Republic of Kenya

Ministry of Environment and Forestry

# The National Forest Monitoring System

Version 1

October 2021

## Foreword

Guided by Paragraph 71 of the Cancun Agreements on REDD+, Kenya has already submitted a Forest Reference Level to the United Nations Framework Convention on Climate Change UNFCCC and is in the process of finalising a REDD+ Strategy & Investment Plan, and a Safeguard Information System. National Forest Monitoring System (NFMS) is one of the elements that must be developed by Country Parties implementing REDD+ activities.

Key to any functional measurement and reporting of forest carbon is reliable data of forest area and forest area changes. National forest monitoring systems should be flexible, allow for improvement and build upon existing systems, as appropriate. They should reflect the phased approach of REDD+ implementation and enable the assessment of different types of forest in the country according to national definitions, including natural forest. They may also provide relevant information to the safeguards information systems.

The data and information provided by national forest monitoring systems should be transparent, consistent over time, and suitable for Measuring, Reporting and Verifying, taking into account national capabilities and capacities. In order to achieve this, the systems should also use a combination of remote sensing and ground-based forest carbon inventory approaches for estimating anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks, forest carbon stocks and forest area changes.

Kenya's NFMS document is a product of several multi-institutional and multi-stakeholder efforts. The System for Land cover Monitoring developed under the System for Land based Emission Estimation for Kenya (SLEEK) programme in the Ministry of Environment and Forestry, developed an appropriate method for land cover monitoring system in Kenya. This resulted in production of eighteen land cover maps (1990 - 2018) with associated Activity Data and a mapping manual that stipulates and guides on mapping protocols and decisions which are based on international best practices and national circumstances. Since 2014, Kenya through a team of local and International experts under the Improving Capacity for Forest Resource Assessment (IC-FRA) programme developed manuals and protocols on National Forestry Resources Assessments (National Forest Inventory) including sampling design simulations, tree volume and biomass modelling, soil organic carbon analysis, Biophysical Forest Resources Assessment. In each of these cases, pilot studies were done to refine the methodologies depending on national circumstances. Data from these sources has been used in Kenya's Reference Level for REDD+ which has been submitted to the UNFCCC and the 3$^{rd}$ GHG inventory for Kenya's National Communication.

Under the Capacity Development Project for Sustainable Forest Management (CADEP - SFM), Kenya has gone further and developed a Forest Information Platform which is a data base for archiving and reporting on forest information including integration of Activity Data from the Land cover mapping and Emission Factors from the National Forest Inventory. The system further provides relevant data and information that will support policy development and management decisions in the forest sector. This system allows registry of REDD+ projects and accounting of emission sources and sinks associated with each project.

This document will guide the implementation of the National Forest Monitoring System and has drawn references to the various manuals, protocols and guidelines mentioned above.

## Acknowledgements

The Government of Kenya, through the Ministry of Environment and Forestry, acknowledges the support and collaboration from various partners and stakeholders during the preparation and development of the National Forest Monitoring System (NFMS) document. The support provided by the Japan International Cooperation Agency (JICA) through the Capacity Development Project for Sustainable Forest Management in the Republic of Kenya CADEP-SFM requires a special mention. The project has supported development of various monitoring methodologies which are outlined in the NFMS document. It has also supported establishment of a Forest Information Platform (FIP) for management of information and data, and the Further it has facilitated in organizing REDD+ technical working TWG group meetings to review and improve the NFMS document. The development of NFMS document used information that had previously been compiled by the System for Land based Emission Estimation for Kenya (SLEEK) at the Ministry of Environment and Forestry which had supported the development of a monitoring methodology to provide land cover and Land cover change. Specifically we want to note and appreciate the good working relationship between the Department of Resource Surveys and Remote Sensing (DRSRS), Survey of Kenya (SoK) and the Kenya Forest Service (KFS) which ensured successful mapping process and its sustainability in future. In addition, the Programme for Improving Capacity in Forest Resources Assessment in Kenya (IC-FRA) made a significant contribution to the design and development of National Forest Inventory (NFI) methodology as covered in this document. The contribution of IC-FRA project is recognised and much appreciated.

We also note with gratitude, active participation of other stakeholders who have immensely supported this task. They include; Karatina University, Dedan Kimathi University, Jomo Kenyatta University of Agriculture and Technology, Kenya Forest Service, Kenya Wildlife Service, National Museums of Kenya, United Nations Development Programme, The Regional Centre for Mapping Resources for Development. These stakeholders worked tirelessly with a Technical team comprising Alfred Gichu, Peter Nduati, Dr. Mwangi Kinyanjui, George Tarus, Peter Sirayo, Merceline Ojwala, Faith Mutwiri, Kazuhisa Kato, Kei Sato, Akinobu Sembo, Yoshihiko Sato and Prof. Balozi Bekuta. Their effort, dedication, commitment and team work is noted, recognised and acknowledged.

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## List of Abbreviations and Acronyms

| | |
|---|---|
| AD | Activity Data |
| AGB | Above Ground Biomass |
| BGB | Below Ground Biomass |
| BUR | Biennial Update Report |
| CADEP-SFM | Capacity development Project for Sustainable Forest Management |
| COP | Conference of the Parties |
| DRSRS | Directorate of Resource Survey and Remote Sensing |
| EF | Emission Factor |
| FAO | Food and Agriculture Organization of the United Nations |
| FCPF | Forest Carbon Partnership Facility |
| FIP | Forest Information Platform |
| FPP | Forest Preservation Program |
| FRA | Forest Resources Aeessment |
| FREL/FRL | Forest Reference Emission Level/ Forest Reference Level |
| GHG | Greenhouse Gas |
| GIS | Geographic Information System |
| GIZ | Gesellschaft für Internationale Zusammenarbeit |
| GOFC-GOLD | Global Observation of Forest and Land Cover Dynamics |
| IC-FRA | Improving Capacity in Forest Resources Assessment in Kenya |
| INDC | Intended Nationally Determined Contribution |
| IPCC | Intergovernmental Panel on Climate Change |
| JAXA | Japan Aerospace Exploration Agency |
| JICA | Japan International Cooperation Agency |
| JJ-FAST | JICA-JAXA Forest Early Warning System in the Tropics |
| KEFRI | Kenya Forest Resource Institute |
| KFS | Kenya Forest Service |
| KFWG | Kenya Forest Working Group |
| KWS | Kenya Wildlife Service |
| LU/LC | Land Use and Land Cover |
| MENR | Ministry of Environment and Natural Resources |
| MRV | Measurement, Reporting and Verification |
| NC | National Communication |
| NCCRS | National Climate Change Response Strategy |
| NFI | National Forest Inventory |
| NFMS | National Forest Monitoring System |
| NFP | National Forestry Programme |

| | |
|---|---|
| NMK | National Museums of Kenya |
| NRS | National REDD+ Strategy |
| NRTFAS | Near Real Time Forest Alert System |
| PaMs | Policies and Measures |
| PDCA | Plan, Do, Check, Act |
| QA/QC | Quality Assurance/Quality Control |
| REDD+ | Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries |
| REL | Reference Emission Level |
| R-PP | Readiness preparation proposal |
| RS | Remote Sensing |
| SIS | Safeguard Information System |
| SLEEK | System for Land based Emission Estimation in Kenya |
| SNC | Second National Communication |
| TWG | Technical Working Group |
| UNFCCC | United National Framework Convention on Climate Change |
| UN-REDD | The United Nations Collaborative Program on REDD |

# Chapter 1. Background and Purpose of NFMS Document

## 1.1 Background

In reference to the National Forest draft Policy 2020 Kenya is endowed with a wide range of forest ecosystems ranging from montane rainforests; savannah woodlands; dryland forests; plantation forests and coastal forests, which include mangroves and Kayas. Kenyan forests have high species richness and endemism, which has made the country be classified as mega diverse. They rank high as the country’s natural capital due to their environmental, life supporting functions, and the provision of diverse ecological and economic goods and services.

Forests are dynamic ecosystems consisting of plants, animals and microorganisms. They play critical ecological, social, cultural, and economic functions and contribute directly and indirectly to the national, regional and local ecosystems and economies through climate stabilisation, revenue generation and wealth creation. It is estimated that forestry contributes 3.6% of Kenya's GDP, excluding charcoal and direct subsistence uses. Forests also support most productive and service sectors in the country, particularly agriculture, fisheries, livestock, energy, wildlife, water, tourism, recreation, trade and industry that contributes 33% to 39 % of the country's GDP. Biomass comprises about 80% of all energy used in the country. Forests also provide a variety of goods, which support subsistence livelihoods of many communities.

Forests comprise the country’s water towers and catchments, where over 75% of the country's renewable surface water originates, and therefore serve critical water regulation roles, which are important for human livelihoods, irrigated agriculture, and production of hydroelectric power.

The contribution of forestry to Kenya's ecology and economy has been grossly undervalued, leading to inadequate allocation of resources to the sector. There is a need for greater appreciation of the value of forests to the environment and the economy, which should be coupled with adequate resource allocation commensurate with the value of the sector from public resources and through other innovative funding mechanisms.

The forestry services provided by the water towers include local climate regulation, water regulation, water purification, waste treatment and water pollution sinks. Forestry services such as carbon storage and sequestration have grown in value in a changing climate. Forests also play a major role of intervention in climate change mitigation and adaptation. Other services provided by forests include atmospheric equilibrium, erosion control and natural hazard and disease regulation.

Forests are critical for communities living around them. They benefit directly and indirectly through subsistence utilization of the forests and the ecosystem services that forests provide.

The forest sector also supports other productive and service sectors like Agriculture, Livestock, Fisheries, Energy, Wildlife, Water, Tourism, Trade and Industry which contribute between 33 % and 39 % of the Gross Domestic Product (GDP). Therefore, forests contribute to national economy by supplying raw materials to be used in industrial processes and creating employment opportunities.

Challenges on sustainable forest management in Kenya include inadequate financial resources and poor enforcement of policy, laws and regulations. The increasing population and poverty are exerting pressure on country’s forest resources resulting to a rise in illegal logging, charcoal making and encroachment for agriculture and settlement. Therefore, decreasing forest cover brought about by unsustainable utilization of forest resources and conversion of forest land to other land uses. Ineffective regulatory mechanisms and inadequate law enforcement have led to forest land use changes due to illegal allocation and insecure property rights and contribution to deforestation and forest land degradation.

Noting that the current forest cover of 6.0% of the national area is still below the constitutional requirement of 10%, and in compliance with the objectives of the national development agenda and the constitution, the forest sector seeks to explore new measures to halt, and reverse the pace of deforestation and forest degradation in the country and increase forest cover. There are emerging opportunities for sustainable forest financing both at national and international level which the country needs to take advantage of to provide credible information about its forest resources and therefore support planning for conservation and management.

## 1.2 Milestones in Forest Sector Legal Legislation

In 1957, the first formal Forest Policy was prepared, it focused on conservation and management of forests on public land. This policy was revised in 1968 as Sessional Paper 1 of 1968 and supported by Forest Act Cap 385 of 1969.

In mid-90's, a revised Forest Policy and Legislation was prepared as a result of emergent challenges facing the forestry sector which included the need to involve stakeholders in forest management. This led to enactment of Forest Act No.7 of 2005. The Act provided for management of forests outside public land and also community and private sector participation in Forest management.

The Forest Act 2005 became effective in 2007 after it was implemented. However, the Forestry sector still faced new challenges and needed to be aligned with the Constitution 2010 which brought in new structures and requirements for natural resource management, entrenching stakeholder participation and benefit sharing taking into cognizance emerging issues such as climate change, governance and development of mechanisms to encourage partnership with communities and the private sector.

In 2015, a draft Forest Policy was prepared so as to align Forests legislation with the Constitution. The draft Policy necessitated the revision of the Forest Act, 2005 The revision of the Forest Act, 2005 led to the enactment of the Forest Conservation and Management Act of 2016 which reflected Article 69 of the Constitution with regard to forest resources; "*to provide for the development and sustainable management, including conservation and rational utilization of all forest resources for the socioeconomic development of the country*". The Act allows harmonization of the forest laws with the land framework and environmental policies and laws, transition to devolved government and other natural resource policies, with the objective of mainstreaming forestry in sustainable development.

Although the Forest Conservation and Management Act, 2016 aligned the Sector with the 2010 Constitution, the Sector still experienced issues such as climate change, payment for ecosystem services, green growth, rights of forest dependent communities, conflicts over natural resources, benefit sharing of natural resources and partnerships with communities and the private sector for commercial forestry and conservation. These current and emerging issues required a review of the Forest Policy that also allowed for harmonization of the Forest Policy with other forest related policies. As such, a draft National Forest Policy, 2020 was formulated and it proposes changes to the Forest Conservation and Management Act, 2016 in order to align it with the current Policies. All these changes in the forest sector legislations are associated to forest conservation and management.

It is noted that international climate change mechanisms require not only development of policy guidelines for forest management but also transparent Measurement, Reporting and Verification (MRV) systems that allow sustainable provision of information on changes taking place in the forest. This information not only supports international report but also guides policy development and conservation interventions.

This document is a build up to the Roadmap for Kenya's NFMS done in 2017 (FAO and KFS, 2017). While the roadmaps provided proposals for implementation, this document has gathered information on specific implementation activities that have been done, institutions that have been involved and their roles, and specific decisions that have been taken to allow implementation. Therefore, the document has borrowed from the Pilot (National Forest Inventory (NFI) under the Improving Capacity for Forest Resource Assessment (IC-FRA) and the Capacity Development Project for Sustainable Forest Management (CADEP-SFM), and has borrowed procedures for land cover mapping under the System for Land based Emission Estimation for Kenya (SLEEK). In addition, this document identifies decisions used in developing the Forest Reference Level submitted to the UNFCCC, and the recently developed deforestation monitoring systems under JICA support and the Forest 2020 programme.

## 1.3 UNFCCC Requirements for NFMS

Kenya has followed the guidance provided by the United Nations Framework Convention on Climate Change (UNFCCC) that make the National Forest Monitoring system (NFMS) a requirement for REDD+ implementation as follows:

➢ **Decision 4 of COP 15 in 2009 in Copenhagen, Denmark**

In Paragraph 1, The Conference of the Parties requests developing country Parties to establish, according to national circumstances and capabilities, a robust and transparent national forest monitoring systems and, if appropriate, sub-national systems as part of national monitoring systems that:

(i) Use a combination of remote sensing and ground-based forest carbon inventory approaches for estimating, as appropriate, anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks, forest carbon stocks and forest area changes;
(ii) Provide estimates that are transparent, consistent, as far as possible accurate, and that reduce uncertainties, taking into account national capabilities and capacities;
(iii) Are transparent and their results are available and suitable for review as agreed by the Conference of the Parties

➢ **Decision 1 of COP 16 in 2010 in Cancun, Mexico**

In paragraph 70, developing countries are encouraged to contribute to mitigation actions in the forest sector, in accordance with their respective capabilities and national circumstances, by undertaking the following activities:

(a) Reducing emissions from deforestation;
(b) Reducing emissions from forest degradation;
(c) Conservation of forest carbon stocks;

(d) Sustainable management of forests;
(e) Enhancement of forest carbon stocks

Also in paragraph 71, developing countries aiming to undertake REDD+ activities under the convention are requested, in the context of the provision of adequate and predictable support, including financial resources and technical and technological support, to develop a number of elements as follows:

(a) REDD+ National Strategy or Action Plan
(b) Forest Reference Emission Level/Forest Reference Level (FREL/FRL)
(c) A robust and transparent National Forest Monitoring System
(d) Safeguards Information System

➢ **Decision 11 of COP 19 in 2013 in Warsaw, Poland**

The conference of the Parties decides that national forest monitoring systems should

(a) Build upon existing systems, as appropriate;
(b) Enable the assessment of different types of forest in the country, including; natural forest, as defined by the Party;
(c) Be flexible and allow for improvement;
(d) Reflect, as appropriate, the phased approach as referred to in Decision 1 of COP 16.

Kenya intends to take a step-wise approach to develop its NFMS based on National circumstances and technological capacities available at the time. As such, the current NFMS reflects the latest available information at present and its scope and methodologies will be modified with improvement in technical capacities.

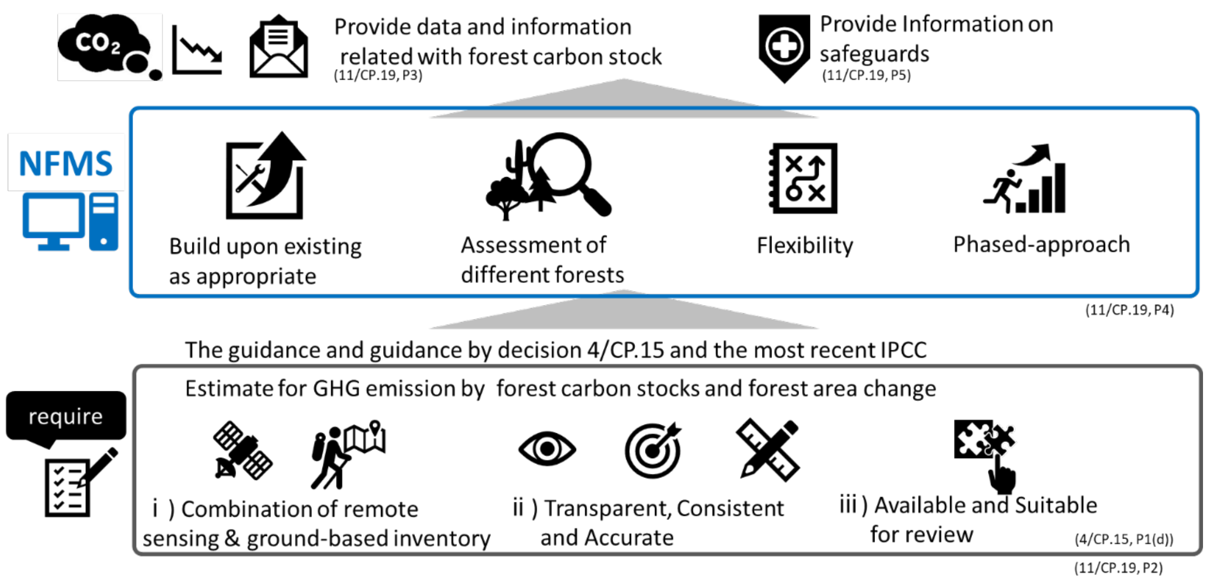



**Figure 1.1 Definition of NFMS in UNFCCC**

## 1.4 The Purpose of the NFMS Document

As a party to the UNFCCC, the Government of Kenya is undertaking REDD+ activities to contribute to

Global Climate Change mitigation and adaptation activities. The National Forest Monitoring System (NFMS) is one of the requirements for countries to participate in REDD+ under UNFCCC.

This NFMS document illustrates the components of Kenya's NFMS consisting of the monitoring function and data management function for reporting emissions under the REDD+ programme and also the Green House Gas Inventory process. The NFMS document describes the detail and methodology of each monitoring item and data management to ensure transparency, consistence and accuracy of NFMS.

The main objectives of this document are presented below.

- ✓ To provide Kenya's agreed methodology for monitoring forest resources for Reporting REDD+ and Greenhouse Gas inventories.
- ✓ To illustrate the data management system for reporting in REDD+ and other sustainable forest management purposes
- ✓ To clarify the institutional arrangement for implementation of NFMS
- ✓ To clarify the mid/long time calendar for implementation of the national forest monitoring system

The NFMS document has to be constantly revised on the basis of new technologies, information/data, and/or methodologies. This is indispensable fort Kenya's forest monitoring programme.

# Chapter 2. Basic Considerations of Kenya's NFMS

The Government of Kenya has customised the basic requirements of the NFMS to suit the country's national circumstances. Below are more elaborative basic NFMS considerations.

## 2.1 Land Use Categorization

As described in the introductory chapter, an NFMS and its measurement, reporting and verification (MRV) functions aims at producing high-quality, reliable data on forests, including forest-carbon emissions, caused by among others deforestation and forest degradation (FAO 2020). The 2006 IPCC Guidelines considers the following six land use categories for reporting GHG inventories:

**Forest Land**: This category includes all lands with woody vegetation that are consistent with thresholds used to define Forest Land in the national greenhouse gas inventory. This also includes systems with a vegetation structure that currently fall below, but in situ could potentially reach the thresholds used by a country to define the Forest Land category.

**Cropland**: This category includes cropped lands, including rice fields, and lands with an agro-forestry system where the vegetation structure falls below the thresholds used for the Forest Land category.

**Grassland**: This category includes rangelands and pasture lands that are not considered Cropland. This also includes systems with woody vegetation and other non-grass vegetation such as herbs and brushes that fall below the thresholds of the Forest Land category. This further includes all grasslands ranging from wild lands to recreational areas as well as agricultural and silvi-pastoral systems that are consistent with national definitions.

**Wetlands**: This category includes areas of peat extraction and lands that are covered or saturated by water for all or part of the year (e.g. peatlands) and do not fall into the four categories of Forest Land, Cropland, Grassland, and Settlements. This also includes reservoirs as a managed sub-division and natural rivers and lakes as an unmanaged sub-division.

**Settlements**: This category includes all developed lands, including transportation infrastructure and human settlements regardless of size, unless they are already included in the other categories. This should be consistent with national definitions.

**Other Land**: This category includes bare soil, rock, ice, and all land areas that do not fall into any of the other five categories.

Kenya has domesticated these land cover classes. However, due to technological limitations, Settlement and Other Land are merged as Other lands and the SLEEK land Cover mapping Technical manual(MOEF, 2019) proposes to manually digitize settlements from the merged class "other lands" using ancillary data, high resolution imagery and Google maps.

## 2.2 Forest Definition

Kenya's national forest definition for REDD+ has been agreed as a minimum 15% canopy cover, minimum land area of 0.5ha and trees with a potential to reach a minimum height of 2 meters[1] at maturity. Perennial

[1] The remote sensing technology described here may not map forests less than 2m height even in areas set aside for forestry. Secondly 2m height was considered as minimum height to allow for inclusions of closed canopy forests of the drylands.

tree crops like coffee and tea were not considered as forests under this definition irrespective of whether they meet the definition of forests.

This definition was informed by five basic considerations;

- Provision of opportunity to many stakeholders within the country to participate in incentivized forestry activities that reduce deforestation and forest degradation, support conservation and those that enhance carbon stocks;
- Inclusion of the variety of forest types in the country ranging from montane forests to western rain forests, coastal forests and dryland forests, all of which are characterised by local ecological conditions but are a priority for conservation under Kenya's national development programmes;
- Possibility of providing consistent data for forest monitoring based on available technology;
- Need to balance the costs of implementation, specifically to allow accuracy of land cover mapping for generation of AD;
- Consistency with the national forest agenda to optimize, manage and conserve the variety of Kenya's forests.

This definition has already been used in developing Kenya's Forest Reference Level for REDD+ which was submitted to the UNFCCC (MoEF, 2020), the FRA 2020 reporting and the development of the 3$^{rd}$ GHG Inventory to advise the 3$^{rd}$ National Communication. It will also be used to inform monitoring of forest sector performance and reporting to other international treaties and protocols to which Kenya has subscribed.

## 2.3 Forest Stratification

Forests in Kenya are stratified into four strata. Three forest strata (Montane and western rain forests, Coastal and mangrove forests, and Dryland forests) are based on ecozones described by climate and altitude. The fourth stratum is a management stratum comprising of commercial plantation forest areas managed by KFS, which spread across the three ecozones. This forest stratification zoning is shown in Figure 2.3.1. A second level stratification is done for the three ecozone based strata using levels of canopy closure (≥15-40 %, for open forests, >40-65 % for moderately open forests, and above 65 % for dense forests). However, for the Plantation forest category managed by KFS, no subdivisions were done for canopy closure because in a properly managed plantation species, it is assumed that canopy openness may not imply a difference in stock because this could be due to thinning as the plantation matures. A description of each forest strata is provided below.

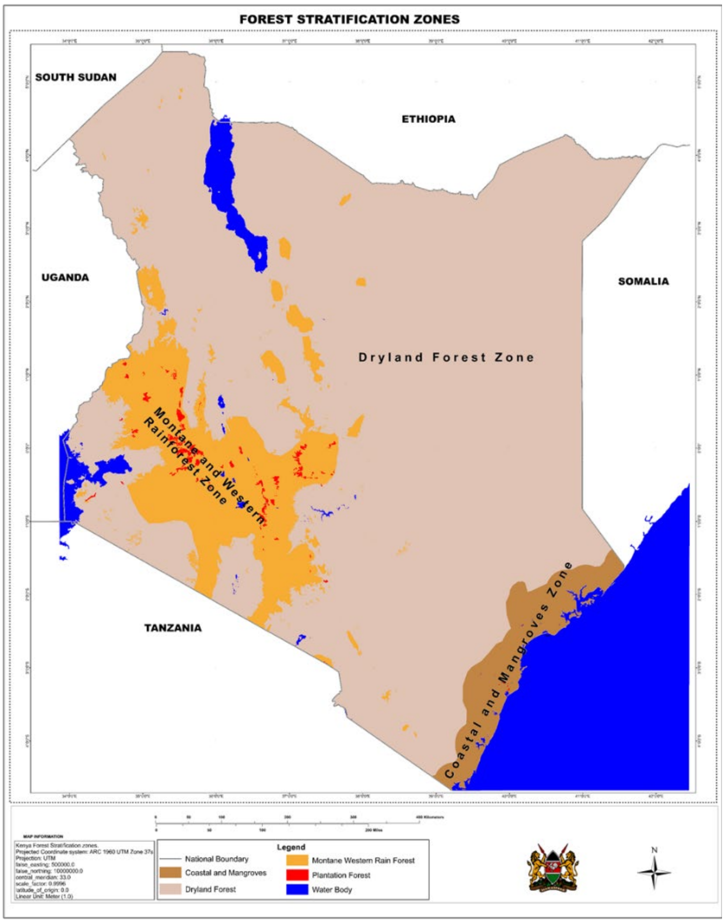



**Figure 2.3.1 Forest stratification zone image**

### 2.3.1 Montane and Western Rain Forests

This forest stratum comprises of montane forests and western rain forests. Further description for each forest type is provided below.

#### (1) Montane forests

These are forests in high altitude regions of Kenya (above 1,500m). They are the most extensive and have been described as water towers due to their support to water catchments (DRSRS and KFWG, 2006). They include the Mau, Mt. Kenya, Aberdares, Cherangany and Mt Elgon blocks, as well as Leroghi, Marsabit, Ndotos, the Matthews Range, Mt Kulal, the Loita Hills, The Chyulu Hills, the Taita Hills, and Mt. Kasigau among others. These forests have different patches of species association which are influenced by climate and altitude. For example, the moist broad-leafed forests occur on the windward sides while the drier coniferous mixed forests are found on the leeward sides (Beentje, 1994). At higher altitudes, the forests are dominated by the highland bamboo (*Yushania alpina*). Bamboo are a common forest type in Kenya and their biomass stocks have been estimated as comparable to those of the adjacent montane natural forests (Kinyanjui et al, 2014).

Delineation of the montane forests is based on Kenya's contours shapefile and includes not only the forests in gazetted and public forests but also forests that are found in private lands and farmlands within the altitudinal range of more than 1500m above sea level.

**(2) Western rain forests**

These are forests with characteristics of the Guineo-Congolean forests and include Kakamega forest, the North and South Nandi forest and Nyakweri forest in Transmara Sub-County (Wass, 1995). The trees are significantly taller and larger as compared to the other forests of Kenya. The shape file describing these forests is based on the forest blocks of Kenya and is available at KFS. However, since these forests are above 1,500m altitude, they were grouped together with montane forests.

### 2.3.2 Coastal and Mangrove Forests

This forest stratum comprises of coastal forests and mangrove forests which are found along the coastal belt of Kenya. Their description is given below.

**(1) Coastal forests**

These are the forests found in the coastal region of Kenya within a 30km strip from the shoreline (Wass 1995). They are part of the larger coastal belt including, Arabuko-sokoke forest, Shimba hills forest and the forests of Tana River region and Boni-Dodori forest complex. They are dominated by species of *Combretum, Afzelia, Albizia, Ekerbergia, Hyphaene, Adansonia* and *Brachestegia* woodlands and are biodiversity hotspots. Delineation of this zone is based on a 30 km buffer from the shoreline and captures forests in public and private lands. Though the mangrove forest has different characteristics from the coastal forests, Kenya has opted to combine them as a single stratum with a single emission factor because of the small area covered by mangroves.

**(2) Mangroves**

Mangroves have been defined as trees and shrubs that have adapted to life in saline environments. They are characterized by a strong assemblage of species according to geomorphological and salinity gradients, and tidal water currents. There are nine species of mangroves in Kenya which occur on a typical zonation pattern with the seaward side occupied by *Sonneratia alba*, followed by *Rhizophora mucronata*, then *Bruguiera gymnorrhiza, Ceriops tagal, Avicennia marina, Lumnitzera racemosa* and *Heritiera litoralis* respectively (Kokwaro, 1985; Kairo et al., 2001). Other mangrove species include *Xylocarpus granatum* and *Xylocarpus mollucensis*.

The earliest mapping of Mangrove forests of Kenya (Doute et al 1981 and FD 1992) gave an area of 64,000ha making these forests an insignificant stratum in the mapping of forests of Kenya. For sustainability, this sub strata has been classified together with the coastal forests to make the coastal and mangrove forest strata. Shapefiles of the mangrove zones which can be used for sub categorization are available at KFS.

### 2.3.3 Dryland Forests

These are the forests found in the arid and semi-arid regions of Kenya. Their tree composition is dominated by *Acacia-Commiphora* species but also include *Combretum, Platycephelium voense, Manilkara, Lannea, Balanites aegyptiaca, Melia volkensii, Euphorbia candelabrum* and *Adansonia digitata*. The category also includes riverine forests in dry areas. This forest stratum has unique characteristics from the other forest strata. First, they shed leaves and provide a challenge for time series mapping and therefore require special attention during mapping. Secondly, they have extensive root systems due to water stress and their below ground biomass component varies from other forests. Thirdly, the harsh conditions of their growth imply higher specific wood densities though these have not been researched on.

### 2.3.4 Plantation Forests

Refers to areas public forests areas with even aged monocultures managed by KFS for commercial purposes. Their boundaries are also clearly defined by compartments and sub compartments and it is possible to delineate them from the other natural forests. The trees are mainly planted for commercial purposes and undergo a series of silvicultural activities like pruning and thinning which affect their carbon stocks. Plantations may be divided based on commonly species grown and the areas where these species are grown. They include *Cupressus lusitanica, Eucalyptus sp*. and several pine species (*P. patula* in montane areas and, *P. carribeae* in coastal forests). Though Information on the age class of the plantations which estimates the carbon content of the plantations is available with the managers of specific forests (e.g. the inventory section of KFS), Kenya's stepwise improvement programme assumes a uniform carbon content for all forests mapped under this strata.

## 2.4 Carbon Pools

Carbon pools being monitored include above ground biomass and below ground biomass because data for estimating their carbon stocks is available from the forest inventories carried out in 2015 through 2017 and the carbon fluxes in those pools are associated with activities of deforestation, forest degradation, enhancement of Carbon stocks and Sustainable management of forests which are identified under Kenya's FRL for REDD+ (GOK, 2020). The Above ground carbon pool is easy to measure based on conventional inventory methods while Kenya has proposed to use the Tier 1 methodology of estimating BGC from IPCC guidelines on shoot root ratio.

The carbon pools included in measurement for Kenya REDD+ in the FRL submission are summarized in Table 2.4.1.

**Table 2.4.1 Pools currently being monitored**

| Carbon pools | Included |
|---|---|
| Above ground biomass (AGB) | Yes |
| Below ground biomass(BGB) | Yes |
| Soil organic carbon | No |
| Dead wood | No |
| Litter | No |

AGB and BGB are included because of their significant size in Kenya. Soil, dead wood and litter carbon pools were not included in Kenya's FRL submission because of lack of consistent data. Carbon dynamics in the soil, dead wood and litter carbon pools also need to be studied in details to know whether they are significant emission sources in Kenya. This would allow a step wised improvement approach of the NFMS.

The reasons of omission from the carbon pools are shown as below:

➢ **Soil organic carbon**

In the 2006 IPCC Guidelines, estimating total change in soil carbon stocks is shown as an annual change in carbons stocks. To use the default value of the 2006 IPCC Guidelines as Tier 1 level, estimation of annual change in carbon stocks in soil requires to set Stock change factors; a land-use factor (FLU), a management factor (FMG) and an input factor (FI). Due to lack of consistent and accurate information on these factors, Kenya did not report emissions from the SOC in the FRL and this monitoring is not covered here. This is an area for future improvement.

- **Litter**

Kenya has not established a monitoring system for the litter pool because of limitation in monitoring methodologies and lack of enough information for this carbon pool. As data becomes available and improvement in cost effective monitoring methods, this pool is under future improvement of the NFMS.

- **Deadwood**

Though measurement of the Deadwood carbon pool is contained in the biophysical Assessment tool for the NFI, available data from the Pilot NFI indicated great variability making it impossible to report on this pool in the FRL. Assessment of this pool and its significance to the national carbon emission estimates is also identified under the future improvement programme of the NFMS.

## 2.5 Scope Gas

Based on the FRL, Kenya decided to focus only carbon dioxide ($CO_2$). Other Non $CO_2$ emissions from the forestry sector such as Methane ($CH_4$), Carbon Monoxide (CO) and Nitrous Oxide ($N_2O$) will be considered in the future when accurate methods and reliable data become available.

## 2.6 REDD+ in Kenya

For REDD+ implementation in Kenya, a number of key decisions were made as outlined below.

### 2.6.1 Scale

The implementation of Kenya's REDD+ under the UNFCCC framework is at the national level as described in the FRL. However, due to national circumstances (diverse forest types, forest management objectives, competing interests), upcoming market mechanisms and the need for accurate reporting, Kenya has considered jurisdictional and site scale REDD+ projects nested to the national MRV framework, as the future implementation plan. This allows harmonization of carbon projects currently using different EF and AD that are very specific to their areas and therefore enhancing the accuracy of the national accounts.

### 2.6.2 Selected REDD+ Activity

In implementing REDD+, there are five activities referred to in the Decision1 / CP.16 of the UNFCCC. Kenya has selected four activities as illustrated in the FRL submission (Table 2.6.1).

**Table 2.6.1 Activities included in Kenya's REDD+**

| REDD+ activity | Included |
|---|---|
| Reducing Emissions from Deforestation | Yes |
| Reducing Emissions from Forest Degradation | Yes |
| Conservation of Forest | No |
| Sustainable Management of Forest | Yes |
| Enhancement of forest carbon stocks | Yes |

### 2.6.3 Definition of REDD+ Activities

The matrix shown in Figure 2.6.1 provides an explanation how each REDD+ Activities will be identified, classified and monitored. In addition, the detail definition of each REDD+ activities is described below.

| Forest strata | | | Area in 20XX+(X) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Forest | | | | | | | | | | Non Forest | | | |
| | | | Montane & Western Rain Forest | | | Costal and Mangrove forest | | | Dryland Forest | | | Public Plantation Forest | Cropland | Grassland | Wetland | Settlement & Otherland |
| | | | D | M | O | D | M | O | D | M | O | | | | | |
| Area in 20XX: Forest | Montane & Western Rain Forest | D | n | dg | dg | | | | | | | | df | df | df | df |
| | | M | e | n | dg | | | | | | | | df | df | df | df |
| | | O | e | e | n | | | | | | | | df | df | df | df |
| | Costal and Mangrove forest | D | | | | n | dg | dg | | | | | df | df | df | df |
| | | M | | | | e | n | dg | | | | | df | df | df | df |
| | | O | | | | e | e | n | | | | | df | df | df | df |
| | Dryland Forest | D | | | | | | | n | dg | dg | | df | df | df | df |
| | | M | | | | | | | e | n | dg | | df | df | df | df |
| | | O | | | | | | | e | e | n | | df | df | df | df |
| | Public Plantation Forest | | | | | | | | | | | n | s | s | s | s |
| Non Forest | Cropland | | e | e | e | e | e | e | e | e | e | s | NA | NA | NA | NA |
| | Grass land | | e | e | e | e | e | e | e | e | e | s | NA | NA | NA | NA |
| | Wetland | | e | e | e | e | e | e | e | e | e | s | NA | NA | NA | NA |
| | Settlement & Otherland | | e | e | e | e | e | e | e | e | e | s | NA | NA | NA | NA |

df Deforestation (F→NF)
n No Change (F→F)
dg Forest Degradation (F→F(Degraded))
s Sustainable Management of Forest (F→NF, NF→F)
e Enhancement (F→F(Improved) ,NF→F)
NA Not Available

**Figure 2.6.1 Matrix for allocating REDD+ activities to land use changes**

**(1) Reducing emissions from deforestation**

Under Decision 16/CMP.1, the UNFCCC defined deforestation as: "the direct, human-induced conversion of forested land to non-forested land". In Kenya, Deforestation is defined as the conversion of Forests to Non forests in all canopy classes of Montane and western rain forest, Coastal and mangrove forests and Dryland forests and is indicated by Red colour in the Matrix (Figure 2.6.1). Based on Kenya's definition of forests, this definition may imply a conversion of forests to wooded landscapes which are mapped in the later year as below the 15% canopy cover threshold as in the case of wooded grasslands or agroforestry. Deforestation releases carbon stored in the forest to the atmosphere and also reduces the source of greenhouse gas absorption/sequestration. Driving forces of deforestation include conversion to cropland, excessive harvest of fuel wood, forest fires, and illegal logging among others.

In this context, reducing emissions from deforestation as REDD+ activity can be defined as addressing and tackling the drivers of deforestation to prevent conversion from forest to non-forest. In order to reduce emissions from deforestation, methods such as improvement of agricultural productivity systems, providing alternatives to charcoal production and firewood use, and forest fire management.

**(2) Reducing emissions from forest degradation**

"Forest degradation" is defined as changes that affect forest production or forest ecosystem function or adversely affect the structure or function of the forest. Forest degradation is considered to be a decrease of forest carbon stocks over time. It is noted that forest carbon stocks vary as a result of periodic natural disturbances and forest management practices such as selective harvests or thinning practices. Therefore, international agreement on the definition of forest degradation has not yet been reached. (Hirata at el, 2012)

In Kenya, forest degradation is defined as the conversion of a forest from a higher canopy class to a lower canopy class in Montane and western rain forests, Coastal & mangrove forests and Dryland forests. This activity results to emission of CO2 in the source category forestlands remaining forest lands. The driving forces of forest degradation include encroachment of forests, partial conversion into croplands, firewood & charcoal production, forest fire, and selective cuttings mainly form illegal activities. In this context, reducing emissions from forest degradation as REDD+ activity can be defined as addressing and tackling the drivers of forest degradation.

**(3) Sustainable management of forests**

Under Decision 16/CMP.1 UNFCCC sustainable management of forests is defined as: “a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner”.

In Kenya, sustainable management of forests is limited to the public plantation forests managed by Kenya Forest Service (KFS), and is defined as the conversion of non-planted forest area to planted forest area and vice versa. All activities such as thinning and including harvesting, which are carried out within these plantation boundaries of gazetted forest are defined as sustainable management of forests. By reducing backlogs of replanting and implementing sustainable harvesting cycles, the public plantation forests of Kenya will tend towards zero net emissions.

**(4) Enhancement of forest carbon stocks**

Enhancement of forest carbon stocks in Kenya occurs, where an inferior forest canopy converts to a higher canopy coverage, or where Non Forestlands converts to forestlands (source category lands converted to forestlands) and this applies only to the three ecozone based strata (Montane and western rain forests, Coastal and mangrove forests, and Dryland forests). Activities that result to enhancement of carbon stocks are mainly associated with conservation which results to improvement of existing forests and regrowth of degraded areas. In addition, anthropogenic activities like enrichment planting, landscape restoration and tree planting often convert non forests into forestlands.

# Chapter 3. Conceptual Design of Kenya's NFMS

## 3.1 Introduction

The chapter highlights the components of the national forest monitoring system (NFMS) as determined by the Kenya's forest sector objective of increasing and maintaining at least 10% cover as well a sector that contribute to the socio-economic development of the nation and local livelihoods. It further speaks to the international commitments under the UNFCCC, Ecosystem restoration and biodiversity conservation.

The development of NFMS is one of four (4) requirements under UNFCCC for implementation of REDD+ for obtaining results-based payment. For the development of NFMS, Paragraph 71, decision1/CP.16 of UNFCCC mentions as follows.

> *"Developing country Parties implementing REDD+ activities are requested to develop NFMS for the monitoring and reporting of the REDD+ activities"*

Based on this decision, the objective of the NFMS in Kenya is gathering accurate and transparent data and information relating the forests of Kenya and providing this information to inform interested stakeholders on the forest resources and their status, to report to international conventions, and to support planning, conservation and management of forests in Kenya.

## 3.2 Composition of NFMS

Under the UNFCCC, according to the paragraph 1, decision4/CP.15, NFMS is described as follow.

> *"The Conference of the Parties requests developing country Parties to establish, according to national circumstances and capabilities, robust and transparent national forest monitoring systems and, if appropriate, sub-national systems as part of national monitoring systems that:*
>
> *(i) Use a combination of remote sensing and ground-based forest carbon inventory approaches for estimating, as appropriate, anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks, forest carbon stocks and forest area changes;*
> *(ii) Provide estimates that are transparent, consistent, as far as possible accurate, and that reduce uncertainties, taking into account national capabilities and capacities;*
> *(iii) Are transparent and their results are available and suitable for review as agreed by the Conference of the Parties"*

On the basis of the guidance provided above, Kenya's NFMS is composed of two mutually related functions: monitoring function and data management function. The monitoring function describes the methodology of "how forests are monitored". The data management function describes the database including information/data collection, submission, storage and dissemination. Necessary information/data are then identified and provided for monitoring purposes according to the monitoring methodology. Figure 3.2.1 depicts the composition of the functions in NFMS identified for Kenya. Details of each function are described in the subsequent sections 3.2.1 and 3.2.2.

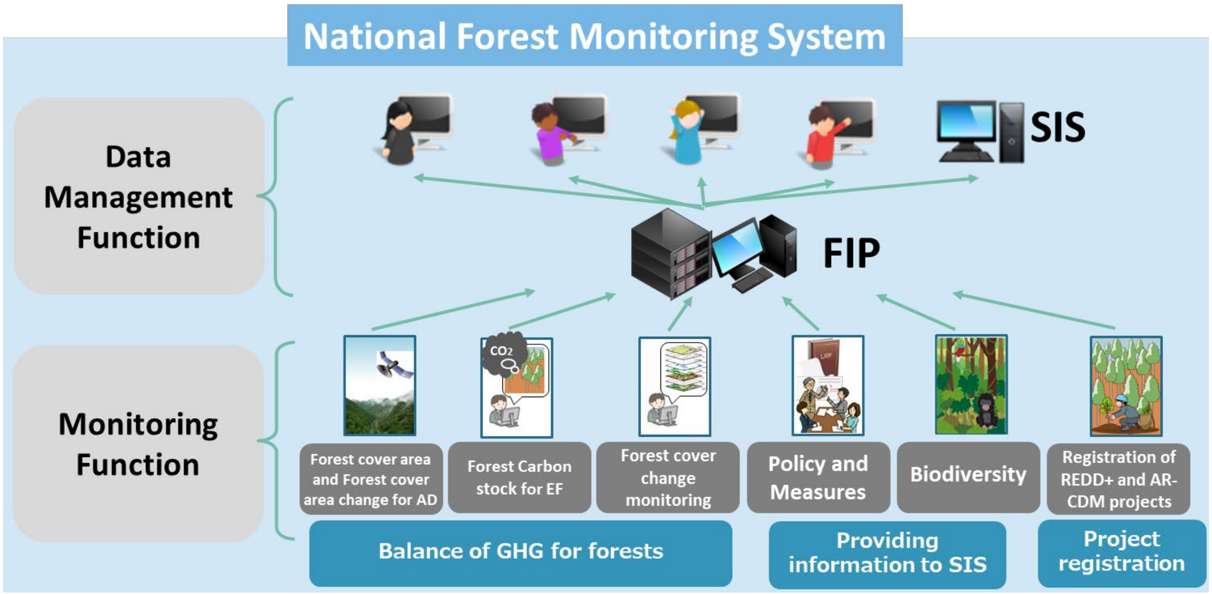



**Figure 3.2.1 NFMS in Kenya**

### 3.2.1 Monitoring Function

The monitoring function includes methodologies for providing time series information on forest carbon stocks, forest area and forest cover changes. It also includes evaluation of effects of policies and measures for forest conservation and REDD+ implementation, and associated non carbon benefits including biodiversity and water catchments.

Detailed conditions of the monitoring function of the NFMS are presented below.

1) To identify definition and methodology for gathering data and information such as activity data, emission factors and amalgamating this into forest carbon stocks at regional and national levels.

| |
|---|
| According to the paragraph 1, decision4/CP.15, the NFMS is required to provide information such as forest cover area and it's change area (for activity data: AD), forest carbon stocks from inventory measurements for each land cover type (for emission factor: EF) and anthropogenic forest related greenhouse gas emissions by sources and removals by sinks (It is calculated from AD and EF). To implement monitoring to provide the information which is transparent, consistent, as far as possible accurate, and that reduce uncertainties, it is necessary to identify and unify the most appropriate methodologies, timeline for, responsibility and etc. for data correction. |

2) To identify the information to be collected other than those indicated in (1) and its methodology. In detail, these are identifying effects of policies and measures on forest conservation including non-Carbon benefits like biodiversity and water catchment roles and therefore complementing the development of a Safeguard Information System (SIS)

3) To determine institutional arrangement with clear roles and responsibilities for the implementation of the Monitoring

The monitoring items which are identified in Kenya's NFMS are shown in Table 3.2.1. Detailed methodology of each monitoring item is described in Chapter 4.

**Table 3.2.1 Monitoring items in Kenya**

| Item | Information resource |
|---|---|
| Forest cover area and forest cover change area (AD) | Land cover/Land use map, Land cover/Land use change map |
| Forest carbon stock (EF) | National Forest inventory, Biomass survey |
| Forest cover change | JJ-FAST, Extraction of deforestation area using optical image (Sentinel 2) developed by Forest 2020 and ground truth using Survey 123. |
| Policies and Measures | National REDD+ strategy and National Forest Program, etc. |
| Biodiversity | Protected area management plan, biodiversity assessment etc. |
| Project registration | Registration form of REDD+, A/R CDM project based on the information and data to be gained through REDD+ and A/R CDM projects in Kenya |

### 3.2.2 Data Management Function

The NFMS proposes a database to input the information and data gathered by the monitoring function for archiving, retrieval and verification purposes for REDD+ implementation and the general forest management activities. The database is called a Forest Information platform (FIP). Detailed conditions of data management function are presented below.

- To ensure transparency and accessibility of information related to the forest sector in Kenya.
- To store and provide the forest data gathered according to the methodologies indicated in the guidelines.
- To provide estimates of the effects of policies and measures for forest sector management.
- To provide useful information to the SIS for REDD+.
- To register the project level activities of the forest sector.

## 3.3 The Phased Approach to NFMS Implementation

Kenya is a developing country with limitations in technology, finance and human capacity to implement a full-scale NFMS. The approach to implement the NFMS guided by UNFCCC guidance involves a stepwise approach as indicated in Chapter 1. The NFMS document will be continuously reviewed and updated to reflect the latest scientific findings, technology and data relevant to Kenya's national circumstances and requirements for international reporting.

Under the UNFCCC, there are detailed description of Phased Approach. According to the paragraph 73 and 74, decision 1/CP.16, Phased Approach is described as follow.
*"73. Decides that the activities undertaken by Parties referred to in paragraph 70 above should be implemented in phases, beginning with the development of national strategies or action plans, policies and measures, and capacity-building, followed by the implementation of national policies and measures*

*and national strategies or action plans that could involve further capacity-building, technology development and transfer and results-based demonstration activities, and evolving into results-based actions that should be fully measured, reported and verified;"*

*"74. Recognizes that the implementation of the activities referred to in paragraph 70 above, including the choice of a starting phase as referred to in paragraph 73 above, depends on the specific national circumstances, capacities and capabilities of each developing country Party and the level of support received;"*

# Chapter 4. Monitoring Function of the NFMS

The activities for monitoring function described in this chapter include Activity Data (AD), Emission Factors (EF), forest cover change, Policies and Measures (PaMs), biodiversity and project registration.

## 4.1 Forest Cover and Forest Cover Change for AD

Under the Stock Change approach, the IPCC 2006 defines Activity Data (AD) for GHG Inventory in LULUCF as forest cover change area data. It refers to the spatial extent of each forest cover and land cover/ land use type at a certain time point, and associated change over time, and is expressed in hectares. For the REDD+ activities of deforestation, forest degradation, and sustainable management of forest, and forest carbon stock enhancements, AD refers to the spatial extent of these changing conditions and the resultant areas. These are necessary for identifying emission sources or sinks from the change areas whose Emission Factors have been established.

Monitoring of forest cover area and forest cover change area has additional benefits besides generation of AD for REDD+ and GHG inventory because it also helps in local planning and development of policy guidelines for sustainable forest management.

### 4.1.1 Forest Cover Area based on SLEEK Programme

#### (1) Outline of SLEEK programme

In 2013, Kenya launched the System for Land-Based Emission Estimation in Kenya (SLEEK) programme to support the National GHG inventory process. The Land Cover Change (LCC) mapping process was developed adopting a consistent, sustainable and technically rigorous process for providing Land Cover / Land Use information required for national land based greenhouse gas (GHG) estimation (MoEF, 2019). The SLEEK has done an extensive mapping using a semi-automated method based on Random forest algorithm and produced the Land Cover / Land Use Maps for the years 1990, 1995, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015 and 2018. These maps were developed form LANDSAT4, 5, 7 and 8 images.

So far, the maps and statistics generated by the SLEEK program are the most consistent and have advised several government and international programmes supporting land use planning, tracking deforestation, and landscape restoration. Thus, Information about forest cover area and forest cover change area for AD in Kenya are provided based on the outcome of the SLEEK land cover change mapping.

#### (2) Purpose

The Land Cover / Land Use maps are developed to achieve two main objectives: (1) the preparation of AD for the NFMS and (2) the provision of information about the areas of each forest cover and land cover / land use class and their changes between the above-mentioned categories.

#### (3) Approaches

To prepare AD for the forest cover change monitoring, the Government of Kenya has three different approach options:

a) Measuring the total area of each land cover/land use category without information on conversions.

b) Tracking area conversions between land cover/land use categories (non-spatially explicit land-use conversion matrix between two time points).

c) Tracking of spatially explicit cover/land use conversions over time. This method shows the specific areas of change over time and follows the IPCC 2006 guidelines on consistent representation of lands (Chapter 3 of volume 4 of the 2006 IPCC guidelines). This method allows better understanding of the drivers of change because it specifies the change areas over each time series mapping.

### (4) Classification system

The categorized classes for Land Cover/Land Use Map were considered based on international guidelines, local definitions of land uses, ability to capture variations of carbon stocks among land uses and simplicity of land cover mapping system. The Six broad classes (Forestland, Cropland, Grassland, Settlement, Wetlands and Other lands) were adopted from IPCC guidelines where these classes were further subcategorized. The subcategorized classes were based on local definitions of land cover and land use.

The forestland was subcategorized based on national forest definition which is canopy density not less than 15%, and was divided into three categories: Open (15% ≤ 40%), moderate (40%< 65%) and dense (above 65% Canopy). The cropland was divided into two categories: annual croplands, and perennial croplands. The grassland was classified into wooded grassland (shrubs and grasses) and open grassland. The wetland was mapped as two categories: water body and vegetated wetland. Other lands, normally defining areas that cannot be classified among the five classes (which includes barren land, rocks, soils and beaches etc.) was classified together with the class settlements. As described in section 3.1, it was not possible to separate settlements from other lands with the automated land cover classification method on a Landsat imagery. This is an area for future improvement of the NFMS.

Table 4.1.1 shows classification of category for Land cover / land use map.

**Table 4.1.1 Classification of category for Land Cover / Land Use Map**

| Broad class | 1st level sub category | 2 level sub category (based on ancillary data) |
|---|---|---|
| Forestland | ➢ Natural<br>• Dense Forest (above 65% Canopy)<br>• Moderate Forest (40% < 65%)<br>• Open Forest (15% ≤ 40%) | Montane and western rain forests<br>Coastal and mangrove forests<br>Dryland forests |
| | ➢ Plantation forests | - |
| Grassland | ➢ Wooded Grassland<br>➢ Open Grassland | - |
| Cropland | ➢ Perennial Cropland<br>➢ Annual Cropland | - |
| Wetland | ➢ Vegetated Wetland<br>➢ Open Water | - |
| Other Land | ➢ Settlements and other lands | - |

### (5) Methodology

The Land Cover/Land Use Map is created based on the following process using Landsat Imagery as show in Figure 4.1.1. The methodology for doing this is detailed in the SLEEK land cover mapping manual. The best available Landsat images for each year are selected from the USGS archive which provides a complete cloud-free (threshold 20% cloud cover) coverage of Kenya. Dry season images are preferred for classification purposes as these allow for better discrimination between trees and grasses or crops.

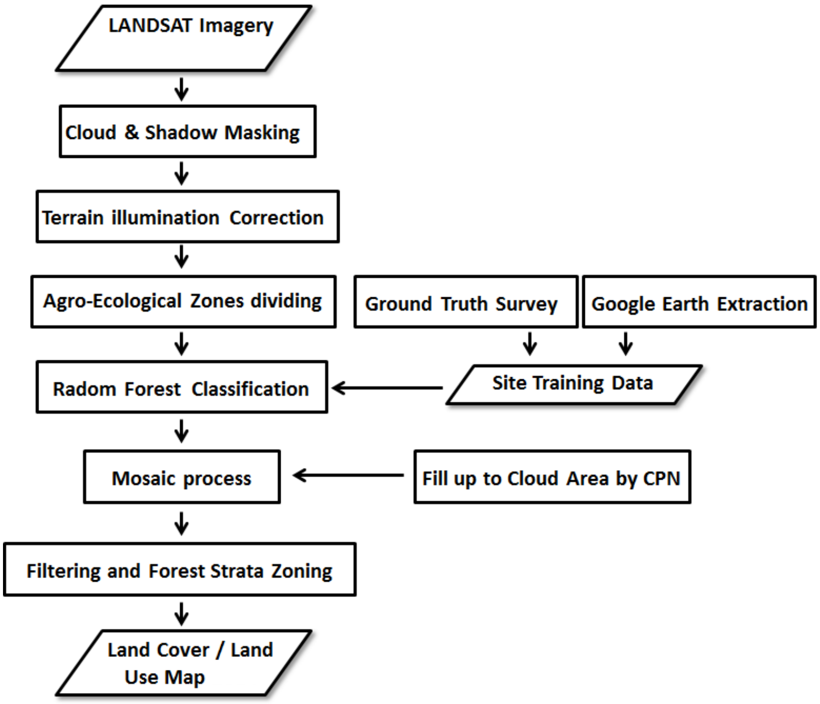



**Figure 4.1.1 Flow chart for preparation of Land Cover / Land Use Map**

**1) Cloud and shadow cover masking**

Minimal cloud cover is a major consideration in scene selection, but the best selected scenes may still contain areas of cloud and cloud shadow. This must be removed prior to the classification. The cloud masking process involves masking all cloud, shadow and affected areas and set them to a null value (0)

**2) Terrain illumination correction**

Terrain illumination variations exist in imagery because of variations in slope and aspect of the land that affects the amount of incident and reflected energy (light) from the surface. For digital classification of land cover, it is desirable to correct terrain illumination effects so that the same land cover will have a consistent digital signal. The correction requires a knowledge of the slope and aspect of each pixel (from a DEM), and knowledge of the solar position at the time of overpass (from Landsat acquisition data).

**3) Agro-Ecological zoning**

Land use and land cover varies tremendously across Kenya. Land cover ranges from the dense forests to vast dry wooded grassland areas. Climate, soil variations, and altitude are the main drivers for differences in natural cover. They also affect agricultural land cover and land use. Stratification is a technique used to divide a set of data into groups (strata) which are similar in some way. For the classification process of Land Cover/Land Use, Kenya is divided into 'spectral stratification zones'. These zones divide the country into geographic areas within which the spectral signatures of land cover types are similar. The classification process is trained and applied separately within zones. The spectral stratification zones (SSZ) are initially based on Kenya's Agro-Ecological Zones.

4) **Random Forest classification with training data (ground truth survey and Google Earth)**

The choice of the Random Forest Classification has been based on trials of several Maximum Likelihood Classifiers as described in the land cover change mapping manual. The random forest classification was found to have better accuracies in comparison to the other classifiers and it also provides an accuracy matrix to indicate the accuracy of mapping each of the land cover classes at each instance and this supports the QA/QC process.

Training sites are extracted from ground truth survey and Google Earth in cases of inaccessible areas, and they are simply groups of pixels which are identified by the operator as having a particular land cover class. These training sites are defined as polygons which are digitized as training data on the image and labelled using the land cover codes. The set of training data for each class represents the full range spectral variation of that class in the zone for that scene, and 'balanced' with respect to the different spectral colours for that class. The set of training data contained enough pixels. The prepared site training data is applied to individual terrain-corrected and masked images to be processed as random forest classification process. And this process is applied separately to each stratification zone within the image.

5) **Mosaic process and fill up to cloud area by CPN**

The mosaic process is required due to the application of random forest classification to be applied to individual images. Individual images are mosaicked as one classified image map. Figure 4.1.2 shows mosaicked individual classification result for a single scene.

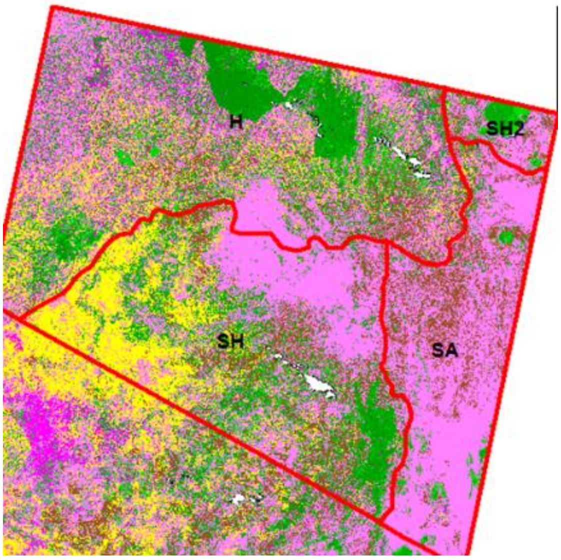



**Figure 4.1.2 Mosaicked individual classification result for a single scene**

The mosaicked classification result has gap area as cloud masked image. To fill up to the gap area, replacement image is generated by the multi-temporal processing. Therefore, the mosaicked maps for all years are modified in the multi-temporal processing.

The multi-temporal processing is carried out in a mathematical model known as a conditional probability network (CPN). The multi-temporal processing resolves the uncertain spectral region and more accurately detects genuine land cover change by using the temporal trends in the probabilities of land covers. CPN are used to combine probabilities from a number of years to give an overall assessment of the likelihood of land cover and its change. The result of multi-temporal processing is utilized to filling up the gap area.

### 6) Filtering and Forest Strata Zoning

The mosaicked and filled up image map is subjected to a filtering process to obtain the minimum mappable area and to meet the agreed forest definition for Kenya. To meet the forest definition, eight (8) neighbours filtering method is preferred and used for mapping. The eight (8) neighbours filtering uses eight (8) direction searching and clumping as one connected forest as shown in Figure 4.1.3. Kenya defines a forest as having a minimum area of 0.5ha which is defined by approximately 6 pixels of 30m by 30m dimensions Therefore a clumped forest of less than 6 pixels is eliminated.

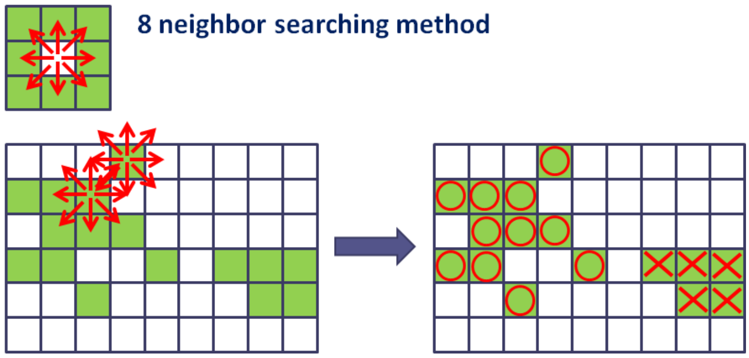



**Figure 4.1.3 Eight (8) neighbours filtering**

The filtered classification result map is zoned by forest stratification shown in Figure 2.3.1.Land cover/land use statistics from 2002 to 2018 based on the methodology mentioned above are described in Appendix 1.

### (6) Frequency of map creation

In Kenya, the frequency of the Land Cover/Land Use Map creation is set to one year interval. This allows Kenya to generate Activity Data on bi annual basis and allows the country to report consistently in its Biannual Update Reports (BUR) to the UNFCCC.

### (7) Accuracy assessment

The accuracy assessment of the land cover/land use individual maps is an important exercise used to check the correctness of these maps. The accuracy information is crucial in estimating area and uncertainty.

The most common approach for accuracy assessment is to conduct ground referencing surveys where pixel in the land cover/land use map is randomly verified. For number of ground referencing survey points, it should be statistically satisfied i.e. should be satisfy the 95 percent confidence interval. However, field work as ground referencing survey is normally expensive and time consuming based on number of verification points. And, in some case, points or area, region is possibly not accessible site. Therefore, the accuracy assessment is conducted by not only ground referencing survey but also utilization of Google Earth, aerial photo image or high resolution satellite image.

The result of accuracy assessment of land cover/land use map in 2018 as an example is described in Appendix 2.

### 4.1.2 Forest Cover Change Area based on Land Cover / Land Use Change Maps

**(1) Purpose**

The measuring of area of change in forest cover aims mainly to estimate the AD, but also to grasp the regional characteristic, and to perform effective policy and REDD+ activities.

**(2) Methodology**

By comparing two subsequent Land Cover/Land Use maps (e.g. for 2018-2022, or 2022-2026 as proposed in the FRL), extracts of land cover change areas can be made and their specific areas calculated. This creates a land cover/land use change map. Then, the extracted change areas are sorted out by using a Land Cover/Land Use Change Matrix as illustrated in Table 4.1.2.Calculations of change area are based on the forest strata (Montane and western rain forests areas, Coastal and mangrove forests areas, Dryland forests areas and Plantation forests land zones) and their specific canopy closure (for Montane and western rain forests, Coastal and mangrove forests and Dryland forests).The colours of each cell in Table 4.1.2 indicate following activities; red for deforestation, yellow for forest degradation, green for enhancement, and blue for sustainable management of forest.

Such a matrix can also be applied at regional or local level and the same calculations done. Such a decision is important for Kenya when Regional and jurisdictional REDD+ projects are implemented.

**Table 4.1.2 Area of Land Cover/Land Use change in each reference periods (ha)**

| Forest strata | | | 2018 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Montane and western rain forests | | | Coastal and mangrove forests | | | Dryland forests | | | Plantation forests | Crop land | Grass land | Wet land | Settlement & Other land |
| | | | Dense | Moderate | Open | Dense | Moderate | Open | Dense | Moderate | Open | | | | | |
| 2014 | Montane and western rain forests | Dense | 834,862 | 49,209 | 19,734 | | | | | | | | 88,835 | 91,840 | 416 | 821 |
| | | Moderate | 40,248 | 83,235 | 12,899 | | | | | | | | 11,406 | 53,825 | 78 | 33 |
| | | Open | 9,843 | 10,324 | 26,260 | | | | | | | | 6,435 | 51,566 | 10 | 25 |
| | Coastal and mangrove forests | Dense | | | | 164,282 | 87,918 | 1,363 | | | | | 6,422 | 160,174 | 1,632 | 825 |
| | | Moderate | | | | 22,023 | 40,366 | 2,040 | | | | | 3,565 | 50,419 | 458 | 233 |
| | | Open | | | | 1,116 | 989 | 452 | | | | | 110 | 2,797 | 9 | 12 |
| | Dryland forests | Dense | | | | | | | 344,985 | 97,928 | 42,170 | | 24,559 | 455,918 | 3,874 | 2,307 |
| | | Moderate | | | | | | | 57,877 | 60,223 | 33,164 | | 4,763 | 127,932 | 1,229 | 1,018 |
| | | Open | | | | | | | 21,221 | 20,412 | 66,984 | | 4,012 | 185,783 | 1,445 | 4,274 |
| | Plantation forests | | | | | | | | | | | 56,315 | 17,880 | 7,263 | 26 | 23 |
| | Cropland | | 78,641 | 8,156 | 6,568 | 1,689 | 2,567 | 438 | 21,204 | 9,163 | 10,163 | 3,886 | | | | |
| | Grassland | | 85,367 | 48,885 | 38,956 | 76,856 | 82,563 | 13,417 | 377,850 | 207,559 | 158,441 | 4,834 | | | | |
| | Wetland | | 267 | 176 | 12 | 343 | 316 | 38 | 1,648 | 1,083 | 1,877 | 14 | | | | |
| | Settlement & Other land | | 866 | 107 | 1,702 | 398 | 470 | 15 | 1,667 | 2,424 | 3,279 | 6 | | | | |

**(3) Uncertainty assessment for AD**

"Activity Data" (AD) refers to the area of land undergoing the transmission in question e.g., the area deforested per hectare. The accuracy assessment of the AD aids in checking the correctness of the land cover and forest cover change maps. The accuracy information is crucial in estimating area and uncertainty. The aim is to reduce uncertainties as far as practicable to have neither over nor underestimates. To allow for calculation of error propagation due to AD and EF, the "Error-adjusted" estimator of area formula (Olofsson, et al, 2013) shown below was used to calculate the uncertainty of the change maps.

$$S(\hat{P}_j) = \sqrt{\sum_{i=1}^{q} W_i^2 \frac{\frac{n_{ij}}{n_i}\left(1-\frac{n_{ij}}{n_i}\right)}{n_i - 1}}$$ ……………….. **Equation 1**

*Where*

$W_i$ is the proportion of the land class area to the total mapped area

$n_i$ is number of samples per land class/category

$n_{ij}$ is the number of samples per land class category that were accurately mapped

$q$ and $i$ refer to the number of land use classes

## 4.2 Forest Carbon Stock for Emission Factor

"Emission Factor" (EF) in the LULUCF sector refers to amount of emissions/removals of GHGs per unit area, e.g. amount of carbon dioxide emitted per hectare of deforestation activities. Emissions/removals resulting from land use conversion are manifested in changes in carbon stocks assigned based on global forest types or collected from ground inventories. For consistency of reporting, IPCC Guidelines have been used for units of carbon, CO2 and/or CO2eq to express EF for deforestation, forest degradation, enhancement of forest carbon stocks and sustainable management of forests for REDD+ reporting.

Kenya has decided to use a combination of available country specific data and IPCC default factors for setting the EF in the FRL. Generally, the EF is obtained from national forest inventory data. However as of 2020, Kenya has not conducted a comprehensive National Forest Inventory (NFI) that would have effectively supported the establishment of a complete set of EF. Therefore, in developing the FRL for REDD+ and the 3rd GHG Inventory, forest stock data collected in a Pilot Forest Inventory by IC-FRA (KFS, 2016a) and CADEP-SFM (JICA, 2017) was used for estimating EF while some IPCC default values were used. The target carbon pools and scope gas for setting EF are described in chapter3.

### 4.2.1 National Forest Inventory

**(1) Purpose**

Based on the data which will be obtained through NFI, it will be possible to estimate the amount of biomass and carbon stock in the forest. Therefore, an NFI is necessary to periodically assess the forest resources of a country.

**(2) Methodology**

In Kenya, a methodology for national forest inventory was developed by IC-FRA (KFS, 2016a). However, IC-FRA methodology adopted a slightly different forest stratification with SLEEK methodology which develops AD based on the time series land cover/land use maps. It is necessary to use same forest strata in AD and EF, so the part of IC-FRA inventory methodology related to the forest stratification such as sample plot setting; sampling design, calculation of the required number of samples, and selection of place of samples, was revised to be consistent with forest stratification for the AD. In other words, the inventory methodology except for the sample plot setting follows IC-FRA methodology. The detailed NFI methodology other than sample plot setting, can be accessed in the "Field Manual for Forest Resource Assessment in Kenya (KFS, 2016a) developed by IC-FRA.

**1) Sampling design**

Since it is impossible to measure all forests in the country, for NFI, generally a statistical sample method is used. In statistical sampling method, instead of conducting inventory in the entire forest, sample plots which are calculated to be statistically sufficient to give an overall picture of the forest stocking are set and the inventory conducted in these sample plots. Kenya has adopted a stratified random sampling method. The strata are the four main forest strata with their sub categorizations as described in Table 4.1.1. Based on results of the pilot inventory the statistically significant number of samples (which in the Kenyan context imply Clusters) were generated and the pre-determined number of samples placed randomly within each stratum. Figure 4.2.1 shows the image of stratified random sampling. The calculation method of pre-determined number of samples is described in 2) and methodology for placement of samples randomly described in 3).

| Forest strata | Necessary sample number |
|---|---|
| Stratum A | 22 |
| Stratum B | 10 |
| Stratum C | 4 |

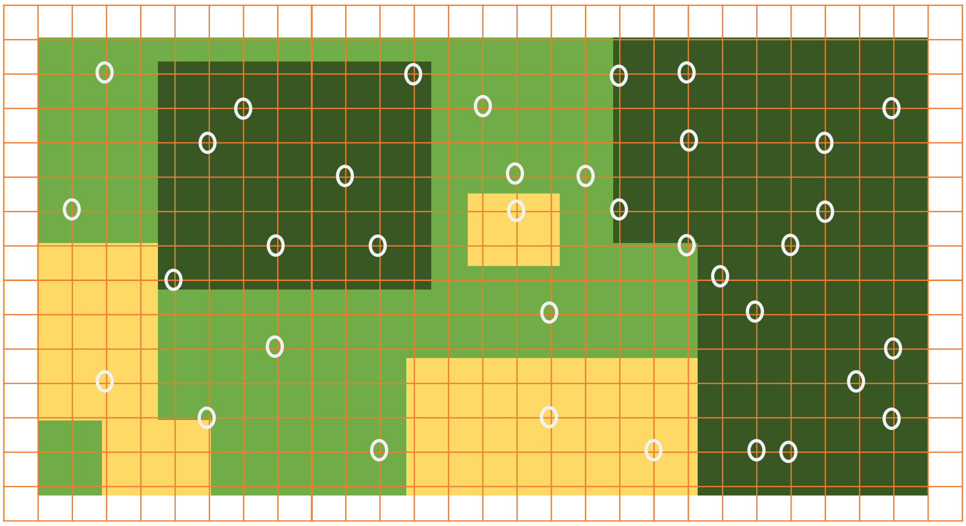


**Figure 4.2.1 Image of stratified random sampling**

To reduce heterogeneity in the forest at the sample point, cluster sampling has been adopted. The cluster sampling method establishes a group of plots (cluster) based on the predetermined position of a sample plot through stratified random sampling. The grouping of plots in a cluster reduces overall inventory costs. For Montane and western rain forests, and Dryland forests where the forests have great variations at short distances, the cluster comprises of six sample plots in a rectangular shape. The plots are placed at Distances 250 meters distance from each other. For Coastal and mangrove forests, and Plantation forests, a cluster comprises of four sample plots in a square shape with a distance of 150 meters between the plots. Each cluster shape is shown in Figure 4.2.2 and the number of plots per cluster in each forest stratum is shown in Table

4.2.1. In the field, these plots are located in a N-S and W-E direction making it easy to trace them using a GPS.

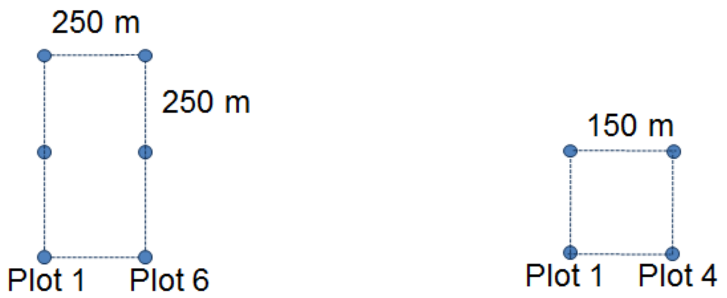



**Figure 4.2.2 Cluster design of 6 sample plots in rectangular shape and 4 sample plots in a square shape**

**Table 4.2.1 Number of plots per cluster in each forest stratum**

| Stratum | Number of plots in a cluster | Plot size (radius meter) | Total plots' area in a cluster($m^2$) |
|---|---|---|---|
| Montane and western rain forests | 6 | 15 | 4,239 |
| Coastal and mangrove forests | 4 | 15 | 2,826 |
| Dryland forests | 6 | 20 | 7,536 |
| Plantation forests | 4 | 15 | 2,826 |

It is noted that though the plots may represent a variety of forest canopy classes at local level, the data collected from each cluster represents the forest class or strata for which it was allocated during stratified random sampling. Therefore, clusters located in dense forests provide data for dense forests despite local variations in canopy while those located in open forests provide data for open forests despite local variations.

**2) Calculation of the required number of samples**

The required number of samples for each forest stratum was calculated based on acceptable confidence intervals and target error rates. In this NFMS document, the required number of samples for the proposed First NFI was calculated using the results of pilot forest inventory data from IC-FRA and CADEP-SFM for standard deviation and mean biomass value per hectare in each stratum, which were used in Kenya's FRL (GOK, 2020), as the results of pre-inventories for NFI since Kenya has not implemented NFI. As mentioned above, the calculation of the sample size also requires the establishment of the required accuracy and confidence intervals for the NFI survey results. For the NFI survey in Kenya, the target error rate is10% and the confidence interval at 95% are set for the calculation.

Table 4.2.2 shows the equation (Hirata at el, 2012) for the calculation of the required number of samples and Table 4.2.3 shows the required number of samples calculated using the equation. The required number of samples is regarded as the required number of clusters in the Kenyan NFI. The minimum number of clusters per forest class is set at 30 clusters. Therefore, if the calculated clusters of a given forest stratum is less than 30, the number of clusters in the actual NFI plan is set to be 30 clusters for a class and/or forest stratum.

**Table 4.2.2 Equation for the required number of samples (clusters)**

| **Estimation of sample plots number for each stratum (n)** |
|---|
| The equation used to calculate the number of plots needed for a given confidence interval for each stratum is as follows<br>$$n = \left(\frac{t_{0.05} * C_v}{e}\right)^2 \quad \textbf{Equation 2}$$<br>*n* = the minimum required number of clusters for a stratum<br>$t_{0.05}$ = Critical value from a two tail-test with n-1 degrees of freedom, based on confidence interval of 95%<br>$C_v$ = Coefficient of variation which is the standard deviation divided by the mean biomass value per hectare in a stratum.<br>*e*= Target error rate |

**Table 4.2.3 Number of sampling clusters calculated for each forest class**

| Stratum | | Pilot Inventory Data | | | *Cv* | *t0.05* | *e* | *n* |
|---|---|---|---|---|---|---|---|---|
| | | Sampling No. | Mean Biomass (t/ha) | Standard Deviation (t/ha) | | | | |
| Montane and western rain forests | Dense | 8 | 335.37 | 216.38 | 0.65 | 1.96 | 0.10 | 160 |
| | Moderate | 7 | 80.05 | 47.46 | 0.59 | 1.96 | 0.10 | 135 |
| | Open | 5 | 25.08 | 9.55 | 0.38 | 1.96 | 0.10 | 56 |
| Costal and mangrove forests | Dense | 18 | 113.55 | 54.04 | 0.48 | 1.96 | 0.10 | 87 |
| | Moderate | 11 | 63.30 | 22.00 | 0.35 | 1.96 | 0.10 | 46 |
| | Open | 14 | 28.81 | 17.01 | 0.59 | 1.96 | 0.10 | 134 |
| Dryland forests | Dense | 7 | 54.31 | 41.10 | 0.76 | 1.96 | 0.10 | 220 |
| | Moderate | 8 | 44.19 | 19.21 | 0.43 | 1.96 | 0.10 | 73 |
| | Open | 7 | 18.26 | 8.82 | 0.48 | 1.96 | 0.10 | 90 |
| Plantation forests | - | 36 | 412.48 | 316.71 | 0.77 | 1.96 | 0.10 | 226 |
| Total | | 121 | | | | | | 1227 |

Though the required number of sampling clusters mentioned in Table 4.2.3 should be considered for the actual implementation of the First NFI, cases may appear where a land use change has occurred since the last mapping that was used to generate the sampling clusters. This is because there may be a time lag between the time of developing the sampling design and the time of implementing the actual NFI. For instance, the sampling design could be carried out using 2018 land cover/land use maps, but the actual survey could be carried out some years later e.g. 2022. In addition, some identified clusters may be quite difficult to access due to terrain, barriers, water bodies or any other causes. Therefore, to prepare for such cases, the NFMS proposes supplementary clusters set at 20% of the calculated number of clusters for each forest stratum/class as a safeguard that allows representation of all stratum/class in the data collected from the NFI. When a priority cluster cannot be surveyed for any of the above reasons, a supplementary cluster of the same forest type with the priority cluster closest to it shall be selected for survey.

The Sampling design described above is for the determination of Temporary Sample Clusters (TSCs). The design will be generated every time before an NFI is carried out based on the distribution and size of forest classes in the previous mapping programme. Therefore, the required number of samples for the subsequent NFIs will be recalculated based on the standard deviation and mean biomass values for each stratum obtained from data of the preceding NFI e.g. Mean biomass values and standard deviation for each stratum/class in the First NFI will be used to calculate the required number of samples for the Second NFI.

**3) Permanent Sample Clusters**

To allow for continuous monitoring of changes within a forest stratum, Permanent Sample Clusters s (PSCs) should also be set in the NFI. The PSCs are defined as Clusters s whose plot positions are marked and known for future reassessment and are periodically re-measured to provide data on changes in land use, forest stocking, volume and carbon. The NFI identified the need to continuously collect information on PSCs to enhance data on changing characteristics of forests. The FRL has specifically identified the purpose of PSCs as provision of data for;

i. Carbon and volume accumulation in areas under enhancement of carbon stocks due to afforested and reforested sites
ii. Carbon and volume increments in areas with under enhancement of carbon stocks where canopy improves from a lower canopy class to a higher canopy class e.g. from open forest to dense forest
iii. Carbon dynamics in areas of forestland remaining forestland
iv. Carbon stocks in deforestation affecting different types of forests such as the national strata, ecological zones, site indices, species etc.
v. Carbon stock removals in areas under various drivers of forest degradation
vi. Monitoring biodiversity indicators

The NFMS identifies that, for management purposes, twenty five percent (25%) of the proposed sampled clusters should be marked as Permanent Sample Clusters (PSCs) to allow continuous monitoring of the different forest units. Table 4.2.4 presents an example of the PSCs derived from the sampled clusters calculated above. The list can be proposed to be Kenya's PSCs.

The plots in the PSCs will be marked during the First NFI. The PSCs will, however, need to be recalculated after the implementation of the First NFI since the above calculated PSCs are only based on Pilot Inventory data, which may be uncertain as the number of plots used were few and may not be a true representation of the forest stocks in the country.

The plots of the additional number of PSCs determined will then be marked during the Second NFI. The NFMS proposes that the total number of PSCs calculated after the implementation of the First NFI be the number to be maintained as PSCs in the subsequent NFIs since the number would have been determined using data from a national forest inventory.

**Table 4.2.4 Example of required number of PSCs**

| Strata | | No of Sampled Clusters | No of Permanent Sample Clusters |
|---|---|---|---|
| Montane and western rain forests | Dense | 160 | 40 |
| | Moderate | 135 | 34 |
| | Open | 56 | 14 |
| Coastal and mangrove forests | Dense | 87 | 22 |
| | Moderate | 46 | 12 |
| | Open | 134 | 34 |
| Dryland forests | Dense | 220 | 55 |
| | Moderate | 73 | 18 |
| | Open | 90 | 23 |
| Plantation forest | | 226 | 57 |
| Total | | 1,227 | 307 |

In marking the plots found in the permanent clusters;

- GPS measurements will be done using high precision GPS receiver
- Direction and distance from the plot centre to each tally tree will be recorded
- The plot centre will be marked by driving a 40cm long metallic pin on to the ground (3cm will be visible on top of the ground)
- Three (3) fixed points (preferably a rock, big stone or recognizable tree that has a Dbh of more than 10cm) shall be marked and data recorded. A paint spray of 10cm diameter will be applied on the fixed point on the part that faces the plot centre. Data to be recorded will include type of object, distance from plot centre, bearing and the general description of the point.

**4) Selection of location of sample clusters**

Location of the clusters is extracted adopting stratified-random sampling using the following procedure.

i. A1 km x 1 km grid on the latest Land Cover/Land Use Map is generated on a GIS platform. Intersections of the grid are candidate for the sampling cluster.
ii. The intersection points are assigned cluster IDs.
iii. All potential clusters (intersection points) for each stratum, in which four (4) or six (6) plots has same forest type on the land cover/land use map, are identified.
iv. Based on the calculated number of clusters per stratum/forest class (Table 4.2.2 and Table 4.2.3), the random sampling tool on GIS used to select priority clusters and supplementary clusters (based on the 20% safeguard described above).
v. The list of randomly selected clusters, their forest stratum, cluster ID, administrative units and coordinate are recorded.
vi. Plot 1 of the cluster is located at the intersection point which is the southwestern part of the cluster. The six (6) or four (4) plots in a cluster are set clockwise from the intersection and their plot numbers follow the order in the clockwise direction. See Figure 4.2.2.

**5) Plot shape**

Kenya has adopted circular shape for the NFI. A circular shape has several advantages over the other Shapes. Philip (1994) described a circular shape as having fewer border line trees due to its minimum perimeter compared to other shapes with its equivalent area. This reduces uncertainty of measuring borderline trees. Secondly for PSPs, circular plots are easy to measure because only coordinates of the centre point are needed to perfectly re-establish the plot.

Two plot sizes were adopted depending on the forest stratum. Figure 4.2.3 is the size adopted for Dryland forests and Figure 4.2.4 is the size adopted for Montane and western rain forests, Coastal and mangrove forests and Plantation forests.

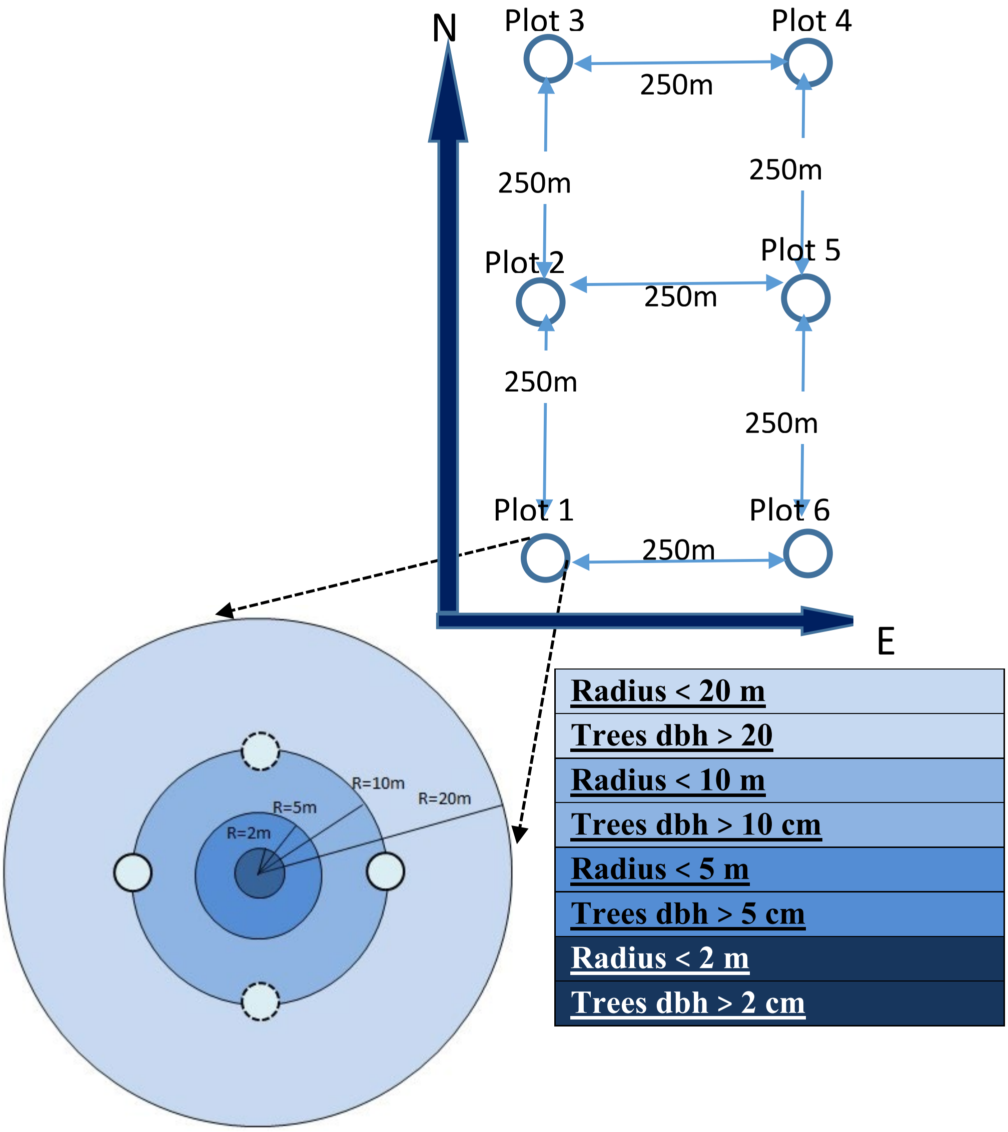



**Figure 4.2.3 Sample plot design for Dryland forests stratum**

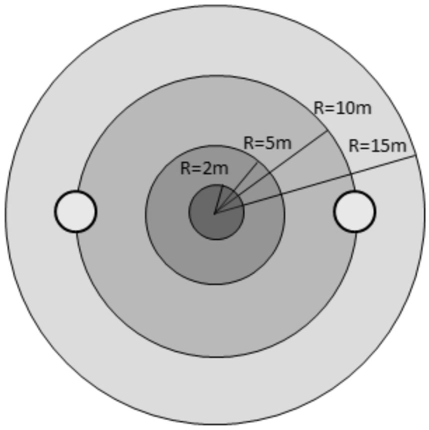



**Figure 4.2.4 Sample plot design for Montane and western rain forests, Coastal and mangrove forests, and Plantation forests strata.**

**6) Data items to be collected and recorded**

The Field Manual for Forest Assessment done by IC-FRA (KFS, 2016a) describes the specific data to be collected in the plot. Table 4.2.5 shows each condition for the measurement by measurement item.

**Table 4.2.5 Condition for measurement**

| Measuring item | Size or location from centre of Sample plot | Data to record |
|---|---|---|
| Tree | Within 2m radius | DBH ≥2cm (seedlings) |
| | Within 5m radius | DBH ≥5cm (Saplings) |
| | Within 10m radius | DBH ≥10cm (poles) |
| | Within 20m radius (Dryland forests stratum) | DBH ≥20cm |
| | Within 15m radius (other than Dryland forests stratum) | |
| Shrubs | Within 15m radius | - |
| Tree regeneration | Two circular (1.5 m radius subplots) locating 10 meters from the sample plot centre. | Height ≥10cm, DBH ≤2cm |
| Dead wood | Within 15m radius (Within 20m for Dryland forests stratum) | Diameter ≥10cm |
| Stumps | Within 15m radius (Within 20m for Dryland forests stratum) | Diameter ≥10cm |
| Bamboo | Within 10m radius | All bamboo shoots ≥1.3m |
| Climbers | Within 2m radius | DBH ≥2cm |
| | Within 5m radius | DBH ≥5cm |

Based on the above condition, at the field, data is collected according to the field forms consisting of nine parts. The contents of field form are shown in Table 4.2.6.

**Table 4.2.6 Contents of field form**

| Field Form | Items of Data Collection | |
|---|---|---|
| 1a Time Study | Cluster number<br>Date<br>Type of measurement<br>Start time/ End time by Stages | GPS Receiver model<br>GPS unit ID<br>Starting position<br>Remarks |

| Field Form | Items of Data Collection | |
|---|---|---|
| b Fixed Points | Type of object<br>Distance/direction from plot centre | Description |
| 2 Sample Plot Form | Walk between sample plots<br>Start time / End time<br>Permanent plot (Yes or No)<br>Group leader<br>Start time / End time<br>Accessibility code<br>Assessment method<br>County name and code | District name and code<br>Division name<br>GPS coordination<br>Distance/direction from plot centre<br>Slope (%)<br>Slope orientation<br>Count of soil pits<br>Photo (Direction and distance) |
| Stand description | Stand<br>Share<br>Owner<br>Land use class/Past land use class<br>Time of change<br>FRA land use /cover<br>Past FRA land use<br>Time of change | Management proposal<br>Canopy coverage<br>Plantation forest, planting year<br>Vegetation<br>Undergrowth<br>Damage/Severity<br>Human impact |
| Surrounding the sample plot | Erosion<br>Grazing<br>Water catchment | Non-wood forest product and service<br>Biodiversity observed |
| 3a Shrubs | Shrub coverage | Mean shrub height |
| b Regeneration | Regeneration subplot code<br>Species code/ name | Health<br>Count of samplings and seedling |
| 4 Tree form | Stand<br>Sample<br>Species code / name<br>Direction and distance<br>DBH<br>Quality | Health<br>Origin (NP/C)<br>Bole height<br>Total height<br>Stump diameter / height |
| 5a Dead wood | Stand<br>Species code / name<br>Diameter | Length<br>Number of stems<br>Decay |
| b Stumps | Stand<br>Species code / name<br>Diameter<br>Height | Number of stumps<br>Years ago<br>Reason |
| 6 Bamboo | Stand<br>Species code / name | Number of stems<br>Average diameter / height |
| 7 Climber | Stand<br>Species code / name | Diameter<br>Height |
| 8 Litter, debris and soil | Sampling locations<br>Amount of litter total / subsample<br>Amount of debris total / subsample<br>Type / thickness of organic layer<br>Effective soil depth<br>Soil stoniness | Munsell colour<br>Soil texture<br>Soil composites layer<br>Number of volumetric subsamples<br>Total volume of alternative corer |
| 9 Crew contact details | Name | Mobile phone |

| Field Form | Items of Data Collection | |
|---|---|---|
| | Title | E-mail |

**7) Tool for data collection**

The basic equipment which is need for the NFI are shown in Table 4.2.7.

**Table 4.2.7 Tools required for inventory survey**

| Tool | Number | Remarks |
|---|---|---|
| **Measurement tools** | | |
| Compass (360°) | 1 | In degrees, Water proof model |
| GPS receiver (precision ca. 5 m)+ extra batteries + charger + downloading cables | 1 | - |
| Measuring tape, 30 m | 2 | Metric, 1 cm units (fibreglass) |
| Measuring tape, 50 m | 2 | Metric, 1 cm units (fibreglass) |
| Calliper for big trees | 1 | Metric, 1 cm units |
| Calliper for small trees (<30 cm) | 1 | Metric, 1 cm units |
| Diameter tape | 1 | mm scale |
| 1.3 m stick | 1 | For measuring tree's breast height level |
| Tree height and land slope measuring equipment | 1 | Laser Ace, Haglöf Vertex hypsometer, TruPulse or Suunto hypsometer with 15m, 20m and % scales to measure both tree height, in meters; and slopes, in percent. |
| Spherical densitometer | 1 | Canopy coverage measuring equipment. Convex model."∩" |
| Coloured flagging ribbon | Several rolls | For marking |
| Waterproof bags | As necessary | To protect measurement instruments and forms in case of rain |
| Digital camera, extra memory card, extra batteries, and charger | 1 | For photographs of sample plot |
| Machete / Bush-knife | As necessary | For bush clearing |
| Pocket knife | 1 | For general use |
| Colour spray | 1 | For marking of fixed points on PSPs |
| Plastic sticks | As necessary | For marking of fixed points on PSPs |
| 40 cm long metallic pin | As necessary | For marking of plot centre points on PSPs |
| Spade | 1 | For digging soil pit |
| Munsell colour book | 1 | For soil colour characterization |
| Soil volumetric corer, 10 cm | 1 | For taking soil samples |
| Soil auger | 1 | For inspecting soil depth and taking indicative soil samples below top 30 cm |
| Plastic bags 3L | As necessary | For storing composite soil samples |
| Plastic bags 80 L | As necessary | For collecting litter or woody debris |
| Kitchen electronic scale | 1 | For weighing composite soil samples |
| Spring scale | 1 | For weighing litter or debris composite samples |
| **Clothing** | | |
| Boots and waterproof outfits | For permanent | - |

| Tool | Number | Remarks |
|---|---|---|
| | team members | |
| Helmet | For permanent team members | Optional, for area where there is risk for branches to fall |
| Rain coats | As necessary | Optional |
| **Documents, papers, recording tool** | | |
| Field forms | As necessary | Also plastic ones for rainy days |
| Code check list with slope correction table | As necessary | - |
| Needs to be laminated Field manual | As necessary | - |
| Flora and species check list | As necessary | - |
| Topographic maps, field maps and printed aerial photo/satellite image | As necessary | - |
| PDA | 1 | To enter data in the sample plot |
| Laptop PC | 1 | To enter/transfer field data into/from PDA |
| Pencils and markers | As necessary | - |
| Supporting board / writing tablet | 1 | To take notes |
| Hand calculator | 1 | - |
| Clipboard | 2 | To take notes |
| A4/A3 size flipchart | 1 | For photo identification |
| Newspapers | As necessary | For collection of samples (plants/ leaves) |
| **Other equipment (camping, security, communication…)** | | |
| Mobile phone | At least 1 | |
| Radio phones | 1+1 | One for the field team, one for the driver |
| Chain saw | 1 | When necessary |
| Field car | 2 | - |
| First aid kit | 1 | With phone numbers of nearest hospitals / emergency centres |
| Flashlight and batteries | As necessary | - |
| Camping equipment and cooking utensils | 1 | - |
| Rucksack | As necessary | - |
| Water and food | As necessary | - |

**(3) Frequency of NFI**

This NFMS document proposes an NFI at every five (5) years.

**(4) QA/QC measures**

For national GHG inventory reporting under the UNFCCC, verification is performed by using quality control (QC) and quality assurance (QA) procedures, either by those directly involved in the calculation or by a third party. Quality Assurance in the NFI is done through use of conventional methods, proper training of inventory teams, use of qualified technicians and ensuring that tools used are properly calibrated

For quality control which involves re-measurement by an independent team, the ICFRA methodology (KFS, 2016a) proposes that for all the sampled plots, a 10% sample be premeasured by an independent team to provide quality control data. It is proposed that Quality Control be done by research institutes such as KEFRI or the University staff. The QC process identifies weaknesses of the NFI process while the data allows calculation of the uncertainty of the NFI data and is a basis for future improvement. A continuous process of quality control keeps on improving data.

### 4.2.2 Conversion of the Inventory Data into Carbon Stock Data

The 2006 IPCC guidance indicates that carbon stocks in a forest are generally considered to be half the forest biomass. Therefore, to determine forest carbon stocks, the forest biomass is first estimated, by using allometric equations (Hirata at el, 2012). Generally, an allometric equation is developed by biomass survey. The IC-FRA project developed a Field Manual for Tree Volume and Biomass Modelling (KFS, 2016b). This manual gives guidelines on how allometric equations may be developed and is based on scientific guidance.

Currently Kenya has limited generic and species specific allometric equations. Examples of such equations are found in Kuyah et al (2012) and Owate et al (2018) but these are for agroforestry species and were developed in small geographical extents. It is proposed that international equations such as those of Chave et al (2014) may be used until when locally developed allometric equations are available and verified for use in the country.

**(1) Biomass survey**

The biomass survey section describes general outline of field measurement, laboratory work, and analysis of the measurement result.

**1) Field measurement**

Field measurement is divided into i) plot survey and ii) destructive sampling.

**i) Plot survey**

Plot Inventory records of species, DBH and tree height are done just in a normal inventory. This process can be omitted if the inventory data is available.

**ii) Destructive sampling**

Trees for destructive sampling are representatives of specific classes such as diameter sizes or tree age. Using the data collected in (i) above, target species are selected for destructive sampling. Representative sample units (trees) are needed to ensure the tree volume or biomass estimated from the tree parameters captures the variety of tree characteristics based on tree allometry. Such representativeness may include capturing the variety of DBH sizes or ages when dealing with a single species or capturing a variety of species when dealing with a generic species. Though destructive sampling is expensive, Roxburg (2015) suggested a minimum 17 trees to achieve 95% Confidence Interval and this sample size should include trees with biggest DBH to capture the variety of characteristics such as diameter distribution and tree allometry.

Selected sample trees are felled and each sample tree is broken down to stem, branches, leaves and roots.

Fresh weight of each component (stem, branches, leaves and roots) is measured recorded for each sample tree. Then extract part of each component as subsample and measure fresh weight of each subsample. These subsamples are brought back to the laboratory for oven drying and further analysis.

**2) Laboratory work**

Oven drying is done at temperatures of 80°C to 90°C for 4 days. After the subsamples have completely dried, they are measured for the dry weight.

**3) Analysis of measurement result**

A relationship between wet weights measured in the field and dry weight measured after oven drying the samples is used to develop a dry weight – wet weight function which is applied to the whole tree to generate the biomass of the whole tree. Such biomass may also be categorised for each component following the guidance of Owate et al (2018) to identify stem biomass, branch biomass, root biomass and leaf biomass. The tree biomass is regressed against easily measurable parameters which were recorded at the inventory stage and these are DBH and tree height to develop whole tree allometric equations or tree component allometric equations.

Whole tree allometric equations are ideal for estimating emissions arising from activities like deforestation due to conversion to croplands. In such cases, the whole tree including the roots are removed. However, some activities under forest degradation may affect only specific components of the tree and in such cases the component allometric equation may be used.

**(2) EF setting**

To estimate EF, it is necessary to calculate amount of $CO_2$ per ha in each forest type (strata and class) and each non forest land classes. The process of EF setting is shown Figure 4.2.5 and the detail of each process is described below.

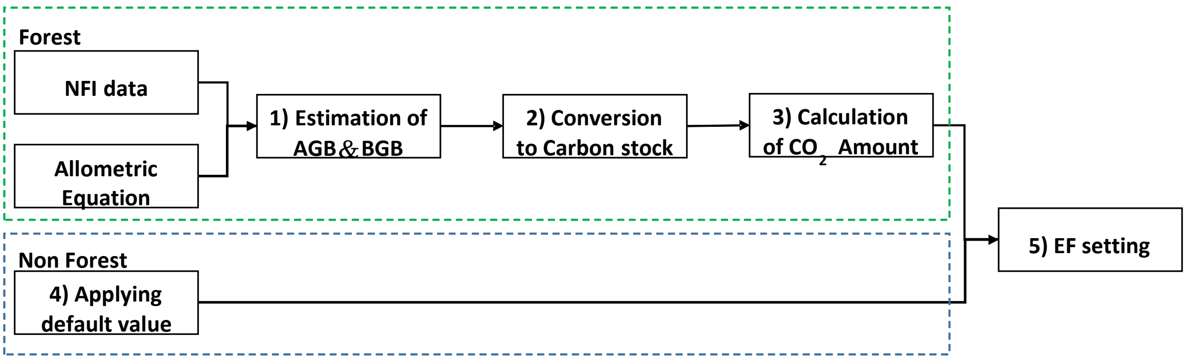



**Figure 4.2.5 Process of EF setting**

**1) Estimation of AGB and BGB in forest land**

When the data of the forest inventories mentioned in biomass survey above is obtained, the amount of above ground biomass (AGB) (t/ha) can be estimated from allometric equations. The allometric equations which were used for the FRL for Kenya are shown in Table 4.2.8 from the individual tree data to the sum of biomass for the whole plot and cluster.

**Table 4.2.8 Allometric equations used in the FRL for REDD+**

| Type | Volume ($m^3$) | Reference | Equation for AGB (kg) | Reference |
|---|---|---|---|---|
| Common for natural forests and plantations | $\pi\times(DBH/200)^2\times H\times 0.5$ | Henry et al. 2011 | $0.0673*(0.598*D^2H)^{0.976}$ | Chave et al. 2009, 2014 |
| *Rhizophora sp.* in mangroves | $\pi\times(DBH/200)^2\times H\times 0.5$ | Henry et al. 2011 | $0.128\times DBH^{2.60}$ | Fromard et al. 1998, Komiyama et al. 2008 |
| Bamboo in montane forests | $d^2-(d*0.7)^2/4*\pi*h*0.8$ | Dan et al. 2007 | $1.04+0.06*d*GW_{bamboo}$<br>$GW_{bamboo}=1.11+0.36*d^2$<br>(bamboo diameter > 3 cm)<br>$GW_{bamboo}=1.11+0.36*3.1^2$<br>(bamboo diameter ≤ 3 cm) | Muchiri and Muga. 2013 |
| Climbers in natural forests | - | - | $e^{(-1.484+2.657*\ln(DBH))}$ | Schnitzer et al. 2006 |

Root shoot ratios may be applied when the allometric equation used only described the AGB. Such root shoot ratios were developed by Owate et al (2018). However, to ensure representation of the variety of ecozones of Kenya, the FRL adopted IPCC guidance for developing root shoot ratios as indicated in Table 4.2.9.

**Table 4.2.9 R/S ratio used in the FRL for REDD+**

| Forest strata | Root shoot ratio | Source in table 4.4 of IPCC 2006 guidelines V4.4 |
|---|---|---|
| Montane and western rain forsts | 0.37 | For Tropical rainforest |
| Coastal and mangrove forests | 0.20 | Above-ground biomass <125 tonnes $ha^{-1}$ for Tropical moist deciduous forest |
| Dryland forests | 0.28 | Above-ground biomass >20 tonnes $ha^{-1}$ for Tropical Dryland forests |
| Plantation forests | 0.27 | For Tropical Mountain systems |

**2) Conversion of the AGB and BGB into carbon stock**

The estimated AGB (t/ha) and BGB (t/ha) are converted into amount of carbon stock (tC/ha) using the formula shown below. The Carbon Fraction (CF) (IPCC, 2006) applied for Kenya's FRL is shown in Table 4.2.10.

$$\text{Carbon stock (t C/ha)} = (\text{AGB (t/ha)} + \text{BGB (t/ha)}) \times CF$$

**Table 4.2.10 Carbon fraction applied in Kenya**

| Part of biomass | Carbon Fraction | Reference |
|---|---|---|
| Above ground biomass (ABG)<br>Below ground biomass (BGB) | 0.47 | IPCC, 2006 |

**3) Estimation of the amount of $CO_2$**

From the amount of carbon stock calculated, the amount of CO2 can be estimated using the formula shown below which is obtained from IPCC 2006 guidelines.

**$CO_2$ amount ($tCO_2$/ha) = Carbon stock (tC/ha) ×44/12**

**4) Estimation of the $CO_2$ amount in Non-Forest land class**

Based on lack of conclusive data on carbon stocks of the non-forests, Kenya has used IPCC default values of $CO_2$ as shown in Table 4.2.11. It is noted that the availability of data on such lands may allow their integration in the REDD+ implementation process as a component of the improvement plan. This allows Kenya to report GHGs at a higher tier.

**$CO_2$ amount ($tCO_2$/ha) of Non Forest area = Area (ha) × applied default value (t/ha)**

**Table 4.2.11 Default value $CO_2$ amount applied in Kenya**

| Class | $CO_2$ Amount(t/ha) | References |
|---|---|---|
| Cropland | 0 | IPCC Guideline 2006 |
| Grassland | 14.99 | IPCC Guideline 2006 |
| Wetland | 0 | IPCC Guideline 2006 |
| Settlement and Other land | 0 | IPCC Guideline 2006 |

*The data is included AGB and BGB, CF applied is 0.47

**5) Growth rates in non-forests converted to forests**

Noting that Kenya does not have data on growth rates and yield curves, IPCC default factors are used (Table 4.2.12) to estimate carbon accumulation in non-forests that are converted into forests and also in forests where canopy status improves over time. Similarly, Table 4.2.13 shows the IPCC default factors adopted in estimating above ground biomass accumulation in forests that increase their status (it is assumed they are over 20 years old based on IPCC categorization)

**Table 4.2.12 Above ground biomass growth rates from afforestation**

| Forest strata | ABG gain (T/ha/year) | Reference AGB value from IPCC V4.4 |
|---|---|---|
| Montane and Western rain forests | 10 | Table 4.9 for Africa tropical rain forests for forests <20 yrs |
| Coastal and mangrove forests | 5 | Table 4.9 for Africa tropical moist deciduous forests for forests < 20 yrs |
| Dryland forests | 2.4 | Table 4.9 for Africa tropical dry forests for forests< 20 yrs |
| Plantation forests | 10 | Table 4.10 for Africa Tropical mountain systems plantation forests |

**Table 4.2.13 Above ground biomass growth rates for forest status enhancement**

| Forest strata | AGB gain (T/ha/year) | Reference AGB value from IPCC V4.4 |
|---|---|---|
| Montane and western rain forests | 3.1 | Table 4.9 for Africa tropical rain forests for forests >20 yrs |
| Coastal and mangrove forests | 1.3 | Table 4.9 for Africa tropical moist deciduous forests for forests > 20 yrs |
| Dryland forests | 1.8 | Table 4.9 for Africa tropical dry forests for forests > 20 yrs |
| Plantation forests | 10.0 | Table 4.10 for Africa Tropical mountain systems plantation forests |

**6) Setting of EF**

The Emission factor for each land use change is the value of $CO_2$ that changes at two points in time based on the initial carbon stock (based on previously mapped land cover class) and the resultant carbon stock (based on the final mapped land cover class). Table 4.2.14 illustrates the emission factor which were calculated for the FRL submission.

**Table 4.2.14 Matrix of EF setting in the FRL report (GOK, 2020)**

| Forest strata | | | End Year | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Montane and western rain forests | | | Coastal and Mangrove forests | | | Dryland forests | | | Plantation forests | Cropland | Grassland | Wetland | Settlement & Other land |
| | | | Dense | Moderate | Open | Dense | Moderate | Open | Dense | Moderate | Open | | | | | |
| Start year | Montane and western rain forests | Dense | 0 | 440.00 | 534.72 | | | | | | | | 577.95 | 562.96 | 577.95 | 577.95 |
| | | Moderate | -29.28 | 0 | 94.73 | | | | | | | | 137.96 | 122.96 | 137.96 | 137.96 |
| | | Open | -29.28 | -29.28 | 0 | | | | | | | | 43.23 | 28.24 | 43.23 | 43.23 |
| | Coastal and mangrove forest | Dense | | | | 0 | 86.61 | 146.04 | | | | | 195.69 | 180.69 | 195.69 | 195.69 |
| | | Moderate | | | | -10.75 | 0 | 59.44 | | | | | 109.08 | 94.09 | 109.08 | 109.08 |
| | | Open | | | | -10.75 | -10.75 | 0 | | | | | 49.64 | 34.65 | 49.64 | 49.64 |
| | Dryland forests | Dense | | | | | | | 0 | 17.44 | 62.13 | | 93.60 | 78.60 | 93.60 | 93.60 |
| | | Moderate | | | | | | | -15.88 | 0 | 44.69 | | 76.15 | 61.16 | 76.15 | 76.15 |
| | | Open | | | | | | | -15.88 | -15.88 | 0 | | 31.47 | 16.47 | 31.47 | 31.47 |
| | Plantation forests | | | | | | | | | | | 0 | 710.84 | 695.85 | 710.84 | 710.84 |
| | Cropland | | -94.44 | -94.44 | -43.23 | -41.36 | -41.36 | -41.36 | -21.18 | -21.18 | -21.18 | -87.55 | | | | |
| | Grassland | | -79.45 | -79.45 | -28.24 | -26.37 | -26.37 | -26.37 | -6.18 | -6.18 | -6.18 | -72.55 | | | | |
| | Wetland | | -94.44 | -94.44 | -43.23 | -41.36 | -41.36 | -41.36 | -21.18 | -21.18 | -21.18 | -87.55 | | | | |
| | Settlement & Other land | | -94.44 | -94.44 | -43.23 | -41.36 | -41.36 | -41.36 | -21.18 | -21.18 | -21.18 | -87.55 | | | | |

## 4.3 Forest Cover Change Monitoring

Besides the land cover change analysis which is done to generate AD and is described in section 4.1, Kenya would like to identify near real time monitoring of deforestation activities which helps setting up deterrent actions. Such a system would also identify effects of policies and conservation measures. For near real time forest cover change monitoring, the existing systems which are JJ-FAST and The Near Real Time Forest Alert System (NRTFAS) are used.

### 4.3.1 Detection of Deforestation Area Using Radar Image (ALOS-2) by JICA-JAXA Forest Early Warning System in the Tropics（JJ-FAST）

#### (1) Outline of JJ-FAST

JJ-FAST is a deforestation monitoring programme covering almost the entire tropical forest belt (includes 77 countries). It is capable of detecting deforestation areas larger than 3 hectares (Ver. 2.1, as of July 2019). Employing the microwave remote sensing technology, detections can be made even under the thick cloud cover which is characteristic for tropical regions especially during the rainy seasons. The system detects deforestation approximately every 1.5 months by means of L-band Synthetic Aperture Radar data acquired by the PALSAR-2 sensor aboard JAXA's Advanced Land Observing Satellite 2 (ALOS-2) and provides the positioning information of detected sites to users free of charge via its web site.

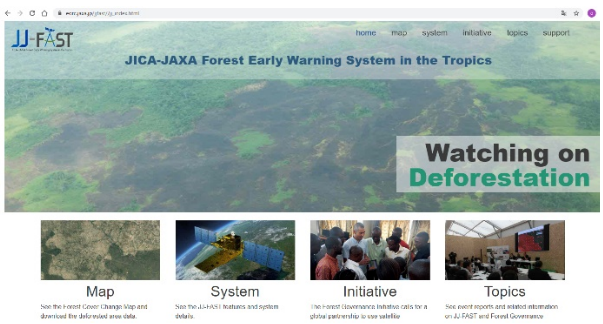
(https://www.eorc.jaxa.jp/jjfast/jj_index.html).

#### (2) Algorithm

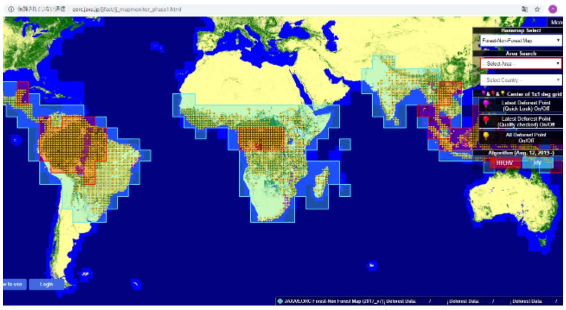
The main input data are PALSAR-2 time-series images, employing the HV and HH polarization images observed in ScanSAR mode. The PALSAR-2 observes the signals that are scattered backward from the ground surface by emitting microwaves from its on board antenna. The HV polarization image changes bright to dark in a deforestation area, because a forest area looks bright due to many backscattered components and a non-forest area looks dark due to reflection of most of the microwaves. Using the characteristics, JJ-FAST detects deforestation sites, where freshly felled trees are left on the ground and deforestation sites, where felled trees left on the ground have already been burned. Regarding the JJ-FAST features and system details, refer the "JJ-FAST Technical Note (JICA-JAXA, 2019). It is noted that structure of JJ-FAST may change after the launch of ALOS4, implying a change in the methodology of deforestation detection.

#### (3) Display of deforestation area by JJ-FAST

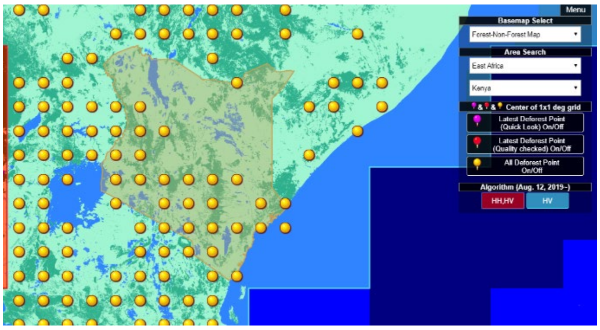
Deforestation information in Kenya as provided by JJ-FAST can be accessed from the Forest Information Platform. Figure 4.3.1 shows how to access and use the JJ-FAST information.



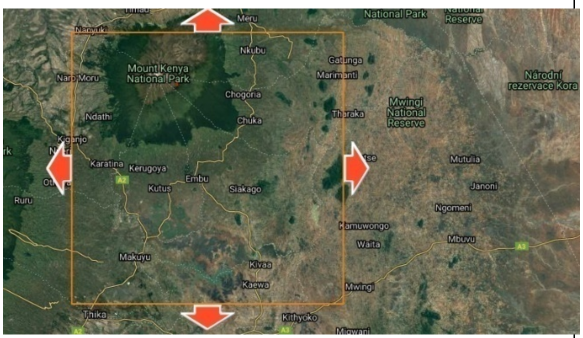

(1) Access to the top page of JJ-FAST web site from FIP. (http://portal.kenyaforestservice.org/portal/apps/MapSeries/index.html?appid=bf97262a51484b0eb4dcddf18c4e570b or https://www.eorc.jaxa.jp/jjfast/jj_index.html)



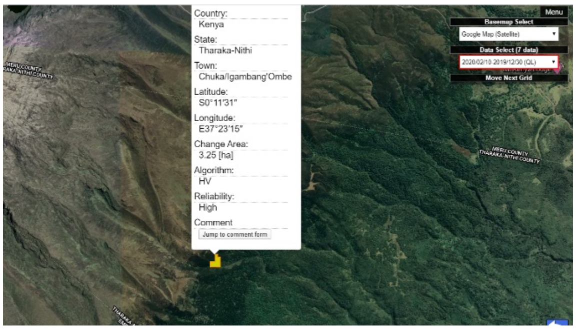
(2) Enter the Map page from top page and select the area and country to survey for deforestation from pull down menu in the upper right of Map page.



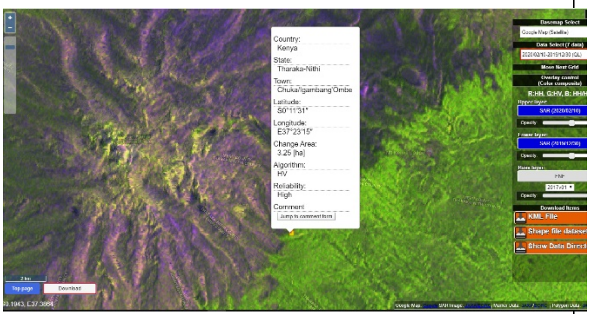

(3)Click a locations marked by a red, purple or yellow pin which are indicate the existence of a deforested area within 1° latitude and longitude.




(4) Click on the deforested area polygon which is surrounded by red lines




(5) Country, state and town names, the latitude longitude of the centre point of the polygon, the size of the deforested area, and level of reliability are displayed.



(6)Click the "Download" button in the lower left menu then a menu for downloading data on deforested areas within the "menu" section to the right is displayed.

**Figure 4.3.1 How to access and use the JJ-FAST information**

### (4) Monitoring interval

JJ-FAST data is updated every 1.5 month.

## 4.3.2 Detection of Deforestation Area Using Optical Image (Sentinel 2) by NRTFAS

### (1) Outline

Near Real Time Forest Alert System (NRTFAS) for deforestation detection using the optical satellite (Sentinel 2) data has been implemented as a pilot project in the UK-sponsored Forest2020 project, covering eight counties in the North Rift region of Kenya. Forest2020 is also supported by the UK Space Agency and has introduced similar systems in five other countries: Indonesia, Brazil, Mexico and Colombia.

The Sentinel 2 satellite was launched and operated by the European Space Agency (ESA) and provides free data for users. It is equipped with a sensor that captures data with 10m resolution multispectral (total 4 bands; R, G, B, and NIR) and 20m resolution multispectral (total 6 bands; 3 bands in R, 1 band in NIR, and 2 bands in SWIR). With 10-day revisit and the operation of twin satellites (Sentinel 2A and Sentinel 2B), deforestation can be monitored at 5 day intervals.

The NRTFAS utilizes satellite image data with a resolution of 10 m and is implemented using PYthon for Earth Observation (Pyeo) developed by the University of LEICESTER. Pyeo is a Python processing chain designed to automate the extraction of land surface information from Earth Observation (EO) data. The package runs on Anaconda distribution that provides a user interface of the Python and R programming languages for scientific computing.

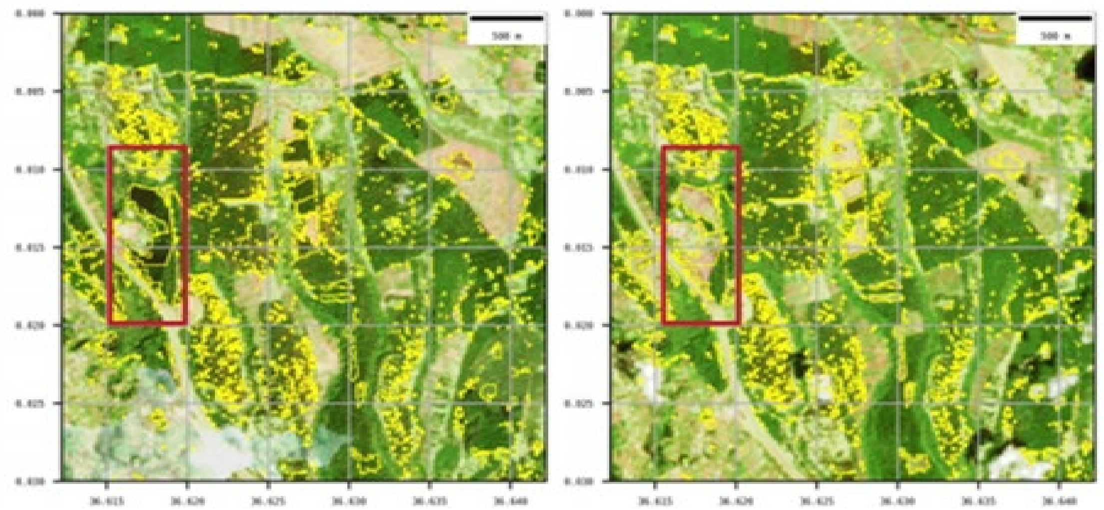


**Figure 4.3.2 Detection of deforestation (Left: before, Right: after)**

**(2) Algorithm**

The NRTFAS downloads Sentinel 2 satellite image data, pre-processes it (includes atmospheric correction and cloud removal), subjects the image into a supervised image classification using inbuilt training data and carries out a change detection over two periods to detect deforestation areas. It consists of three block chains of data generation processing for output as illustrated below.

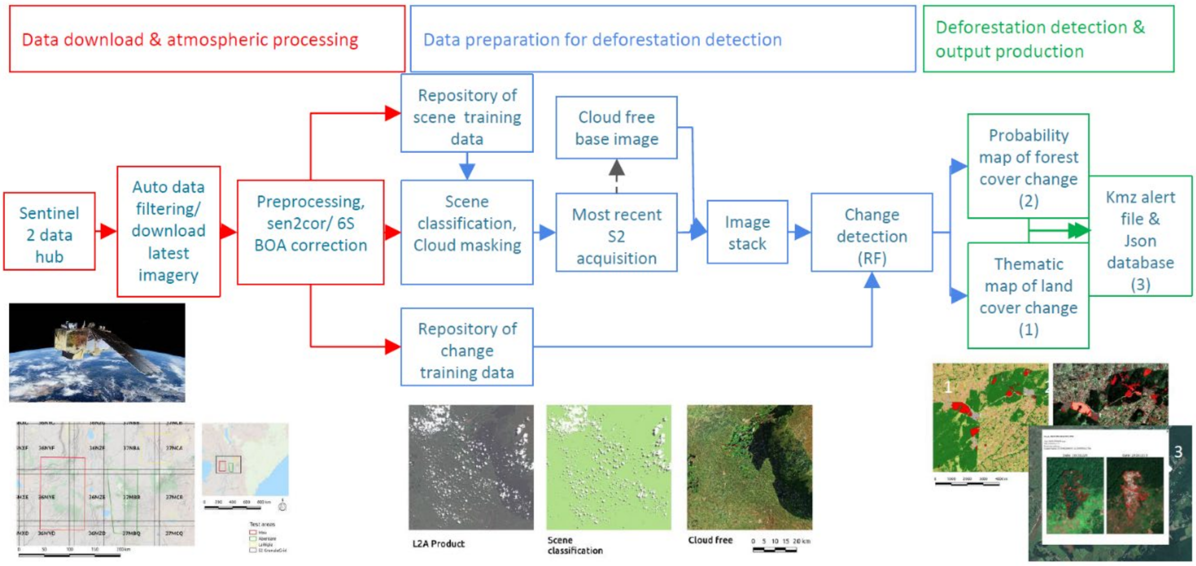



**Figure 4.3.3 Flow chart of NRTFAS**

**(3) Monitoring interval**

Near Real Time Forest Alert System data is updated every 1 week.

### 4.3.3 Ground Truthing Using Survey 123

**(1) Outline**

The deforestation alert information detected by JJ-FAST and NRTFAS is availed for field verification and reporting by KFS rangers who go to the site and use a mobile smartphone or tablet device equipped with an application that utilizes Survey123. In addition, when the rangers discover forest-related incidents besides what was provided in the JJ-FAST and NRTFAS alerts such as deforestation and fire during patrol, or receive a report from the local residents, the rangers go to the site to report the situation from a smartphone or tablet terminal. The newly reported data is automatically uploaded in the FIP and can be viewed online. All reports are displayed as statistical information in a dashboard format which is one of the functions of "Forest cover change monitoring" in FIP.

**(2) Input process**

Information collected using Survey123 can be easily entered from smartphones and tablet devices. Attributes of the data includes Conservancy name, County name, Station name, location information (automatic input based on device location), forest type (natural forest, planted forest), location characteristics (free description), Incidence type (logging, fire, etc.), Information source (ranger, residents, etc.), on-site action, on-site photo, reporter name, and signature.

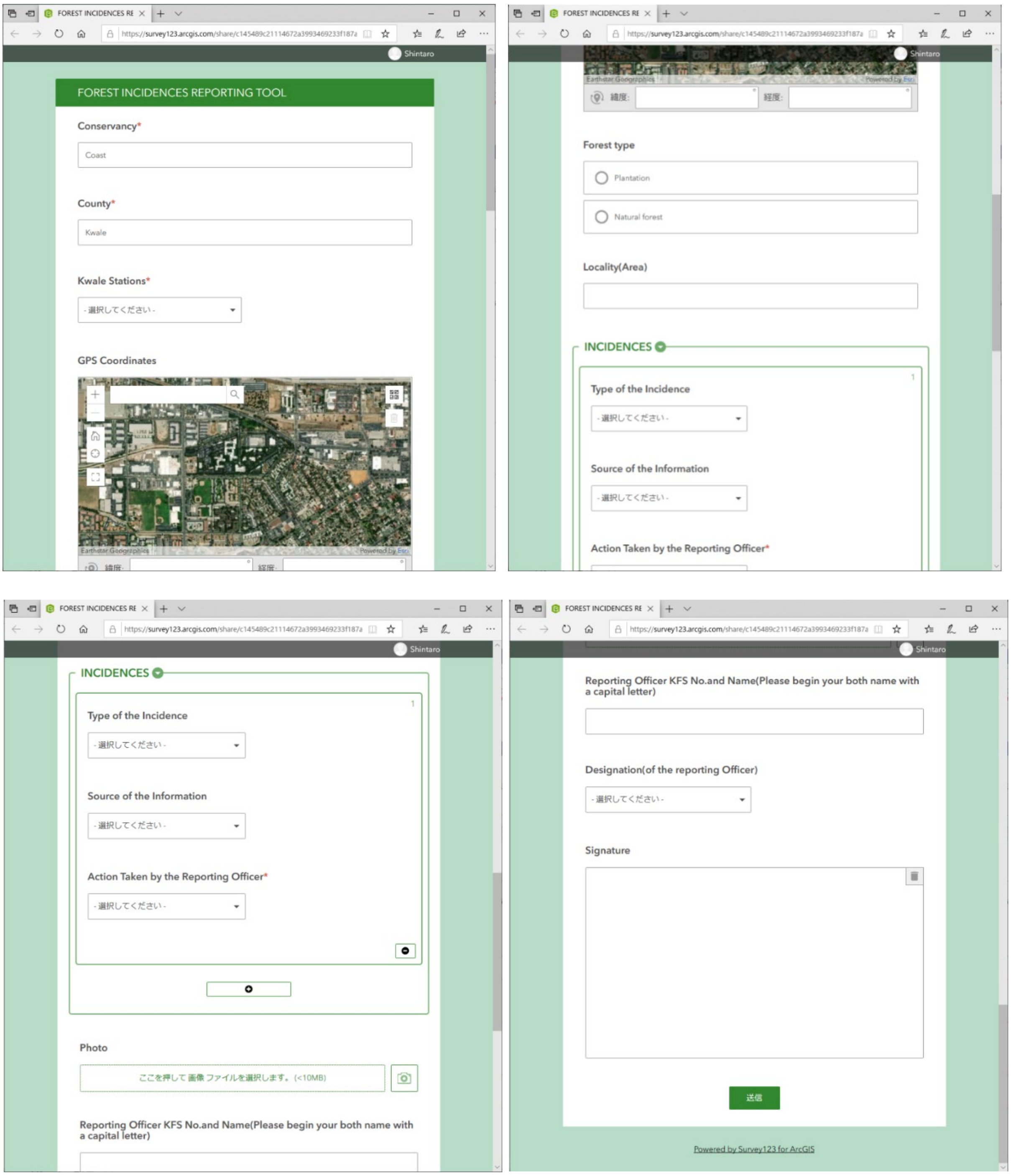



**Figure 4.3.4 Input form at tablet tool**

### (3) Reporting result

The dashboard is one of the functions of “Forest cover change monitoring” in FIP. On the dashboard, the total number of reported forest accidents, the number of incident in each county, the ratio of each incidence by type, and the location information are arranged in an easy-to-read manner so that these can be confirmed not only by numerical values but also by graphs. In addition, the location information displays the location of occurrence on the map as a point. By clicking on the point, contents of the report at that location can be viewed.

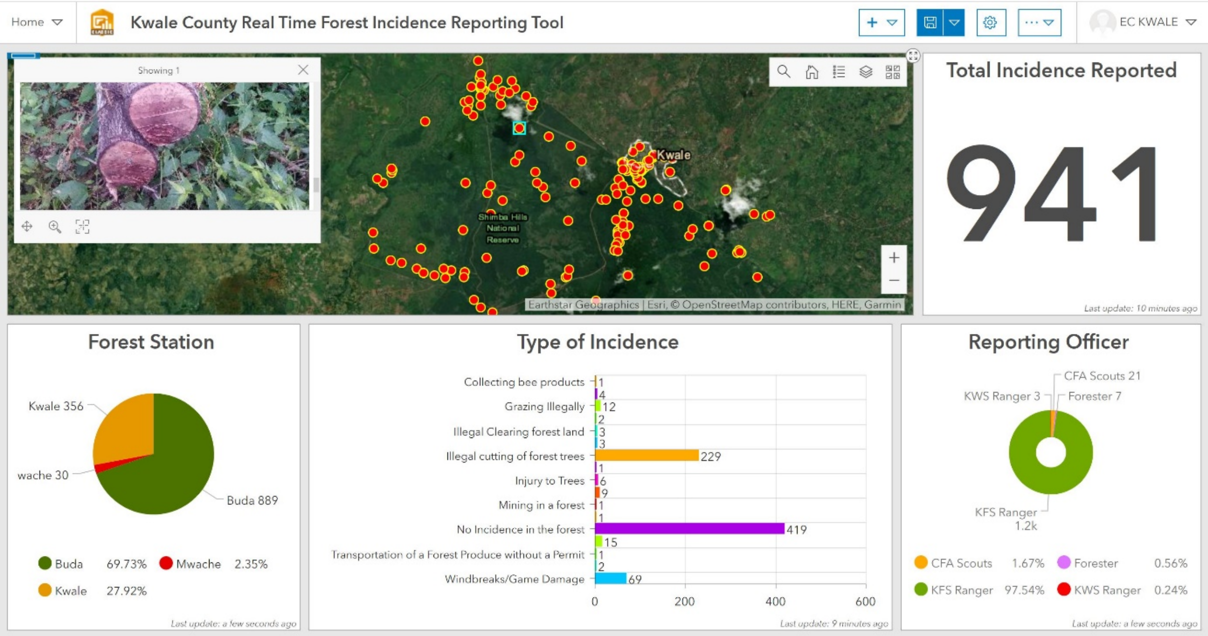



**Figure 4.3.5 Dashboard for reporting result**

## 4.4 Policies and Measures (PaMs)

To identify the specific effects of Policies and Measures (PaMs) in forest conservation and REDD+ implementation, the NFMS has identified indicators of monitoring. Using the strategic options and investment areas agreed in Kenya's Strategy for REDD+, Table 4.4.1 illustrates the specific indicators for monitoring that can be used to advise the performance of the intervention. It is noted that new strategies on forest conservation may introduce new strategic options but the table is just a guide on how monitoring indicators can be identified and performance monitored.

**Table 4.4.1 Composition of NFP and items selected as PaMs monitoring items**

| Strategic Options | investment areas | Actions | Monitoring indicators |
|---|---|---|---|
| 1. Scaling up afforestation, reforestation and landscape restoration programmes | 1.1. Incentivize large scale tree planting investments on private land. | 1.1.1. Develop and implement a commercial forestry strategy<br>1.1.2. Implement the tree improvement strategy<br>1.1.3. Create incentives for large scale afforestation and reforestation programmes in private land<br>1.1.4. Establish tree growers cooperatives to support large scale tree planting<br>1.1.5. Provide platforms for corporates to support large scale SRI/CSI/CER tree planting and management programmes.<br>1.1.6. Create mechanisms for PPP in REDD+<br>1.1.7. Improve germplasm and develop mass production programmes | ✓ A strategy is in place<br>✓ An improvement plan of the strategy is in place<br>✓ Area of private forests and plantations<br>✓ Number of grower cooperatives established<br>✓ Number of forests established by corporates<br>✓ Number of PPP mechanisms in place<br>✓ Number of seedlings of improved germplasm provided |
| | 1.2. Create mechanisms for afforestation in community lands to enhance cultural, environmental and biodiversity benefits | 1.2.1. Map out community lands with potential for REDD+ implementation and create Targeted campaigns for tree planting<br>1.2.2. Develop integrated livelihood strategies that incorporate trees within community lands<br>1.2.3. Develop and implement management plans that catalyze tree planting in community forests with clear guidelines on roles, responsibilities and benefits for all actors | ✓ Area of community forests mapped as REDD+ potential areas<br>✓ Area under forests in community lands<br>✓ Number of management plans implemented |
| | 1.3. Increase afforestation and reforestation activities through landscape | 1.3.1. Develop large scale tree planting programmes using ideal dryland species<br>1.3.2. Develop and implement an integrated system for fire management in fire prone areas<br>1.3.3. Provide options for land preparation without burning<br>1.3.4. Promote alternatives to land clearing and charcoal making including alternative sources of energy | ✓ Number of large sacle planting programes<br>✓ Area afforested<br>✓ Reduction in fore incidences and fore areas<br>✓ Adoption levels of alternative energy<br>✓ Number of grazing management plans and Area undergrazing management plans |

| Strategic Options | investment areas | Actions | Monitoring indicators |
|---|---|---|---|
| | restoration in drylands | 1.3.5. Implement improved livestock grazing management systems. | |
| | 1.4. Promote PES systems including carbon by the private sector | 1.4.1. Establish a national registry with a documentation and approval system for REDD+ projects<br>1.4.2. Establish an accounting system where the contribution of the private sector in meeting national GHG targets can be assessed<br>1.4.3. Clarify definitions of carbon rights and tenure rights to streamline benefit sharing mechanism for all stakeholders<br>1.4.4. Nest site scale activities in the National REDD+ process<br>1.4.5. Strengthen capacity at the County level to develop projects | ✓ A national registry<br>✓ A running accounting system<br>✓ Clarified carbon rights- policy document<br>✓ A streamlined nesting programme<br>✓ Number of counties implementing REDD+ projects |
| | 1.5. Improve productivity of agricultural value chains. | 1.5.1. Implement the National Agroforestry strategy<br>1.5.2. Create mechanisms that support sustainable management of livestock grazing<br>1.5.3. Support planting of tree crops that provide wood resources (besides livelihood benefits)<br>1.5.4. Support commercial Bamboo production<br>1.5.5. Introduce credit facilities for farmers to plant trees<br>1.5.6. Promote tree farmer cooperatives<br>1.5.7. Support domestication of high value trees on farms | ✓ Existence of an agroforestry strategy<br>✓ Livestock management strategy<br>✓ Increase in farm forests or area under farm forests<br>✓ Volume of bamboo produced and area under bamboo forests<br>✓ Mechanisms for credit facilities |
| | 1.6. Enhance protection of existing forest resources | 1.6.1. Strengthen capacity of KFS and KWS in enforcing protection of forests<br>1.6.2. Enhance institutional coordination for forest protection of existing forests | ✓ Improved forest protection.<br>✓ Fewer cases of illegal activities<br>✓ Improved institutional cooperation |

| Strategic Options | investment areas | Actions | Monitoring indicators |
|---|---|---|---|
| 2. Enhance governance and policy implementation to prevent conversion of forests to other land uses | 2.1. Support implementation of the national values and principles of governance | 2.1.1. Develop, adopt and enforce anticorruption policies and guidelines (e.g. REDD+ anti-corruption guidelines )<br>2.1.2. Support public participation in matters pertaining REDD+<br>2.1.3. Adopt and domesticate international guidelines on FLEGT | ✓ Presence of anticorruption guidelines<br>✓ Number of stakeholders involved<br>✓ International guidelines adopted |
| | 2.2. Strengthen capacity of County Governments, private sector and Communities to implement the devolved forestry functions. | 2.2.1. Integrate REDD+ in County planning (CIDP) and Climate change action plans as well as in spatial and physical planning processes<br>2.2.2. Clarify land ownership and benefit sharing arrangements to stimulate participation of communities and private sector in REDD+ activities<br>2.2.3. Implement registration of forests held in trust by County governments, and on Community lands by KFS, to plan for extension support<br>2.2.4. Support registration of community forests to ensure their conservation in group ranches undergoing subdivision<br>2.2.5. Develop incentives for forest conservation including PES programmes in community forests<br>2.2.6. Establish a framework for Nesting REDD+ activities | ✓ Number of CIDPs with REDD+ integration<br>✓ Number of community lands registered<br>✓ Registered forests held in trust by counties<br>✓ Number of PES programmes implemented<br>✓ Number of site scale/jurisdictional REDD+ projects |
| | 2.3. Review and harmonize policies, laws and institutions relating to forest management | 2.3.1. Establish a forest regulatory authority to coordinate forest sector development in the country<br>2.3.2. Review the National Forest policy<br>2.3.3. Amend the FCMA 2016<br>2.3.4. Strengthen KFS<br>2.3.5. Develop and implement a code of ethics<br>2.3.6. Develop and implement a benefit sharing mechanism for REDD+<br>2.3.7. Strengthen KEFRI as a research institution in Forestry<br>2.3.8. Strengthen Community based institutions to support REDD+ implementation<br>2.3.9. Review the PPP Act to strengthen private sector engagement<br>2.3.10. Develop County level forest management plans | ✓ Presence of a regulatory body<br>✓ Reviewed National Forest Policy<br>✓ Amended FCMA<br>✓ Presence of a code of ethics<br>✓ Existing benefit sharing mechanism<br>✓ Number of research projects in forestry<br>✓ Number of active CFAS and indigenous peoples groups<br>✓ Number of county forest management plans |

| Strategic Options | investment areas | Actions | Monitoring indicators |
|---|---|---|---|
| | 2.4. Support implementation of management plans for all forests. | 2.4.1. Develop and implement management plans for public, community and private forests with clear guidelines on roles, responsibilities and benefits for all actors<br>2.4.2. Involve communities in design and implementation of REDD+ programmes in community forests through FPIC<br>2.4.3. Develop protocols for total valuation of forests and ecosystems to determine the true value of forest products and services<br>2.4.4. Incentivize activities that result to reduced deforestation | ✓ Number of Management plans in private and community forests and area of forest under the management plans<br>✓ FPIC programmes in REDD+<br>✓ Number of forests with total valuation.<br>✓ Standardized forest valuation methods<br>✓ Mechanisms of incentives in place |
| 3. Increase productivity of public plantation forests | 3.1. Efficient and effective management of public forest plantations. | 3.1.1. Increase funding for public plantation management to support sustainable management<br>3.1.2. Increase forest productivity using high quality germplasm and appropriate silvicultural practices.<br>3.1.3. Develop protocols to monitor implementation of forest management plans for public forest plantations | ✓ Amount of funding availed to SFM<br>✓ Proportion of increased productivity<br>✓ Volume of wood form public plantations<br>✓ Revenue accrued from public plantations<br>✓ System for monitoring implementation of Management plans |
| | 3.2. Support participation of non-state actors in public plantation programmes | 3.2.1. Map out forest with potential for concessions<br>3.2.2. Develop guidelines for Concessions and contracts to allow the private sector secure long term investments.<br>3.2.3. Streamline the participation of communities in the plantation establishment and Livelihood improvement Scheme (PELIS)<br>3.2.4. Develop a framework for integrating non state actors in the sale of forest products | ✓ Area of forests under concessions<br>✓ Concessional guidelines in place<br>✓ Area under PELIS<br>✓ Number of forest products in market |
| | 3.3. Enhance transparency in management including information sharing | 3.3.1. Support Inclusive participation of stakeholders in decision making and implementation<br>3.3.2. Develop and implement a transparent forest information system | ✓ Number of stakeholders involved<br>✓ Information system in place |
| 4. Enhance efficiency, | 4.1. Promote cost-effective | 4.1.1. Engage charcoal producers to adopt improved kilns and retorts for charcoal production | ✓ Number of kilns implemented<br>✓ Volume of charcoal produced |

| Strategic Options | investment areas | Actions | Monitoring indicators |
|---|---|---|---|
| effectiveness and skills throughout forest related value chains | technologies to achieve high emission reductions at large scale | 4.1.2. Support small scale saw millers to adopt low waste logging and saw milling equipment<br>4.1.3. Promote use of improved cook stoves for urban and rural households. | ✓ Number of saw mils with efficient saw milling equipment<br>✓ Adoption levels of improved cook stoves |
| | 4.2. Improve the forest resource value chain | 4.2.1. Promote the tree value chain for better wood valuation and increased returns on investment<br>4.2.2. Promote wood certification to improve chain of custody<br>4.2.3. Promote sustainable production and efficient utilization of biomass energy including use of wastes to produce pellets and briquettes.<br>4.2.4. Develop building codes for the construction industry<br>4.2.5. Create incentives for high efficiency wood conversion technologies<br>4.2.6. Develop an eco labelling standard for marketing of charcoal | ✓ Number of actors in the tree value chain<br>✓ Wood certification systems in place<br>✓ Volume of pellets and briquettes<br>✓ Existence of building codes<br>✓ Incentive mechanisms in place for improved technologies<br>✓ Eco Labelled charcoal in markets |
| 5. Mobilise Finance for implementation of REDD+ in Kenya | 5.1. Strengthen capacity for mobilization of local and international funds | 5.1.1. Undertake a full economic valuation of forestry resources to support increased funding from the exchequer<br>5.1.2. Strengthen capacity for project development targeting global multilateral financiers<br>5.1.3. Establish mechanisms for attracting private finance<br>5.1.4. Implement the Green Fiscal incentive policy<br>5.1.5. Develop a dedicated policy for Green Financing<br>5.1.6. Develop Dedicated forestry bonds<br>5.1.7. Build capacity of local experts to certify and monitor REDD+ projects<br>5.1.8. Support policies that increase finance allocation to the forestry sector at County level<br>5.1.9. Establish a domestic carbon pricing policy that includes REDD+ as an eligible offset type to incentivize investments in REDD+ credits).<br>5.1.10. Establish clear national authorization processes for reviewing and approving, and accounting for mitigation outcomes for use toward an international compliance obligations | ✓ Forest role in GDP improved<br>✓ Number of projects funded by multilateral donors<br>✓ Green Fiscal Policy in place<br>✓ Established carbon pricing policy |

| Strategic Options | investment areas | Actions | Monitoring indicators |
|---|---|---|---|
| | 5.2. Establish a multi partner trust fund for forestry development | 5.2.1. Align the fund to the public finance management Act<br>5.2.2. Develop guidelines for access and management of funds from the pool<br>5.2.3. Support an aggressive resource mobilisation program<br>5.2.4. Develop a framework for operationalization of the fund | ✓ Existence of a fund |

Regarding PaMs monitoring, Kenya adopts a phased approach and aims to measure how each PaMs contributes to reducing deforestation and forest degradation, sustainable management of forest and enhancement of forest carbon stock.

## 4.5 Biodiversity

Biodiversity is generally described by three levels of diversity: ecosystems, species and genes. Lusweti (2011) explained that Kenyan forests are endowed with a rich array of plant and animal life with western rain forests described biodiversity hotspots while coastal forests serving as centres of endemism with rare species found nowhere else in the world. Plantation forests which exist as monocultures have the least plant biodiversity because their prime management objective is commercial productivity. Documenting biodiversity indicators helps understand the non-physical values of the forest while monitoring such indicators identifies the role of drivers of change on the hidden roles of the forest. Based on this understanding, the objectives of biodiversity monitoring in the NFMS are documenting the roles of the forests as biodiversity hotspots and identifying how the biodiversity is affected by the proposed conservation and management measures. Information on biodiversity is also important for the Safeguard Information System (SIS) for REDD+ implementation.

It is noted that a variety of biodiversity assessments are carried out by various mandated institutions in Kenya. For example, the Kenya Wildlife Service (KWS) carries periodic assessments of wildlife species to advise conservation measures. Similarly, the National Museums of Kenya (NMK), maps biodiversity hotspots through periodic data collection of the flora and fauna components of ecosystems. Thirdly research and academic institutions periodically carry out biodiversity assessments as part of research programmes. Each of these biodiversity assessments adopts designs that suit the kind of species being monitored but they all provide relevant information of the status of biodiversity in each of the studied ecosystems and are therefore relevant for the NFMS.

Noting that the tree component in a forest is a significant indicator of the forest biodiversity, assessment for biodiversity in the NFMS will be primarily based on the NFI design. The field Manual for forest Assessment (KFS, 2016a) provides a data collection sheet (which can also be converted into electronic form) for collection of tree information from the various Carbon pools. This data includes tree information in terms of species, size (diameter and height), form, health status and location in the plot. This data is appropriate for calculation of biodiversity indicators. For temporary sample plots (TSP), biodiversity information can be obtained at one time instance and can be compared among forest strata (Montane and western rain forests, Dryland forests, or Coastal and mangrove forests), among ecosystems (e.g. Afromontane broadleaved moist forests vs Afromontane mixed dry forests) or among clusters or among plots in a cluster. Table 4.5.1 presents a variety of biodiversity indicators that will be used to inform effects of conservation measures.

**Table 4.5.1 Assessment of biodiversity indicators**

| Biodiversity indicator | Purpose for monitoring | Methodology for monitoring |
|---|---|---|
| Abundance by numbers | Identifies the number of trees identified in a forest. Noting the uneven distribution of trees in forests, a forest with more trees is better stocked compared to one with less trees | Abundance is derived from the total number of individuals recorded in a forest |
| Species richness | Identifies how many species are found | Species richness is calculated from |

| Biodiversity indicator | Purpose for monitoring | Methodology for monitoring |
|---|---|---|
| | in a forest. A forest with more species is richer and has a wider variety | total number of species in a forest |
| Relative abundance | Identifies the contribution of a species to the total population of a forest. A species with more numbers in the population has a higher relative abundance. Such a species may not be threatened by overuse in that forest | Calculated from the total number of individuals of each species as a fraction of the total population |
| Relative frequency | Identifies the distribution of a species among sample sites. A species that is recorded in most sample sites is well distributed and can be described as adaptable to different ecological conditions or different levels of anthropological/natural stress | Calculated from the total number of samples a species is recorded as a proportion of the total number of sample sites |
| Relative dominance | Identifies the contribution of a species to the total basal area of a forest. Large trees with more basal area normally form the dominant trees in the forest and may comprise emergent/top canopy trees, mother trees for seed production. They may also influence water catchment and are major hosts of biodiversity. | Calculated from the total basal area of a species as a proportion of the total forest biomass |
| Importance Value Index | This is a combined index that caters for relative abundance, relative frequency and relative dominance and indicates the overall dominance of a species based on several indicators | Calculated as the sum of relative abundance + relative frequency + relative dominance per species (Kinyanjui, 2009) |
| Species similarity | Forests exists as associations where certain group of species grow together. A forest with a wide variety of associations deviates from monoculture characteristics and therefore host more biodiversity | Calculated from a variety of similarity indices e.g. Sorenson’s or Jacard’s indices (Washington, 1984) |
| Diversity | Diversity of species in a forest explain the variety of roles the forest has. This variety includes the opportunities for hosting flora and fauna as well as microorganisms | The most commonly used index for species diversity is the Shannon-wiener diversity index (Omayio and Mzungu, 2019) it takes into account the number of species present, as well as the relative abundance of each species |
| Species evenness | Describes how homogenous or evenly distributed the species described in the diversity index occur | Is calculated form the diversity index and the species richness of the forest |

The NFI data collection sheet allows for recording of non-tree components whenever they are observed in the plot. The recorded biodiversity components are classified as; No biodiversity component, presence of Big mammals, presence of Other mammals, presence of Reptiles, presence of Birds, presence of insects, and Butterflies, presence of climbers, presence of Epiphytes, presence of fungus, observed Rare biotope (e.g. spring, oasis etc.)

### 4.6 REDD+ and AR-CDM Projects

The Function of a REDD+ and AR-CDM project registration is to compile GHG reduction efforts in forests of Kenya and to prevent duplication of credits in emissions trading. This is also proposed in the National Strategy for REDD+. It requires that all Carbon projects provide information to the National Registry to include;

- Name of Project
- Implementer,
- Location of the project (County, Sub-County, Location)
- Area(ha)
- Start date of the project
- End date of the project (expected)
- Target emission reduction amount ($CO_2$t)
- Actual emission reduction amount ($CO_2$t)
- Quantities for which payments ware received ($CO_2$t, Year)
- Entity paying for results
- Kinds of activities
- Monitoring method
- Pools measured

It is proposed that all these information for each project will be updated and published through FIP to allow monitoring of progress and proper accounting.

# Chapter 5. Data Management Function of the NFMS

To facilitate efficient and effective information sharing, this chapter focuses on the FIP components, operations, and its linkage with other systems.

## 5.1 Component and Contents of the FIP

The data management function aims to establish and operate the Forest Information Platform (FIP) as the shareable database. It is important to design the FIP with the output-consciousness which means that what the FIP will perform. Therefore, the first thing to do is to focus on the goal of the FIP operation. The six concrete objectives are shown in Figure 5.1.1 as the goals of the FIP operation.

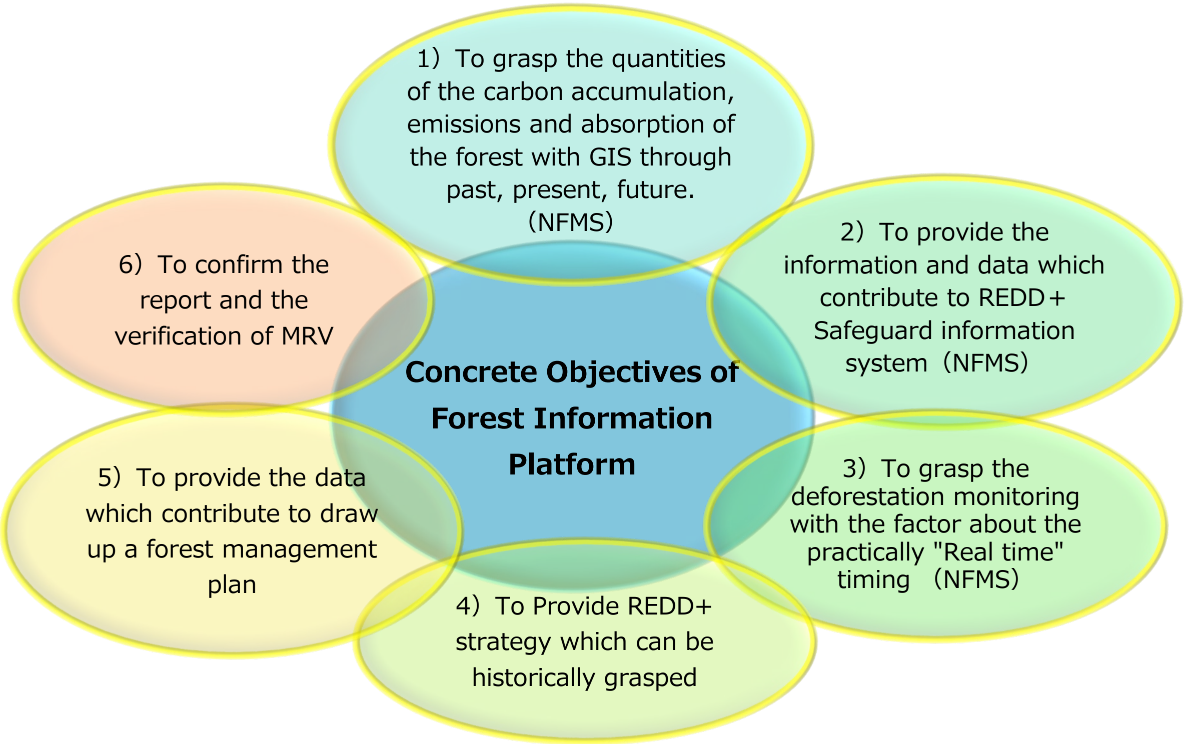



**Figure 5.1.1 Concrete objectives of FIP**

Based on the above six objectives, the FIP consists of the eight components shown in Figure 5.1.2.

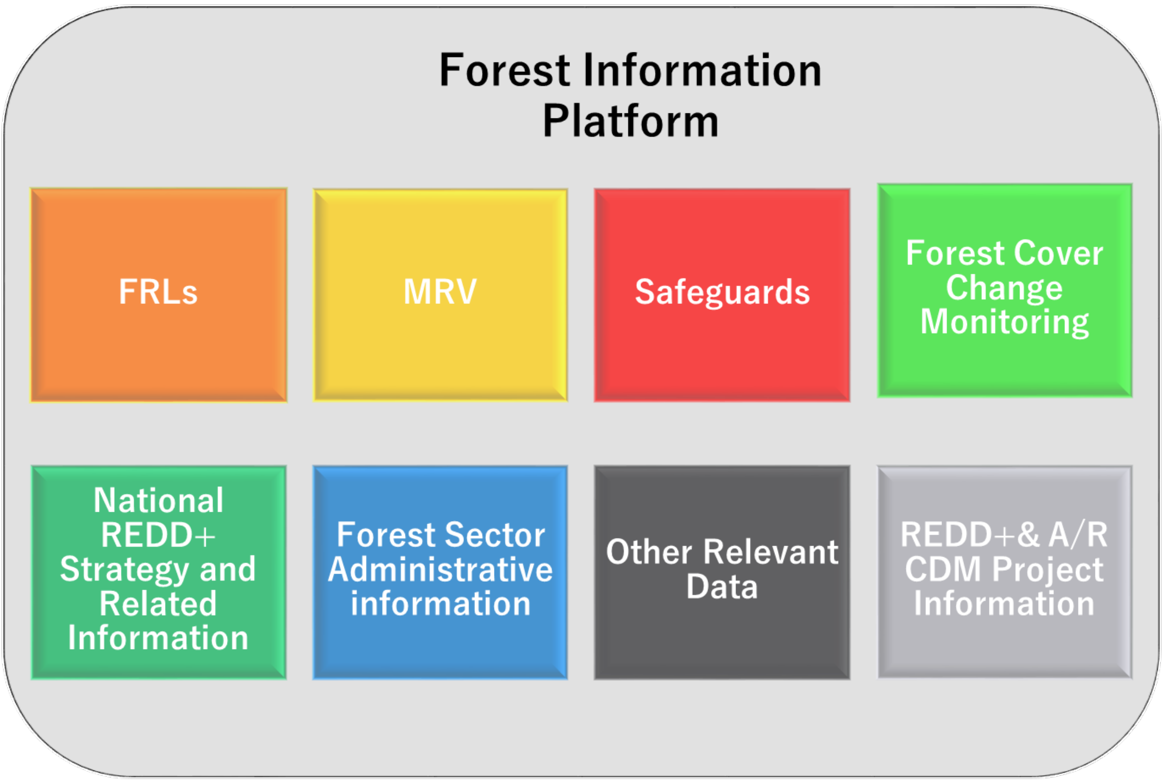



**Figure 5.1.2 Components of FIP**

Functions provided by the FIP are shown in Table 5.1.1.

**Table 5.1.1 Outline of functions of the FIP**

| Target Information | Outline of Functions |
|---|---|
| **FRLs** | • FRLs to provide historical information on emissions based on a reference period is shown<br>• Provide projections of emissions reduction to be achieved through the REDD+ activities is shown.<br>• All the elements relating to the activity data, emission factors and estimations used for setting FREL/FRL are clearly shown. |
| **MRV** | • Concept and plans indicating what and how to measure, report and verify with respect to REDD+ are shown.<br>• Monitoring results of AD by land cover/land use change, EF by forest inventory, and carbon stock removal and emissions are shown. |
| **Safeguards Information System** | • Information as to how safeguards were handled and respected through the REDD+ activities is provided through the safeguard information system. |
| **Forest Cover Change Monitoring** | • Near real time deforestation area provided by JJ FAST and NRTFAS are shown.<br>• Field survey information of detected deforestation area are shown. |
| **National REDD+ Strategy and Related Information** | • Information concerning the National REDD+ Strategy is provided.<br>• Driving forces of forest logging and degradation are shown quantitatively.<br>• Quantitative evaluation of the policy, strategy and measures (PaMs) is shown. |
| **Forest Sector Administrative Information** | • Forest plantation allocations for harvesting and concession information are provided.<br>• Information necessary for the REDD+ Project implementers and investors to determine the feasibility of PDD before the submission is provided as REDD+ registry. |

| Target Information | Outline of Functions |
|---|---|
| **Other Relevant Data** | • Other Relevant Data are provided. |
| **REDD+ & A/R CDM Project Information** | • Projects area and information related to REDD+ and A/R CDM are shown as map and attribute. |

In the above context, the data contents stored in FIP as the data management system is shown in Table 5.1.2.

**Table 5.1.2 Information to be operated in FIP**

| Component | Information to be operated in the data management system |
|---|---|
| **FRLs** | What is FRLs?<br>Kenya FRL<br>Kenya FRL Dec. 2019<br>Kenya FRL Aug. 2020<br>Evidence of formulation of FRELs/FRLs<br>Activity data<br>Land cover / land use change table<br>Land cover / land use change map<br>Land cover/land use map of the historical reference years<br>Emission factor<br>Forest inventory survey<br>Biomass conversion information<br>Emission estimate<br>Projection of emissions into the future |
| **MRV** | What is MRV?<br>Measurement system<br>Monitoring Activity data<br>Land cover / land use change table<br>Land cover / land use change map<br>Land cover/land use map of the historical reference years<br>Emission factor<br>Forest inventory survey<br>Biomass conversion information<br>Forest carbon stock removal and emissions<br>Reports from Reporting system<br>Verification system<br>MRV Training<br>Community Monitoring of Forest |
| **Safeguards Information System** | Safeguard information |
| **Forest Cover Change Monitoring** | JJ-FAST<br>NRTFAS<br>Field Survey Report |
| **National REDD+ Strategy and Related Information** | National REDD+ strategy<br>Legislation and strategy related REDD+<br>Other information related REDD+ in Kenya<br>Conventions related climate change ratified |
| **Forest Sector Administrative Information** | Forest related organization chart<br>Legal jurisdiction of Forest Management |
| **Other Relevant Data** | Relevant information<br>Information on protected areas including national parks<br>Demographic information including ethnic communities<br>Forest and Landscape Restoration<br>Earth Observation Laboratory (EOLAB)<br>Other related maps<br>Soil maps<br>Precipitation map |

| Component | Information to be operated in the data management system |
|---|---|
| | Temperature map<br>Land use 2010<br>FMS<br>Forest Fires<br>Glossary |
| **REDD+ & A/R CDM Project Information** | REDD+ & A/R CDM Project Information |

Apart from the components of FIP, Figure 5.1.3 shows the conceptual design image of the FIP. The FIP was designed based on commercial products that manage ESRI's GIS data. Taking into consideration of security and sustainability of the FIP, and considering hardware redundancy, it was decided to operate ArcGIS Enterprise on Microsoft-SQL Server with respect to server software and it was also designed to use it in the headquarters and on-site field. Moreover, it is designed that Web references are possible inside KFS referring to information from related stakeholders such as SLEEK, KEFRI, SOK by use of Arc GIS Online etc.

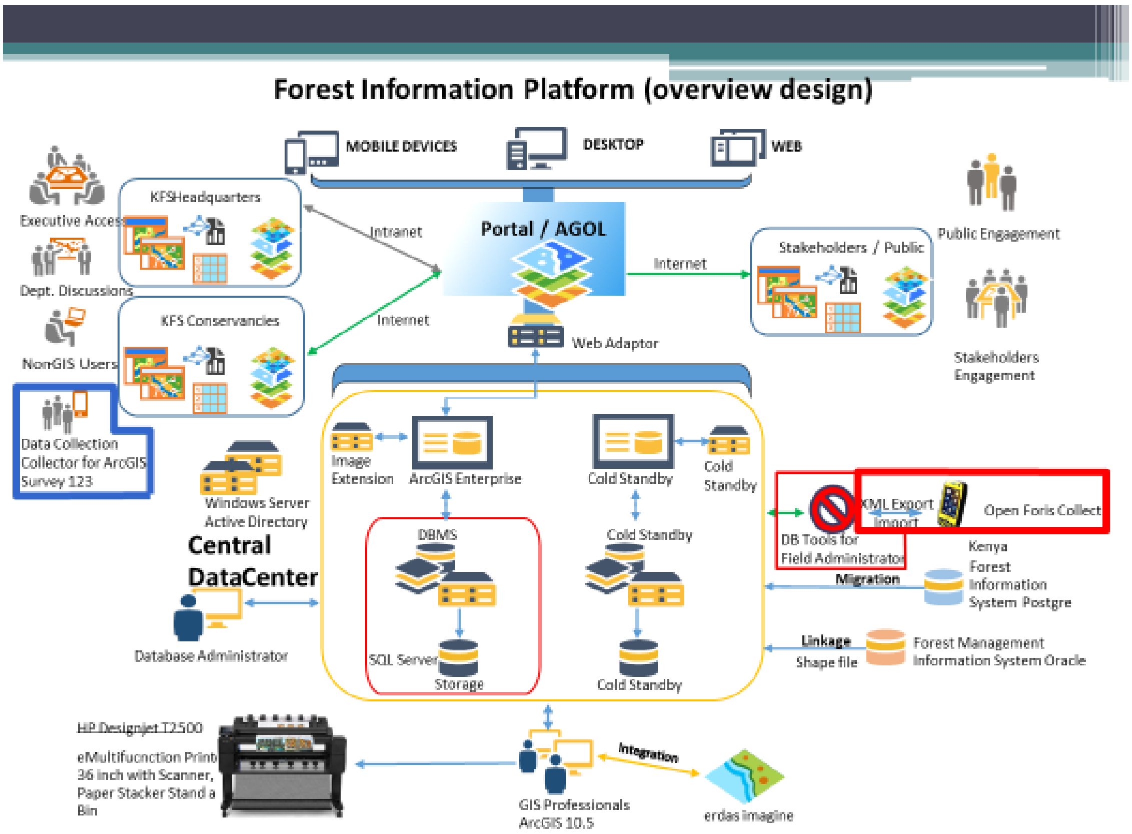



**Figure 5.1.3 Image of overview design for FIP**

In addition, through the operation, the system tuning will be performed to extract points of improvement and the system will be improved. For extracting the points of improvement and improving the system, the database system will be operated with PDCA cycle. The database implementation aims at the level of the easy maintenance to enable the sustainable operation of system.

## 5.2 Linkage with FMIS

The Forest Management Information System (FMIS) currently contains about 6,000 records of plantation sub-compartments which are within 65 stations in 10 conservancies. The FIP should be able to read data from the FMIS database to avoid duplication of data sources. The linkage with FMIS means updating FMIS GIS-data into FIP. Figure 5.2.1 shows the flowchart of FMIS Linkage process and Figure 5.2.2 shows the image of the FMIS on FIP by coloring with the attribution of “Landcover”.

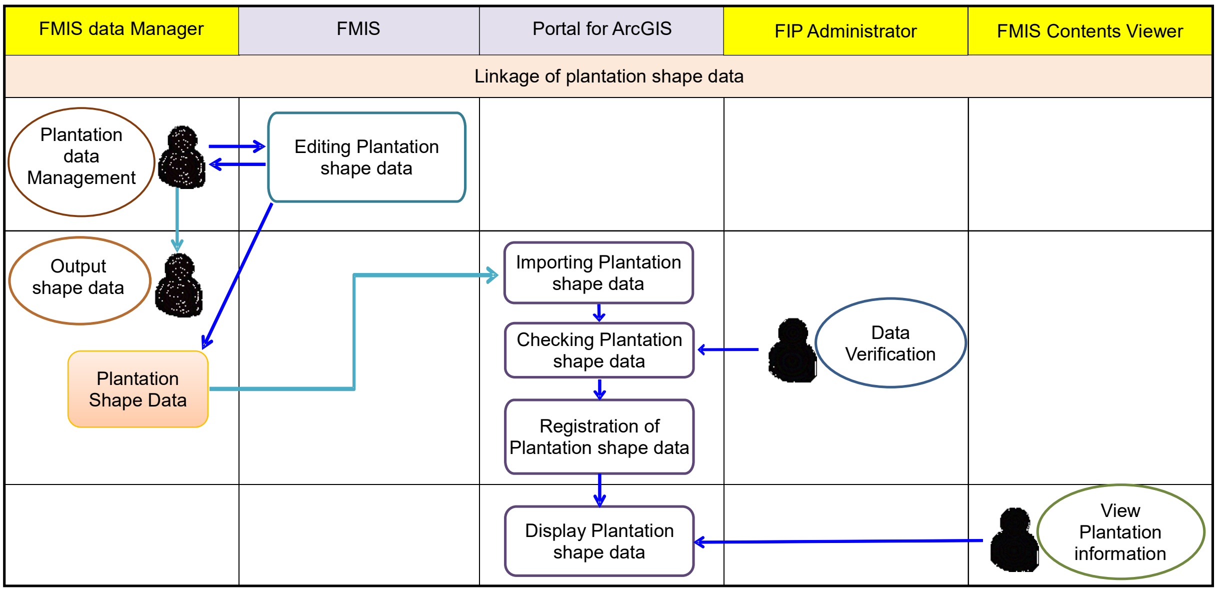



**Figure 5.2.1 Flowchart of FMIS linkage process**

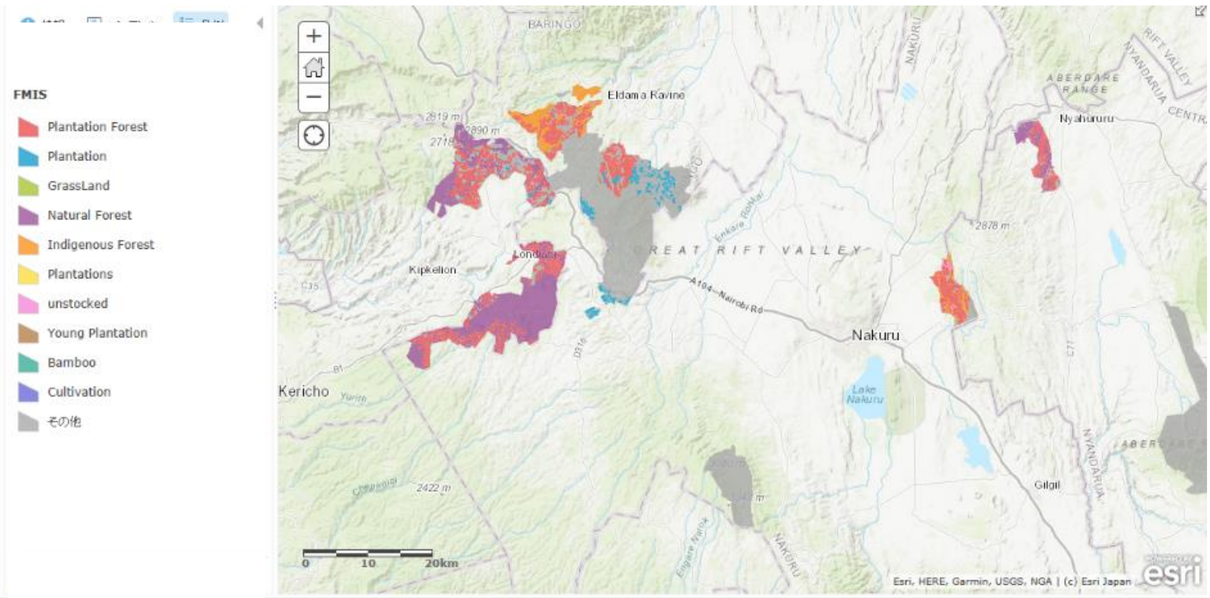



**Figure 5.2.2 An image of FMIS on FIP**

## 5.3 Operation of FIP

In order to manage and operate the FIP, following things should be considered.

### 5.3.1 Operational Structure

The operation of the FIP is illustrated in Figure 5.3.1.

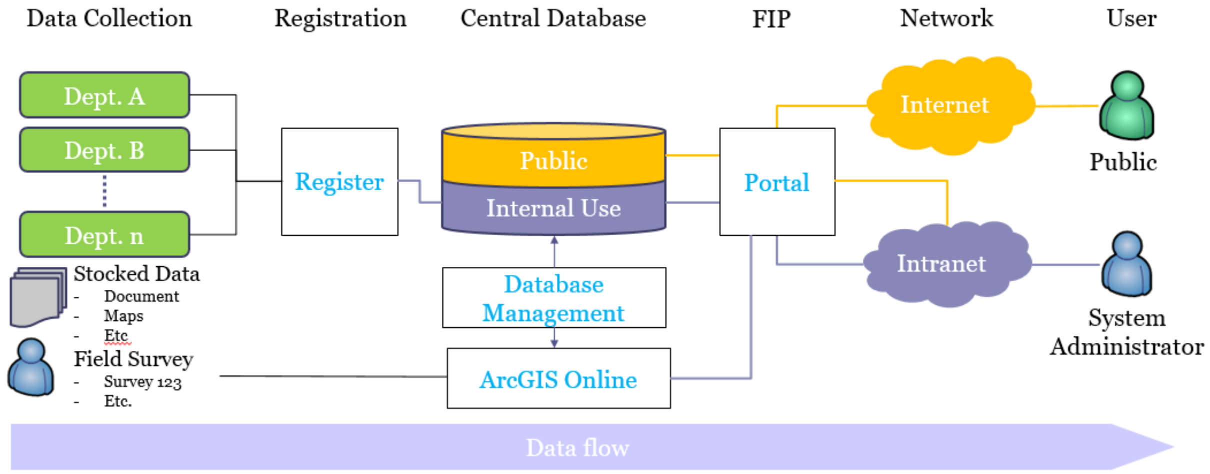



**Figure 5.3.1 Image of system diagram of FIP**

**[Data Collection]**

Research and Collect the data related to the FIP.

- Manage the requirement (Which department / section should be joined or want to join)
- Manage the dataset (What kind of data they have / should be registered to the Central Database)
- Create and provide the tools for data collection.
- Validation for collected data
- Training

**[Registration]**

Register the collected data to the Central Database

- Define the rules for registration (Access rights, Data verification, etc.)
- Provide the tools for data registration.
- Training

**[Central Database]**

Store the huge datasets for project

- Define the section for maintenance (Database, hardware, software)
- Training

**[FIP]**

Provides the information to the public and to the internal staff

- Define the structure, operation and maintenance for FIP (hardware, software, portal site)
- Training

**[Network]**

Provides the project datasets to user

- Security management
- Service policy (24/7/365)
- Training

**[Users]**

Search and view the information on FIP

- Some data will be hidden from public users to ensure data is not invalidated
- System administrator can access to the all data through the intranet or administrator menu

Figure 5.3.2 shows the diagram of institution arrangement of FIP operation. The portal service group (mainly contents management) and IT group (technical management) will operate FIP. The upper level commission will manage the FIP totally. All stake holders are joined to this commission.

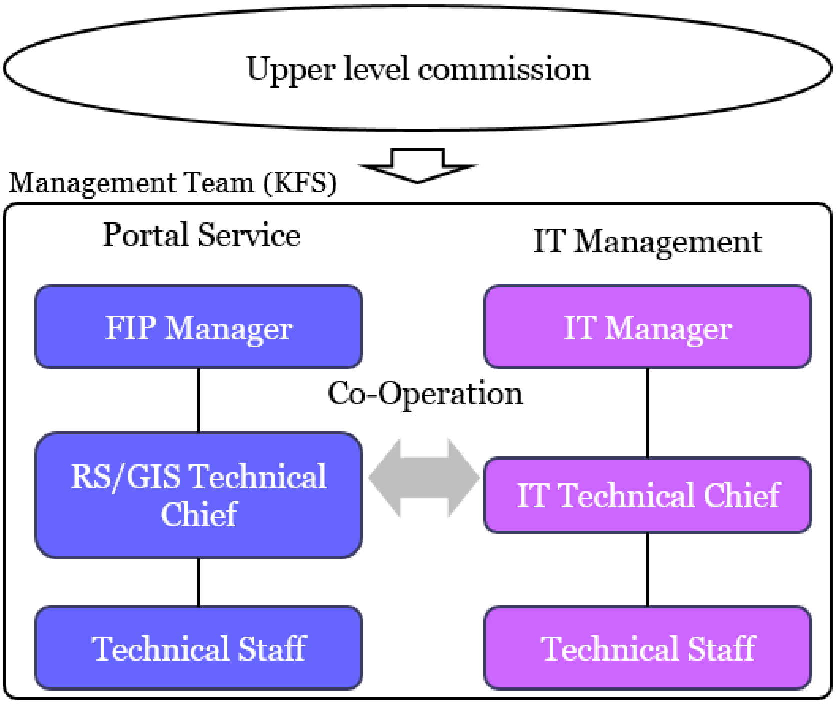



**Figure 5.3.2 Institutional organization of FIP**

Here shows the responsibility of each role.

**[Upper level commission]**

- All stake holders of FIP
- Own the total responsibility of the FIP.

**[Portal Service]**

FIP Manager

- Responsible person of the FIP
- Authorization of the proposal on FIP management from RS/GIS technical chief

RS/GIS technical chief

- Manage the information (contents, quality, publish, etc.)
- Manage the RS/GIS application database and portal

Technical Staff

- Work with RS/GIS application database and portal

**[IT Management]**

IT Manager

- Responsible person of the IT

IT technical chief

- Manage the hardware, network, and basic software

Technical Staff

- Working with IT system

Contents of the FIP should be authorized by responsible person before providing to users. Figure 5.3.3 shows the operation flow of contents publishing.

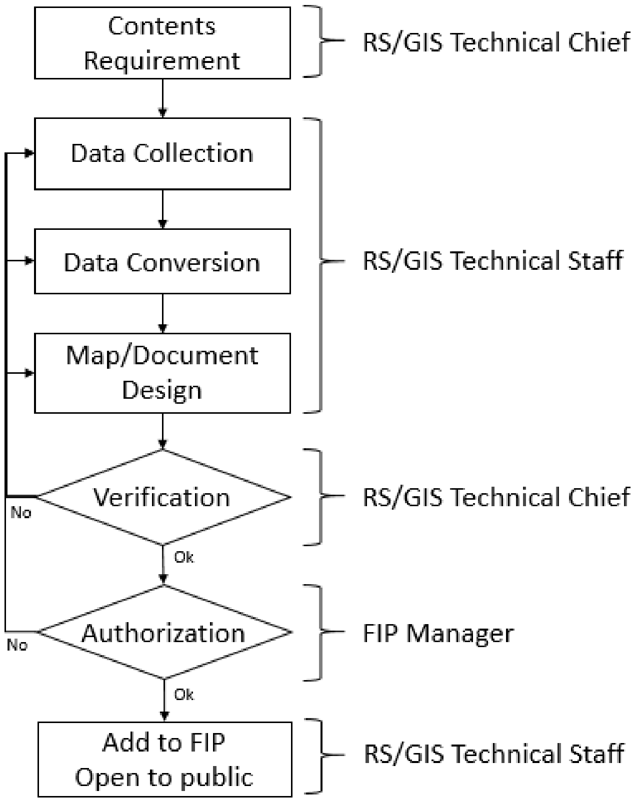


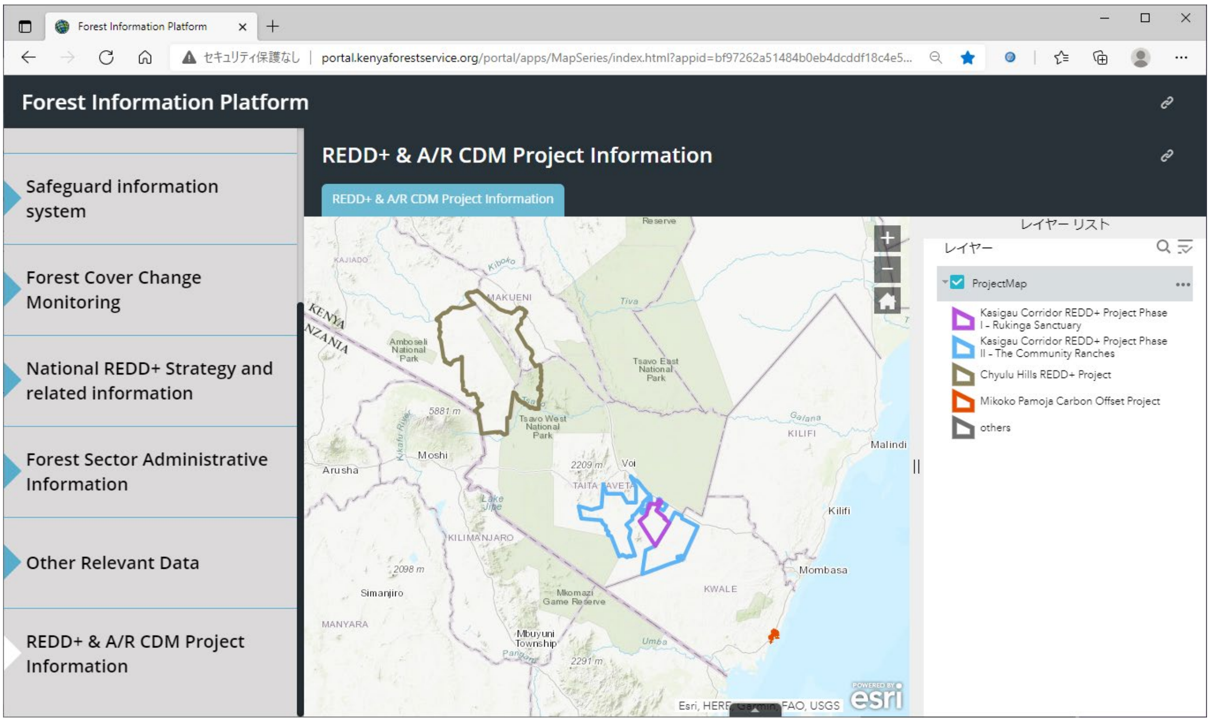

**Figure 5.3.3 Operation flow of contents publishing**

This workflow shows that the "FIP Manager" should have the responsibility for the published information.

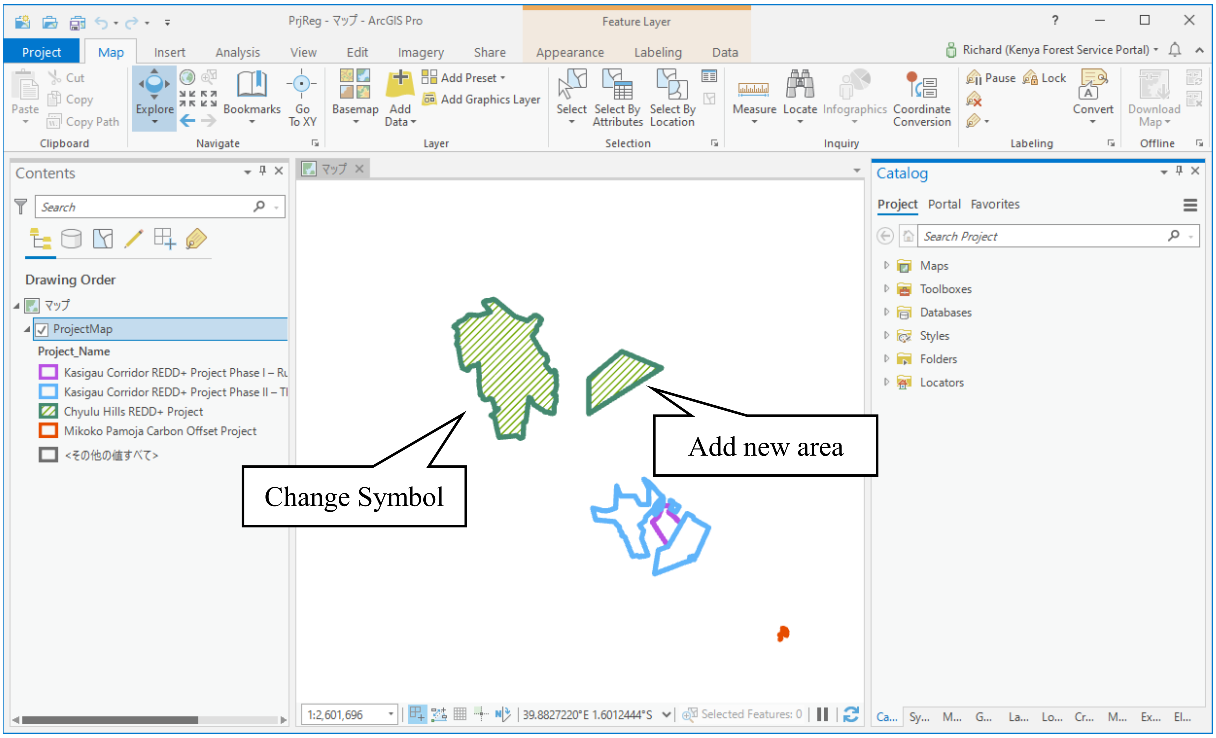
### 5.3.2 Update of Data and Information

Each content including RS/GIS data and document information of FIP is consisted by web page link on Portal for ArcGIS which allows updating data and information in the same web page link or replacing into another web page link. Procedural illustrations in

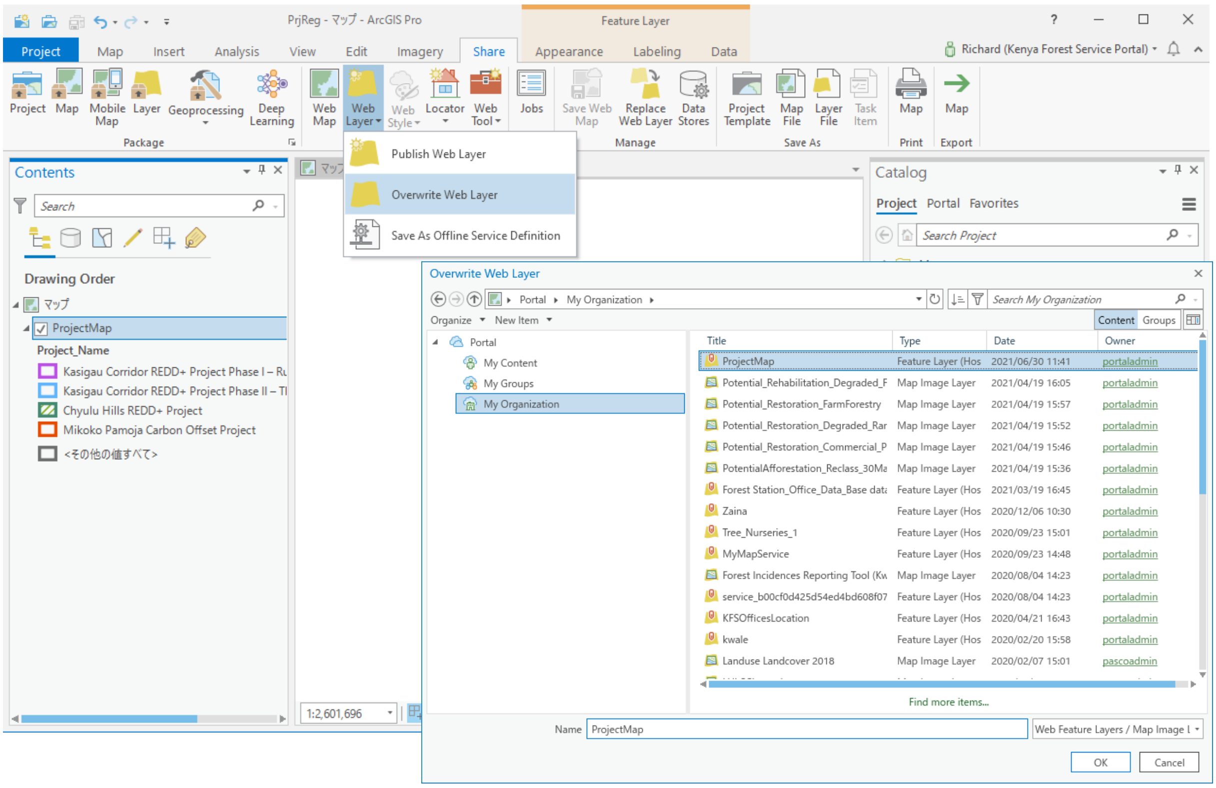
Figure 5.3.4 show how to update data and information on FIP from local GIS application.



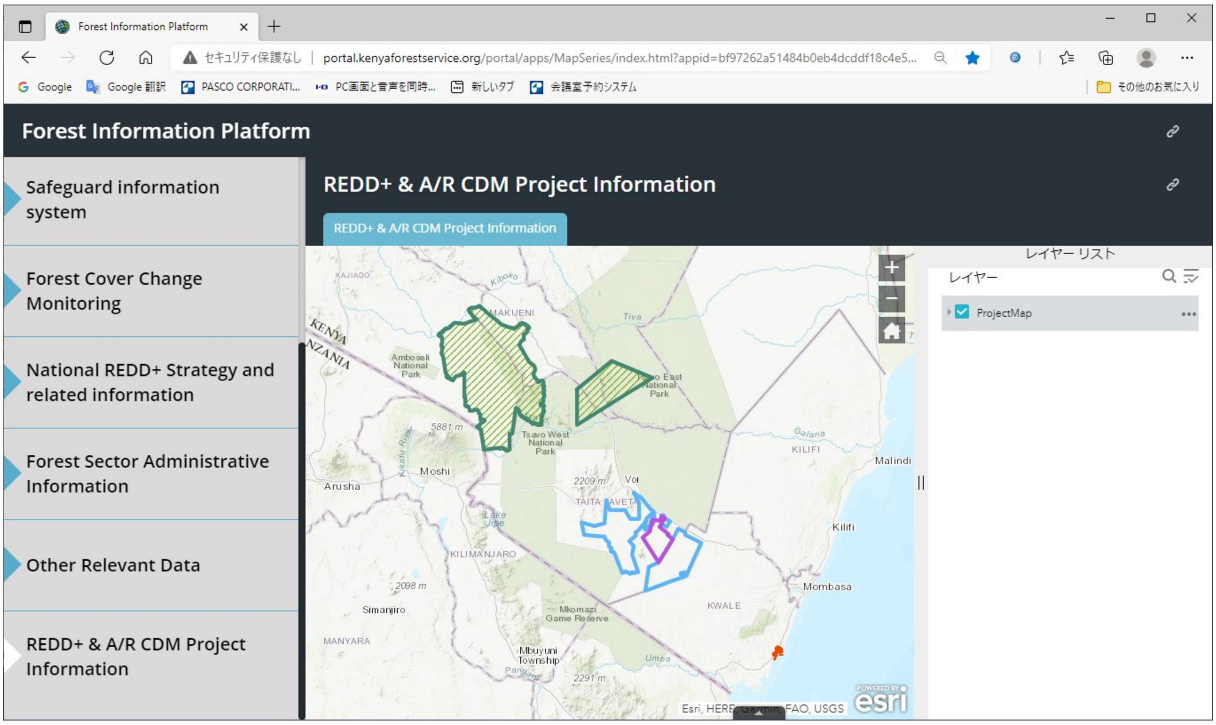
Current REDD+ Project Map (FIP)



Change symbol and add new area with ArcGIS Pro (administrator's local PC).




Overwrite the REDD+ Project map (FIP) with new symbol and updated data.




FIP Contents are updated. No need to touch the FIP from online administrator menu.

**Figure 5.3.4 How to update data and information on FIP**

### 5.3.3 Management of Equipment and Software

Table 5.3.1 shows the equipment related to FIP and how to manage them. Table 5.3.2 shows an example of a tablet management by Rental Agreement

**Table 5.3.1 Equipment related to FIP and how to manage it**

| *No.* | Equipment | Role | How to Manage |
|---|---|---|---|
| *1* | Workstation | ・Editing RS/GIS data and document information for FIP<br>・Uploading data and information on FIP<br>・Editing FIP on web browser | ・Management by IT equipment number in KFS<br>・Updating pattern file of installed anti-virus software<br>・Applying latest windows update |
| *2* | Tablet | ・Field Survey by Survey123 | ・Management by IT equipment number in KFS<br>・Management by Rental Agreement |
| *3* | Data base server | ・Operation Server for Portal for ArcGIS and FIP | ・Management by IT equipment number in KFS<br>・Temperature and humid control in server room<br>・Cold back-up for server regularly |
| *4* | Data storage server | ・Data storage server related to FIP | ・Management by IT equipment number in KFS<br>・Temperature and humid control in server room<br>・Back through Back-up device |
| *5* | Rack for servers & Customized Accessories | ・Rack for server equipment | ・Management by IT equipment number in KFS |
| *6* | UPS | ・UPS for server | ・Management by IT equipment number in KFS<br>・Confirming UPS signal regularly |
| *7* | L3 Switching Hub | ・Connection between server and KFS network | ・Confirming network connection from Server regularly |
| *8* | Back-up Device | ・Back-up for server | ・Management by IT equipment number in KFS<br>・Temperature and humid control in server room<br>・Changing back-up tape regularly |

**Table 5.3.2 Example of a tablet management by Rental Agreement**

| Tablet Rental Agreement | | |
|---|---|---|
| Item | Example | Contents |
| Tablet No. | No1 | |
| Start date of Rental | 21st Nov. 2018 | |
| Return Schedule | 30th Nov. 2018 | |
| Department of user | CADEP-TEAM | |
| Objective of use | Forest survey tool training for KFS staff | |
| Signature of user before rental | | |
| Signature of Tablet Administrator before rental | | |
| After returning, please fill in Date ________________________Recipient _______________ | | |
| Return Date | 29th Nov. 2018 | |
| Signature of user after rental | | |
| Signature of Tablet Administrator after rental | | |
| *Note; in principle, rental more than 2 weeks are prohibited.* | | |

Table 5.3.3 shows equipment related to FIP and how to manage them.

**Table 5.3.3 Software related to FIP and how to manage it**

| *No.* | Software | Role | How to manage |
|---|---|---|---|
| *1* | ArcGIS Online | ・License for field survey tool and Arc GIS Pro | ・Deleting unnecessary data on the cloud database regularly to prevent consumption of data credit<br>・Continuous contract with ESRI |
| *2* | ArcGIS for desktop with spatial analyst, 3D analyst, geo-statistics analyst, publisher | ・GIS data management and license for ArcGIS Pro | ・Continuous maintenance contract with ESRI |
| *3* | survey 123 for mobile mapping | ・Field Survey tool | ・Continuous contract to Arc GIS Online with ESRI |
| *4* | SQL Server | ・ Database for document information and RS/GIS data for FIP | ・Access Management by System Administrator |
| *5* | ArcGIS for Server Enterprise Standard, Portal for ArcGIS | ・Software to manage FIP | ・Continuous maintenance contract with ESRI |

| *No.* | Software | Role | How to manage |
|---|---|---|---|
| *6* | ArcGIS Image Extension for Server Enterprise | ・Management of image data on Server | ・Continuous maintenance contract with ESRI |
| *7* | Kaspersky | ・For Anti-virus | ・Applying latest pattern file |
| *8* | Windows server 2016 | ・Server Operation System | ・Applying latest windows update |

# Chapter 6. Institutional Arrangements for NFMS

The tasks of each party involved in the monitoring function and data management function of the NFMS, and the procedures for the management, will be formalized through institutional arrangements to ensure the long-term sustainability and accountability of the system. The NFMS secretariat will be established in KFS to oversee implementation and operation of NFMS.

## 6.1 Institutional Arrangements for the Monitoring Function

**Table 6.1.1 Consideration of institutional arrangement for monitoring function**

| Item | Activity/Data Type | Lead Institution | Mandated institutions | |
|---|---|---|---|---|
| | | | Institutions | Role |
| Land cover mapping based on SLEEK methodology | Development, validation and publication of the Land cover/Land use (LCLU) map | DRSRS | KFS | Periodic mapping of Creation of the LCLUC |
| | | | DRSRS | |
| | | | Survey of Kenya | |
| | | | KEFRI | |
| | | | Universities | QA/QC |
| | | | SLEEK | Technical guidance based on mapping manuals |
| Maps of forest areas | Provide information on forest area by type and region | KFS | KFS | Periodic mapping of forest cover in Kenya |
| | | | DRSRS | |
| | | | Survey of Kenya | |
| | | | KEFRI | |
| | | | Universities | QA/QC |
| Maps of Forest cover change (AD) | Development of forest cover change maps (Activity Data) | KFS | KFS<br>DRSRS<br>KEFRI<br>SLEEK | provide periodic information on forest cover changes |
| | | | Universities | QA/QC |
| National forest inventory (NFI) | Implementation of the NFI | KFS | KFS | Carry out NFI |
| | | | KEFRI | Support NFI |
| | | | Universities | Carry out QA/QC |
| | | | County Government | Facilitate inventories in County forests |
| Carbon stocks and Emission Factors | Development of forest carbon stock values from analysis of NFI data and Generation of associated Emission factors | KFS | KFS | Data analysis |
| | | | KEFRI | Support analysis improvement of allometric equations and other related factors |
| | | | Universities | Carry out QA/QC |
| JICA-JAXA Forest Early Warning System in the Tropics（JJ-FAST） | Monitoring of deforestation | KFS | KFS | Management of the monitoring system |
| The Near Real Time Forest Alert System (NRTFAS) | Receiving and analyzing of forest destruction alerts | KFS | KFS | Management of the monitoring system |
| Field validation for deforestation according to data | Ground truth survey by use of Survey 123 | KFS | KFS | Carry out ground truthing, and analysis |

| Item | Activity/Data Type | Lead Institution | Mandated institutions | |
|---|---|---|---|---|
| | | | Institutions | Role |
| from JJ-FAST and NRTFAS | | | | |
| Policies and Measures (PaMs) | Monitor Policies and Measures based on indicators | MoE&F | MoE&F | Manage the monitoring system |
| | | | KFS | Support the monitoring of PaMs |
| | | | KWS | |
| | | | KEFRI | |
| Biodiversity | Biodiversity Monitoring | KFS | KFS and Universities | Analysis of NFI data to provide biodiversity indicators |
| | | | NMK | Support monitoring and share data on biodiversity |
| | | | KEFRI | |
| | | | KWS | |
| REDD+ and AR-CDM projects | Monitoring of REDD+ & AR-CDM projects in Kenya | MoE&F | MoE&F | Manage the results of monitoring |
| | | | KFS | Collect data of the projects |
| | | | REDD+ and A/R CDM Projects | Provide data |

## 6.2 Institutional Arrangements for Data Management Function

Institutional arrangements for the data management function are, in short, how the FIP is to be managed. While the management of the FIP is shown in chapter 5.3, this section focuses on the roles and responsibilities of each institution for data updates and server management.

**Table 6.2.1 Institutional arrangements for data management function**

| Item | Activity/Data Type | Lead Institution | Mandated institutions | |
|---|---|---|---|---|
| | | | Institutions | Role |
| Data/Information update | Collection, verification & Uploading of data/Information | KFS | KFS | Manage the updating of data/information including providing access rights |
| | | | KEFRI | Provide data/information to be uploaded to FIP |
| | | | Survey of Kenya | |
| | | | ICRAF | |
| | | | DRSRS | |
| | | | Universities | |
| | | | Other institutions | |
| Server Management | Maintenance and renewal of hard and soft ware | KFS | KFS | The maintenance and renewal |
| | | | ME&F | Support budget for the maintenance and renewal |
| | | | Treasury | |
| | Publish data | | DRSRS | |
| | Store data | | Survey of Kenya | |
| | Receive data | | ME&F | |

## Chapter 7. Calendar of NFMS

It is indispensable for preparation of a calendar of NFMS to implement each component of the NFMS. The calendar is shown in Table 7.1.

**Table 7.1 Calendar of NFMS (draft)**

| Year | Forest cover area and forest cover change area for AD | Forest Carbon stock for EF | FREL/FRL | Submission of NC and BUR | Remarks |
|---|---|---|---|---|---|
| 2017 | Land cover/Land use map in Year 2000, 2014 | | | | |
| 2018 | The map in Year 2015 | | | | |
| 2019 | The map in Year 2018 | | | | |
| 2020 | | | (Period 2002-2018) | | Paris Agreement came into force |
| 2021 | The map in Year 2020 | | | | |
| 2022 | | | | BUR | |
| 2023 | The map in Year 2022 | First NFI | | | |
| 2024 | | | | NC/BTR | |
| 2025 | The map in Year 2024 | | | | |
| 2026 | | | | BTR | |
| 2027 | The map in Year 2026 | | | | |
| 2028 | | Second NFI | | NC/BTR | |
| 2029 | The map in Year 2028 | | | | |
| 2030 | | | | BTR | End year of Vision 2030 |

# Chapter 8. Future Improvement

The following considerations will be made in the future improvement programme

## 8.1 Improvements in the NFMS based on Proposals in the FRL

The FRL submitted to the UNFCCC identified the areas of improvement in the NFMS

1. Implementation of an NFI to allow provision of site specific (based on strata and substrata) emission factors. This enhances the certainty for reporting and allows Kenya to use conventional statistics for uncertainty assessment because bootstrap simulation was used as an alternative due to data limitation
2. Enhancing land cover mapping to
    a. Accurately capture all the land cover classes
    b. Provide short term mapping intervals (e.g. annual) to allows better capturing of land cover changes
    c. Use of the pixel based approach that allows monitoring of activities at the pixel level to reduce uncertainties that result from analysing data based on net area changes
    d. Improving the mapping of dryland forests which have deciduous trees that constantly imply large changes in terms of afforestation and deforestation
3. Implementing the NFI to avail data for pools that have been estimated from the IPCC defaults
    a. Growth rates arising from afforestation
    b. Shoot root ratios for Below ground Biomass
    c. Provision of information that allows estimation of non-covered pools; Dead wood, litter and Soil Organic Carbon
4. Provision of information that allows estimation of An estimate for the Harvested wood products (post deforestation factors) because the use of instantaneous oxidation for all deforestation may exaggerate emissions
5. Developing a system for monitoring non $CO_2$ emissions e.g. $CH_4$ from mangrove forests and biomass burning, and $N_2O$ from forest fires

## 8.2 Improvement on the NFMS based on Proposals from National REDD+ Strategy

Some of the proposal that have arisen in the development of the National strategy for REDD+ include

1. Supporting methodologies for estimating the tree component on farms. It is noted that the current mapping methodology identifies changes in land cover and does not consider any planting activities. This need arises from Kenya's tree cover strategy that aims at identifying the component of planted trees that survives and forms forests. This is an important activity in PaMs monitoring
2. Developing a method for monitoring private plantations in a similar manner as has been done for public plantations. This requires georeferencing these forests and providing information about changes occurring here just as is being done for public plantations. In such forests, it is proposed that species specific or site-specific Emission factors be developed
3. Developing a method that includes participation of communities in NFI e.g. testing the feasibility of using Survey123 among community groups
4. Considering the role of conservation of carbon stocks as a REDD+ activity
5. Considering the application of results from the KWS and NMK in enhancing biodiversity indicators identified from the NFI. This makes biodiversity not a point assessment programme as indicated in

the ICRFA manual but an integrated process that allows accurate reporting for the variety of ecosystems. This need arises from the fact that biodiversity has been used in enhancing feasibility of Carbon projects in Kenya as illustrated in the Wildlife Carbon Works project of Kasigau

## 8.3 Participatory Approach

The Forest Conservation and Management Act, 2016 identifies participation of communities and private sector in forest management. The Act identifies community participation through Communities Forest Associations (CFAs). It is noted that there are other community groups that may not belong to CFAs. Similarly private sector groups and individuals provide an opportunity for monitoring and reporting on forest resources.

The NFMS has provided standard methodologies for monitoring and reporting forest resources. In cases where community groups will be involved, training of these communities will be done to allow them participate in data collection and submission using the Conventional methods described in this document for either the NFI, validation of land cover maps and land cover change maps and validation of deforestation based on deforestation alerts.

Involvement of communities and private sector facilitates not only inclusion but also makes these groups better placed to protect the forest resources. A pilot survey in Kirisia forest[2] indicated that community involvement in forest inventories can reduce the cost of data collection in by 90%

## 8.4 Non Carbon Benefits

The monitoring of non-carbon benefits such as environmental safeguards is a consideration for future improvement. In the case of Kenya they include biodiversity as described in chapter 4, water catchment, climate amelioration, enhancement of agricultural and forested landscapes through control of soil erosion and landslides and enhancement of livelihoods from tree products can be monitored when a system for collecting such information is available. It is noted that Kenya is in the final processes of identifying REDD+ related safeguards and also developing a system for monitoring such safeguards. This system when fully finalised should be embedded in the NFMs as a future improvement activity.

[2] Development of a Community Based Carbon Monitoring System for Kirisia (Leroghi) Forest. A report submitted to the Capacity, Policy and Financial Incentives for PFM in Kirisia Forest and integrated Rangelands Management project (GCP/KEN/073/GFF). FAO Kenya

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**Appendix 1 Land Cover / Land Use statistics from 2002 to 2018 for AD**

For the development of FRL, the Land Cover / Land Use Maps are selected based on LANDSAT imagery quality and cloud cover ratio. And it is divided by individual forest type of ecological zone, such as Montane and western rain forests, Costal and mangrove forests, Dryland forests and Plantation forests.

**Land Cover statistics generated for each year used in the reference period**

| Land Use Strata | 2002 | | 2006 | | 2010 | | 2014 | | 2018 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Area (ha) | % | Area (ha) | % | Area (ha) | % | Area (ha) | % | Area (ha) | % |
| Dense Forest | 2,057,649 | 3.5 | 2,139,703 | 3.6 | 2,463,674 | 4.2 | 2,558,363 | 4.3 | 2,205,189 | 3.7 |
| Moderate Forest | 1,021,083 | 1.7 | 657,767 | 1.1 | 889,327 | 1.5 | 609,436 | 1.0 | 816,174 | 1.4 |
| Open Forest | 591,035 | 1.0 | 522,508 | 0.9 | 525,469 | 0.9 | 415,061 | 0.7 | 441,173 | 0.7 |
| **Sum Forests** | **3,669,768** | **6.2** | **3,319,978** | **5.6** | **3,878,470** | **6.6** | **3,582,861** | **6.1** | **3,462,536** | **5.8** |
| Wooded Grassland | 33,447,438 | 56.5 | 32,286,628 | 54.5 | 31,742,295 | 53.6 | 32,388,566 | 54.7 | 32,271,452 | 54.5 |
| Open Grassland | 8,985,269 | 15.2 | 9,299,024 | 15.7 | 9,331,841 | 15.8 | 8,821,893 | 14.9 | 8,980,656 | 15.2 |
| **Sum grassland** | **42,432,707** | **71.7** | **41,585,652** | **70.2** | **41,074,136** | **69.4** | **41,210,459** | **69.6** | **41,252,109** | **69.7** |
| Perennial Cropland | 281,755 | 0.5 | 299,776 | 0.5 | 261,821 | 0.4 | 299,727 | 0.5 | 284,357 | 0.5 |
| Annual Cropland | 4,995,761 | 8.4 | 5,798,968 | 9.8 | 5,800,963 | 9.8 | 5,901,652 | 10.0 | 6,455,816 | 10.9 |
| **Sum cropland** | **5,277,516** | **8.9** | **6,098,743** | **10.3** | **6,062,784** | **10.2** | **6,201,378** | **10.5** | **6,740,173** | **11.4** |
| Vegetated Wetland | 29,327 | 0.0 | 40,541 | 0.1 | 45,956 | 0.1 | 38,868 | 0.1 | 40,212 | 0.1 |
| Open Water | 1,212,707 | 2.0 | 1,177,785 | 2.0 | 1,215,342 | 2.1 | 1,223,689 | 2.1 | 1,227,320 | 2.1 |
| **Sum Wetland** | **1,242,034** | **2.1** | **1,218,326** | **2.1** | **1,261,298** | **2.1** | **1,262,557** | **2.1** | **1,267,532** | **2.1** |
| Settlements &Otherland | **6,581,764** | **11.1** | **6,981,089** | **11.8** | **6,927,099** | **11.7** | **6,946,533** | **11.7** | **6,481,438** | **10.9** |
| **Grand Total** | **59,203,788** | **100.0** | **59,203,788** | **100.0** | **59,203,788** | **100.0** | **59,203,788** | **100.0** | **59,203,788** | **100 .0** |

**Appendix 2 Accuracy assessment of Land Cover / Land Use Map 2018**

Randomly generated sampling points as ground referencing were prepared for the 2018 map as the land cover / land use map verification exercise. A total of 3649 sampling points were verified by not only ground referencing survey but also utilizing aerial photo image and high resolution satellite image such as Google Earth. For utilizing high resolution image such as aerial photos, it was for sampling points on non-accessibility area and security situation zone.

The accuracy assessment results was 76.04 % for the 2018 map. The following tables illustrate the accuracy assessment for the 2018 map. Table 1 correct ness of the 2018 map and Table 2 error matrix of the 2018 map.

**Table 1 Correctness of the 2018 map**

| Class Name | Reference Totals | Classified Totals | Number Correct | Producers Accuracy | Users Accuracy |
|---|---|---|---|---|---|
| **Dense Forest** | 270 | 232 | 171 | 63.33% | 73.71% |
| **Moderate Forest** | 213 | 174 | 87 | 40.85% | 50.00% |
| **Open Forest** | 152 | 118 | 51 | 33.55% | 43.22% |
| **Wooded Grassland** | 1084 | 1157 | 945 | 87.18% | 81.68% |
| **Open Grassland** | 499 | 599 | 413 | 82.77% | 68.95% |
| **Perennial Cropland** | 216 | 230 | 169 | 78.24% | 73.48% |
| **Annual Cropland** | 875 | 846 | 696 | 79.54% | 82.27% |
| **Vegetated Wetland** | 86 | 61 | 50 | 58.14% | 81.97% |
| **Open Water** | 41 | 36 | 30 | 73.17% | 83.33% |
| **Otherland** | 212 | 195 | 162 | 76.42% | 83.08% |
| **Totals** | 3648 | 3648 | 2774 | | |
| **Overall Classification Accuracy =** | | 76.04% | | | |

**Table 2 Error Matrix of the 2018 map**

| Classified Data | Dense Forest | Moderate Forest | Open Forest | Wooded Grassland | Open Grassland | Perennial Cropland | Annual Cropland | Vegetated Wetland | Open Water | Otherland | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dense Forest | 171 | 35 | 8 | 4 | 4 | 2 | 5 | 0 | 2 | 1 | 232 |
| Moderate Forest | 36 | 87 | 34 | 6 | 3 | 1 | 7 | 0 | 0 | 0 | 174 |
| Open Forest | 7 | 33 | 51 | 6 | 0 | 0 | 21 | 0 | 0 | 0 | 118 |
| Wooded Grassland | 9 | 8 | 13 | 696 | 16 | 30 | 50 | 1 | 18 | 5 | 846 |
| Open Grassland | 17 | 12 | 9 | 15 | 169 | 0 | 6 | 1 | 1 | 0 | 230 |
| Perennial Cropland | 3 | 1 | 0 | 86 | 13 | 413 | 44 | 0 | 10 | 29 | 599 |
| Annual Cropland | 27 | 35 | 34 | 38 | 11 | 50 | 945 | 1 | 1 | 15 | 1,157 |
| Vegetated Wetland | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 30 | 3 | 0 | 36 |
| Open Water | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 5 | 50 | 0 | 61 |
| Otherland | 0 | 0 | 3 | 18 | 0 | 3 | 5 | 3 | 1 | 162 | 195 |
| **Total** | **270** | **213** | **152** | **875** | **216** | **499** | **1,084** | **41** | **86** | **212** | **3,648** |