Improving Capacity in Forest Resources Assessment in Kenya (IC-FRA)

Proposal for National Forest Resources Assesement in Kenya (NFRA)

May 2016

Luke
NATURAL RESOURCES INSTITUTE FINLAND

KENYA Forest Service

KENYA FORESTRY RESEARCH INSTITUTE KEFRI

HARAMBEE

University of Eldoret
flame of knowledge and innovation

Prepared by:
The Project *Improving Capacity in Forest Resources Assessment in Kenya (IC-FRA)* implemented 2013–2015

Compiled by:
Mbae N. Muchiri, John Ngugi, Mwangi Kinyanjui, Balozi B. Kirongo, Fredrick Ojuang, Peter Nduati, Willis Atie, Beatrice Ndakwe, Helena Haakana, Pekka Hyvönen, Jukka Alm, András Balázs, Heikki Parikka, Juha Heikkinen

Cover caption: Front page photograph by H. Haakana: Measuring tree diameter in the IC-FRA pilot inventory.

Table of Contents

List of Tables

List of Figures

List of Appendices

ABBREVIATIONS AND ACRONYMS

AGB	Above-ground Biomass
ASAL	Arid and Semi-Arid Land
dbh	Diameter at the breast height (1.3 m)
DRSRS	Department of Resource Surveys and Remote Sensing
ERMIS	Environmental Research, Mapping and Information System
FAO	Food and Agriculture Organization of the United Nations
FRA	Forest Resources Assessment Programme
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GPS	Global Positioning System
ha	Hectare
ICRAF	International Center for Research on Agroforestry
IPCC	Intergovernmental Panel on Climate Change
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KEFRI	Kenya Forestry Research Institute
KFS	Kenya Forest Service
*k*NN	*k*-Nearest Neighbour
KMFRI	Kenya Marine and Fisheries Research Institute
KNBS	Kenya National Bureau of Statistics
KWS	Kenya Wildlife Service
LC	Land Cover
LU	Land Use
LULUCF	Land Use, Land-Use Change and Forestry
Luke	Natural Resources Institute Finland
MENR	Ministry of Environment and Natural Resources
MRV	Measurement, Reporting and Verification
NFI	National Forest Inventory
NFMA	National Forest Monitoring and Assessment
NFRA	National Forest Resources Assessment
OF	Open Foris
OWL	Other Wooded Land
PDA	Personal Digital Assistant
PSP	Permanent Sample Plot
QA	Quality Assurance
QC	Quality Control
RDA	Regional Development Authority
REDD	Reducing Emissions from Deforestation and Forest Degradation
RS	Remote Sensing
SFM	Sustainable Forest Management
TOF	Trees Outside Forests
TWG	Technical Working Group
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nation's Reducing Emissions from Deforestation and Degradation (UN-REDD) Programme
UoE	University of Eldoret
UTM	Universal Transverse Mercator
WB	World Bank

1 Introduction

1.1 Background

Today, the need for forest monitoring has never been greater because of growing demand for information both for national and international policy processes. Forests have a key role in mitigating climate change, preserving biodiversity, maintaining water catchments, producing various goods and services, providing livelihood and increasing food security. To manage and develop forests in environmentally, economically and socially sustainable way, it is crucial to have accurate information on forest and tree resources. This implies that all land use areas growing trees, and all forest products and services including commercially grown tree species must be assessed accurately. Comprehensive and representative information provides a basis for national-level analyses and strategic planning, and enables knowledge-based decision making. Data that is correctly and accurately collected (right design, correctly measured with minimum error) and statistically analysed data and time series increase knowledge of trends in forests and understanding of interactions between forests and other land uses.

In Vision 2030 forests are identified as one of the key drivers of the economy in Kenya, and the overall goal is to conserve natural resources; using them wisely in a sustainable manner without compromising economic growth (Kenya 2007). Consequently, forest policy aims to ensure adequate supply of forest products and services by increasing forest cover from the current 6.9% to 10% through environmental conservation and tree-planting. National strategies should take cognizance of the country's commitments to international conventions and processes, such as Convention on Biological Diversity (CBD), United Nations Framework Convention on Climate Change (UNFCCC) and Reducing Emissions from Deforestation and forest Degradation (REDD), sustainable management of forests and enhancement of forest carbon stocks (REDD+). Information requirements in these processes and in other international reporting, e.g. FAO's Global Forest Resources Assessment (FRA) (FAO, 2012, 2013), are similar as in the national forest policy: accurate, consistent and representative information on forest resources, products and services at regular intervals.

Sustainable forest management is defined and assessed by criteria and indicators that are tools for measuring and monitoring the status and changes in a forest. The indicators should capture quantitative and qualitative information on the following thematic areas (FAO, 2003): 1) Extent of forest resources; 2) Forest biological diversity; 3) Forest health and vitality; 4) Productive functions of forest resources; 5) Protective functions of forest resources; 6) Socio-economic functions of forest; and 7) Legal, policy and institutional framework. The forest resources in this context encompass also trees outside forests (TOF).

The main challenges in REDD+ and reporting to UNFCCC include assessing carbon emissions by various sources and removals by sinks, and changes in carbon stocks over time (IPCC, 2006). The Government of Kenya has committed herself to submitting UNFCCC a National Greenhouse Gas (GHG) Inventory report every four years. The REDD+ mechanism under UNFCCC in turn provides incentives to climate change mitigation activities and the payments are based on credible evidence of the achievements. To assess forest carbon stocks and verify REDD+ activities, the country must establish a transparent monitoring system for measurement, reporting and verification (MRV) which captures both drastic changes such as deforestation and felling (clear felling or selective felling) and gradual changes related to growth or degradation (UNFCCC, 2010). Given that mitigation activities are likely to affect availability of other forest products and services especially at the local level, information on other uses and values are required to help in forest management and optimizing total benefits.

Currently, the quantity, quality and trends in growth and yield of forest and tree resources are poorly known especially outside gazetted forests in Kenya. It is only from state plantations that sufficient data on the growing stock available was collected in Natural Resource Management project (NRM) in 2008 – 2011 for operative forest management planning. At the national level, there is no accurate, comprehensive and up-to-date information on forest biomass and volume to provide for strategic management planning and forest policy processes. The estimates of forest coverage and its changes are based on satellite remote sensing (FPP 2013) and volume estimates on partial or outdated inventories. Satellite imagery is adequate in assessing drastic changes such as deforestation or clear felling but not for growth or degradation. Regarding forest carbon stocks by five pools (above-ground biomass, below-ground biomass, dead wood, litter and soil), there is limited information based on research on restricted areas or global allometric functions. However, accurate data at the national level is lacking.

1.2 Objectives

The Government of Kenya (GoK) is in the process of developing a national greenhouse gas (GHG) accounting and reporting system as part of the National REDD+ Programme and establishing a National Forest Monitoring System. This document is a proposal for a National Forest Resources Assessment (NFRA) design and (technical) implementation in Kenya. The suggested NFRA is based on statistical sampling procedures and includes both a biophysical field inventory and a socioeconomic survey. The NFRA will produce accurate information on the current status of forest resources at the national level and form a sound basis for the monitoring system. Repeated field inventories will provide information on changes, for example, in land use, forest cover and biomass, for monitoring purposes. The socioeconomic survey will provide data for analysing the driving forces behind the changes.

With regard to the national forest policy and management, the NFRA will produce information on indicators of sustainable forest management. The indicators are attributes that can be measured and help in monitoring the status and changes in forests. The information produced by the NFRA will cover thematic areas of sustainable forest management (FAO, 2003) required for the global FRA reporting (FAO, 2013). The main information produced by the NFRA can be summarized as follows:

1. area by land use categories and forest types, by dominant tree species, age classes etc. (changes in forest area through repeated inventories);
2. volume and biomass of the growing stock including trees outside forests (TOF);
3. change in the growing stock (through repeated inventories);
4. carbon stocks by the five carbon pools defined in the IPCC guidelines;
5. forest biodiversity;
6. forest health and vitality;
7. productive and protective functions of forest resources; and
8. socio-economic functions of forest.

For the international reporting to the UNFCCC, the NFRA will cover all five carbon pools on forest land and additionally, part of the pools on all land use areas (Table 1). Due to the optimized NFRA sampling design, soil and litter sampling is carried out only on forest land in the NFRA, and therefore, litter and soil organic carbon on other lands such as agricultural or pasture land are not covered by the proposed NFRA.

Table 1. Carbon pools to be measured and monitored in the NFRA by FAO/ FRA land use classes.

Carbon pool	Forest land	Other wooded land	Other land
Above-ground biomass	Field measurements	Field measurements	Field measurements
Below-ground biomass	Apply developed allometric equations to field measurements of above-ground tree variables	Apply developed allometric equations to field measurements of above-ground tree variables	Apply developed allometric equations to field measurements of above-ground tree variables
Dead wood	Field measurements	Field measurements	Field measurements
Litter	Field measurements and laboratory samples	-	-
Soil organic carbon	Field measurements and laboratory samples	-	-

This proposal is an outcome of the Improving Capacity in Forest Resources Assessment in Kenya (IC-FRA) project implemented in 2013 – 2015. A pilot inventory in five test areas in different vegetation types was carried out during the project and in the planning of the proposed NFRA sampling design, the forest data measured during the pilot inventory was utilized. Moreover, the suggested measurements, technology and applications in data recording and calculations were tested in the pilot inventory, and gained experiences were utilized in improving this proposal.

1.3 Institutional framework

National forest monitoring is a continuous undertaking that should be institutionalized. Technical implementation of a NFRA requires long-term availability of expertise, availability of data and data management tools and adequate infrastructure for further improvement. This is best guaranteed by a permanent NFRA organization built on existing capacity within the national administration. Integration of the NFRA into a government institutional framework will create a legal and financial basis for the long-term functioning and development of the system. It will also demonstrate the country's ownership and commitment to the forest monitoring task, and in line with the strategy of National Forest Assessment and Monitoring in the National Forest Programme (NFP) prepared by the Ministry of Environment and Natural Resources and Regional Development Authority (MENR+RDA).

In a forest monitoring system, the implementing organization must have a clear mandate for the task to get access to all land, to get access to relevant background data and to facilitate long-term planning, investments and capacity building. In Kenya, the mandate of a NFRA is not given to any institution in the legislation. There are two government institutions in the forest sector; the Kenya Forest Service (KFS) and the Kenya Forestry Research Institute (KEFRI) with competence and technical capability for the NFRA. Currently the KFS in consultation with the County Government has a duty to prepare a Forest Status Report and a Resource Assessment report on the public forests every two and five years respectively (Forest Conservation and Management Bill, 2014). The Kenya Forestry Research Institute (KEFRI) in turn shall provide information and technologies for sustainable development of forest resources.

The MENR+RDA should have the overall responsibility for formulating and mandating the NFRA implementation. Constituting a NFRA, or more broadly a Forest Monitoring unit, i.e. entity in organization structure within an existing institution, is recommended. Technical implementation of the NFRA will require operational capacity and expertise in various fields, such as forest mensuration, statistics, remote sensing and information technology, which does not exist in one institution. Consequently, the NFRA will require national cooperation, recruitment of new experts and experienced staff, and continuous capacity building in order to ensure sustainability.

The KFS has strong experience in operational forest inventory and expertise in international processes (FAO/FRA, REDD+), and KEFRI in the fields of soil carbon analyses, inventory research and development, and quality control. It is recommended that the NFRA unit will be built on these institutional capacities. A formally assigned mandate and a permanent NFRA structure with clear responsibilities are essential for operational efficiency and sustainability. In strengthening research and capacity in forest monitoring, the NFRA unit should cooperate with the Universities, especially with the University of Eldoret (UoE) having a school of natural resource management and the Jomo Kenyatta University of Agriculture and Technology (JKUAT) with expertise in information technology. In the field of Remote Sensing (RS) and forest mapping, cooperation with DRSRS is recommended.

The NFRA also needs cross-sectoral coordination and linkages with national and global stakeholders to response to their information needs. The NFRA and monitoring system will provide extensive information, not only on tree and forest resources but also on land use, biodiversity, non-timber and non-wood forest products and services, and socio-economics. The collected and generated information will support policy processes and decision making at different levels, including outside the forest sector.

The NFRA stakeholders include at least the following national institutions: DRSRS, KWS, KEMFRI, UoE, JKUAT, MENR, ERMIS, Kenya National Bureau of Statistics (KNBS), Natural Museums of Kenya, Forestry Society of Kenya, Survey of Kenya, Metrological Institute and County governments. The most important international stakeholders are FAO, ICRAF, UNDP, UNEP and WB.

2 Sampling design

2.1 Sampling method

Due to geographical and climatic conditions, there is a large variation in forest biomass, and consequently in forest carbon storage, between regions in Kenya. The forests are scattered and concentrated in favourable, humid areas in South-West Kenya. In addition, the size of certain vegetation types such as mangroves is small compared to the other vegetation types, for example, grasslands and farm forests. To provide results on forest resources with required accuracy and cost-efficiently for the whole country, a double stratified two-phase sampling method is recommended for the NFRA in Kenya.

In this method, stratification is applied in both sampling phases. First, the country is divided into geographical strata according to the agro-ecological zones and administrative units. The stratification improves the precision of results, for example, biomass and volume estimates, if the forest structure is homogenous, i.e. variation of biomass is low within a stratum and heterogeneous (variation is high) between strata. The geographical stratification also enables the use of different sampling designs in different strata.

The first-phase sample is a dense grid of clusters of sample plots systematically laid over the whole country. Only a part of the clusters is measured in the field and to select this second-phase sample optimally, the clusters are further stratified into second-phase strata according to the number of forested sample plots in a cluster. Technically, the sample plots are interpreted as forest or non-forest on the basis of auxiliary data available prior to the field measurements. The stratification enables selection forested clusters with a higher probability, and thus, putting more emphasis on the sampling of forested clusters in the field (more weight given to forested clusters compared to their counter parts).

The recommended sampling design is based on a simulation study conducted in the IC-FRA project. The simulation technique and results are described in detail in a technical report (Appendix 1) and an overview of results is given in the sections which follow.

2.2 Land use of Kenya and Stratification

The total area of Kenya is 58.0 million ha, of this 1.1 million ha are inland water bodies. Kenya is composed of seven different agro-ecological zones (Figure 1). The land consists of 82% arid and semi-arid land (ASAL) and 18% humid to semi-humid land.

The official estimate of the forest cover in Kenya is 6.9% of the land area (Forest Preservation Programme, 2013). This area comprises natural forests, plantation forests, open woodlands and a small amount of mangrove forests in coast. The most luxuriant forests are found in the humid to semi-humid areas in Western Kenya, the montane areas and in the coast. According to the Land Use (LU) map by the Forest Preservation Programme (FPP, 2013) most forest plantations are found in Central and Western Kenya (Figure 1).

The ASAL zone extends over the whole Northern and Eastern Kenya except the lower south East (Lamu County where Boni forest is found) and according to the LU map, the main land use type in these areas is grassland (Figure 1). In the ASAL area, there are also scattered natural forests which are, however, small in area.

Along the coastal strip of Kenya there are unique forests, namely mangrove forests. Mangrove forests are scattered along the coastline. The most common tree genera are *Rhizophora*, *Ceriops* and *Avicenia*. The largest continuous mangrove forests are found in Lamu, Gazi and Mombasa areas.

In principle, vegetation types and forest structure follow the agro-ecological zones. Forests with large amounts of above-ground biomass (AGB) are found in humid to semi-humid zones and forests with less AGB are found in arid areas. However, below-ground biomass (BGB) can be high also on arid areas, as was found out in the IC-FRA pilot inventory when the soil samples were analysed.

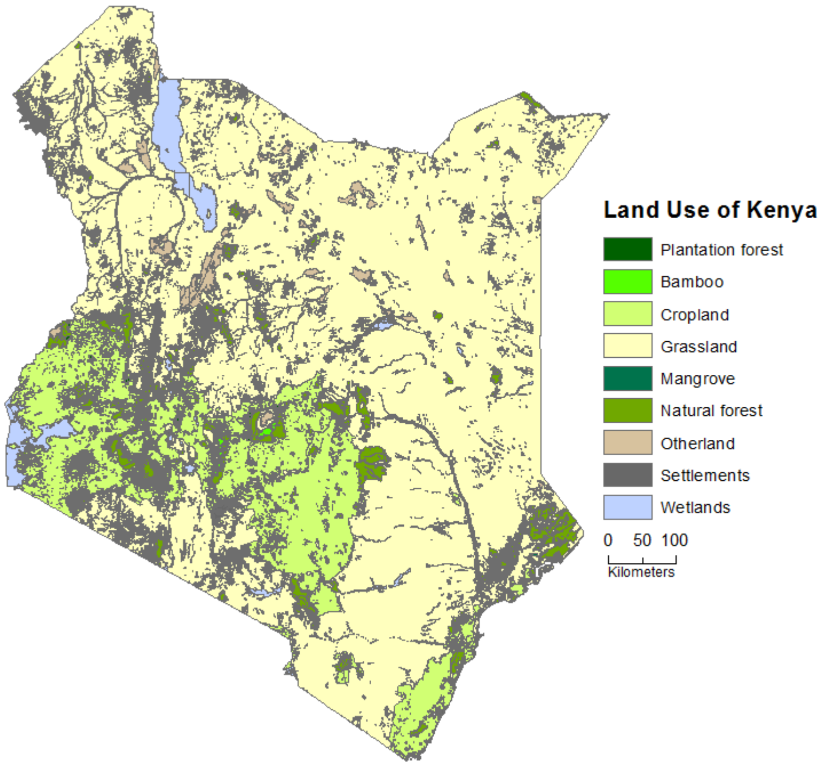

Figure 1. Land use map of Kenya (FPP, 2013).

As the agro-ecological zones are quite different in respect of vegetation and biomass, it is recommended that the country should be divided into different strata according to these zones. The delineation of agro-ecological zones is, however, ambiguous on the ground, and therefore, the division should also follow some spatially explicit boundaries such as administrative units. The suggested geographic strata are shown in Figure 2 and described in the following section. The areas of land use classes and forest types are based on the LU map (Figure 1).

Stratum 1: grasslands

The area of Stratum 1 is about 355,000 square kilometres (km^2) and the share of forests is about 3.9% of the land area (Table 2). According to the LU map, there are only natural forests in Stratum1. The most common land use class is grassland with a share of 93.4% of the land area.

Stratum 2: forested areas

The area of Stratum 2 is about 210,000 km^2 and forests cover about 12.0% of the land area. The most common forest type is natural forest (88.8% of the forest area). According to the LU map, plantation forests (7.9% of the forest area) and bamboo forests (3.5%) are found only in this stratum.

Stratum 3: coastal areas

The area of Stratum 3 is about 27,000 km^2 and the most common land classes are grassland and cropland, which cover 48.7% and 37.5% of the land area, respectively. According to the LU map, there are scattered natural forests covering about 12.8% of the land area in Stratum 3.

Stratum 4: mangroves

The area of Stratum 4 is about 1 000 km^2. This area also includes a buffer zone (100 m) around the mangrove forests. The actual area of mangrove forests is approximately 700 km^2. There are also some scattered natural forests within Stratum 4.

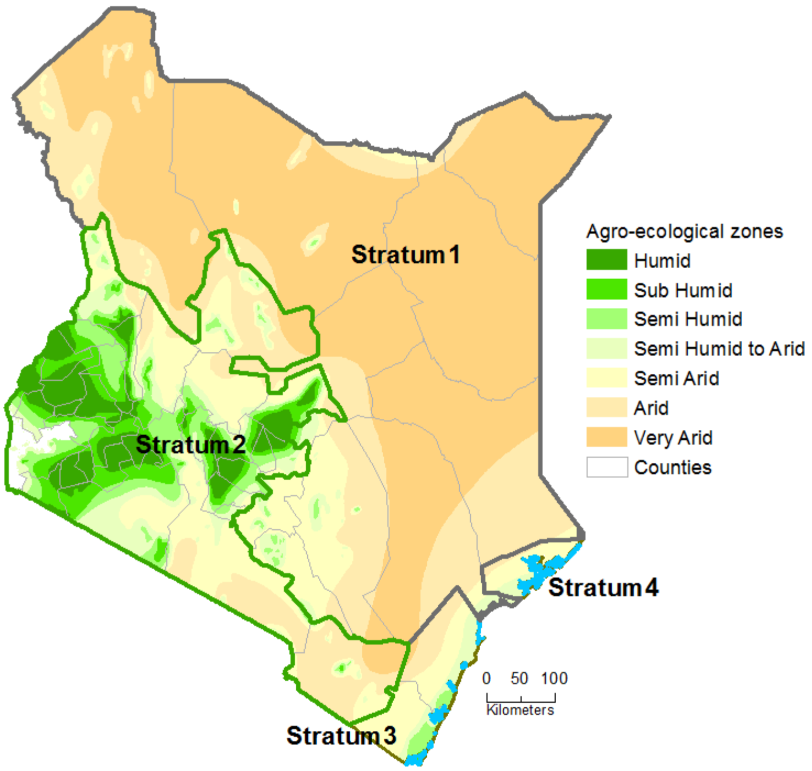

Figure 2. Agro-ecological zones and suggested geographic strata for the NFRA in Kenya.

Table 2. Area of different forest types and land use classes* in Kenya by different strata (km^2).

	Stratum1 Grasslands	**Stratum2 Forested areas**	**Stratum3 Coastal area**	**Stratum4 Mangroves**	**In total**
Bamboo	0.0	856.9	0.0	0.0	856.9
Mangrove	0.0	0.0	0.0	661.1	661.1
Natural Forest	13,390.3	21,647.2	3,429.8	6.5	38,473.9
Plantation	0.0	1,922.6	0.0	0.0	1,922.6
Forest in total	**13,390.3**	**24,426.7**	**3,429.8**	**667.6**	**41,914.5**
Grassland	322,938.7	87,091.9	13,099.4	143.6	423,273.6
Cropland	1,151.8	89,463.8	10,096.7	51.9	100,764.2
Settlements	119.7	1,026.7	107.7	3.1	1,257.2
Other land	8,005.0	2,405.5	175.7	139.2	10,725.3
Land in total	**345,605.5**	**204,415**	**26,909.3**	**1,005.4**	**577,935**
Wetlands	9,096.7	5,649.7	84.8	5.7	14,837.0
In total	**354,702**	**210,064**	**26,994**	**1,011**	**592,772**

*) Land use information according to the Forest Preservation Programme (FPP), 2013.

2.3 Two-phase sampling

The first-phase sample consists of clusters of sample plots systematically laid, in a distance of 2 km-by-2 km (4 km^2 grids) over the whole country. This density results in a total amount of ca. 148 100 clusters in the country. The map projection applied was UTM-37S/Arc 1960 and the first sample plot location was allocated randomly to enable estimation of valid probability values.

To select the second-phase sample, i.e. the clusters to be measured in the field, the clusters were further stratified into three strata according to the number of forested sample plots in a cluster (Table 3). In classifying the sample plots as forest and non-forest, the land use map of Kenya produced by Forest Preservation Programme (FPP, 2013) was used.

The intensity of the second-phase sample, i.e. the amount of clusters to be measured in the field in each geographical stratum, was then determined by optimizing the precision of the main variable of interest with the time cost as a limiting factor. Specifically, an optimal allocation was obtained by minimizing the relative standard error of the total biomass on forest land with the restriction of time consumption. To incorporate spatial balance to the second-phase sample, and hence, to achieve a representative sample of the whole population, a spatially balanced survey designer, Generalized random tessellation stratified (GTRS), was applied in the allocation.

Table 3. Number of forested plots in a cluster in different second-phase strata (class).

	Number of forested plots		
	Class 1	**Class 2**	**Class 3***
Stratum 1, Grasslands	0-2	3-4	5-n
Stratum 2, Forested area	0-1	2-3	4-n
Stratum 3, Coastal area	0-1	2-3	4-n
Stratum 4, Mangroves	0-1	2-3	4-n

*) “n” is the maximum number of sample plots in a cluster.

A precondition was that the NFRA field measurements should not take more than three years, and it is assumed that 15 field teams will work in the field 8 months per year. According to the simulation study, the time consumption of 55 000 hours in the field work, which is approximately 2.9 years, results in a second-phase sample of 5300 clusters which are allocated to the geographic strata as listed in Table 4. With this approach of allocation of the second-phase sample, the error of the total biomass estimate for the whole country is 1.54%. The errors of forest area and mean biomass estimates are 0.94% and 1.23%, respectively.

The two-phase sampling described above will produce accurate estimates of biomass and forest area for the whole country but the estimates for the sub-areas, e.g. geographical strata or forest types, are less accurate. The accuracy in Stratum 2, forested areas, is nearly the same as for the whole country, because the second-phase sampling is densest in this stratum. The errors of biomass estimates in Stratum 1 and 3 are also reasonable, 3.9% and 4.6% for the total biomass and 2.2% and 2.4% for the forest area, respectively. The errors in Stratum 4, i.e. mangroves are highest, 7.6% of the total biomass and 2.8% of the forest area. This is due to low sampling intensity and the small size of Stratum 4, as the second-phase sampling is optimized for the whole country.

As an option, the first-phase sample (clusters in 2-by-2 km grid) can be used in the estimation of forest area if a more accurate estimate for sub-areas, for example, mangroves, is required. In this case, the land use class and forest type are visually interpreted for all the first-phase sample plots by means of high-resolution remote sensing imagery. One option is to use Google Earth or other available material. To guarantee accurate and up-to-date results, the images must be very recent, not more than 3 years old. In interpreting a land use class for each sample plot, same classification should be used as in IPCC Guidelines and the Kenyan LU map (FPP, 2013) (Figure 1, Table 2).

Table 4. Number of clusters in different geographical strata.

	First-phase	**Second-phase**		
	All	**All**	**On land**	**Forested**
Stratum 1, Grasslands	95 661	1028	1014	423
Stratum 2, Forested area	45 293	3992	3933	2070
Stratum 3, Coastal area	6876	230	230	121
Stratum 4, Mangroves	283	50	50	41
Total	148 113	5300	5226	2655

3 Sampling units

3.1 Cluster design

A sampling unit is a cluster of circular sample plots. The sample plots are grouped into clusters for practical reasons in order to take into account the inventory costs. The aim is that a field team can measure one cluster per day. A simulation study was conducted to test different cluster designs to come up with the "best" designs for each regional strata taking into account accuracy (error of biomass and area estimates) and inventory costs (time taken in measuring and walking in the field). The forest and time consumption data from the IC-FRA pilot inventory carried out in 2013 in five test areas, four around Nakuru and one in the mangroves near Gazi, were used in the simulation.

For the test areas, forest biomass maps were produced by means of field sample plots, Landsat imagery and the *k*NN estimation method. Several cluster designs, that is, cluster forms, number of sample plots and distances between sample plots in a cluster, were tested. The results showed that an optimal distance between the sample plots in a cluster was about 250 meters, after which spatial correlation between volumes on sample plots started to decrease. With longer distances the relative error, especially that of mean biomass, still decreased but at the same time, the time taken increased because more time was spent in walking between sample plots. The simulation technique and the results are described in detail in Appendix 1.

Based on the simulation study and practical experiences from the pilot inventory, the following cluster designs are recommended. In the Strata 1 – 3, clusters consisting of 6 sample plots in rectangular form and a distance between plots of 250 m (Figure 3) is recommended. In Stratum 4, i.e. mangroves, 4 sample plots in a square layout with the distance between sample plots being 150 m (Figure 3) is recommended.

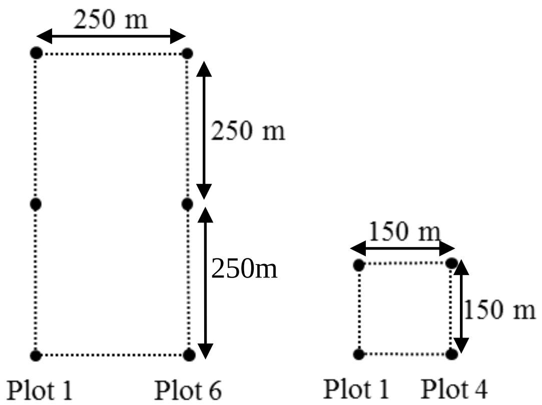

Figure 3. Cluster designs in Strata 1 – 3 (left) and in Stratum 4 (right).

3.2 Sample plots

For tree measurements, concentric circular sample plots are recommended for all the strata (Figure 4 and Table 5). The use of concentric plots in forest inventory aims at increasing the accuracy of the measurements and sampling intensity of large trees, and at the same time, at saving time. Tropical natural forests are characterized by having negative exponential diameter distribution, i.e. there are a lot of small trees but the number of trees decreases with increasing tree size. The concentric plot design ensures that not too many small trees are in a plot and enough large trees, which constitute most of the biomass per unit area, will be measured. The design results in measuring approximately the same number of trees for the different size classes.

From a practical point of view, circular plots are efficient because only one point, the plot centre needs to be identified and marked on the ground. It is not necessary to clear or mark the plot boundary, especially when there is good visibility in the stand. Compared to other geometric shapes (of plots) of the same size, a circular plot has the shortest perimeter, and consequently, the lowest expected number of border trees.

Nested circular plots were tested in the IC-FRA pilot inventory in 2013 (Technical report on the Pilot inventory, 2016). According to the feedback from the field teams, the circular plot shape was widely accepted and considered to be flexible and quick to measure. Because the plot radius is a horizontal distance, use of electronic distance measuring equipment such as Haglöf Vertex or TruPulse Rangefinder, are recommended in establishing circular plots.

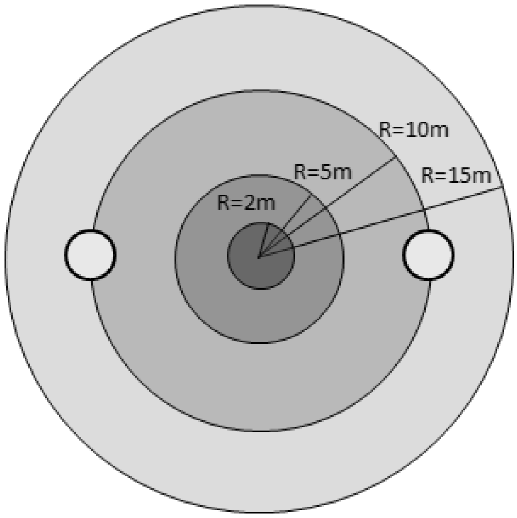

Figure 4. Sample plot design for Stratum 2 (forested areas) and Stratum 4 (mangroves).

Because Stratum 1 (grasslands) and Stratum 3 (coast) are mainly grassland with scattered natural forest patches or cropland with trees on farm, a radius of 20 m instead of 15 m for the largest sample plot is recommended (Figure 4). Using this approach, scattered trees, e.g. TOF, will be better captured. On the basis of the time consumption data from the IC-FRA pilot inventory, the enlargement will not radically increase the time spent for measurements on a sample plot. On grasslands and croplands there are fewer trees than in forests and they are mainly of smaller diameter classes. Thus, the extra 5 m in the outer radius will not increase the amount of trees or time consumption significantly.

The cumulative plot area in a cluster is 0.424 ha in Strata 2 and 4, and 0.754 ha in Strata 1 and 3, which can be regarded as sufficient in tropical forest to capture species composition and diameter distribution of trees. Previous studies have shown that a plot size of approximately 0.35 – 0.5 ha is necessary for estimating aboveground biomass accurately in tropical forests (Brown *et al*., 1995; Clark and Clark, 2000).

Tree measurements on the concentric sample plots include measurements of both living and dead standing trees and palms. Climbers (lianas), bamboos, lying dead wood, shrubs and stumps are measured from the same concentric sample plots as trees (Table 5). Bamboos are primarily measured by clumps within a sample plot of 10 m radius but in case bamboos are evenly situated (no groups/clumps), two subplots with a radius of 2 m located in the west and east in 5 meters distance from the sample plot centre can be used to calculate all bamboos. Number of saplings (regeneration) will be recorded from two subplots located at a distance of 10 m to the west and east from the sample plot centre. Regeneration subplots are circular with a radius of 2 m (Figure 4). The sample plot measurements are described in more detail in the field manual (Appendix 2).

Table 5. Measurements on the nested circular sample plots.

	Dbh / diameter (cm)	Height / length (m)	Plot radius (m)	Plot area (m^2)
Tree	≥ 2	≥ 1.3	2	12.6
Tree	≥ 5	≥ 1.3	5	78.5
Tree	≥ 10	≥ 1.3	10	314.2
Tree (Strata 2 and 4)	≥ 20	≥ 1.3	15	706.9
Tree (Strata 1 and 3)	≥ 20	≥ 1.3	20	1256.6
Climber	≥ 2	≥ 1.3	2	12.6
Climber	≥ 5	≥ 1.3	15	706.9
Bamboo		≥ 1.3	10 or 2 x 2.0	314.2 or 25.13
Lying dead wood	≥ 10	≥ 1.0	15	706.9
Shrub		≥ 1.3	15 or 2 x 2.0	706.9 or 25.13
Stump			15	706.9
Regeneration	< 2	≥ 0.10	2 x 1.5	14.13

In addition to the sample plot measurements, information on stand level variables around (surrounding) the plot are assessed. A stand is a connected land area which is homogenous with respect to land use, vegetation type, growing stock and possibly accomplished measures and proposed future management. Stand variables include, for example, land use and land cover class, past land use class and time of change, damage and human impact. In addition, observations on biodiversity, erosion, grazing, non-wood forest products and services, and water catchment are recorded. All variables with definitions and classifications are described in the field manual (Appendix 2).

3.3 Soil sampling

To estimate Soil Organic Carbon (SOC) in forests, soil samples from the top 30 cm layer are collected and delivered to soil laboratories for further analyses. In addition, samples of litter and woody debris are collected to characterize the relative carbon amount from the above-ground forest ecosystem layer. The soil, litter and woody debris samples are collected from all second-phase clusters that have sample plots in forested areas. The expected number of forested clusters is 2655. In a cluster, samples are taken from as many sample plots in the forested areas as possible in a working day taking into account that the field team should complete a cluster a day and leave the cluster together.

In a sample plot, composite samples of soil, litter and woody debris are collected from 4 subplots located in the cardinal directions 1 m outside the largest concentric circle plot (15 m or 20 m). The subplot for litter and woody debris sampling is a circle of 1 m^2 area, and volumetric soil samples are taken from a soil pit within a 2 m x 2 m area close to the theoretical sampling point. Detailed instructions for soil, litter and woody debris sampling and assessment of soil characteristics are described in the field manual (Appendix 2).

In mangroves, soil, litter and woody debris sampling is somewhat different than on uplands. Mangroves are exceptional ecosystems and expected to have large carbon stocks in belowground biomass. In tidal conditions, decomposed organic matter and water transported mineral particles accumulate water-saturated and muddy sediments. Given the relative small area of mangroves in Kenya, sampling is carried out on all second-phase sample plots. Furthermore, sediment samples are collected from layers down to 100 cm. The expected number of forested clusters in mangroves is 41, and each cluster consists of 4 sample plots.

4 Laboratory analyses

Soil, litter and woody debris samples collected from the second-phase sample plots will be delivered to soil laboratories for carbon analysis. The expected number of soil samples is approximately 3900 assuming that from each forested cluster in uplands (2614) soil samples are collected at least from one sample plot and every second cluster from two sample plots. In mangroves, soil sampling is carried out in each cluster (41) and hence, there will be about 60 sediment samples to analyse. Considering the expected number of samples, it is recommended that four soil laboratories around Kenya be engaged in the NFRA soil analyses. The analyses task will be shared regionally taking into account laboratory resources and soil transport costs.

In the IC-FRA project, an inventory of active soil laboratories in Kenya was conducted to assess their potentials in terms of equipment and personnel. On the basis of this assessment, the following laboratories are suggested for analysing soil samples in the NFRA from the regions mentioned:

- KEFRI Gede, the coastal region and mangroves;
- KEFRI Maseno, Western Kenya;
- UoE, Rift valley, central highlands; and
- KEFRI Muguga (Hqs), central highlands and all other areas.

In addition to these, an external laboratory, either universities (Jomo Kenyatta, UoE) or ICRAF, should be involved in Quality Assurance (QA) to control the analyses methods used and accuracy of the results. In internal Quality Control (QC) in the NFRA laboratories, regular cross-checking of same samples is used for calibrating the methods.

It is recommended that organic carbon content of upland soil samples be determined by means of the Walkey-Black method, which is based on wet combustion with traditional manual analytics. This is to conduct analyses with moderate costs and commonly available laboratory equipment. More sophisticated methods based on dry combustion would require costly and specialized equipment. Because mangrove sediments have high chloride concentration and are also expected to have very high organic carbon content, instead of the Walkey-Black method, the Loss on Ignition (LOI) method is recommended for analysing sediment samples. This method is based on burning the organic matter and widely used in OC analyses of organic rich soils and matters, such as manure, compost and sediments. The organic carbon content of litter and woody debris is estimated as a proportion of dry biomass.

Procedures for analysing soil and sediment samples in a laboratory is described in the manual for Preparation and organic carbon analyses from forest soil and mangrove sediment samples (Appendix 3). Preparatory measures include stabilization by air drying, oven-drying, weighing, sieving and homogenization. In addition, the manual provides tools for calculating results and for computation, an Excel workbook application developed in the IC-FRA pilot inventory is available.

5 Socioeconomic survey

The socioeconomic survey will provide information on contribution of forest resources to livelihoods of forest adjacent households and community interaction with the forests. Socioeconomic data is collected by interviewing households and communities' key informants. The ultimate objective is to generate information about forest use and needs of local communities to support decision making and improved land use policy at national level.

The socioeconomic survey should be undertaken simultaneously with the biophysical inventory for synergy and logistics in the field work. The recommended sampling design for the socioeconomic survey follows the design for biophysical measurements for reasons of consistency and credibility. The same sampling design provides an unbiased sample of communities, and the socioeconomic data can be linked with the biophysical data, which in turn enables analytical approach to the interaction between communities and forest goods and services.

Proposed data collection procedures are based on FAO's guidelines for Integrated Land Use Assessments (ILUA) and National Forest Monitoring and Assessment (NFMA) which have been adopted, for example, in Zambia and Tanzania. Socioeconomic data includes variables describing forest use and users. Content of key informant and household survey questionnaires are described in a sepatate field manual in detail.

Socioeconomic survey will be conducted on 50% of the permanent clusters and 25% of the temporary clusters. In each cluster, four households are randomly sampled within 2 kilometre-radius around the cluster centre. In case there are no households available within 2 kilometres, two households are sampled within 4 kilometres and if still there are no households available, then up to 10 kilometres radius. The survey requires careful preparation before the field work, including sampling of households, identification of key informants, selection of local enumerators and interpreters if needed due to language barriers, and sensitization of local leaders.

In the selected clusters, NFRA field teams will include two socioeconomic interviewers. They move to the field together with the rest of the team and have transport available to reach the selected households during the day. The interviewers need a GPS for navigating and need training on its use. The survey questionnaires are planned in a way that answers can be easily entered digitally during the interview, if not (while interviewing) later during the same day. Before the field work, interviewers are trained on the survey questionnaires to understand and to get 'meaningful' answers so as to reduce the time taken in administration, and to increase accuracy.

6 Quality Assurance

It is important to implement Quality Assurance and Quality Control (QA/QC) procedures at the same time when establishing a NFRA and monitoring system. As defined in IPCC (2006) Guidelines, QC activities are internal routines and checks to assess and maintain the quality in all phases of the inventory. The QC is designed to ensure data quality, identify errors and address practices that need to be improved, and to document and archive all inventory material. QA procedures in turn are external assessments of the quality.

It is recommended that the quality system of NFRA and monitoring be outlined and documented as a Quality handbook. The Quality handbook should describe NFRA organisation and responsibilities, personnel and their competence requirements, work safety instructions, NFRA procedures and equipment. The NFRA procedures, that is, key activities in carrying out the NFRA from preparing for the field work to the reporting of the results, are described in detail in separate procedure guidelines. These are to document how the NFRA is carried out and to guarantee that the work in each phase is efficient and coherent. A field manual is an example of such procedure guidelines. The quality system should also include registers of equipment.

In addition to the high quality in all NFRA work, special QC activities should be conducted in the field work and in the laboratory analyses. It is recommended that ca. 5% of the field sample plots are re-measured to guarantee data quality. The QC measurements should be carried out by separate QC field teams shortly after the actual measurements to enable quick feedback and corrections in case some errors are detected.

7 Forest monitoring

The NFRA and forest monitoring is a continuous process and it is suggested that the field inventory will be carried out periodically to provide up-to-date information on forest and tree resources with known accuracy. This is to keep up with international reporting requirements and also produce relevant information to national decision and policy processes. In a monitoring system, capability to produce information on changes in forest and tree resources (cover, growth, removal) plays a key role.

The proposed NFRA field work is scheduled to be carried out in three years and the results will be available in the fourth year. The next field inventory could then start by the fifth year. If the second round is carried out equally in three years, the first information on changes could be obtained eight years after starting the first inventory. A feasible cycle, however, depends on the financial resources available. It is recommended that the proposed sampling method, and furthermore, the same sampling design be applied also in the future inventories. The two-phase sampling method has an advantage that an optimal allocation of the second-phase sample can be based on the current situation at each round.

Establishing sample plots as permanent and re-measuring the same plots in subsequent inventories would benefit in estimation of changes, e.g. in land use and biomass. Permanent plots are more efficient, because changes can be estimated at the plot and tree level, whereas in the case of temporary plots, change estimates are based on the difference between the results in subsequent inventories. Permanent plots, however, have some drawbacks that may affect their applicability. For instance, if their existence is known to local people and forest managers, trees on the sample plot may be treated differently than otherwise.

The proposed allocation of the second-phase sample for the first NFRA is based on the current forest cover (FPP 2013) and may not capture all areas where changes in land use and biomass are likely to occur, for example afforestation and tree planting on farms. In the allocation, more weight was given to the forested clusters but it should be noted that the second-phase sample includes also clusters without any forested plots, only that their number is lower.

It is recommended that a combination of permanent and temporary plots will be used in the first NFRA round, and a quarter (25%) of the second-phase clusters will be established as permanent. The relatively low amount of permanent sample plots will allow for more flexible second-phase sampling in the future. In the field, permanent sample plots are marked with a metal stick or peg, hidden in the ground to keep the location secret, and sample plot coordinates recorded. This is to locate the permanent sample plots for re-measurements. However, their existence should not impact local forest management or other activities.

In the allocation of the second-phase sample, the LU map of Kenya (FPP, 2013) based on ALOS AVNIR-2 and DMC satellite imagery acquired in 2009 – 2011 was used. The ground resolutions of the imagery were 10 m x 10 m and 22 m x 22 m, respectively. The LU map represents the land use cover in Kenya in 2010. For an optimal allocation of the second-phase sample in the next field inventory, similar LU or land cover map is required. It is proposed that the LU map is updated periodically, for example, in 5-year-intervals to facilitate the allocation. For that purpose, for example, freely available Landsat satellite imagery with a resolution of 30 m x 30 m would be sufficient. Satellite imagery can also be utilized in assessing drastic changes on the sample plots such as deforestation or (clear) felling but not growth or degradation (see e.g. Maniatis & Mollicone, 2010).

8 Data management and reporting

8.1 Data management software

Open Foris Software tools developed by FAO are proposed for data management in the NFRA. Open Foris (OF) is a set of open, freely available software tools that can be modified for different tasks in forest assessment, monitoring and reporting (http://www.openforis.org/). The OF tools are recommended for NFRA field data recording, data management, calculations and reporting. The Open Foris software was used in the IC-FRA pilot inventory and the tools modified and further developed to adapt to the Kenyan conditions.

Open Foris (OF) Collect is recommended for field data collection (data entry and cleansing) and data management. OF Collect includes a survey designer for formulation of database and validation rules in the data entry. Mobile Collect is an android App run on a smartphone or PDA and data recorded need to be integrated with OF Collect for data management. Therefore, OF Collect run on a field tablet is recommended because with OF Collect, the data is entered directly to the database and thus extra data transfers are avoided. As a database, SQLite or PostgreSQL can be used. The workflow in OF Collect is as follows: The field teams enter data, fix or confirm data validation and logical errors in the field, and by evening of the same day, export the data to a laptop and submit the data to the central or a cloud server for cleansing. The original data is saved for backup. In the data cleansing, expert users nominated for the task and working at the office correct or remove errors and submit data for analyses.

In the data analyses, OF Calc software based on R calculation engine is recommended. OF Calc is fully customizable and enables building of complex data processing chains that are required in calculating country level results from the sample plot measurements. R in turn is an open-source statistical software and also freely available. OF Calc is designed for both experts and end users. Field data can be imported directly from OF Collect to OF Calc. For expert users it is possible to develop the calculation chain, for example, by importing external equations, such as new tree volume and biomass models, and this way continuously improve the accuracy of the results. For end users it is possible to repeat the calculations and look at the results shown as tables, graphs and figures.

Aggregated results from OF Calc can be analysed and visualised using the open-source software Saiku. Saiku provides a user-friendly interface to the data and it can be used for exploring and reporting the results for multiple purposes, for example, for REDD+ and GHG reporting to the UNFCCC.

8.2 Data management system

A data management system has to be designed as an early step of establishing the NFRA. The data management system should include protocols and documentation for data entry, back-up, data cleansing, archival, data analyses and estimation, and reporting. The NFRA data is ideally stored in a central server to guarantee data integrity and long-term availability for time series calculations. In addition to hardware, software and processes, the data management system should define responsibilities and data sharing policy. It must be clearly defined who can access and modify the data in each step, and who is responsible for each task. This is typically described also in the Quality Handbook, which should include guidelines for all NFRA processes and an organization structure with responsibilities.

In the IC-FRA project, the data management was implemented with the Open Foris software as described above. The OF Collect data entry forms and database developed in the IC-FRA are available and can be easily modified if necessary. For the proposed sampling method, i.e. two-phase sampling for stratification, the estimation and error estimation tools programmed by R are available in OF Calc.

As part of the data management system, data sharing policy for the NFRA needs to be agreed up on. The sample plot data is sensitive because the plot locations are known. With the help of coordinates the plots can be located and identified in the field and connected with, for example, property owners. This may lead to misuse of the sample plot data concerning, for example, value of the growing stock, rare species or biodiversity hotspots. Especially socioeconomics data must be considered carefully because it includes personal information.

Kenyan national legislation and information policy set the guiding principles for data publicity. In Vision 2030, the strategy for transparency and accountability encourages public access to information and data (Kenya, 2007). The NFRA data policy should determine which data can be shared publicly and which are restricted. Generally, aggregated results on forest resources should be public information and easily available for everyone interested, especially to all relevant stakeholders both within the forest sector and across other sectors such as agriculture and tourism. Strengthened sharing and dissemination of forest information is best achieved through a web-based interphase.

In contrast, access to the sample plot data with coordinates could be limited to the NFRA staff or analysts processing the data. Similarly, socioeconomic data should be accessible for specified staff members only. However, it is recommended that the NFRA raw data can be available for research purposes on request. The sample plot data will provide material for various research topics and it can also be used as ground trothing data in RS analyses, for example, in producing forest biomass maps over the country. Because the data has commercial value, a signed agreement determining data ownership and rights of use is recommended when sharing the raw data with an external party.

9 Organization and management

9.1 Organization structure

The overall responsibility for the implementation of the NFRA and Monitoring system should be vested in one governmental institution, potentially KFS, and a permanent unit constituted within it to manage and lead the implementation. Whether through reorganizing or establishing a new unit, NFRA staff members should be assigned to their tasks on a long-term basis and exploiting existing expertise in forest inventory and monitoring. Though co-operating with the other government agencies, DRSRS and KEFRI and Universities, it is recommended that in the areas where expertise is outside KFS, staff members are seconded to work for the NFRA unit. An operational NFRA will require also recruiting of new staff.

The NFRA organizational structure should clearly define the responsibilities and duties in the technical implementation. In the NFRA there are clear thematic areas, such as field inventory, laboratory analyses, data management and reporting, forest mapping, and research and development work, which require specific skills. One option is to form the organizational structure according to these thematic areas (Figure 5) and set up working groups of experts and technicians with the best capacity to carry out the activities in question. One person should be given the overall responsibility of that thematic area, and for the operational continuity and sustainability, a deputy for him or her nominated. Hereafter these thematic groups are called Technical Working Groups (TWG).

Above the TWGs, a management team is required to plan, facilitate, advise and monitor NFRA activities and to coordinate between TWGs (Figure 5). The Management Team is also responsible for financial management and reporting as required at the host institution. One person should be given overall responsibility of the NFRA and he or she should lead the management team. Responsibilities of the management team should include also coordination between collaborating institutions and linking up to national GHG reporting, KNBS and other primary stakeholders and data users.

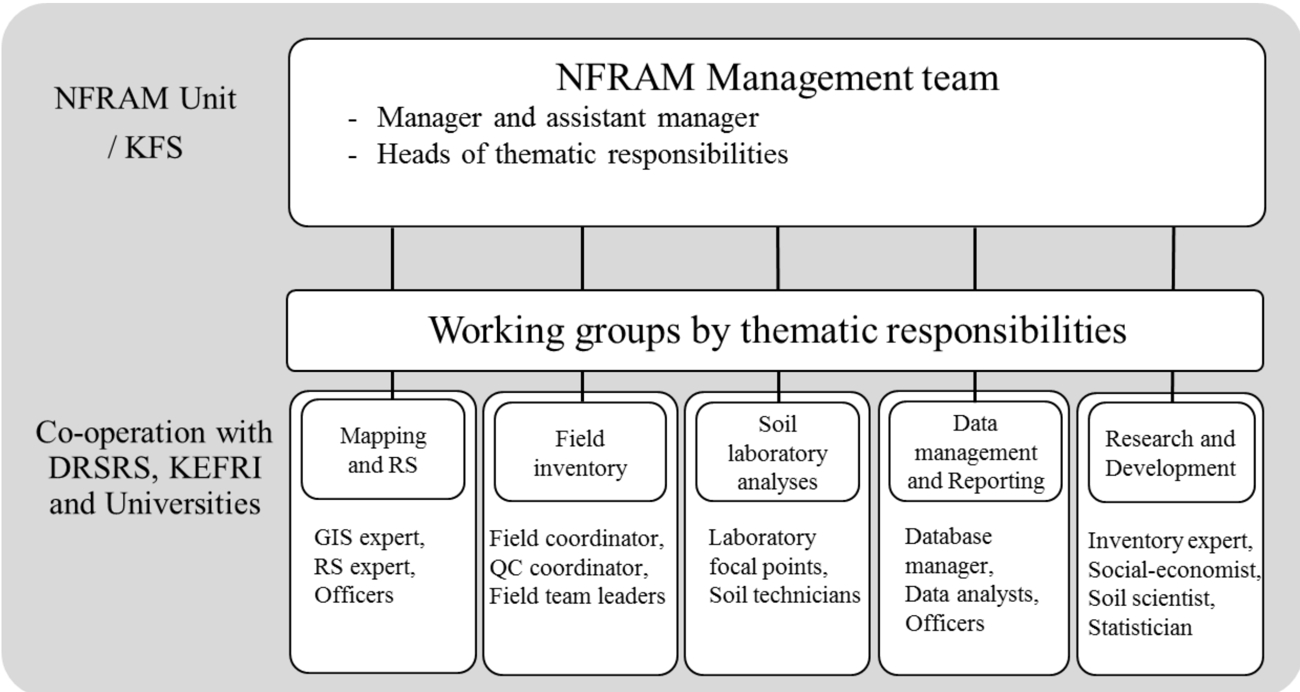

Figure 5. Organizational structure of the NFRA and Monitoring (NFRAM).

9.2 Organization of field inventory

This proposal concentrates on the technical implementation of the NFRA and therefore, the structure of the key TWG, i.e. Field inventory, is elaborated further. It should be noted that the organizational structure needs to be adapted to the structure of the host institution. Most importantly, the TWGs should work closely together and the roles and responsibilities need to be assigned clearly.

The TWG of Field inventory is responsible for carrying out the sample plot measurements and the socioeconomic survey in the whole country. The TWG should encompass expertise in biophysical measurements and socioeconomics, and there should be an expert responsible for the field work of each subject separately. TWG's responsibilities include preparatory activities before the actual field work, such as procurement of field equipment and training of the field teams, and Quality Control (QC) during the field inventory. The TWG is also responsible for logistics (acquiring and maintenance of equipment, transportation of soil samples from field to the laboratories) and supervision of the field personnel.

The TWG of Field inventory has common interfaces with the other TWGs, and the division of roles is important to guarantee efficient operation. Regarding the data collection software, it is recommended that the TWG of Data management and reporting will take the responsibility of modifying the field survey forms as this is directly linked to the database management. Regarding the soil sampling and SOC analyses, the TWG of Field Inventory should be responsible for the collection and delivery of soil samples to the laboratories and the TWG of Laboratory analyses for the rest, i.e. actual analyses, compiling the results and storing the samples as necessary.

Given the scope of responsibilities and the high number of staff involved in the field work, the TWG of Field inventory should have a structure of two levels. The TWG should consist of the persons responsible and their deputies for the whole field work and separately for biophysical measurements, socioeconomic survey, soil and sediment sampling and QC. The second level under the TWG should comprise field team leaders and QC team leaders. The persons responsible for biophysical measurements and QC are the contact persons to the field team leaders.

The proposed sampling design is based on preconditions that there are 15 field teams working in the field. Each team will comprise of 10 permanent workers and in addition, one or two local casuals hired to help in the field work (clearing brush on the way, measuring trees, soil sampling, etc.). The recommended composition of a field team should include:

- 2 Foresters (one team leader and an assistant team leader);
- 1 – 2 Rangers (as needed, when needed for security);
- 1 Taxonomist (as needed, when needed);
- 2 Soil technicians;
- 2 Socio-economic interviewers;
- 2 Drivers; and
- 1 – 2 Casuals to do biophysical measurements (enumerators).

The team composition may differ depending on the region and vegetation type. For example, rangers or taxonomist may not be needed in plantations or in farm forests. One of the foresters is nominated as a team leader and he or she has the overall responsibility of the team's work, measurements, data quality, equipment and logistics.

To guarantee data quality, two Quality Control (QC) teams should be established to re-measure about 5% of the sample plots. The QC teams are similar to the actual field teams but slightly smaller. A QC team is assumed to move in one vehicle. Soil sampling and socioeconomics survey are not repeated in the QC, and therefore, the QC teams do not include soil technicians or socioeconomic interviewers. In addition, the team composition should vary between vegetation types as necessary, for example, more rangers and casuals are needed more in natural forests than in plantations.

10 Capacity Building

10.1 Training of field teams

Implementation of the NFRA will require a considerable workforce. The field measurements alone will employ 150 staff members (17 teams, 10 members each); of these 32 should be foresters by profession. In addition, 30 soil technicians and 15 taxonomists need to be recruited for the NFRA. Each post in the NFRA should have competence requirements in order to guarantee quality of the work following the competence requirements documented in the NFRA Quality handbook together with the organizational structure. Besides professional competence, training on specified NFRA tasks will be of the utmost importance.

Altogether three weeks' training is recommended in the first year before the actual field work. In case new workers are hired during the three years' inventory period, adequate training has to be organized for them as well. The training should cover all phases of the field work from preparations to the data cleansing. Field team members are trained on the inventory methods, navigation to the plots (use of GPS), field measurements (sample plot, forest and tree measurements, soil sampling), correct use and maintenance of field equipment, and data recording (use of field tablet). The training should include both theoretical and practical sessions where all measurements are practised in the field. Field team members should also be familiarized with personnel issues such as contract of employment (privileges and responsibilities), work safety and practical arrangements of the field work (travel, time schedules, etc.). After the training, the teams should be able to carry out the field work independently, efficiently and correctly according to the field manual and other relevant instructions.

Taking into account the large number of field staff, training in smaller groups is recommended. It is rational that part of the training is separate e.g. for soil technicians to practise the soil sampling, and for socioeconomic interviewers to learn questionnaire technics. The team leaders need the most comprehensive training as they have overall responsibility of the team's work. Together with assistant team leaders (another forester in the team) they should also learn to use all technology applied in the field work such as GPS, data recording and management with Open Foris tools, and Vertex laser hypsometer. Similarly, supervisors should have the same knowledge and it is recommended that in the first year they should be trained thoroughly on how to do the field measurements accurately. The aim is that supervisors and experienced team leaders can be instructors in the future.

The competence of field team members can be verified after the training, for example, by arranging test measurements which the teams should qualify. Supervisors can also join the field teams for the first inventory days and ensure that the measurements are carried out correctly. It is recommended that they visit the teams also during the field work for monitoring and motivation. In any case, team leaders are responsible for controlling and ensuring that the data is collected reliably and the forms filled in properly. If some mistakes are detected, feedback and guidance to the field workers is given directly and immediately. Also QC results should be utilized and more emphasis put on training on how to take measurements that cause most difficulties in the field.

10.2 Research and development

Implementation and continuous development of the NFRA require national capacity to ensure sustainability and national ownership. The existing human and institutional capacities need to be strengthened and extended to cover identified capacity gaps. Research institutions, especially KEFRI and universities need to be engaged in the development work, for example, to improve calculation chain by providing new species-specific biomass models. The NFRA will offer good opportunities for students to increase their knowledge and skills in forest inventory. To guarantee capacity for NFRA, also in the future, students should be involved in different tasks such as field measurements and data management, and in the form of master and doctoral theses in the NFRA research work, for example, on error sources and accuracy of measurements.

In the IC-FRA project, officers and scientists from four national institutions (KFS, KEFRI, DRSRS and UoE) acquired capacity in planning and carrying out forest inventory, including use of modern equipment in field measurements and capability to calculate results using Open Foris tools. Four field teams and two QC teams were trained for the field work. Soil technicians in KEFRI Muguga acquired capacity in collecting and analysing soil organic carbon samples and reporting the results. In addition, IT personnel were involved in inventory data management. Altogether ca. 50 staff members were engaged in the IC-FRA project and they acquired capacity required in conducting a NFRA. In addition to increasing the amount of NFRA staff, the following capacity gaps were identified and should be further strengthened:

- Sampling designs, measurements and error estimation;
- Inventory data analyses, efficient application of the recommended software, especially R;
- Data management with Linux Server and Virtual machine and database system;
- Volume and biomass models for more tree species;
- Volume and biomass models for shrubs and mangroves;
- Adequate infrastructure and personnel; and
- Timely implementation of work plans, administration and operational management.

11 Budget

The estimated budget for the first NFRA is 784 million KSh (7.13 million Euros), which includes field work, physical assets required, laboratory analyses, data management and reporting, and management costs during the first field inventory (Table 7). In the budget for field work, daily allowances (DSAs) of field team (15), QC team (2) and supervisory team (2) members are included but not the wages. This is the same for the other activities; the wages of permanent staff are not included in the budget. Accordingly, the budget shows estimated costs of the NFRA data collection during the first three years but not the cost of establishing a permanent NFRA unit and infrastructure.

It is assumed that the field teams will work for 8 months per year, i.e. there is a break in the field measurements during the rainy season. According to the sampling design and the objective of measuring one cluster per day, 15 teams will be able to accomplish the suggested amount of second-phase clusters approximately in 7,000 days which is a little less than three years. If the teams can not measure all the sample plots of a cluster during one working day, it is assumed that they overnight in the field. In practice, it is recommended that the field teams be flexible and motived enough to work longer hours if needed to finish one cluster per day. Overnighting in the field is recommended only in situations where it takes almost a day to reach the sample plot location and there is no point in waking there twice. On the other hand, there will be clusters with only few forested plots, which are faster to measure. In these cases the field teams should continue measurements on another cluster during the same day. The rates applied in the estimation of travel costs are listed in Table 6.

Table 6. Unit cost of NFRA field team members.

Field team member	Per diem (KSh)
Forester	8400
Ranger	1000
Soil technician	8400
Taxonomist	8400
Casual	500
Farmer	1000
Social economist	8400
Driver	4900

The two QC teams are expected to work 3 months per year and the same rates (Table 6) are applied for the QC team members. In addition, two supervisory teams consisting of two senior foresters each are expected to visit the field teams during the field measurements. The estimated budget includes four 5 days travel per year with a rate of 10,500 KSh for a supervisor.

The budget for fixed assets includes procurement of required inventory equipment for 15 field teams and 2 QC teams, laboratory equipment to facilitate organic carbon analyses in four soil laboratories, and vehicles for the field teams (Table 7). A list of inventory equipment required by each team is in the Field Manual (Appendix 2), including toughpads and laptops for recording biophysical measurements and socioeconomics data, respectively. In the IC-FRA project, inventory equipment and toughpads were purchased for five field teams. These and other existing equipment should be utilized as well. In the field work, equipment wear out and extra items are needed for backup.

Procurement of new vehicles for the field teams constitutes a considerable cost in the budget (181 million KSh). Half of this amount and part of the running costs could be saved if one field team could move with one vehicle. A full team however consists of 12 members if rangers and a taxonomist are included. In addition, 2 socioeconomic interviewers need to move independently between households around a cluster during a work day. Careful planning of logistics is extremely important because the socioeconomics survey is carried out only on part of the clusters, and a taxonomist or rangers are not needed in all vegetation types. For cost-efficiency, a team should use only one vehicle whenever possible.

In the estimated budget, the share of NFRA data collection and SOC analyses is 747 million KSh (6.79 million Euros) (Table 7). The remaining part of the budget consists of data management and operational management costs. It is assumed that 6 skilled IT persons will be hired to help in data cleansing and calculations in the first NFRA round. Enough permanent NFRA staff should be recruited and trained to conduct the data analyses and reporting in the future. Costs of further capacity building in data management are however not included in this budget.

Operational management of the NFRA will be a major challenge, especially in the first round. A great deal of planning and preparations before the field work is imperative. These include recruiting staff, procurement, training, extensive communication, creating awareness about the NFRA and contacting local administration about forthcoming field work. The estimated budget for the management includes lump sums for the running costs but again, not staff wages (Table 7).

Table 7. NFRA budget for the first field inventory by years.

Item	Year 1		Year 2		Year 3		Year 4		Total costs				
	No of units	Total (EUR)	No of units	Total (EUR)	No of units	Total (EUR)	No of units	Total (EUR)	No	Unit costs	Unit	Total (EUR)	**Total (Ksh)**
NFRA Biophysical inventory and socio economics survey, field work													
DSAs for field team members, 15 teams	1 100	634 700	2 400	1 384 800	2 400	1 384 800	1 100	634 700	7 000	577	Days	4 039 000	444 290 000
DSAs for QC team members, 2 teams	60	26 700	120	53 400	120	53 400	50	22 250	350	445	Days	155 750	17 132 500
DSAs for supervisory team, 2 teams, 5 days/2 months	20	4 960	40	9 920	40	9 920	20	4 960	120	248	Days	29 760	3 273 600
Fixed assets for field teams:													
- Inventory equipment for field teams	15	106 800							15	7 120		106 800	11 748 000
- Inventory equipment for QC teams	2	10 000							2	5 000		10 000	1 100 000
- PDA/Toughpad	17	54 400							17	3 200		54 400	5 984 000
- Radio phones	17	6 800							17	400		6 800	748 000
- GPS	17	5 100							17	300		5 100	561 000
- Laptop	17	15 300							17	900		15 300	1 683 000
Vehicle	33	1 650 000							33	50 000		1 650 000	181 500 000
Vehicle running costs (fuel, service, etc.)		45 600		99 200		99 200		45 400				289 400	31 834 000
Communication (internet and phones)		3 300		6 500		6 500		3 300				19 600	2 156 000
Maintenance of field equp., miscellaneous		2 500		5 000		5 000		2 500				15 000	1 650 000
Total field work costs		**2 566 160**		**1 558 820**		**1 558 820**		**713 110**				**6 396 910**	**703 660 100**
Training of field teams													
DSAs for team members, 15 teams, 3 weeks	225	129 825							225	577	Days	129 825	14 280 750
DSAs for QC team members, 2 teams, 3 weeks	30	13 350							30	445	Days	13 350	1 468 500
DSAs for supervisory team members, 2 teams, 3 weeks	30	7 440							30	248	Days	7 440	818 400
Vehicle running costs (fuel, service, etc.)		10 200										10 200	1 122 000
Communication, venue, miscellaneous		8 000										8 000	880 000
Total training costs		**168 815**										**168 815**	**18 569 650**
Laboratory analyses of soil, litter and woody derbis													
Transportation of soil, litter and woody debris samples		1 500		3 000		3 000		1 500				9 000	990 000
Analysing Upland soils		22 500		45 000		45 000		22 500				135 000	14 850 000
Analysing Mangrove sediments		1 150		2 300		2 300		1 150				6 900	759 000
Fixed assets for 4 soil laboratories:	4	62 800							4	15 700		62 800	6 908 000
Maintenance and calibration of lab. equipment		2 000		4 000		4 000		2 000				12 000	1 320 000
Total laboratory analyses		**89 950**		**54 300**		**54 300**		**27 150**				**225 700**	**24 827 000**
Data management and reporting													
6 Skilled casuals	36	8 640	72	17 280	72	17 280	72	17 280	252	240	Months	60 480	6 652 800
Meetings, communication, miscellaneous		5 000		5 000		5 000		5 000				20 000	2 200 000
Total data management		**13 640**		**22 280**		**22 280**		**22 280**				**80 480**	**8 852 800**
Management													
Meetings and workshops (launch)		10 000		5 000		5 000		10 000				30 000	3 300 000
Communication, miscellaneous		3 000		5 000		5 000		3 000				16 000	1 760 000
Total management		**13 000**		**10 000**		**10 000**		**13 000**				**46 000**	**5 060 000**
Total		**2 851 565**		**1 645 400**		**1 645 400**		**775 540**				**6 917 905**	**760 969 550**
Contingency (3 %)		**85 547**		**49 362**		**49 362**		**23 266**				**207 537**	**22 829 087**
TOTAL		**2 937 112**		**1 694 762**		**1 694 762**		**798 806**				**7 125 442**	**783 798 637**

REFERENCES

Brown, I.F., Martinelli, L.A., Thomas, W.W., Moreira, M.Z., Ferreira, C.A.C., and Victoria, R.A. (1995). Uncertainty in the Biomass of Amazonian Forests - an Example From Rondonia, Brazil. Forest Ecology and Management 75: 175–189.

Clark, D.B. and Clark, D.A. (2000). Landscape-scale variation in forest structure and biomass in a tropical rainforest. Forest Ecology and Management 137:185-198.

FAO (2003). Report of the International Conference on the Contribution of Criteria and Indicators for Sustainable Forest Management: The Way Forward (CICI-2003). Volume 1. CICI-2003, 3 – 7 February 2003, Guatemala City, Guatemala. Available at http://www.fao.org/docrep/005/Y8694E/Y8694E00.htm

FAO (2010). Global Forest Resources Assessment Main Report 2010. FAO Forestry Paper 163. 378 pages. Available at http://www.fao.org/docrep/013/i1757e/i1757e.pdf

FAO (2012). Voluntary guidelines on national forest modelling. Draft version for discussion of sections I and II.Available at http://www.fao.org/3/a-mk174e.pdf

FAO (2012). FRA 2015 Terms and Definitions. Forestry Department. Forest Resources Assessment Working paper 180. Rome, 2012. 36 pages. Available at http://www.fao.org/docrep/017/ap862e/ap862e00.pdf

FAO (2013). Guide for country reporting for FRA 2015. Forest Resources Assessment Working paper 184. 103 pages. Available at http://www.fao.org/3/a-au190e.pdf

Food and Agriculture Organization of the United Nations (2015). FAO Voluntary Guidelines on National Forest Monitoring. First draft section III. 08.09.2015.

The Forest Conservation and Management Bill, 2014. (2014). 26.2.2014.57 pages. Available at http://www.kenyaforestservice.org/documents/Forests%20Conservation%20and%20Management%20Bill,%202014%20%2826-2-2014%29.pdf

Forest Preservation Programme (2013). Report on National Forest Resource Mapping and Capacity Development for The Republic of Kenya, Volume 2. Kenya Forest Service. Rep No.:KEF09/11494/01. Submitted by PASCO CORPORATION, February 2013. 160 pages.

Intergovernmental Panel on Climate Change (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. IPCC National Greenhouse Gas Inventories Programme. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/

Kenya Vision 2030 (2007). Government of the Republic of Kenya.

Maniatis D. and Mollicone D. (2010). Options for sampling and stratification for national forest inventories to implement REDD+ under the UNFCCC. Carbon Balance and Management 5:9. Available at http://www.cbmjournal.com/content/5/1/9

Technical Report on the Pilot inventory. Improving Capacity in Forest Resources Assessment in Kenya (IC-FRA). May, 2016.

United Nations, Framework Convention on Climate Change (2010). FCCC/CP/2009/ 11/Add.1, 30 March 2010. Conference of the parties. Report of the Conference of the Parties on its fifteenth session, held in Copenhages from 7 to 19 December 2009. Available at http://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf