Kg of common salt and 5 Kg of mineral premix
- Add 25 Kg of molasses in the running mixer, 35 Kg of maize germ and mix the paste until it is homogeneous
- Mould the paste using plastic containers and dry in the sun for about two hours
- Remove the blocks from the moulds and keep indoors for 2 weeks to harden



Figure 4.1.1: Opuntia spp pads in Baringo County



Figure 4.1.2: Opuntia Salt Lick

4.2 Refinement of New TreePproducts

4.2.1 Refining Marula (*Sclerocary abirrea*) Fruit Jam

The utilization and commercialization of indigenous fruits has in the past been undervalued due to the misconception that they do not play a significant role in contributing to diets. Due to lack of value added products, there are a lot of losses of such fruits when they are in season. Make products such as wine, jam, and juice is one way of prolonging the shelf life of the indigenous fruits. KEFRI refined marula jam which had been previously developed.

The process of refining marula jam involves;

- Collection and cleaning ripe mature marula fruits
- Extracting pulp by crushing using a pestle and filtering to separate the pulp from seeds
- Adding water to pulp on a ratio of 1:1
- Adjusting the pH of solution to 4 by adding Sodium bicarbonate (NaHCO_3)
- Adding 0.2% of pectin and sugar in the recipe.
- Boiling the mixture while constantly stirring to ensure a proper mixing of all the ingredients and to obtain a thick consistency paste of $65^\circ - 68.5^\circ \text{C}$ (Brix is achieved)
- Hot filling into glass jars and seal immediately.

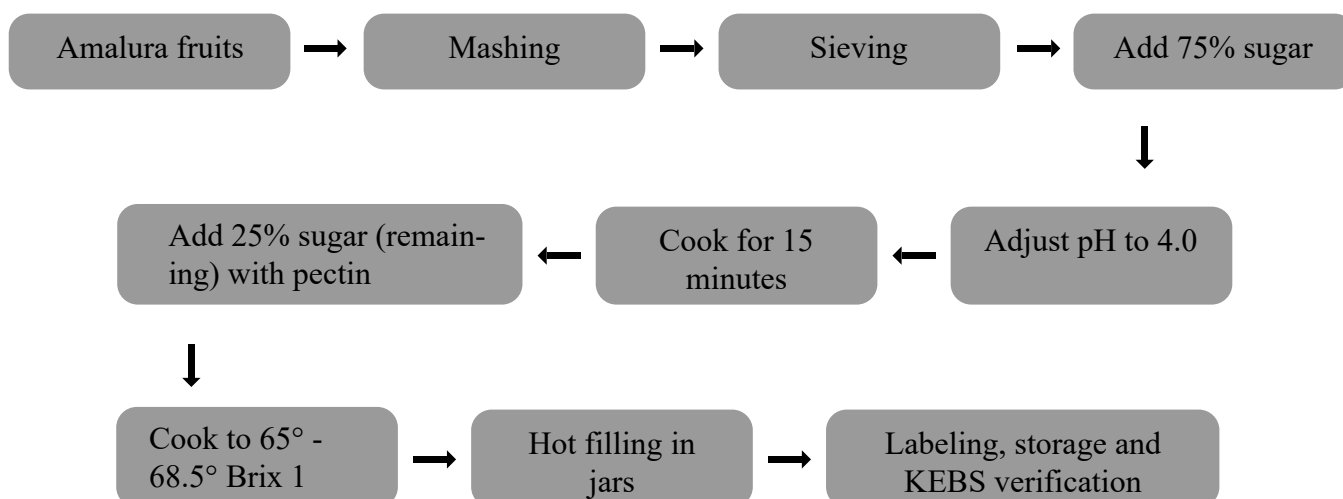


Figure 4.2.1: Flow diagram illustrating jam preparation processing



Figure 4.2.1: Processed jam, and sensory evaluation exercise to test suitability

The refined jam showed good consistence which compared very well with commercial brands, it had no syneresis (collection of liquid on the surface of jam), the texture was appreciated by tasters. The pH of the jam was adjusted to 4 to reduce acidity and this was found to be desirable to taste in turn enhancing its acceptability.

4.2.2 Refining of Animal Feed from Baobab Seed Cake

Baobab (*Adansonia digitata*) is one of the potential indigenous fruits for development of both human nutrition and animal feed. Utilization of such fruits in Africa can greatly improve livelihoods and food security.

KEFRI undertook studies on the suitability of baobab seed cake in animal feed production. The process involved harvesting ripe baobab fruits, splitting them to remove the seeds, dehulling and cleaning, oven drying at 60°C for 6 days and analyzing nutritional values. The result showed the seed has low crude lipid which makes it suitable supplement (protein) for animal feeds. The seeds is a good source of carbohydrate concentration with high caloric values of 4465 kcal/kg suitable to supplement the daily energy for livestock intake. The seeds cake also contains vitamin A and C, essential elements such as Iron and Zinc mineral such as Phosphorus, Calcium, Potassium and Sodium necessary for livestock daily requirements. The levels of anti-nutrients in the baobab seeds are below toxic levels. Baobab could be used in mixed animal feed. However, analysis of amino acid and feeding studies are needed before they can be used.

4.2.3 Refining of Shoe Polish from Gum Arabic and Bee Wax

Gum Arabic from *Acacia senegal*, var. Senegal has the highest quality compared to other gums. The gum is a polymer with about 3% protein, highly soluble in water and forms viscous solutions up to 60%. The protein fraction is responsible for the emulsification properties of the gum. The gum is high in dietary fiber and humans and primates sometimes consumed solely as a laxative. Food and cosmetic industries use it as a stabilizer and in paints respectively.

KEFRI developed a shoe polish from a mixture of gum Arabic and bee wax.

4.2.4 Ingredients and Procedure of making shoe polish

1. Melt the Bee wax 7.5 gm in water bath at a temperature of 70°C. The Bee wax act as water proofing agent.
2. Add white spirit and paraffin wax 10gm for dissolving the wax
3. Add *Aluminium silicate* 2gmas thickening agent and gum arabic 0.5 gm emulsifier / stabilizer until dissolved.
4. Silicon oil (*Dimethyl polysiloxane*) 2gm
5. Add dye 0.5gm, *Trimethyl Benzene* for impacting shine and Heavy naptha



Fig. 4.4 Acacia shoe polish

4.3 Protocols for Producing Refined Tree Products

4.3.1 Protocols for Processing of *Opuntia ficus* Juice Concentrate

Opuntia species are widely distributed in most arid regions of Kenya. *Opuntia* is rich in iron, calcium, potassium, sodium, magnesium, minerals, vitamin C, it has low saturated fat and cholesterol and is a good source of dietary fiber making it suitable for food. However, freshly harvested fruits are highly perishable leading to nutrient and quality losses. To lengthen shelf life the cactus fruits can be processed into cactus pear juice, concentrates and fruit powders. KEFRI developed a protocol for *Opuntia ficus* juice concentrate.

4.3.2 Processing of *Opuntia ficus* Juice Concentrate

4.3.3 Requirements

- Micro filter, Rotary evaporator, Freeze dryer, Spray dryer, Refractometer
- Whatman filter paper, Boiling system

4.3.4 Protocol for Processing *Opuntia ficus* Juice Concentrate

- Harvest ripe fruits
- Sort the fruits
- Wash, peel, and slice fruit
- Put the fruit in a pot; add water to just cover
- On medium heat, bring to a boil (uncovered)
- Boil at least until the fruit is a mushy pulp. Boiling longer will reduce water content, but may alter the flavor of your concentrate.
- Strain pulpy fruit sludge.

N.B. The pulp must be concentrated up to 30° Brix



Figure 4.4: Procedure for preparation of *Opuntia ficus* juice concentrate

4.4 Linking New Products to Markets

4.4.1 Linking Framed Chainsaw Technology to Users

Felling trees and sawing them site on-site as opposed to transporting them to the nearest sawmill, is the better option as it increases wood value and consequently revenues to tree farmers. Chainsaw system is the main means of processing trees at farm level. However, most of the sawing systems are inefficient. KEFRI has therefore developed a framed chainsaw to improved timber recovery.

During the year under review, KEFRI linked the framed chainsaw technology to tree growers, timber merchants, chainsaw machine owners and operators in *Melia volkensii* of Kitui and Makueni Counties. The community was trained on the advantages of framed chainsaw system for on-farm timber processing, linking the technology to local fabricators while chainsaw operators were trained on the modification of the felling chains for use with the frames and operation of the framed chainsaw system. Farmers were advised not to sell trees standing but instead have them processed into sawn timber for value addition.



Figure 4.4.1: On-farm timber sawing training: group training and individualized skill impacting sessions

5.0: Dissemination and Publicity Activities

During the Fiscal Year 2018-2019, KEFRI disseminated forestry technologies and shared related information through various platforms to reach its stakeholders and the public.

The objective was to enhance adoption and upscale of forestry developed technologies that included - propagation and utilization of tree species, tree nursery establishment, planting and management of trees, rehabilitation and conservation of biodiversity, processing and utilization of forestry products and allied natural resources.

The platforms applied to share information and technical advice on forestry matters included

exhibitions, open days, farmers field days, centre research advisory committee (CRAC) meetings, print and electronic media (radio talks and TV), social media, demonstration sites, study tours and customized trainings. Mobilization and awareness campaigns was accomplished through Chief's baraza, formal invitations, advertisements and announcements, site surveys, posters and banners.



Figure 5.1: Exhibition of forestry technologies

Table 5.1: Number of Field days conducted in different Eco-regions

Eco-region	No. Field Days	Specific Areas Addressed	Place/ County	Impact
CERP	7	Demonstration of establishment and management of <i>Melia volkensii</i> , <i>C. equisetifolia</i> , <i>G. arborea</i> , rehabilitation of mangroves and degraded forest ecosystem	Kwale, Kilifi, Lamu, Taita Taveta, Mombasa	347 attended with 50% indicating interest in adopting
DERP	7	Sandalwood, Bamboo, <i>Melia volkensii</i> , <i>Vitex payos</i> , <i>Prosopis juliflora</i> , <i>Gmelina arborea</i>	Embu, Makueni, Machakos, Garissa, Marsabit Tharaka-Nthi	
CHERP	9	Climate change mitigation, <i>Prosopis juliflora</i> management, participatory forest Management, establishment and management of commercial tree nursery, riparian conservation, tree seed collection	Kiambu, Kajiado, Narok, Nyandarua, Nyeri	
RVERP	6	Bamboo value chain, <i>E. camaldulensis</i> , invasive <i>Cestrum aurantiacum</i> , forestry rehabilitation, thinning of <i>C. lusitanica</i> , agroforestry spp	Turkana, Uasin Gishu, Nakuru	
LVBERP	7	<i>Acacia polyacantha</i> and <i>A. xanthophloe</i> a management charcoal production, invasive woody species, establishment and management of <i>Moringa stenopetala</i> for seed production, rehabilitation of degraded forests	Siaya, Homa bay Vihiga, Bungoma	
NFPDP	9	Onfarm timber sawing, bamboo and aloe processing, indigenous fruits and charcoal production	Nyeri, Kwale, Taita taveta, Kisumu	
Total	45			

5.2 Open Day

The Institute held an open day in each of the six eco-regions to showcase its research technologies, products and services. The event aimed at enhancing public knowledge in tree as an investment, environment conservation, climate shift mitigation and livelihood improvement.

KEFRI technical staff shared experiences with farmers, public and private sector representative, students and teachers from local schools, NGOs and other stakeholders. Generally, the displays included seed collection and processing, propagation of bamboo and valuable tree species, value addition to wood and non-timber forest products, information dissemination and entrepreneurship.

5.3 Exhibition at Agriculture Society of Kenya show

KEFRI participated in 12 Agricultural Society of Kenya shows countrywide, under the theme ‘Promoting Innovation and Technology in Agriculture and Trade’. The show were held at Machakos, Makueni, Nakuru, Kisumu, Kakamega, Mombasa, Nyeri, Nairobi, Kabarnet, Eldoret, Migori and Kitale. Tree seeds production, tree improvement, soil sampling, propagation of bamboo and commercial or valuable tree species like Eucalypts, *Osyris lanceolata*, *Vitex payos* and *Melia volkensii* were displayed, in addition to techniques on tree planting and management, soil and water conservation, rehabilitation and energy saving models. Other exhibits supporting cottage industry include development of non-timber products from bamboo, aloes, indigenous fruits, gums and resins.

The Institute scoped trophies in Research and Development category, seed production and marketing, the most striking display of locally manufactured products, show theme interpretation, demonstrating the Application of Environmental Quality standards.

5.4 Radio Talks

The Institute accomplished eight (8) radio talks and 2 TV show aired through national or local FM or TV station to sensitize public on various forestry technologies as well as to mobilize public for events.

5.5 Production of Publications


At total of 34 publications (see Appendix 1.) were produced plus Annual Report and Record of Research for fiscal year 2018-2019, as indicated in the table 5.2:



Figure 5.1: A Radio talk session in a local FM

Table 5.2: Publications produced in Fiscal Year 2018-19

Type of Publication	No.
Peer reviewed journal papers	12
Technical/Research Notes	9
Extension materials	11
Policy briefs	2
Total	34



The publications were distributed mainly to KEFRI regional research centres for further re-distribution to stakeholders. The publications were also issued during trainings and to interested parties during key events.

5.6 Building capacity of KEFRI Scientists

KEFRI scientific attended the 6th Devolution Conference various among other foras locally and international where they presented papers and interacted with diverse stakeholders and policy makers.

5.7 Building Capacity of KEFRI Partners

KEFRI through Social Forestry Training Centre (SFTC) conducted interactive training courses and seminars to shared research technologies. The participants were mainly derived from partner institutions at national and county government as well as international level establishments.

Table 5.2: Publications produced in Fiscal Year 2018-19

Course/ Seminar	Course/Seminar objective	Target group	Duration
The 5th Regional Training Course on Adaptation to Climate Change in Africa through Social Forestry, 28th Jan. to 27th Feb. 2019	Impact knowledge and skills to practice forestry farmer field school social forestry extension methodology, conservation and management, livelihood as well as climate change	17 countries in Horn of Africa, central and eastern, south Africa	5 weeks
Dissemination Officers Training Workshsop on Writing and Repackaging Extension Materials JICA – CADEP -SFM Project 10th - 14th September 2018, KEFRI Marigat Sub-centre, Baringo County	Impact basic communication skills, data collection tools development, designing and packaging extension materials, photo and videography	KEFRI Dissemination Officers with excursions to selected farmers' fields, and jointly implemented by KEFRI, Agricultural Information Resource Centre (AIRC)	5 days
2nd CADEP Regional Technical Workshsop for Horn of Africa on Collection, Documentation and Sharing of Good Practices, 1st – 12th October 2018	Create awareness of AI-CD; familiarize with CADEP-SFM tools for identification, collection, documentation and development of country based action for implementation of AI-CD activities	11 participants from six Horn of Africa countries namely; Djibouti, Eritrea, Ethiopia, Somalia, South Sudan and Sudan	2 Weeks
3rd Regional Forum of AI-CD in Horn of Africa on Resource Mobilization 11th to 16th May 2019.	Interact with donor partners in order to improve access to finance, review progress and develop awareness creation strategy	6 AI-CD Horn of Africa countries	4 days

5.8: Raising KEFRI Profile

During the Year under review, Corporate Affairs and Quality Assurance implemented various activities to intensify the Institutes image and visibility. Notable activities implemented include: communication and publicity, customer care and hospitality, corporate social responsibility, Intellectual Property Rights, performance contracting (PC) and Strategic Plan monitoring and evaluation. Furthermore, implementation of Citizens' service delivery charter, branding vision 2030 flagship projects, presentations by KEFRI Choir and submission of reports to vision 2030 delivery secretariat.

The Institute participated in national and international events, exhibitions and other partners events that include: Public Forum on the Draft National Bamboo Policy held at Sosa Resort in Vihiga County; National bamboo planting day at Ruiru dam in Kiambu County; the 6th Devolution Conference in Kirinyaga County, World Environmental day at Rumuruti in Laikipia County, International Day Of Forests (IDF) Celebrations at Bondo Teachers Training College in Siaya County, International Day of Biodiversity at Busia ATC, Busia County, World Meteorological Day in Vihiga County, World Water Day celebrations at Migwani in Kakamega County.

At the end of the fiscal year Performance Contract evaluation, KEFRI was ranked the leading parastatal at the Ministry of Environment and forestry having been rated Very Good, with a score of 2.6.

6.0: KEFRI Partnership & Resource Mobilization

Partnerships and Resource Mobilization (PRM) is a section responsible of fundraising for research and development activities from donor and development partners to supplement GoK funds.

During the Financial year 2018/2019 PRM office accomplished various activities based on the following 4 relevant specific objectives: enhance linkages and partnerships with stakeholders; increase revenue; improve resource mobilization; improve Operational efficiency.

6.1 Partnerships and linkages

The section enhanced linkages and partnerships with stakeholders by seeking partnership with relevant institutions, government ministries, state agencies, universities, international based organization, youth groups, and other partners with mutual interest in forestry and allied resources. During the year under review, nine (9) new partnerships were establishment with strategic institutions, maintenance and update of KEFRI's partners database clicking 92 by the end of the Fiscal Year. Currently, the institute subscribes to 14 Networks and Memberships.

KEFRI continued to improve engagement with County government and a joint activity implementation program is currently ongoing. A framework for engagement developed with office of County of Governors is waiting ratification. In addition, KEFRI staff through invitation by County of Governors participated in the 6th Devolution Conference, held at Kirinyaga County.



Figure: 6.1: Signing of MoU between KEFRI and Tsavo Heritage Foundation on joint research and conservation of degraded landscapes

6.2 Resource Mobilization strategy

In an effort to increase revenue, KEFRI through PRM section submitted two consultancy bids and 3 projects were funded out of 15 proposals submitted for national and international competitive grants.

The PRM section developed reports from quarterly M&E and planning meetings, participation in all the CRAC meetings across the eco-regions and in two forums which increased KEFRI's visibility on a national and global platform. The section experienced challenges due to inadequate staffing, development of competitive proposals, low donor response among others.

During the period under review, the Human Resource division undertook both routine activities and those signed in the 2018/19 financial year Performance Contract. The activities included human resource planning, recruitment and selection of staff, training and development of staff, performance management, reward management, employee relations, personnel administration, employee separations and provision of medical services at the KEFRI clinic.

7.1 Staff Strength

The Institute as at 30th June 2019 had 910 employees out of which 816 are on permanent and pensionable terms of service whereas 94 are on contract terms as presented in Table 7.1:

Table 7.1: Staff strength as at 30th June 2019

S/No.	Cadre	Number of staff
1	Research Scientist	108
2	Technologist / Technicians	91
3	Foresters	24
4	Finance /Audit	44
5	Human Resource	3
6	Administrators	17
7	Supply Chain	26
8	Other professional support	70
9	Auxiliary support	527
	Total	910

7.2 Recruitments and Selection

The Human Resource Division facilitated recruitment of twenty two (22) staff out of which nine (9) are on permanent and pensionable terms of service and thirteen (13) on contract. The candidates were competitively recruited internally or from external source.

7.3 Training and Development

The division continued implementing training of various staff which included supporting PhD scholar as per the PC and the staff appraisal of 2017/2018 FY requirements. A number of staff were sensitized on various PC items as signed in the 2018/2019 FY.

7.3.1 Supports on PhD Training

During the period, the Institute supported Research Scientists who had fulfilled all requirements for the sponsorship such as submission of progress reports to pursue PhD. The current number of PhD holders in the Institute is 29 Scientists.

7.4 Internship

The Institute engaged twenty six (26) interns for the year 2019 following the Government directives to transfer knowledge by offering internship programme. The interns were posted to various Centres/Sub- regional centres to serve for one year.

7.5 Infrastructure Development

During the FY 2018/2019, the Administration division oversaw infrastructural development, maintenance and repair of buildings, motor vehicles, generators and water pumps. Other services included; ground maintenance, provision of security, transport, janitorial, secretarial services, overseeing both main and secret registries including the archives.

The division serviced all serviceable vehicles, repaired over 30 vehicles, two generators and water pumps at KEFRI headquarters. Further, valuation of vehicles and property was carried out enabling accurate information for the Institute to procure insurance for these assets. General maintenance of staff houses, buildings at KEFRI stations both electrical and mechanical services were done.

Water supply was done at KEFRI station, staff houses and the community. Sewerage maintenance, septic tanks at staff houses and at KEFRI show ground in Nairobi exhausted and replacement of main line leaking pipes, taps, toilets (3) and urinal push valves. The division continued to oversee outsourcing security services in most of the KEFRI Centres and Sub-centres. Advertisement for outsourcing of grounds maintenance services and the procurement process was still ongoing.

7.5.1 Construction at Taita Taveta and Lamu Sub-regional Centres

The Division oversaw completion of the office block, laboratory and access road to the farmer's resource centre at KEFRI Taita Taveta Sub-Regional Research Centre. Construction of a ramp to provide access to persons with disability to the upper floor of the building, a nursery house as well as a perimeter wall were ongoing.

The division also oversaw construction of a perimeter wall at the KEFRI Lamu Sub-regional Research Centre, kitchen and dining hall done attaining 80% completion rate.



Figure 7.5.1: Completion of access road at Taita Taveta, wall, kitchen dining hall at Lamu Sub-centre

7.5.2 Relieving water shortage at Kakamega and Marigat Sub-regional Centres

The division facilitated the sinking of a well, at Kakamega Sub Regional Research Centre alleviating water challenges experienced over the years.

At the Baringo Sub-regional Research centre, a water tower was put up and an additional water storage tanks provide to supplement water for the hostel as well and the entire facility.



Figure 7.5.2: Sunk well and water tower at Kakamega and Baringo respectively

7.5.3 Cleaning of records at KEFRI Headquarters

During the year under review, installation of modern lockable filers to safeguard the storage of Institute's records commenced at headquarters registry. The activity phased out wooden cabinets that occupied much space.

Additionally, files at the archives were appraised in collaboration with personnel from the Kenya National Archives. Over two thousand files were earmarked for destruction and other assorted files were reserved for disposal at a later stage as per the records retention schedule.



Figure 7.5.3: Newly installed lockable filers

7.5.4 Painting of KEFRI Show Stands

This was done at Jamhuri Park ground in preparation for the 2019 Nairobi International Trade Fair (see figure 7.5.4.)

7.5.5 Renovation at Nyeri Sub-regional Centre

At Nyeri Sub-regional Centre Phase I of the renovation of the office block was carried out. This entailed repairing of cracks on the walls and drainages which were causing water to seep into the building (see figure 7.5.4.).

7.5.6 Tree nursery house at Migori Sub-regional Centre

To strengthen research work at the KEFRI Migori Sub-regional Research Centre, construction of tree nursery house was completed. This will provide the much needed space for nursery operations (see figure 7.5.4.).

7.5.7 Upgrading of Power at Lodwar Sub-regional Centre

Upgraded electricity supply from single phase to three phase at KEFRI Lodwar Sub Regional Research Centre thus enabling suitable capacity to run equipment and machines at the centre(see figure 7.5.4.).

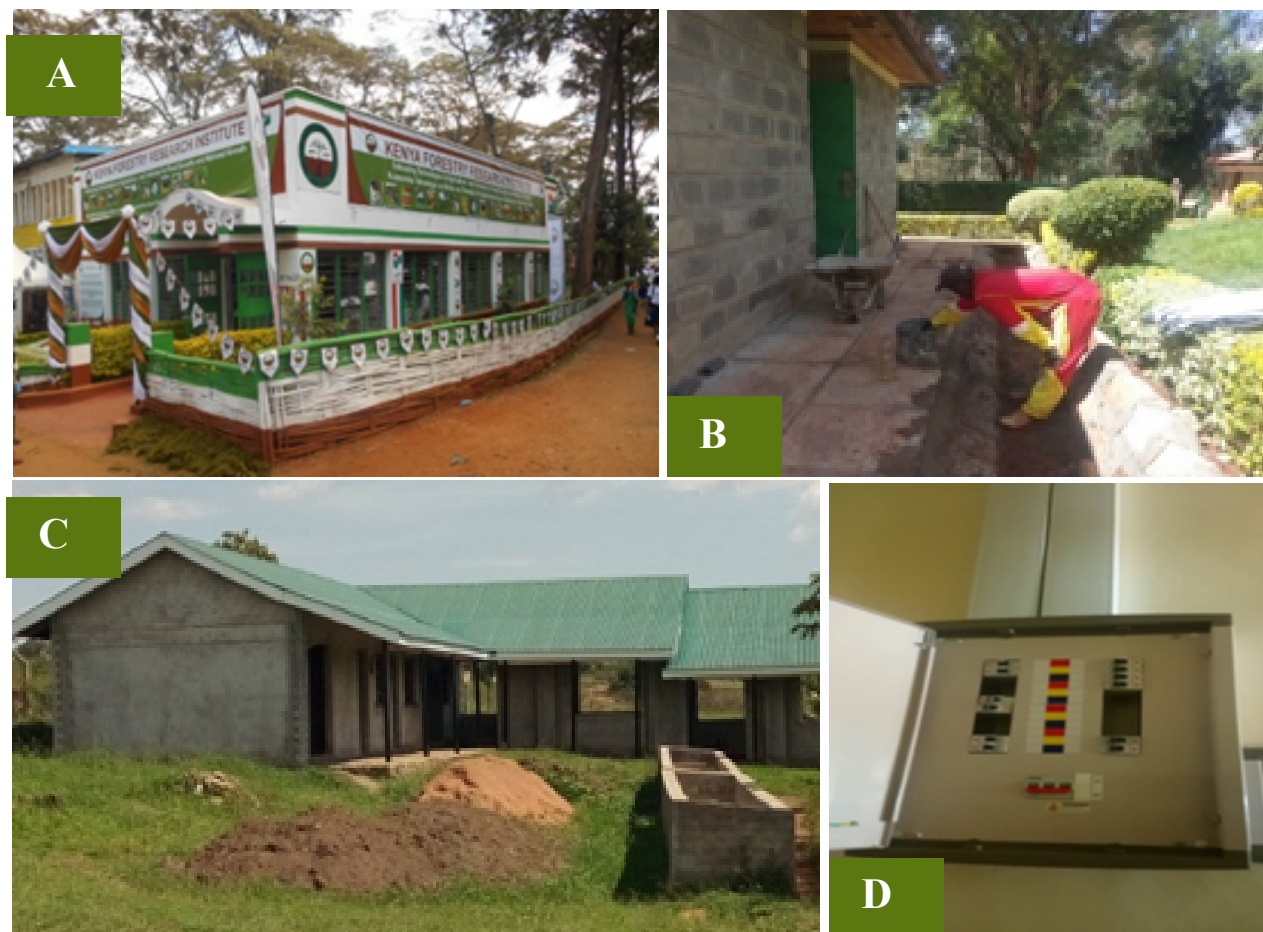


Figure 7.5.4: (A.) painted stand at Nairobi ASK ground, (B.) renovation of drainage at Nyeri, (C.) nursery house at Migori and, (D.) Installed electricity supply distributor at Lodwar sub region office

8.1 Implementation of ISO Standards

KEFRI operates in conformity with international standards as well as relevant national legislations. During the Fiscal Year 2018/2019, quality assurance was achieved through implementation and maintenance of ISO 9001:2015 Quality Management System (QMS) and Environmental ISO 14001:2015 Environmental Management System (EMS) standards.

For the first time, the institute adopted the top hierarchy format having revised both QMS and EMS documentation to fit the requirements of the revised 2015 standard. The global revision of ISO standards allowed operation of the integrated management systems concurrently.

Quality Management Systems (QMS) procedures and documents was modified and rolled out in all the regional and sub-regional centres. Both internal and external audits were also carried out to ensure adherence to the adopted ISO standards.

8.2 Occupational Safety and Health Act (OSHA)

The Institute committed to occupational health and safety requirements by ensuring safety and clean work environment, training Safety and Health Committee members in occupational safety and health, maintaining amenities and infrastructures in all the centres.

Internal work environment survey was carried out in accordance with the requirements of the Occupational Safety and Health Act (OSHA), 2007 and KEFRIs' Performance Contract 2018/2019 under Work Environment category. The survey was undertaken in all KEFRI premises to assess management of safety, health and welfare issues in the workplace. Some of the relevant subsidiary legislations under OSHA 2007 which also formed basis of the survey included:

- 1. First Aid Rules, L.N. 160 of 1977.**
- 2. Safety and Health Committee Rules, 2004.**
- 3. Medical Examination Rules, L.N. 24 of 2005.**
- 4. Noise Control and Prevention Rules, L.N. 25 of 2005.**
- 5. Fire Risk Reduction Rules, L.N. 59 of 2007**

During the survey, good occupational safety and health practices were identified as well as areas that required improvement. No major incidents or sickness were reported during this period.

KEFRI publications produced in FY 2018 - 19

Peer reviewed journal papers

1. Cheboiwo J.K., Mutta D., Kiprop J. and Gattama S. 2018. Public Private Partnerships Opportunities for Forestry Sector Development in Kenya: Synthesis of Primary and Secondary Production Actors, and Trade. *Journal of Environment and Earth Science* 8 (1): 47 – 69. ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
2. Cheboiwo J.K., Nasroun T.H., Mwamakimbullah R., Kyeyune R.K. and Mutaganda A. 2018. Public Private Partnership (PPP) in Forest Sector in Eastern Africa. Synthesis of Primary and Secondary Production Actors, and Trade. *Journal of Economics and Sustainable Development* 9 (2): 43 – 58. ISSN 2222-1700 (Paper) ISSN 2222-2855 (Online)
3. Kagombe J.K., Cheboiwo J.K., Gichu A., Handa C., and Wamboi J. 2018. Payment for Environmental Services: Status and Opportunities in Kenya. *Journal of Resources Development and Management* 40: 1 – 13. ISSN 2422-8397
4. Kagombe J.K., Kungu J., Mugendi D., Cheboiwo J.K. 2018. Evaluating the Willingness to Pay for Watershed Protection in Ndaka-ini Dam, Muranga County, Kenya. *Civil and Environmental Research* 10(1): 1 – 16. ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
5. Kagombe J.K., Mbuvi M.T.E. and Cheboiwo J.K. 2017. Role of Devolved Governance in Enhancing Incentives in Participatory Forest Management in Kenya. *Journal of Environment and Earth Science* 7(2): 12 – 16. ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
6. Muthike G. and Githiomi J. 2017. Review of the Wood Industry in Kenya; Technology Development, Challenges and Opportunities. *International Journal of Research Studies in Agricultural Sciences (IJRSAS)* 3 (10): 45-52. ISSN No. (Online) 2454–6224 DOI: <http://dx.doi.org/10.20431/2454-6224.03010005>.
7. Nadir, W.S, and Ng’etich, K. W (2018). Effects of water soluble polyphenols in *Eucalyptus grandis* trees and their effects on crops and soil water repellency. *Allelopathy Journal*. 44 (1): 79-92. DOI: 10.26651/allelo.j./2018-44-1-1154
8. Nadir, W.S., Othieno, O.C., Kebeney, J.S (2018). Nutrient Dynamics in Eucalyptus Plantations of Different Ages before and during Intercropping. *International Journal of Plant & Soil Science*, 22(1): 1-13. DOI: 10.9734/IJPSS/2018/38388
9. Ndung’u Stephen M. and Kimiti Jacinta M. 2017. Effect of Moisture Content and Temperature on Viability and Longevity of *Cordia sinensis* Lam. Seeds. *Journal of Resources Development and Management* www.iiste.org. ISSN 2422-8397 An International Peer-reviewed Journal. Vol.28: 14 - 19.
10. Othim Roxventa and Owuor Benjamin. 2017. Exclusion of Community Forest Associations in Decision Making and Its Impact on Forest Condition: Case Study of Mt. Elgon and Cherangany Ecosystems. *Indian Forester*, 143 (9): 834-839, 2017. <http://www.indianforester.co.in>. ISSN No. 0019-4816 (Print). ISSN No. 2321-094X (Online)
11. Robinson L.W. and Kagombe J. 2018. Institutional linkages and landscape governance systems: the case of Mt. Marsabit, Kenya. *Ecology and Society* 23(1): 27. <https://doi.org/10.5751/ES-09933-230127>
12. Wekesa C., Maranga E.K., Kirui B.K., Muturi G.M. and Gathara M. 2017. Interactions between native tree species and environmental variables along forest edge-interior gradient in fragmented forest patches of Taita Hills, Kenya. *Forest Ecology and Management* 409 (2018) 789-798

Technical Notes, Research Notes, Guidelines and Extension materials,

13. Cheboiwo J.K., Langat D., Ongugo P. and Kipsaat J. 2017. A Guideline for Market Surveys for Farm Forestry Tree Products in Kenya. KEFRI, Nairobi, Kenya.
14. KEFRI & FAO. 2018. Restoration of Arid and Semi-Arid Lands (ASAL) of Kenya Through Bio-Enterprise Development and Other Incentives Under The Restoration Initiative (TRI): Report on consultative meetings with key stakeholders in Laikipia, Isiolo and Marsabit Counties and visit to proposed projects sites. Compiled by Meshack Muga, Bernard Kamondo, Dorothy Ochieng, John Ngugi, Betty Njoki, Dr. Gabriel M. Muturi, Dr. Clement Ngoriareng' and Jim Okuto
15. Langat D., Otuoma J., Kagombe J., Cheboiwo J.K., Ongugo P. and Kigomo B. 2017. Guidelines for Establishing Payment for Ecosystem Services Schemes in Kenya. KEFRI, Nairobi, Kenya.
16. Mengich E.K., Cheboiwo J.K., Mulatya J., Owino J. and Ongugo P. 2017. Guidelines for Integrating Trees in the Irrigated Agriculture Landscapes of Kenya. KEFRI, Nairobi, Kenya.
17. Mwadalu R. and Gathara M. Edaphic Characterisation Of Arabuko Sokoke Forest. Chapter 3. In: Ochieng' D., Luvanda A., Wekesa C., Mbuvi M.T.E and Ndalilo L. (eds) September 2017. Biodiversity Status of Arabuko Sokoke Forest, Kenya. KEFRI /World Bank /Global Environmental Facility /Kenya Coast Development Project. pp 15 – 21.
18. Ndalilo L., Mbuvi M.T.E. and Luvanda A.M. Utilization and Governance of Arabuko Sokoke Forest Chapter 7. In: Ochieng' D., Luvanda A., Wekesa C., Mbuvi M.T.E and Ndalilo L. (eds) September 2017. Biodiversity Status of Arabuko Sokoke Forest, Kenya. KEFRI /World Bank /Global Environmental Facility /Kenya Coast Development Project. pp 47 – 59.
19. Ongugo Roxventa A., Osumba Purity A. and Tuzo Pasiens M. Traditional Forest Use and Institutional Change: Case Study of Loita Community Forest, Narok South District, Kenya. Chapter 10. 12 pages
20. Wekesa C., Otuoma J., Ongugo P., Muturi G. and Ochieng D. 2017. Background Information. Chapter 1. In: Ochieng' D., Luvanda A., Wekesa C., Mbuvi M.T.E and Ndalilo L. (eds) September 2017. Biodiversity Status of Arabuko Sokoke Forest, Kenya. KEFRI /World Bank /Global Environmental Facility /Kenya Coast Development Project. pp 1 – 7.
21. Wekesa C., Otuoma J., Ngugi J. and Muturi G. Floristic Composition and Structure of Arabuko Sokoke Forest. Chapter 2. In: Ochieng' D., Luvanda A., Wekesa C., Mbuvi M.T.E and Ndalilo L. (eds) September 2017. Biodiversity Status of Arabuko Sokoke Forest, Kenya. KEFRI /World Bank /Global Environmental Facility /Kenya Coast Development Project. pp 8 – 14.

Policy briefs

22. KEFRI, 2017. Forestry Research Strategy on Climate Change. KEFRI, Nairobi, Kenya.
23. Wekesa C., Ongugo P., Ndalilo L., Amur A., Mwalewa S. and Swiderska K. 2017. Small holder farming systems in coastal Kenya: Key trends and innovations. Country Report, September, 2017. IIED and KEFRI.

APPENDIX II:

Statement of financial performance for the year ended 30th June 2019

	Note	2018-2019	2017-2018
REVENUE			
Revenue from non-exchange transactions:			
Government Grants	3	1,478,666,770	1,536,359,277
External Grant for Research	4	145,214,489	206,315,381
Deferred Income from Donors	5(b)	26,831,046	30,279,269
Revenue from exchange transactions:			
Other Income	6	126,177,683	121,685,564
TOTAL REVENUE		1,776,889,987	1,894,639,491
EXPENSES			
Employee Costs	7	(1,178,546,081)	(1,194,485,137)
Operating Expenses	8	(518,375,815)	(583,905,815)
Board of Directors Expenses	9	(11,426,979)	(9,772,816)
Establishment Cost(Sinking Fund)	10(a)	(15,000,000)	(5,000,000)
Depreciation	5(a)	(81,574,755)	(88,610,913)
Amortization on Intangible Asset	11	(3,488,958)	(4,144,506)
TOTAL EXPENSES		(1,808,412,588)	(1,885,919,186)
OTHER GAINS/(LOSSES)			
Gain on Sale of Fixed Assets	12	491,351	1,060,747
Exchange Gain/(Loss)	12(b)	(1,094,717)	(2,731,729)
		(603,366)	(1,670,982)
Surplus/(Deficit) for the Year		(32,125,968)	7,049,323

APPENDIX III:

Statement of financial position as at 30th June 2019

	Note	2018-2019	2017-2018
ASSETS			
CURRENT ASSETS			
Cash and cash equivalents	13	381,133,474	298,878,846
Receivables from exchange transactions	14(a)	18,268,486	15,067,566
Receivables from non- exchange transactions	14(b)	3,156,870	1,283,774
Inventories	15	58,466,839	64,410,175
		461,025,669	379,640,361
NON-CURRENT ASSETS			
Property, Plant & Equipment	5(a)	5,752,762,412	5,796,221,100
Intangible Assets	11	13,955,832	16,578,022
		5,766,718,244	5,812,799,122
TOTAL ASSETS		6,227,743,913	6,192,439,483
LIABILITIES			
CURRENT LIABILITIES			
Payables from exchange transactions	16	2,477,771	12,458,567
Auditor General- accrued audit fee	16(c)	1,320,000	1,980,000
Payables from non-exchange transactions	16(d)	8,124,400	8,124,400
Unexpended External Donor Grants	4	140,122,059	192,174,312
Medical Scheme Funds	17	742,883	742,883
		152,787,113	215,480,162
NET ASSETS			
Government Grants for capital assets	18(a)	1,132,837,511	990,880,904
Deferred Income on Donated Assets	5(b)	559,968,157	586,799,202
Sinking Fund	10(b)	20,496,321	5,498,436
Revaluation Reserves	18(b)	4,467,199,488	4,467,199,488
Revenue Reserves	18(e)	(105,544,676)	(73,418,709)
		6,074,956,800	5,976,959,322
TOTAL NET ASSETS & LIABILITIES		6,227,743,913	6,192,439,483

APPENDIX IV:

Statement of changes in net assets for the year ended 30th June 2019

	Deferred Income on Government Grants for Capital Assets Kshs	Deferred Income on Donated Assets Kshs	Revenue Reserves Kshs	Revaluation Reserves Kshs	Sinking Fund Kshs.	Total Kshs.
Balance as at 1st July 2017	888,244,669	617,078,471	(78,806,870)	4,467,199,488	17,209,165	5,910,926,924
As restated	888,244,669	617,078,471	(78,806,870)	4,467,199,488	17,209,165	5,910,926,924
Surplus/(Defi- cit) for the year			7,049,323			7,049,323
Adjustments			(1,661,162)			(1,661,162)
Transfers from Sinking fund	8,251,817					8,251,817
Sinking Fund expenses					(17,636,979)	(17,636,979)
Additions during the year	143,231,199				5,926,250	149,157,449
To Income & Expenditure	(48,846,781)					(48,846,781)
Deferred Income for the year	-----	(30,279,269)	-----	-----	-----	(30,279,269)
Balance as at 30th June 2018	990,880,904	586,799,202	(73,418,709)	4,467,199,488	5,498,436	5,976,959,322
Balance as at 1st July 2018	990,880,904	586,799,202	(73,418,709)	4,467,199,488	5,498,436	5,976,959,322
As restated	990,880,904	586,799,202	(73,418,709)	4,467,199,488	5,498,436	5,976,959,322
Surplus/(Defi- cit) for the year	-	-	(32,125,968)			(32,125,968)
Adjustments						
Transfers from Sinking fund						
Sinking Fund expenses					(2,115)	(2,115)
Additions during the year	187,000,000					
To Income & Expenditure	(45,043,393)				15,000,000	202,000,000
Deferred Income for the year	-----	(26,831,046)	-----	-----	-----	(26,831,046)
Balance as at 30th June 2019	1,132,837,511	559,968,157	(105,544,676)	4,467,199,488	20,496,321	6,074,956,800

APPENDIX V:

Statement of cash flows for the year ended 30th June 2019

	Note	2018-2019 Kshs.	2017-2018 Kshs.
Cash Flows from Operating Activities			
Surplus(Deficit) for the Year		(32,125,968)	7,049,323
Adjustment for:			
Depreciation	5(a)	81,574,755	88,610,913
Amortization for Intangible Asset	12	3,488,958	4,144,506
Deferred Income	5(b)	(26,831,046)	(30,279,269)
KEFRI Surcharge		(244,611)	(204,738)
Commission Income		(217,827)	(220,144)
Adjusted Surplus		25,644,262	69,100,590
Working Capital Changes:			
Decrease (Increase) in Debtors	14	(5,074,016)	(6,880,417)
Decrease (Increase) in Stock	15	5,943,336	24,144,650
Increase (Decrease) in Creditors	16	(62,693,048)	(71,529,091)
Net Cash from operating activities		(61,823,728)	(54,264,858)
Cash Flows from Investing Activities:			
Purchase of Assets	5(a)	(38,134,966)	(101,254,523)
Purchase of Intangible	11	(866,768)	(1,417,765)
Establishment Cost(Sinking Fund)	10(a)	(15,000,000)	(5,000,000)
Proceeds from sale of assets	12	510,250	1,098,000
Net Cash from Investing activities		(53,491,484)	(106,574,288)
Cash Flows from Financing Activities:			
Development capital grants	3	141,956,607	94,384,418
Research Grants Received	4	94,916,928	130,783,168
Transfers/Adjustments		80,266,532	74,776,274
Research Grants Paid	4	(145,214,489)	(206,315,381)
Net Cash from Financing activities		171,925,578	93,628,479
Net Increase (Decrease) in Cash & Cash Equivalent		82,254,629	1,889,924
Opening Cash & Cash Equivalent		298,878,846	296,988,922
Closing Cash & Cash Equivalent		381,133,474	298,878,846
Cash & Cash Equivalent			
Bank balance	13(a)	381,133,474	298,878,846
Receivables from non- exchange Transactions(staff debtors)	14(b)		-
Travelling Imprest		421,036	-
Station/Special Imprest		2,709,695	1,219,950
Salary in Advance		-	11,045
Salary Advance		26,139	52,779
Closing Cash & Cash Equivalent		384,290,344	300,162,620

APPENDIX VI:

Statement of comparison of budget and actual amounts for the year ended 30th June 2019

	Notes	Original budget 2018-2019	Adjustments 2018-2019	Full budget 2018-2019	Actual on Comparable 2018-2019	Performance difference 2018-2019	Budget vs Actual
Revenue		Kshs	Kshs	Kshs	Kshs	Kshs	%
Recurrent Grants	3	1,433,623,377	-	1,433,623,377	1,433,623,377	-	100
Development Grants	3	205,000,000	(18,000,000)	187,000,000	187,000,000	-	100
Research Grants	4	145,214,488.60	-	145,214,489	145,214,489	-	100
Deferred Income from donors	5b	26,831,046	-	26,831,046	26,831,046	-	100
Other Income	7	127,243,433	-	127,243,433	127,243,433	-	100
Total Income		1,937,912,344	(18,000,000)	1,919,912,344	1,919,912,344		
GoK Development Grants for capital assets		(159,000,000)	17,000,000	(142,000,000)	(141,956,607)	(43,393)	
NET TOTAL INCOME		1,778,912,344	(1,000,000)	1,777,912,344	1,777,955,737	(43,393)	
Expenses		Kshs	Kshs	Kshs	Kshs	Kshs	
Employees Costs	8	1,178,550,000	-	1,178,550,000	1,178,546,081	3,919	100
Operation Expenses	9	518,400,500	-	518,400,500	518,375,815	24,685	100
Board Expenses	10	10,500,000	1,500,000	12,000,000	11,426,979	573,021	100
Establishment						-	
Cost(Sinking Fund)	11	15,000,000	-	15,000,000	15,000,000	-	100
Depreciation	5a	81,640,500	-	81,640,500	81,574,755	65,745	100
Amortization							
Expenses	12	3,500,500	-	3,500,500	3,488,958	11,542	100
Total Expenditure		1,807,591,500	1,500,000	1,809,091,500	1,808,412,588	678,912	
Other Gains/ (Losses)							
Gain on Sale of Fixed Assets	13	492,000	-	492,000	491,351	-	
Exchange	13b	(1,094,717)	-	(1,094,717)	(1,094,717)	-	
Gain/(Loss)							
Sub-Total		(602,717)		(602,717)	(603,366)		
Surplus /(Deficit) for the period without capital assets		(29,281,873)	(2,500,000)	(31,781,873)	(31,060,218)	(722,305)	
Capital Expenditure		45,120,000	(7,000,000)	38,120,000	(38,134,966)		100

Notes.

1. GoK Development - Grant Summary

Budget Estimates	205,000,000
Less: Not Received from Exchequer	
Total Grants received	(18,000,000)
Recognized Income:	187,000,000
Development Grants:	
Deferred income recognized	45,043,393
Referred income Capitalized	141,956,607
Total	187,000,000

2. Part of the Development Budget for Counterpart funding was not received in the current year

3. Capital Expenditure comprises of funds from Exchequer and other development partners funded projects

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