Analysis of Land Cover / Land Use in Kenya

Preface

Land Cover / Land Use map for the year of 1990 to 2014 was developed in the project of Readiness for REDD+ component of the Capacity Development project for sustainable forest management in the republic of Kenya. Land Cover / Land Use Change map was made using this map by extraction of the area where land cover has been changed.

The main object of this report is to analyze the Land Cover / Land Use map to understand characteristics of forest change in Kenya, and to consider REDD+ activities in the future.

1. Development of the Land Cover / Land Use Change map

1.1. Data to be used

The Land Cover / Land Use map was developed by use of satellite data of LANDSAT4, 5, 7 and 8 from 1990 to 2014.

1.2. Period Covered

In Kenya, the disturbance of clouds in the satellite data or noise effect of satellite imagery were examined carefully, and the Land Cover / Land Use maps of 1990, 2000, 2010, 2014 in which these effects are relatively small were developed. As for Land Cover/ Lane Use Change map three periods of the year 1990 to 2000, 2000 to 2010 and 2010 to 2014 were developed.

1.3. Definition of Forest

Definition of forest in Kenya was made for reporting to the UNFCCC. Forestlands are areas occupied by forests and characterized by tree crown cover ≥ 15%, an area ≥ 0.5ha and tree height ≥ 2.0m. Forestlands also include areas managed for forestry where trees have not reached the height of 2.0m but with potential to do so (*1*). In Land Cover/ Land Use map and Land Cover and Land Use Change map forest was extracted in accordance with this definition.

1.4. Imagery analysis and Land Cover / Land Use map development

Random Forest classification method was used for image analysis of satellite data. After the machine learning using the training site and the verification of the field study based on the supervised data, the Land Cover / Land Use classification was decided. In this analysis, 1pixel is 0.09ha (30×30m), and the smallest unit in the classification consists of six or more pixels of the adjacent in the vertical or horizontal or diagonal position.

Land Cover / Land Use Change map was developed by detecting the area where the change was observed in the land use category in comparison of two Land Cover / Land Use maps before and after 1990, 2000, 2010, 2014.

1.5. Classification of the Land Cover / Land Use

The Classification of the Land Cover / Land Use in Kenya is classified into six categories: Forest Land, Grassland, Wetland, Settlements, Other Lands, according to the IPCC standards. Besides, the Forest Land is classified into four forest types shown in the figure of the forest classification in Kenya (Figure 1.5.1), i.e. Montane and Western Rain Forests (M&W Forests), Mangroves and Coastal Forest (M&C Forest), Plantations and Dryland Forest (D Forest), further it is subdivided into dense (canopy closure ≥ 65%), Moderate (canopy closure between 40 and 65%) and Open (canopy closure ≥ 15% but less than 40%) based on the canopy closure rate. In addition, Cropland is classified into Perennial Cropland and Annual Cropland, Grassland is classified into Wooded Grassland and Open Grassland, Wetland is classified into Vegetated Wetland and Water Body. Table 1.5.1 shows the classification list of the Land Cover / Land Use map.

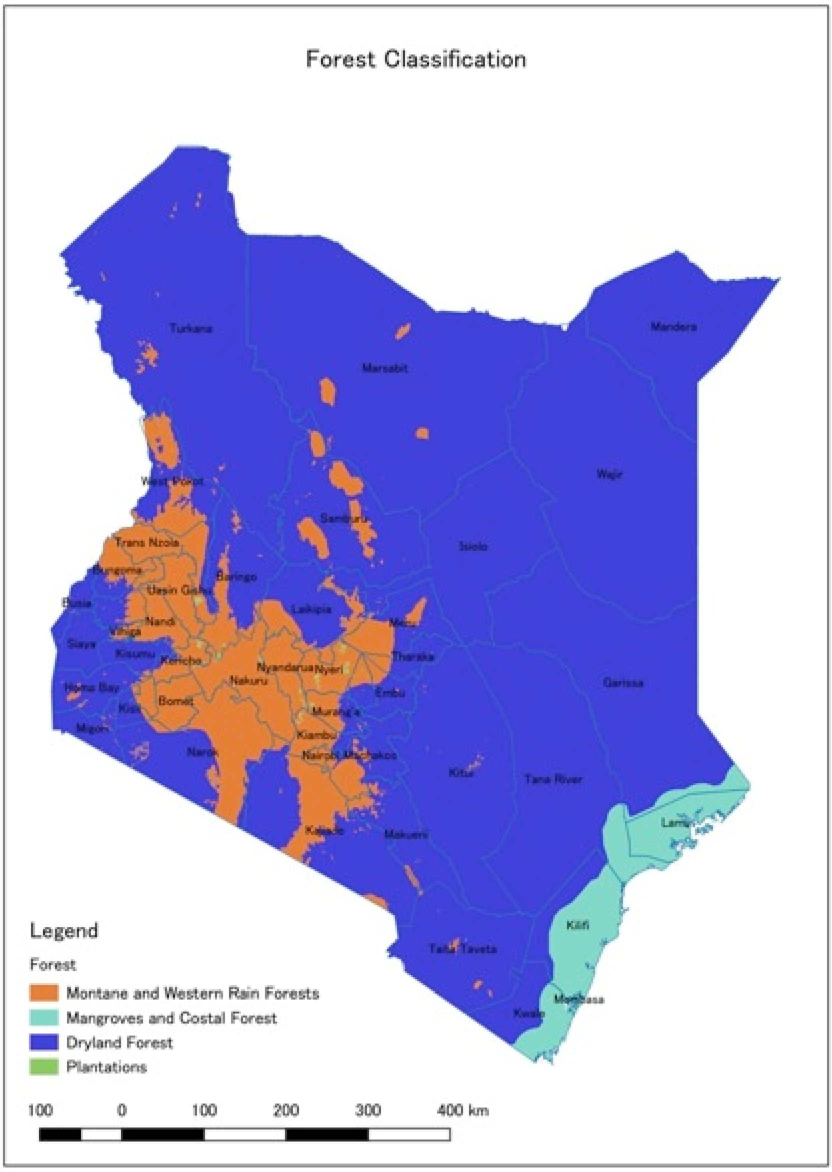

Figure 1.5.1 Forest land classification

Table1.5.1 List of Land Cover / Land Use Classification

Land Cover/Land Use		Class
Forest Land	Montane and Western Rain Forests (M&W Forests)	Dense
		Moderate
		Open
	Mangroves and Costal Forest (M&C Forest)	Dense
		Moderate
		Open
	Dryland Forest (D Forest)	Dense
		Moderate
		Open
	Plantations	Dense
		Moderate
		Open

Land Cover/Land Use	Class
Cropland	Annual Cropland
	Perennial Cropland
Glassland	Open Grassland
	Wooded Grassland
Wetland	Water body
	Vegetated Wetland
Settlements / Other Lands (Other Lands)	-

1.6. The classification of the Land Cover / Land Use Change

Table 1.6.1 shows the classification list of the Land Cover / Land use Change map that is used for development of Land Cover/ Land Use Change map. In addition, the legend of the Land Cover / Land Use Change map and the response to the REDD+ activities selected by Kenya

Table 1.6.1 Land Cover / Land Use Change classification and REDD+ activities

No	Forest Cover Change	The Legend of Forest Cover Change Map	REDD+ activities
1	Forest remaining as Forest (No Change)	Forest (No Change)	-
2	Forest remaining as Forest (Degradation)	Forest (Degradation)	Reducing emissions from degradation
3	Forest remaining as Forest (Enhancement)	Forest (Enhancement)	Enhancement of forest carbon stocks
4	Plantations remaining as Plantations	Plantations	Sustainable management of forests
5	Cropland converted to Forest	Cropland to Forest	Enhancement of forest carbon stocks
6	Grassland converted to Forest	Grassland to Forest	Enhancement of forest carbon stocks
7	Cropland and Grassland converted to Plantations	Cropland and Grassland to Plantations	Sustainable management of forests
8	Other Land uses converted to Forest	Wetland and Other Lands to Forest	Enhancement of forest carbon stocks
9	Forest converted to Cropland	Forest to Cropland	Reducing emissions from deforestation
10	Forest converted to Grassland	Forest to Grassland	Reducing emissions from deforestation
11	Plantations converted to Cropland and Grassland	Plantations to Cropland and Grassland	Sustainable management of forests
12	Forest converted to Other Land uses	Forest to Wetland and Other Lands	Reducing emissions from deforestation

are added in the Table 1.6.1.

The Land Cover / Land Use Change area was totaled based on the summarized table in Table 1.6.2, using the Land Cover / Land Use Change map at each period of 1990-2000, 2000-2010 and 2010-2014. As a fact unrealistic change in Land Cover / Land Use such as M&W Forests to M&C Forest or the change non relation to the Forest Lands such as Cropland to Grassland are excluded.

Table 1.6.2 Summarized table of Land Cover / Land Use Change（20XX-20XX+X）

			20XX + X															
			M&W Forest			M&C Forest			D Forest			Plantations			Cropland	Glassland	Wetland	Other Lands
			D	M	O	D	M	O	D	M	O	D	M	O				
20XX	M&W Forest	D	n	dg	dg										d	d	d	d
		M	e	n	dg										d	d	d	d
		O	e	e	n										d	d	d	d
	M&C Forest	D				n	dg	dg							d	d	d	d
		M				e	n	dg							d	d	d	d
		O				e	e	n							d	d	d	d
	D Forest	D							n	dg	dg				d	d	d	d
		M							e	n	dg				d	d	d	d
		O							e	e	n				d	d	d	d
	Plantations	D										s	s	s	s	s	d	d
		M										s	s	s	s	s	d	d
		O										s	s	s	s	s	d	d
	Cropland		e	e	e	e	e	e	e	e	e	s	s	s				
	Glassland		e	e	e	e	e	e	e	e	e	s	s	s				
	Wetland		e	e	e	e	e	e	e	e	e	e	e	e				
	Other Lands		e	e	e	e	e	e	e	e	e	e	e	e				

（注） D：Dense、M：Moderate、O：Open、df：Deforestation、dg：Forest Degradation、e：Enhancement、
N：No Change、S：Sustainable Management of Forest

Ratio of forest of the Land Cover/ Land Use classification was calculated by using the area of each classification of the Land Cover / Land Use Change, and it was identified that at which forest the land Cover/Land Use Change occurs.

2. Result

2.1. Land Cover / Land Use

Area and ratio of Land Cover / Land Use at each year in Kenya is shown in Table 2.1.1. The area of Grassland is the largest in each year and occupies about 70% of the entire country. The coverage of Forest Land, including M&W Forests, M&C Forest, D Forest and Plantation has

Table 2.1.1 Area and ratio of Land Cover / Land Use

（1,000ha）

Land Cover/ Land Use	class	1990		2000		2010		2014	
M&W Forests	Dense	1,175	2.0%	978	1.7%	1,074	1.8%	1,111	1.9%
	Moderate	243	0.4%	249	0.4%	227	0.4%	203	0.3%
	Open	141	0.2%	132	0.2%	87	0.1%	105	0.2%
M&C Forest	Dense	284	0.5%	178	0.3%	304	0.5%	421	0.7%
	Moderate	297	0.5%	374	0.6%	248	0.4%	125	0.2%
	Open	12	0.0%	23	0.0%	14	0.0%	6	0.0%
D Forest	Dense	844	1.4%	972	1.6%	966	1.6%	971	1.6%
	Moderate	360	0.6%	533	0.9%	331	0.6%	287	0.5%
	Open	321	0.5%	334	0.6%	315	0.5%	305	0.5%
Plantations	Dense	63	0.1%	41	0.1%	49	0.1%	53	0.1%
	Moderate	3	0.0%	2	0.0%	3	0.0%	1	0.0%
	Open	0	0.0%	1	0.0%	0	0.0%	1	0.0%
Forest Total		3,741	6.3%	3,816	6.4%	3,618	6.1%	3,589	6.1%
Cropland	Annual Crops	3,139	5.3%	4,227	7.1%	5,786	9.8%	5,900	10.0%
	Perennial Crops	304	0.5%	223	0.4%	260	0.4%	300	0.5%
Grassland	Open Grasses	9,431	15.9%	9,774	16.5%	9,488	16.0%	8,826	14.9%
	Wooded Grass	34,847	58.9%	33,239	56.1%	31,848	53.8%	32,375	54.7%
Wetland	Water body	1,206	2.0%	1,216	2.1%	1,216	2.1%	1,224	2.1%
	Vegetated Wetland	27	0.0%	20	0.0%	45	0.1%	39	0.1%
Other Lands	-	6,505	11.0%	6,686	11.3%	6,939	11.7%	6,948	11.7%
Total		59,201	100.0%	59,201	100.0%	59,201	100.0%	59,201	100.0%

remained at 6% (approximately 3,500 ~ 3,800 thousand ha), and the proportion of Forest Land excluding Plantations was approximately M&W Forests : M&C Forest : D Forest = 3 : 1 : 3.

Figure 2.1.1 shows the percentage change of area of the Land Cover / Land Use based on the year 1990 (100%). Cropland increased from 1990, and the area in 2014 increased to about 180%. The area of Plantations decreased to less than 70% in 2000, but thereafter the area has increased, and the area in 2014 recovered to 80%. The percentage fluctuation of other Land Cover / Land Use area was less than 20%.

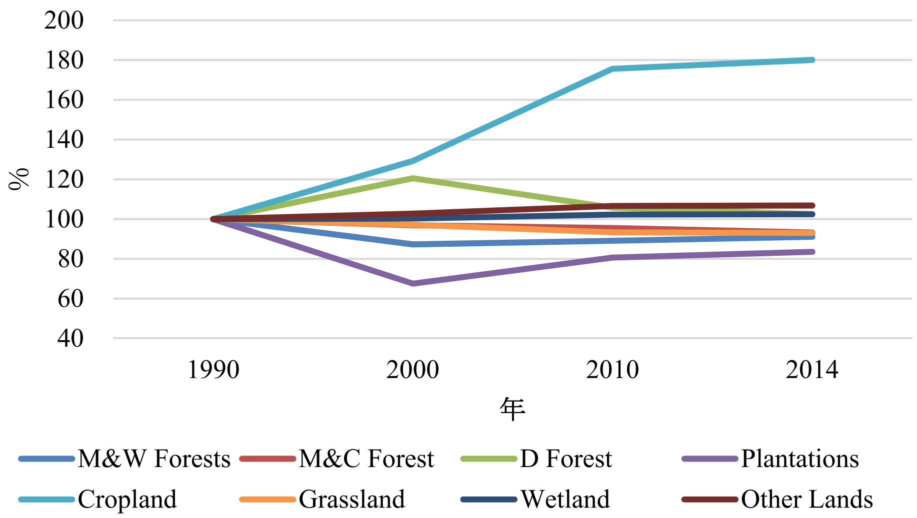

Figure 2.1.1 Percentage change of Land Cover / Land Use area based on 1990

2.2. Land Cover / Land Use Change

Figures 2.2.1 ~ 2.2.3 shows the Land Cover / Land Use Change map of each period. Throughout the 1990-2014, it is as characteristics: (1) the areas (Colored areas) where changes in the forest were extracted are concentrated in the southern part of Kenya, (2) many of the areas that are maintained as large forest are forest reserves (Green), and (3) areas where enhancement (Yellow green) and degradation (Orange) are confirmed are small compared to other areas of change. By period, in 1990-2000, there is a lot of increase of forest in D forest. In addition, a large area of Cropland conversion can be detected in some areas. In 2000-2010, the large-scale deforestation in D Forest is confirmed, and the Cropland conversion confirmed in 1990-2000 continues to occur. In 2010-2014, there are few change in the large-scale compared with other periods. In addition, Cropland conversion that had been confirmed until 1990-2010, was not confirmed in 2010-2014.

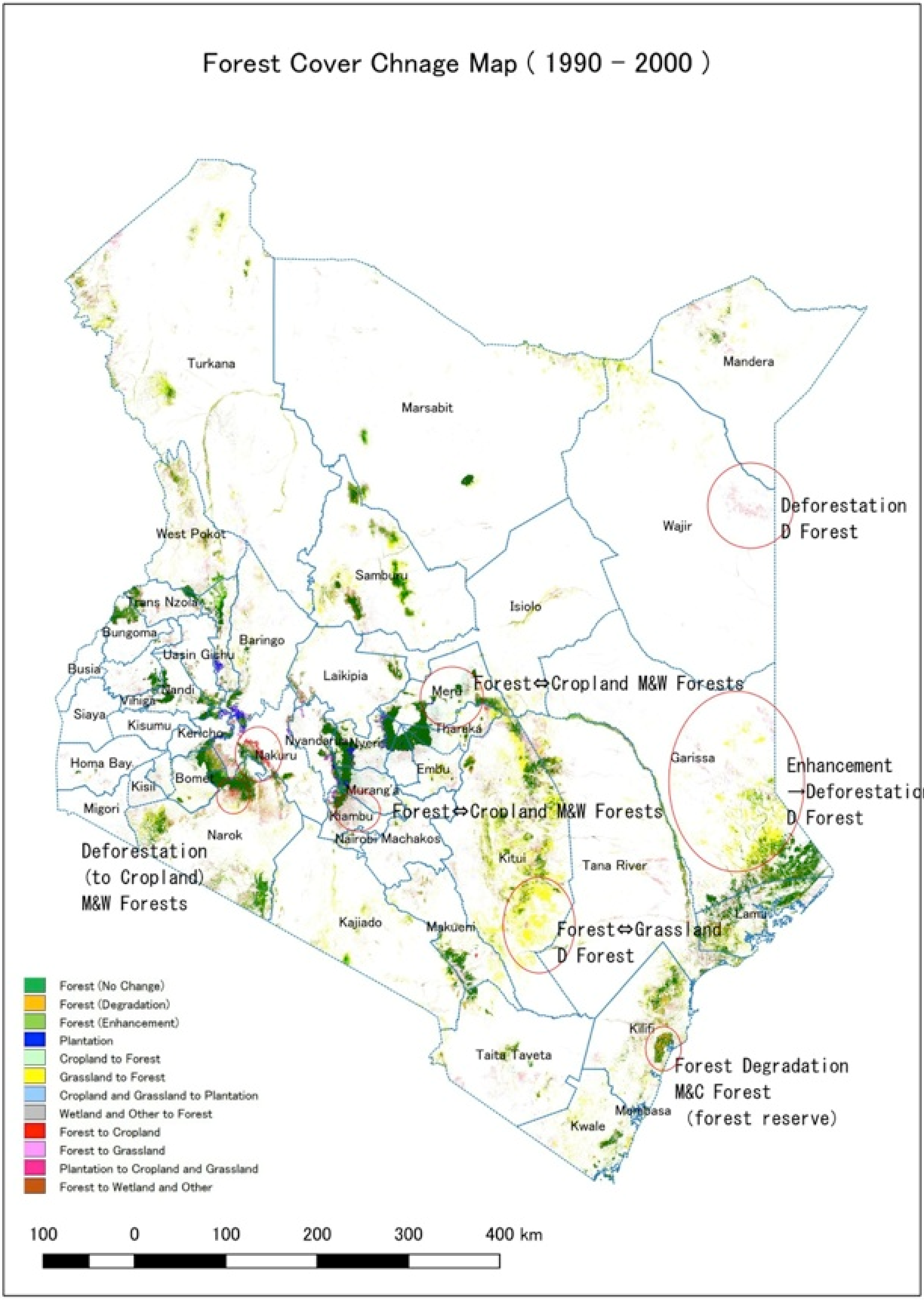

Figure 2.2.1 Land Cover / Land Use Change map（1990-2000）

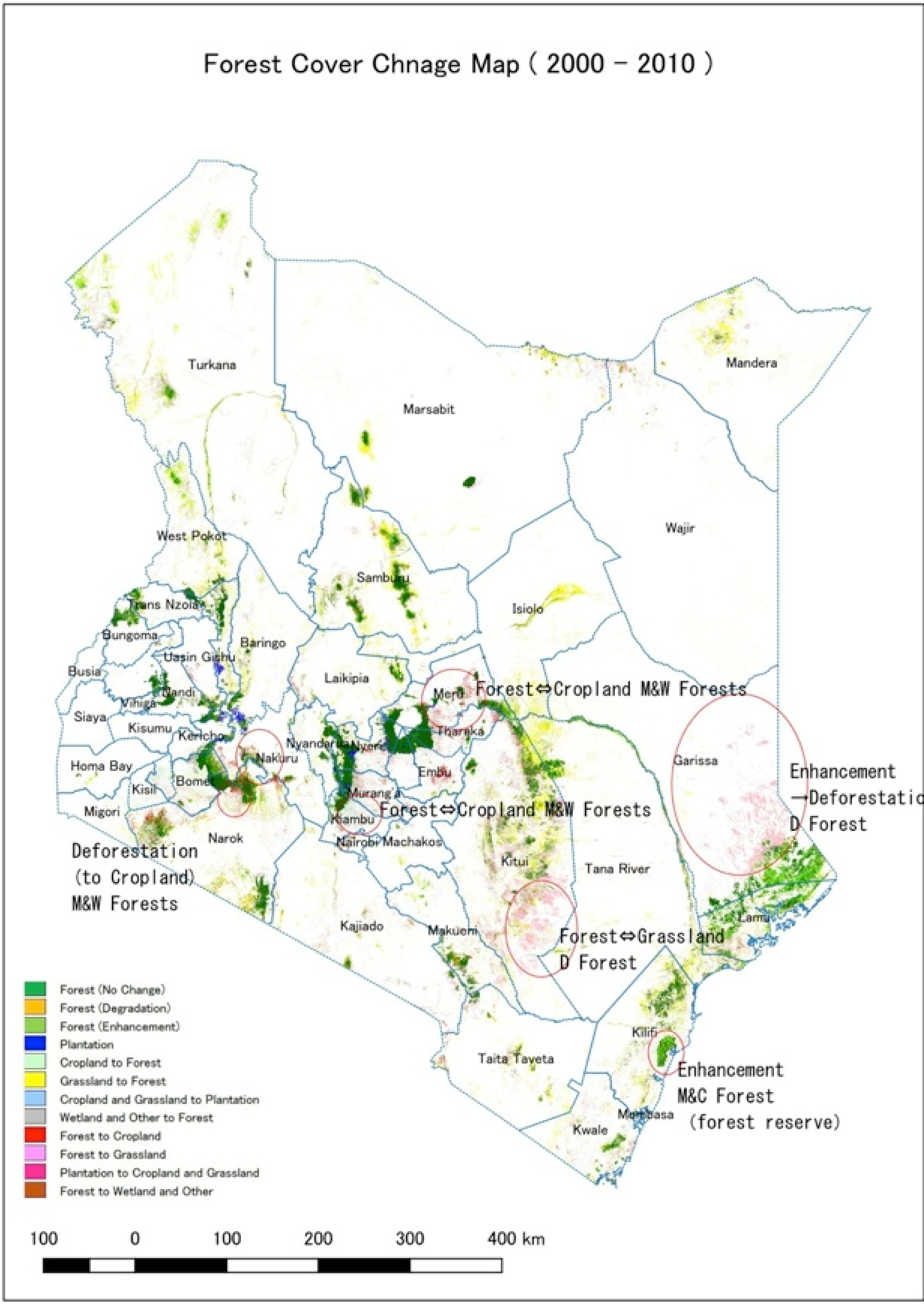

Figure 2.2.2 Land Cover / Land Use Change map (2000-2010)

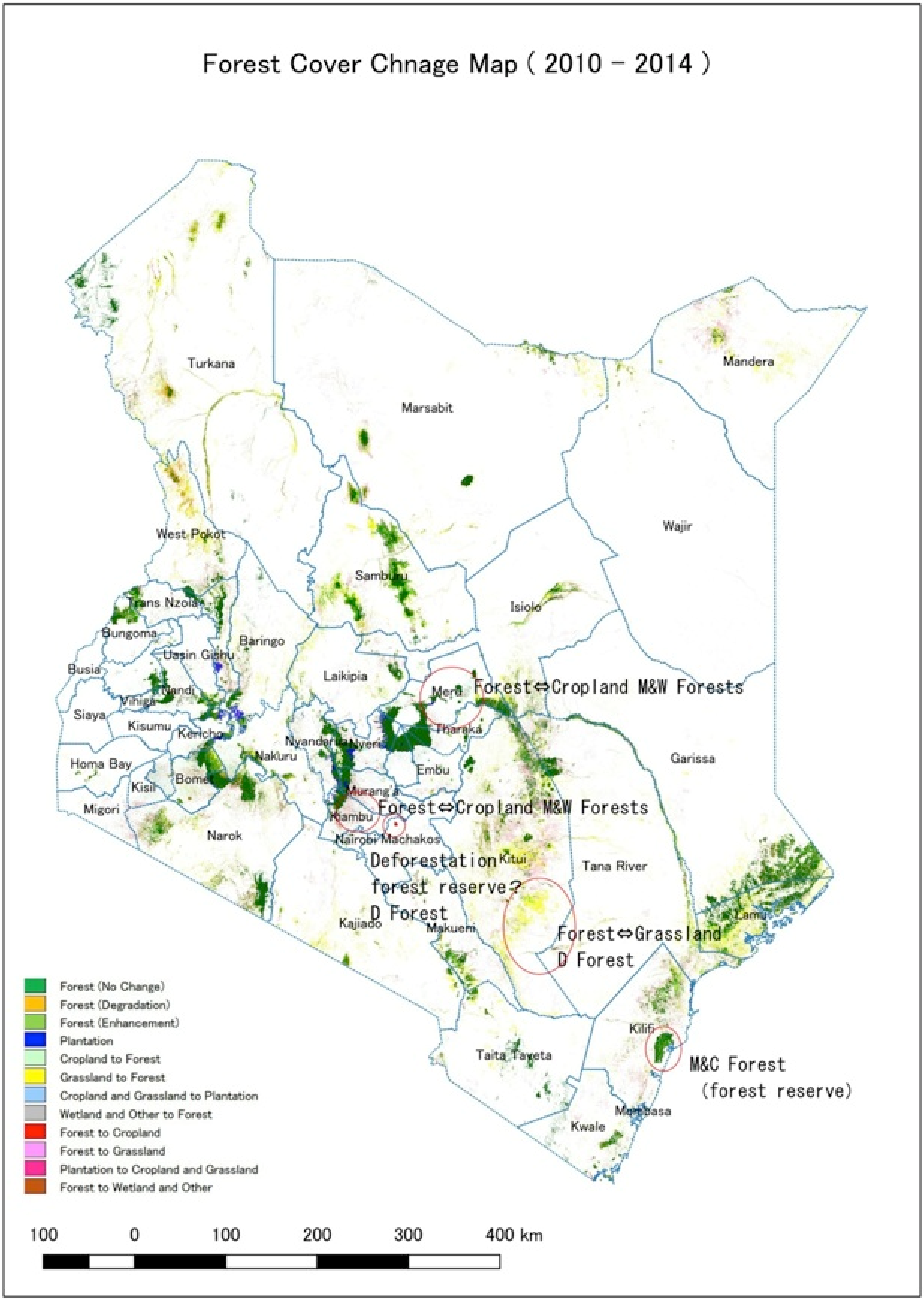

Figure 2.2.3 Land Cover / Land Use Change map （2010-2014）

Table 2.2.1 shows characteristic of forest cover change in each county that can be read from the land cover change map of each period of Figures 2.2.1~2.2.3.

Table 2.2.1 Land Cover / Land Use Change by county

County	1990-2000	2000-2010	2010-2014	Note
Kilifi	△	○	○	Arabuko Sokoke Forest Reserve
Garissa	◎	×	-	Forest ⇔ Grassland
Wajir	×		-	Forest ⇒ Grassland
Kitui	◎	×	◎	Forest ⇔ Grassland
Meru	◎	×	◎	Forest ⇔ Cropland
Machakos	-	-	×	Ol Donyo Sabuk National Park
Murang'a	◎ ×	◎ ×	◎ ×	Forest ⇔ Cropland
Kiambu	◎ ×	◎ ×	◎ ×	Forest ⇔ Cropland
Nakuru	×	×	-	Forest ⇒ Cropland
Naroku	×	×	-	Forest ⇒ Cropland

◎ : Enhancement(Non Forest to Forest) ○ : Enhancement (Forest to Forest) △ : Forest degradation × : Deforestation

In addition, Figure 2.2.4 shows area of the Land Cover / Land Use Change. In each period, Forest (No change) area showed the largest value, followed by Grassland to Forest or Forest to Grassland. In 1990- 2000 Forest (Degradation) exceeded the value of Forest (Enhancement), while in 2000-2010 and 2010-2014, Forest (Enhancement) exceeded the value of Forest (Degradation).

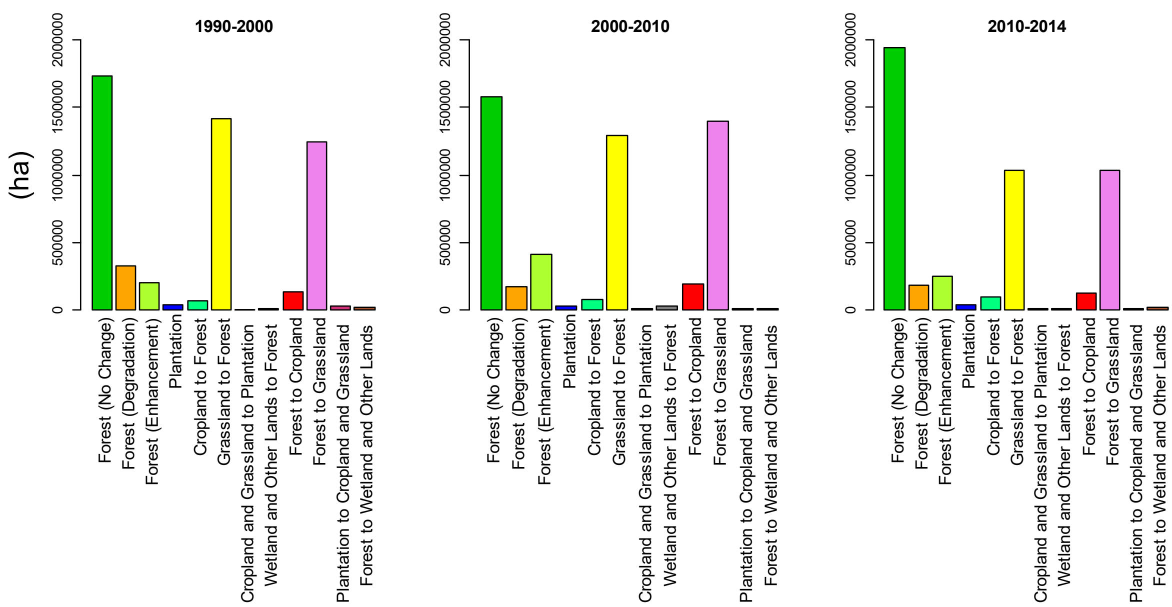

Figure 2.2.4 Area of Land Cover / Land Use Change by Land Cover / Land Use Classification

The value of the land cover change between Forest Land and Grassland was large. In the forest category of about 3,500~3,800 thousand ha of Land Cover/Land Use classification, about 1,000 thousand ha of Forest Land changed from Grassland to Forest Land, and about 1,000 thousand ha changed from Forest Land to Grassland at each period. Figure 2.2.5 shows proportion of each forest type in the Land Cover / Land Use change area for each Land Cover

/ Land Use classification. As shown in “2.1 Land Cover and Land Use”, the area ratio of M&W Forests, M&C Forest and D Forest is approximately 3:1:3 = 43% : 14% : 43%. Comparing the occurrence ratio of the Land Cover / Land Use Change, the ratio of M&C Forest in the area of the Forest (Enhancement) is low in 1990-2000, and high in 2000-2010 and 2010-2014. The ratio of the change between Forest and Cropland in M&W Forests is high, and the ratio of M&C Forest is low. In addition, there was a high proportion of D Forest in the change between Forest and Grassland as well as the change between Forest and Wetland and Other Lands. The area of Dense, Moderate and Open forest, which changed from Grassland to D Forest, was 530 thousand ha: 300 thousand ha: 221 thousand ha respectively in 1990-2000, 460 thousand ha: 169 thousand ha: 212 thousand ha respectively in 2000–2010 and 385 thousand ha: 124 thousand ha: 147 thousand ha respectively in 2010-2014. Dense showed the highest value in all period.

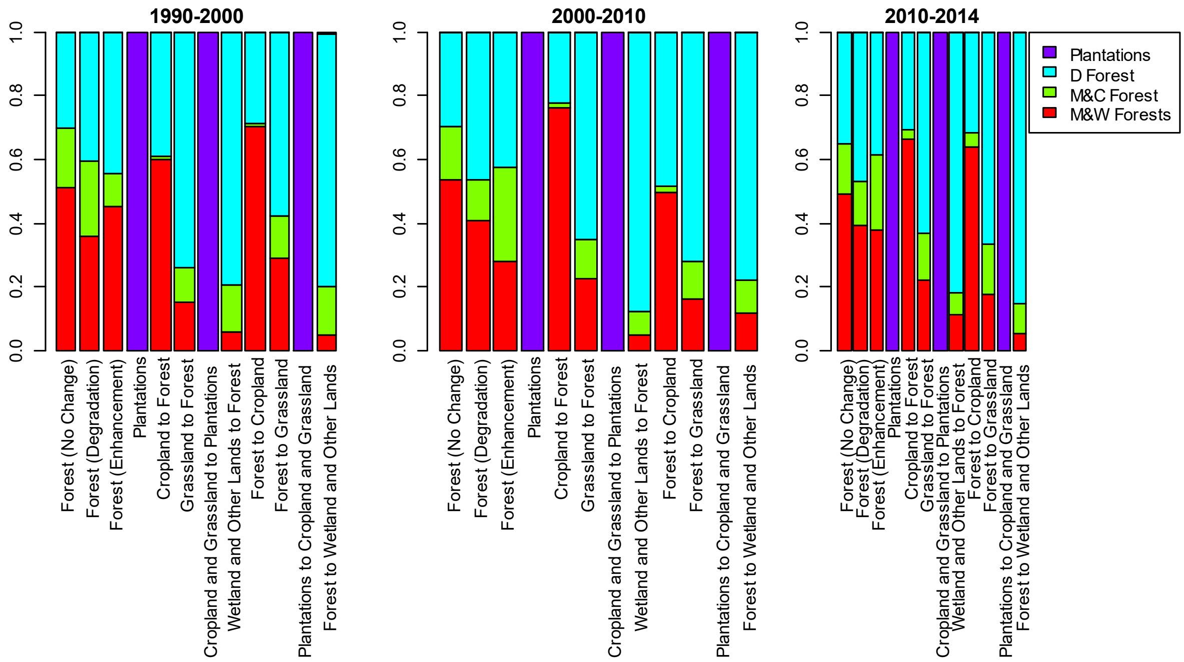

Figure 2.2.5 Rate of Land Cover / Land Use Change by Forest Classification

In addition to the extraction of general change, Figures 2.2.6 and 2.2.7 show the details of the change in order to see more characteristic land cover/land use change. In M&W Forests, there were many changes between Forest and Cropland, and two kinds of trend were confirmed in this change. First, the change between Forest and Cropland is found in a group form in a small area, and the change occurs reversibly, and the Land Cover / Land Use Change is very fluid (Figure 2.2.6). Another point is a change to Cropland from a large-scale Forest Land seen in Nakuru county and Narok county, and this change has never been diverted to Forest again after conversion to the Cropland. In D Forest, large-scale changes between Forest and Grassland were confirmed in many cases (Figure 2.2.7). In this change, the case where the change occurs reversibly, and other case where Forest disappears unilaterally was confirmed.

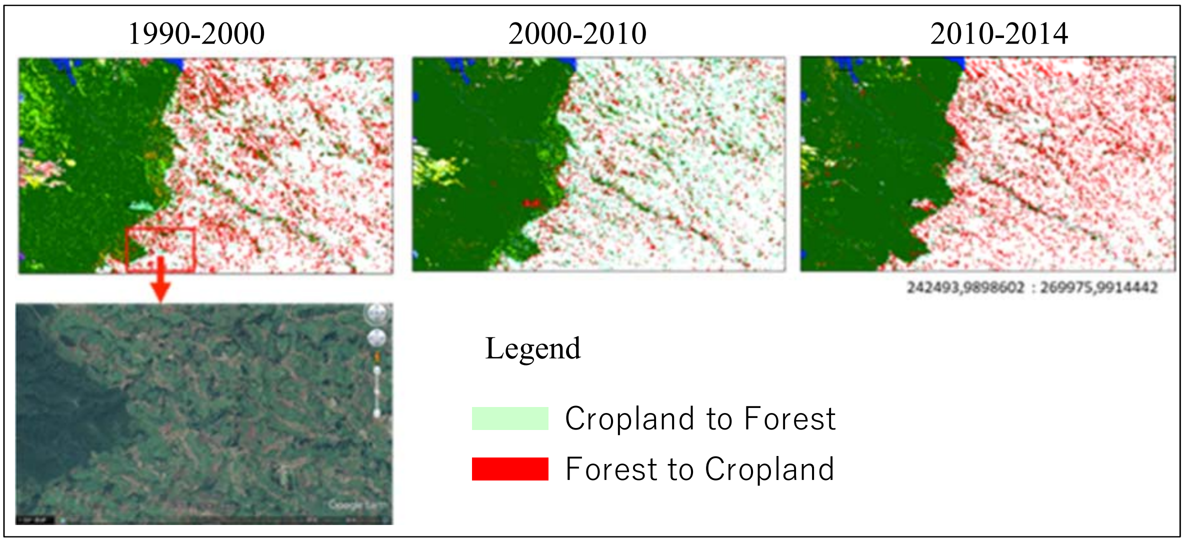

Figure 2.2.6 Detail of Land Cover / Land Use Change 1：between Forest（M&W Forests）to Cropland（Boundary between Murang'a county and Kiambu county）

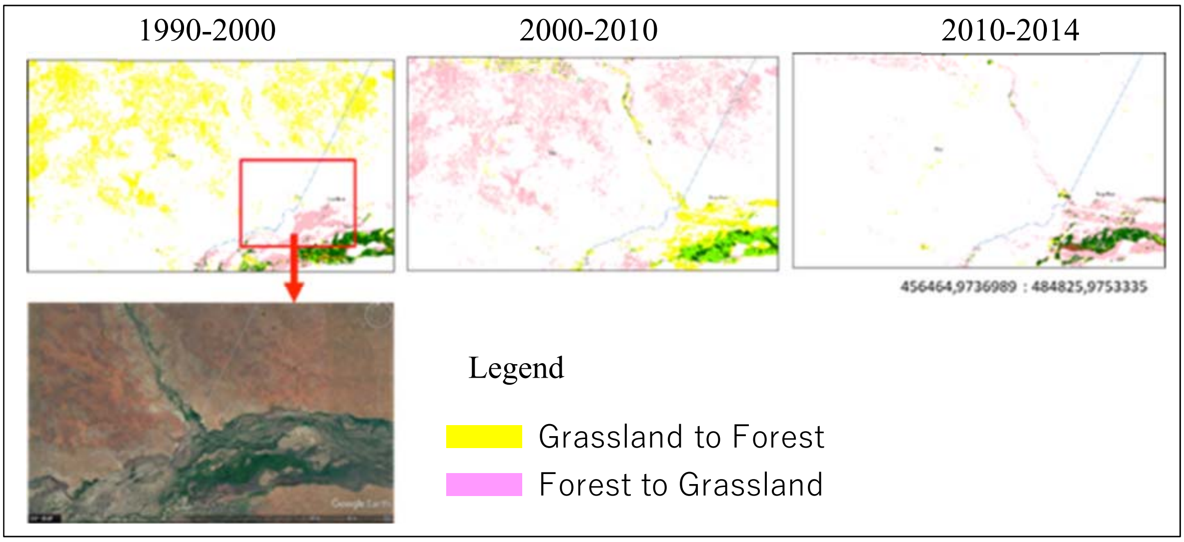

Figure 2.2.7 Detail of Land Cover / Land Use Change 2 : between Forest(D Forest) to Grassland（Boundary between Kitui county and Mto Tana county）

3. Discussion

3.1. Conversion of Forest to Cropland

From fluctuation of the area of each Land Cover / Land use classification, Cropland has the highest growth rate since 1990 in Kenya (Figure 2.1.1). The area of Annual Crops is large compared with Perennial Crops in Cropland (Table 2.1.1), and many of Cropland are presumed to be used for the food self-sufficiency such as maize and cassava. In developing countries, the increase in demand for food and firewood materials (household fuels) due to population growth has led to the conversion of forest to cropland and excessive intake of firewood, and is feared to lead to deforestation and forest degradation. Population trends and human activities in Kenya seem to be one of the factors of the Land Cover / Land Use Change (*2*). Figure 3.1.1 shows the population density of Kenya (*3*). From this figure, it is possible to confirm that the population in Kenya is concentrated in some regions, and the region where the population is concentrated can be divided into three parts of the central part including capital Nairobi, the west part including Kisii county and Vihiga county, the southeast part including Mombasa county. In the Land Cover / Land Use classification (Figure 1.5.1), all of the central part and a part of the west part that the population concentrates are included in M&W Forests, and the southeast part is included in M&C Forest (the rest of the west part is included in D Forest). Regarding the Land Cover / Land Use Change, the ratio of M&W Forests to the change between Forest and Cropland is high as shown in the Figure 2.2.5. A geographical relationship with a population concentration area is considered as one of the factors that are generating a lot of cropland conversion in M&W Forests. In M&W Forests, changes between Forest and Cropland have been confirmed to repeat. Therefore, in M&W Forests, it is necessary to watch in the future whether the forest won't be recovered after it is converted to the cropland. In addition, large-scale cropland conversion has been generated in M&W Forests in Nakuru county and Narok county during 1990-2000 and 2000-2010. As shown in Figure 3.1.2, the population of Kenya is in increasing trend (*4*). Since it is thought that conversion of forest to the cropland increases to secure the food source for the increasing population in the future, it is necessary to watch the trend of the Land Cover / Land Use Change especially on the region where the population concentrates. Moreover, it is important to consider a measure to conversion of forest to cropland in the future REDD+ activity based on the medium and long-term plan by cooperation with not only the forestry department but also the related ministries.

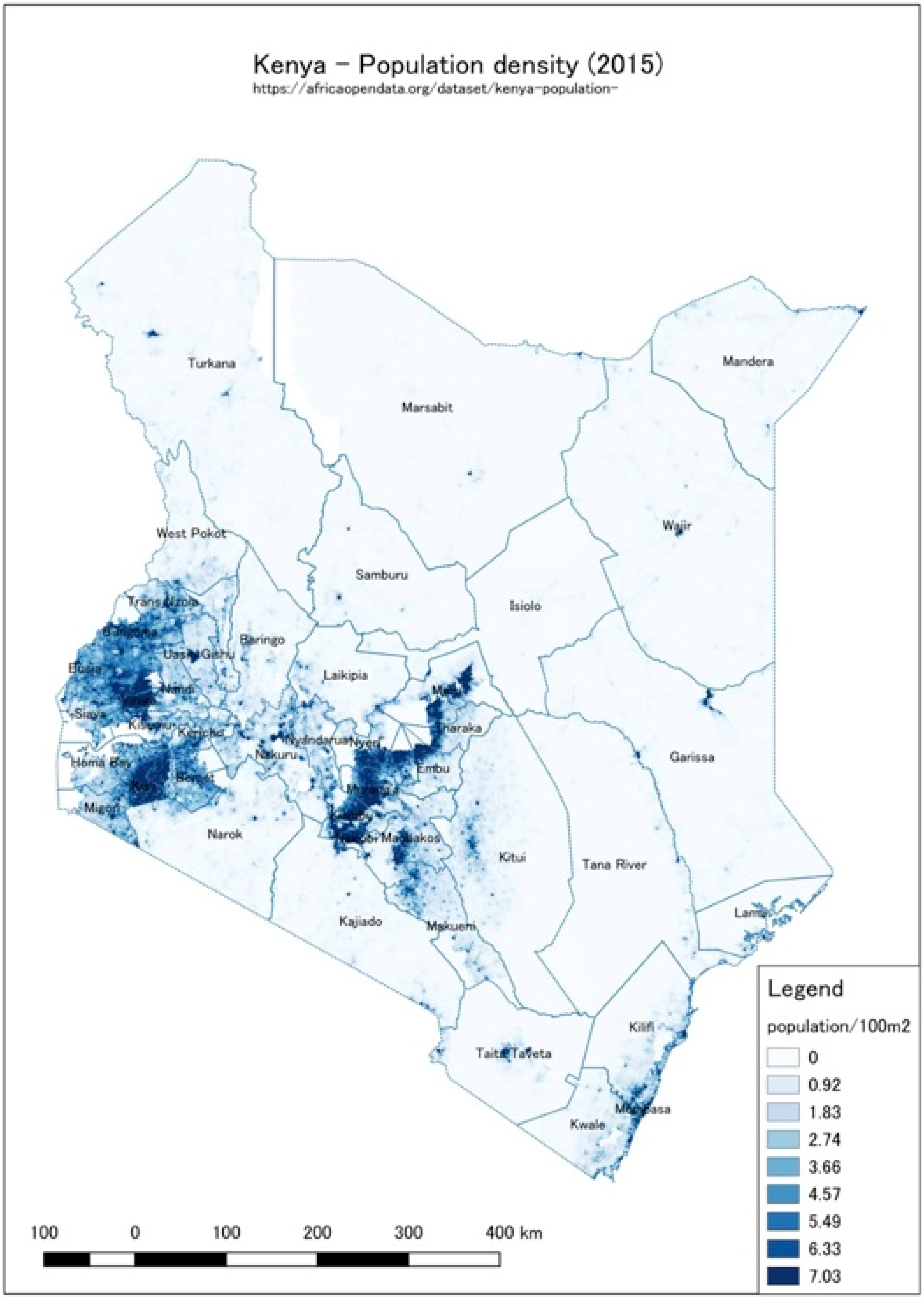

Figure 3.1.1 Population density of Kenya

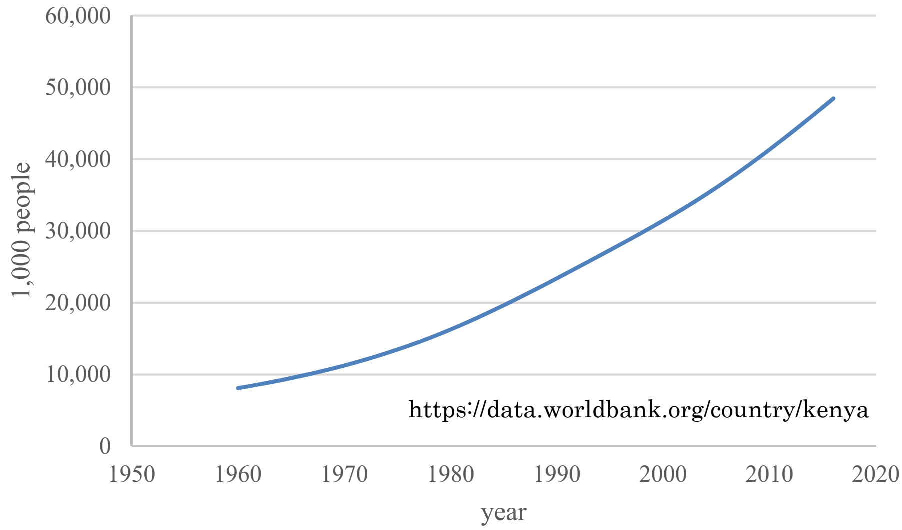

Figure 3.1.2 Population trends of Kenya

Regarding the southeast part where the population concentrates, it is included in M&C Forest, the change between Forest and cropland seen in M&C Forest is smaller than in M&W Forests. Although it is difficult to identify the cause at the present why the conversion of forest to cropland is small in C&M Forest where the population concentrates, it is presumed that there is an influence of growth pattern of the population, geographical relation of cropland and forest, etc.

3.2. Large-scale deforestation other than cropland conversion

In D Forest, a relatively large-scale change occurs between forest and grassland (For example, in Wajir county, Garissa county, Kitui county, Machakos county). In D Forest especially in the county where large-scale changes occurred in the past, activities to prevent deforestation are important such as regularly monitoring forest area where currently forest exists. It is also important to investigate the causes of the large-scale deforestation that occurred so far and it makes use for future measures.

As a result, most of Forest in Kenya has changed from the forest to grassland or from the grassland to forest in each period, and the majority of this Land Cover / Land Use Change occurred in D Forest. In D Forest, many of the forest that changed from grassland are classified into Dense Forest. The growth of forests is expected to take a long time, but this trend was not only for a period of ten years, i.e. 1990-2000 and 2000-2010, but also for a short time of four years of 2010-2014 confirms a similar result. At present, it is difficult to explain in detail the process that grassland changes to Dense Forest in D Forest. In the future, it is important to examine the process of the change through the monitoring investigation and the survey of the forest utilization and conservation by the local population, and examine the necessary conditions lead the change.

3.3. Examination on the analysis method of the Land Cover / Land Use Change

This analysis is able to grasp the trend of land cover change in Kenya, but it is difficult to understand the details of some changes at present. The Land Cover / Land Use Change map was developed by use of the change in the Land Cover / Land Use classification extracted by comparison of the Land Cover / Land Use map at the starting point and the ending point of the period. However, there is no criterion for extraction of change through the whole period from 1990 to 2014, and it is not able to consider the change simply the same at each period. In the future, it is necessary to improve the accuracy of analysis by examining the improvement of the method to develop the Land Cover / Land Use Change map.

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（3）Andy Tatem (2017) Kenya – Population density (2015) URL :https://www.africaopendata.org/tl/dataset/kenya-population-density-2015 (2017.8.21download)

（4）World Bank URL: https://data.worldbank.org/country/kenya?display= (2017.9.15download)

Appendix

Appendix 1: Area of Land Cover/Land Use change in each reference periods (ha)（AD）

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

			2000																			
			Montane and Western Rain Forests			Mangroves and Costal Forest			Dryland Forest			Plantation			Cropland		Glassland		Wetland		Other Lands	
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Annual Cropland	Perennial Cropland	Open Grassland	Wooded Grassland	Water Body	Vegetated Wetland	Settlement	Other
1990	Montane and Western Rain Forests	Dense	787,762	78,175	25,152	-	-	-	-	-	-	-	-	-	64,990	13,714	62,089	142,004	230	28	-	372
		Moderate	63,308	73,871	12,138	-	-	-	-	-	-	-	-	-	8,998	2,736	19,011	62,246	55	2	-	267
		Open	12,900	18,099	25,741	-	-	-	-	-	-	-	-	-	4,573	1,069	12,384	65,540	68	22	-	189
	Mangroves and Costal Forest	Dense	-	-	-	137,269	72,999	1,640	-	-	-	-	-	-	465	46	7,888	62,617	533	139	-	371
		Moderate	-	-	-	18,799	182,990	3,646	-	-	-	-	-	-	781	94	9,717	78,118	1,333	1,073	-	309
		Open	-	-	-	263	2,681	1,633	-	-	-	-	-	-	74	4	200	6,923	12	5	-	54
	Dryland Forest	Dense	-	-	-	-	-	-	351,918	78,996	27,457	-	-	-	32,563	1,561	23,600	321,152	1,642	562	-	4,850
		Moderate	-	-	-	-	-	-	54,388	119,413	24,134	-	-	-	2,998	171	15,446	138,000	1,754	733	-	2,552
		Open	-	-	-	-	-	-	14,491	23,415	52,395	-	-	-	2,118	63	15,057	205,386	464	1,279	-	6,306
	Plantations	Dense	-	-	-	-	-	-	-	-	-	33,776	1,413	650	7,430	563	11,855	6,834	0	0	-	141
		Moderate	-	-	-	-	-	-	-	-	-	1,035	309	17	253	46	433	426	0	0	-	0
		Open	-	-	-	-	-	-	-	-	-	113	14	1	29	6	45	42	0	0	-	0
	Cropland	Annual Cropland	14,960	4,321	4,057	61	607	243	13,789	6,662	2,995	1,284	62	85	1,955,411	50,372	401,236	675,625	1,724	411	-	5,308
		Perennial Cropland	15,873	3,570	1,340	25	65	4	4,015	699	416	99	14	3	107,435	118,221	12,036	39,517	203	92	-	176
	Glassland	Open Grassland	26,929	7,073	15,823	200	461	61	11,969	7,907	25,920	2,670	142	58	725,273	13,041	4,318,042	3,446,552	10,838	1,968	-	816,063
		Wooded Grassland	56,237	63,869	47,673	20,329	112,229	15,660	517,970	292,431	194,960	2,119	263	54	1,297,317	20,865	3,937,182	27,092,759	16,589	7,572	-	1,151,387
	Wetland	Water body	102	177	8	394	906	26	1,248	963	558	0	0	0	5,783	91	6,980	15,786	1,164,673	691	-	8,102
		Vegetated Wetland	94	139	18	31	104	3	481	575	393	3	0	0	2,284	64	4,900	7,755	3,587	5,679	-	525
	Other Lands	Settlement	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Other	143	117	28	184	555	40	1,377	1,501	4,646	0	0	0	8,522	206	915,494	871,781	11,999	156	-	4,688,700

			2010																			
			Montane Forest and Western Rain Forest			Mangroves and Costal Forest			Dryland Forest			Plantations			Cropland		Glassland		Wetland		Other Lands	
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Annual Cropland	Perennial Cropland	Open Grassland	Wooded Glassland	Water Body	Vegetated Wetland	Settlement	Other
2000	Montane and Western Rain Forests	Dense	753,138	46,941	13,262	-	-	-	-	-	-	-	-	-	53,793	13,758	28,432	67,617	139	57	-	1,171
		Moderate	68,994	78,243	12,077	-	-	-	-	-	-	-	-	-	13,221	2,313	7,416	66,616	131	59	-	341
		Open	35,213	11,603	15,082	-	-	-	-	-	-	-	-	-	12,663	770	9,364	47,143	14	10	-	115
	Mangroves and Costal Forest	Dense	-	-	-	135,718	17,853	373	-	-	-	-	-	-	502	21	569	21,996	358	0	-	164
		Moderate	-	-	-	115,986	126,608	3,629	-	-	-	-	-	-	2,244	122	1,245	122,707	511	0	-	545
		Open	-	-	-	984	4,689	699	-	-	-	-	-	-	291	19	56	16,059	13	0	-	147
	Dryland Forest	Dense	-	-	-	-	-	-	345,349	38,551	22,138	-	-	-	52,897	2,737	17,750	488,414	1,068	992	-	1,750
		Moderate	-	-	-	-	-	-	108,197	78,746	21,555	-	-	-	23,244	800	11,348	285,511	707	1,015	-	1,437
		Open	-	-	-	-	-	-	33,292	32,667	46,547	-	-	-	13,905	274	17,600	183,205	564	574	-	5,246
	Plantations	Dense	-	-	-	-	-	-	-	-	-	31,335	1,611	167	2,365	163	3,484	1,970	3	0	-	1
		Moderate	-	-	-	-	-	-	-	-	-	1,296	389	14	126	11	177	201	0	0	-	2
		Open	-	-	-	-	-	-	-	-	-	709	18	3	49	16	36	37	0	0	-	0
	Cropland	Annual Cropland	34,260	3,888	3,570	450	421	40	11,714	1,816	2,793	3,240	264	20	3,107,675	86,326	295,042	655,624	5,451	3,184	-	11,520
		Perennial Cropland	14,322	1,839	197	92	171	0	557	189	65	504	22	0	86,722	102,204	2,680	13,027	63	118	-	159
	Glassland	Open Grassland	44,794	9,585	11,043	5,571	6,432	178	18,167	14,944	25,786	7,455	499	60	923,760	15,852	4,279,563	3,301,379	7,041	5,728	-	1,095,754
		Wooded Grassland	123,050	73,861	31,250	44,258	90,536	9,196	441,892	154,431	186,387	4,520	566	57	1,476,870	34,180	3,931,745	25,599,811	16,100	15,112	-	1,005,240
	Wetland	Water body	210	27	25	345	1,036	14	1,378	651	1,129	0	0	0	4,111	134	6,409	13,749	1,166,509	10,498	-	9,478
		Vegetated Wetland	13	9	3	23	285	1	454	938	866	0	0	0	3,451	382	1,132	4,676	322	7,588	-	269
	Other Lands	Settlement	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Other	491	523	136	383	128	25	5,123	8,013	7,484	31	0	0	8,441	265	873,999	958,192	16,935	310	-	4,805,196

			2014																			
			Montane and Western Rain Forests			Mangroves and Costal Forest			Dryland Forest			Plantations			Cropland		Glassland		Wetland		Other Lands	
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Annual Cropland	Perennial Cropland	Open Grassland	Wooded Grassland	Water Body	Vegetated Wetland	Settlement	Other
2010	Montane and Western Rain Forests	Dense	845,718	32,507	29,506	-	-	-	-	-	-	-	-	-	50,261	17,366	16,931	81,598	155	69	-	374
		Moderate	69,871	89,888	9,357	-	-	-	-	-	-	-	-	-	6,868	2,181	4,177	43,842	73	37	-	226
		Open	20,916	6,198	16,209	-	-	-	-	-	-	-	-	-	8,138	204	4,706	30,117	24	19	-	114
	Mangroves and Costal Forest	Dense	-	-	-	238,012	22,107	916	-	-	-	-	-	-	922	50	735	40,018	245	25	-	780
		Moderate	-	-	-	57,737	71,215	2,101	-	-	-	-	-	-	3,323	107	494	112,298	259	341	-	282
		Open	-	-	-	617	1,333	995	-	-	-	-	-	-	955	3	24	10,165	13	1	-	51
	Dryland Forest	Dense	-	-	-	-	-	-	468,621	41,540	23,396	-	-	-	25,674	1,751	9,273	391,049	1,850	510	-	2,458
		Moderate	-	-	-	-	-	-	60,602	103,758	19,484	-	-	-	3,635	266	5,974	131,579	631	708	-	4,309
		Open	-	-	-	-	-	-	25,931	11,820	105,878	-	-	-	10,481	270	17,322	135,754	716	1,136	-	5,442
	Plantations	Dense	-	-	-	-	-	-	-	-	-	40,442	598	231	3,490	303	2,221	1,800	2	0	-	5
		Moderate	-	-	-	-	-	-	-	-	-	2,367	152	20	299	12	246	268	5	0	-	0
		Open	-	-	-	-	-	-	-	-	-	190	8	2	51	0	41	30	0	0	-	0
	Cropland	Annual Cropland	48,106	6,210	3,317	2,442	324	7	22,839	3,816	3,325	2,289	55	47	4,189,597	132,239	377,102	974,841	3,599	4,742	-	11,430
		Perennial Cropland	9,763	383	143	41	54	11	1,317	255	48	393	1	0	101,656	124,283	4,927	15,779	176	283	-	833
	Glassland	Open Grassland	30,609	5,537	6,062	4,939	321	38	14,953	8,589	22,044	4,430	163	140	376,807	3,273	4,668,946	3,397,545	9,386	2,769	-	931,498
		Wooded Grassland	84,170	62,226	39,948	116,677	29,452	2,162	370,540	115,118	124,514	2,918	97	106	1,090,907	16,685	2,824,402	25,956,801	16,839	9,352	-	985,023
	Wetland	Water body	226	5	4	835	153	7	1,637	550	240	4	0	0	6,214	99	4,241	10,429	1,175,218	2,876	-	13,193
		Vegetated Wetland	80	3	6	2	0	0	1,771	473	124	3	0	0	5,985	276	2,527	11,985	5,329	15,800	-	882
	Other lands	Settlement	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Other	1,264	124	238	151	80	5	2,423	1,090	6,078	11	0	0	15,000	147	881,297	1,029,333	9,715	178	-	4,991,402

Analysis of Land Cover / Land Use Changes in Kenya

Preface

Land Cover / Land Use change map for the year 2002 to 2018 was developed in the project of Readiness for REDD+ component of the Capacity Development project for sustainable forest management in the republic of Kenya. Land Cover / Land Use Change map was made by extraction of the area where land cover has changed.

The main objective of this report is to analyze the Land Cover / Land Use Change map to understand characteristics of forest change in Kenya and to consider REDD+ activities in the future.

1. Development of the Land Cover / Land Use Change map

1.1. Utilized satellite image data

The Land Cover / Land Use map was developed by use of satellite data of LANDSAT 4, 5, 7 and 8 from 2002 to 2018.

1.2. Period for analysis

In Kenya, the disturbance of clouds in the satellite data or noise effect of satellite imagery was examined carefully, and the Land Cover / Land Use maps of 2002, 2006, 2010, 2014 and 2018 in which these effects are relatively small were developed. As for Land Cover/ Land Use Change map, four year periods i.e, 2002 to 2006, 2006 to 2010, 2010 to 2014 and 2014 to 2018 were adopted.

1.3. Definition of forest

Kenya has decided upon a definition of forest for reporting to the UNFCCC. Forestlands are areas occupied by forests and characterized by tree crown cover ≥ 15%, an area ≥ 0.5ha and tree height ≥ 2.0m. Forestlands also include areas managed for forestry where trees have not reached the height of 2.0m but with potential to do so [FAO and KFS, 2017]. In land cover / land use map and Land Cover / Land Use Change map, forest was extracted in accordance with this definition.

1.4. Imagery analysis and Land Cover / Land Use map development

Random Forest algorithm which is supervised classification method was used for image analysis of satellite image data. After the supervised classification, the Land Cover / Land Use map was generated and verified the result by ground truth survey. For satisfying to the forest definition, 1pixel is 0.09ha (30×30m), clustering to same category type with consists of six or more pixels and filtering to omitting of small cluster which is less than six pixels was applied.

Land Cover / Land Use Change map was developed by detecting the area where the change was observed in the land cover and use category in comparison between two Land Cover / Land Use maps before and after 2002, 2006, 2010, 2014 and 2018.

1.5. Classification of the Land Cover / Land Use

Land Cover / Land Use in Kenya is classified into five categories according to the IPCC standards: Forest

Land, Grassland, Wetland, Settlements, Other Lands [FAO and KFS, 2017]. Besides, the Forest Land is classified into four forest types shown in the figure of the forest strata in Kenya (Figure 1.5.1), i.e., Montane and Western Rain Forests (M&W Forests); Mangroves and Coastal Forest (M&C Forest); Plantations and Dryland Forest (D Forest). Further, it is subdivided into dense (canopy closure ≥65%), Moderate (canopy closure between 40 and 65%) and Open (canopy closure ≥ 15% but less than 40%) based on the canopy closure rate. In addition, Cropland was subdivided into Perennial Cropland and Annual Cropland, Grassland was subdivided into Wooded Grassland and Open Grassland, Wetland was subdivided into Vegetated Wetland and Water Body. Table 1.5.1 shows the classification list of the Land Cover / Land Use map.

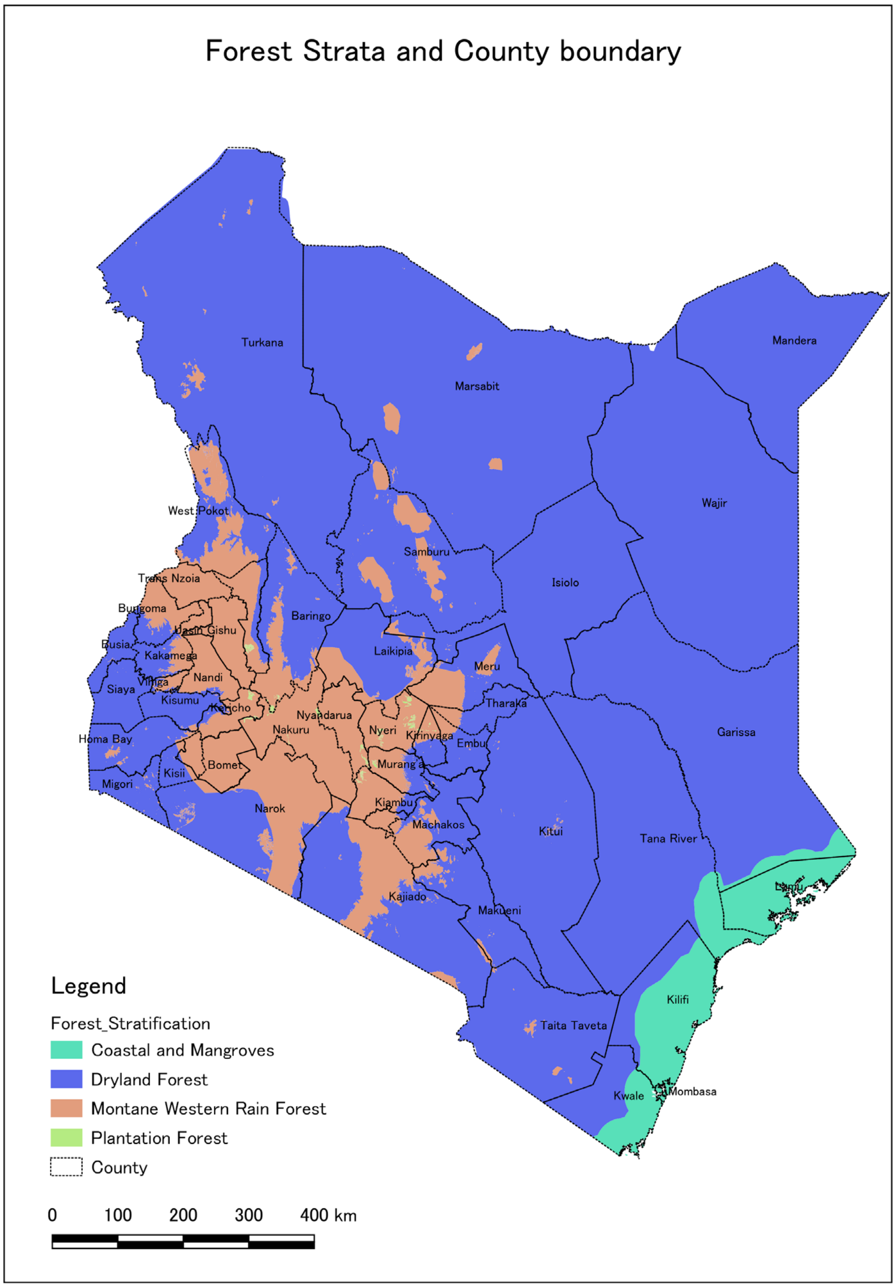

Figure 1.5.1 Forest strata and Counties in Kenya

Table 1.5.1 List of Land Cover / Land Use Classification

<table>
<tr><th colspan="2">Land Cover/Land Use</th><th>Class</th></tr>
<tr><td rowspan="12">Forest Land</td><td rowspan="3">Montane and Western Rain Forests (M&W Forests)</td><td>Dense</td></tr>
<tr><td>Moderate</td></tr>
<tr><td>Open</td></tr>
<tr><td rowspan="3">Mangroves and Costal Forest (M&C Forest)</td><td>Dense</td></tr>
<tr><td>Moderate</td></tr>
<tr><td>Open</td></tr>
<tr><td rowspan="3">Dryland Forest (D Forest)</td><td>Dense</td></tr>
<tr><td>Moderate</td></tr>
<tr><td>Open</td></tr>
<tr><td rowspan="3">Plantations</td><td>Dense</td></tr>
<tr><td>Moderate</td></tr>
<tr><td>Open</td></tr>
<tr><td rowspan="7">Non Forest</td><td rowspan="2">Cropland</td><td>Perennial Cropland</td></tr>
<tr><td>Annual Cropland</td></tr>
<tr><td rowspan="2">Grassland</td><td>Wooded Grassland</td></tr>
<tr><td>Open Grassland</td></tr>
<tr><td rowspan="2">Wetland</td><td>Vegetated Wetland</td></tr>
<tr><td>Water body</td></tr>
<tr><td>Settlements / Other Lands</td><td>-</td></tr>
</table>

1.6. The classification of the Land Cover / Land Use Change

Table 1.6.1 shows the classification list of the Land Cover / Land use Change map that was used for development of Land Cover/ Land Use Change map. In addition, the legend of the Land Cover / Land Use Change map and the response to the REDD+ activities selected by Kenya were added in Table 1.6.1.

Table 1.6.1 Land Cover / Land Use Change classification and REDD+ activities

No	Forest Cover Change	The Legend of Forest Cover Change Map	REDD+ activities
1	Forest remaining as Forest (No Change)	Forest (No Change)	-
2	Forest remaining as Forest (Degradation)	Forest (Degradation)	Reducing emissions from degradation
3	Forest remaining as Forest (Enhancement)	Forest (Enhancement)	Enhancement of forest carbon stocks
4	Cropland converted to Forest	Cropland to Forest	Enhancement of forest carbon stocks
5	Grassland converted to Forest	Grassland to Forest	Enhancement of forest carbon stocks
6	Other Land uses converted to Forest	Wetland and Other Lands to Forest	Enhancement of forest carbon stocks
7	Forest converted to Cropland	Forest to Cropland	Reducing emissions from deforestation
8	Forest converted to Grassland	Forest to Grassland	Reducing emissions from deforestation
9	Forest converted to Other Land uses	Forest to Wetland and Other Lands	Reducing emissions from deforestation

The Land Cover / Land Use Change area was totaled based on the summarized data in Table 1.6.2, using the Land Cover / Land Use Change map at each period of 2002-2006, 2006-2010, 2010-2014 and 2014-2018. As a fact unrealistic changes in Land Cover / Land Use such as M&W Forests to M&C Forest or the change in relation to Forest Lands such as Cropland to Grassland are excluded.

Table 1.6.2 Summarized table of Land Cover / Land Use Change（20XX-20XX+X）

			20XX + X															
			M&W Forest			M&C Forest			D Forest			Plantations			Cropland	Glassland	Wetland	Other Lands
			D	M	O	D	M	O	D	M	O	D	M	O				
20XX	M&W Forest	D	n	dg	dg										d	d	d	d
		M	e	n	dg										d	d	d	d
		O	e	e	n										d	d	d	d
	M&C Forest	D				n	dg	dg							d	d	d	d
		M				e	n	dg							d	d	d	d
		O				e	e	n							d	d	d	d
	D Forest	D							n	dg	dg				d	d	d	d
		M							e	n	dg				d	d	d	d
		O							e	e	n				d	d	d	d
	Plantations	D										n	dg	dg	d	d	d	d
		M										e	n	dg	d	d	d	d
		O										e	e	n	d	d	d	d
	Cropland		e	e	e	e	e	e	e	e	e	e	e	e				
	Glassland		e	e	e	e	e	e	e	e	e	e	e	e				
	Wetland		e	e	e	e	e	e	e	e	e	e	e	e				
	Other Lands		e	e	e	e	e	e	e	e	e	e	e	e				

（Note） D：Dense、M：Moderate、O：Open、df：Deforestation、dg：Forest Degradation、e：Enhancement、
N：No Change、S：Sustainable Management of Forest

1.7. Land Cover / Land Use area and Land Cover / Land Use Change area by each forest strata and county

The area of Land Cover / Land Use maps and Land Cover / Land Use Change maps was analyzed by Zonal histogram on QGIS ver.3.10.2 [QGIS.org, 2021]. The boundary of forest strata and county [Muthami, 2015] is described on Figure 1.5.1Figure 1.5.1

2. Result

2.1. Land Cover / Land Use

Area and ratio of each Land Cover / Land Use classification in each year in Kenya is shown in Table 2.1.1. The area of Grassland is the largest in each year and occupies about 70% of the entire country. The coverage of Forest Land, including M&W Forests, M&C Forest, D Forest and Plantation has remained at 6% (approximately 3,300 ~ 3,800 thousand ha), and the proportion of Forest Land excluding Plantations i.e. M&W Forests to M&C Forest to D Forest was approximately 3 : 1 : 3.

Table 2.1.1 Area and ratio of Land Cover / Land Use

(Area:1,000ha)

Land Cover/ Land Use	Class	2002		2006		2010		2014		2018	
M & W Forests	Dense	1,120	1.9%	980	1.7%	1,058	1.8%	1,090	1.8%	1,054	1.8%
	Moderate	216	0.4%	239	0.4%	219	0.4%	201	0.3%	199	0.3%
	Open	153	0.3%	105	0.2%	97	0.2%	103	0.2%	105	0.2%
M & C Forests	Dense	169	0.3%	281	0.5%	301	0.5%	422	0.7%	266	0.5%
	Moderate	342	0.6%	136	0.2%	261	0.4%	119	0.2%	215	0.4%
	Open	38	0.1%	69	0.1%	13	0.0%	5	0.0%	18	0.0%
D Forest	Dense	703	1.2%	819	1.4%	1040	1.8%	973	1.6%	828	1.4%
	Moderate	456	0.8%	276	0.5%	403	0.7%	287	0.5%	400	0.7%
	Open	399	0.7%	346	0.6%	415	0.7%	305	0.5%	317	0.5%
Plantations	-	73	0.1%	68	0.1%	71	0.1%	75	0.1%	60	0.1%
Forest Total		3,670	6.2%	3,320	5.6%	3,878	6.6%	3,583	6.1%	3,463	5.8%
Cropland	Annual Cropland	4,996	8.4%	5,799	9.8%	5,801	9.8%	5,902	10.0%	6,456	10.9%
	Perennial Cropland	282	0.5%	300	0.5%	262	0.4%	300	0.5%	284	0.5%
Grassland	Open Grassland	8,985	15.2%	9,299	15.7%	9,332	15.8%	8,822	14.9%	8,981	15.2%
	Wooded Grassland	33,447	56.5%	32,287	54.5%	31,742	53.6%	32,389	54.7%	32,271	54.5%
Wetland	Open Water	1,213	2.0%	1,178	2.0%	1,215	2.1%	1,224	2.1%	1,227	2.1%
	Vegetated Wetland	29	0.0%	41	0.1%	46	0.1%	39	0.1%	40	0.1%
Other lands	Other lands	6,582	11.1%	6,981	11.8%	6,927	11.7%	6,947	11.7%	6,481	10.9%
Total		59,204	100%	59,204	100%	59,204	100%	59,204	100%	59,204	100%

Figure 2.1.1 shows the fluctuation of area by Land Cover / Land Use classification based on the year 2002 (100%) in Kenya. Cropland increased from 2002, and the area in 2018 increased to about 130%. The percentage fluctuation of other Land Cover / Land Use area was less than 10%.

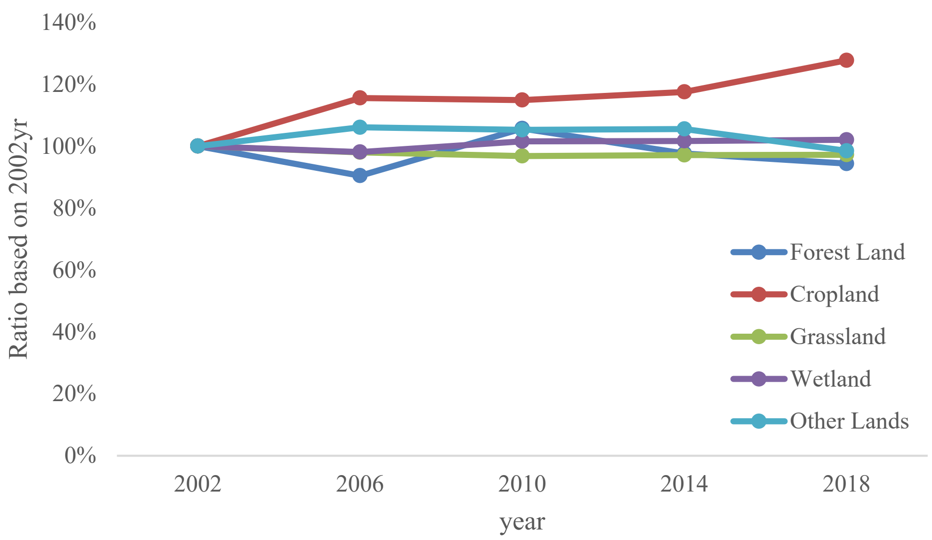

Figure 2.1.1 Fluctuation of area by Land Cover / Land Use classification

Figures 2.1.2-5 show the fluctuation of area by Land Cover / Land Use classification based on the year 2002 (100%) in each Forest strata.

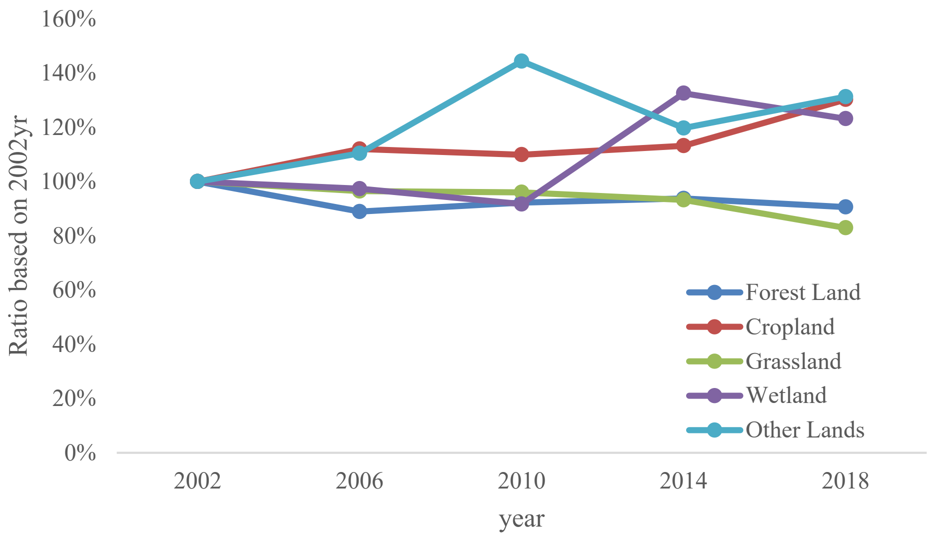

Figure 2.1.2 Fluctuation of area by Land Cover / Land Use classification in M&W Forests

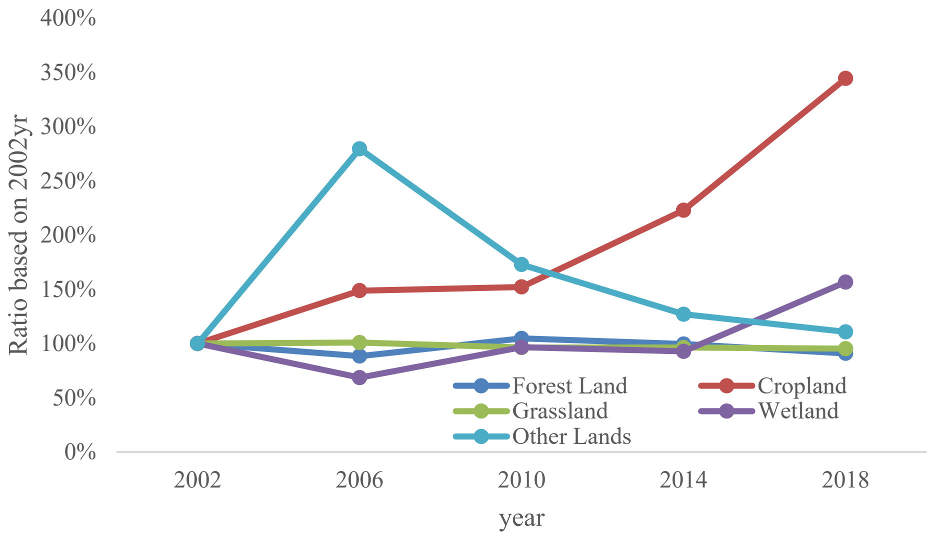

Figure 2.1.3 Fluctuation of area by Land Cover / Land Use classification in M&C Forest

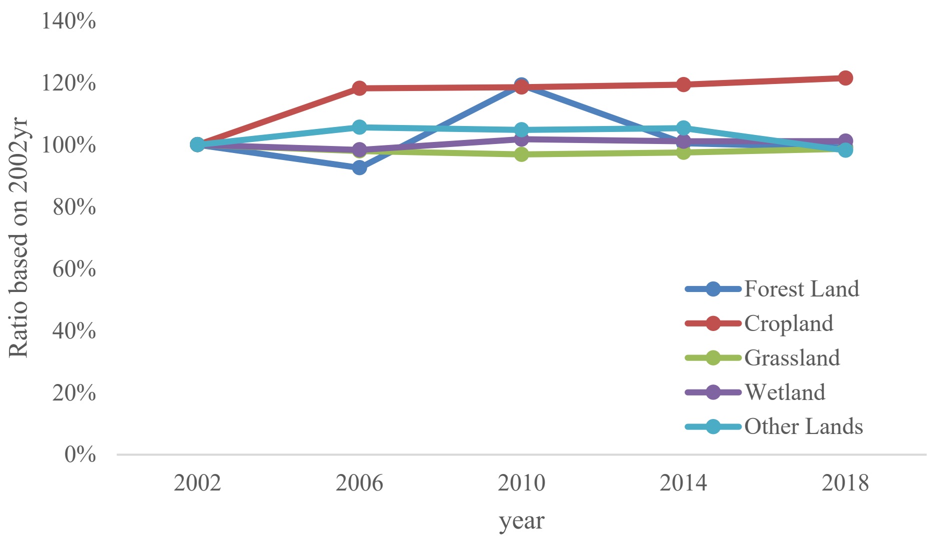

Figure 2.1.4 Fluctuation of area by Land Cover / Land Use classification in D Forest

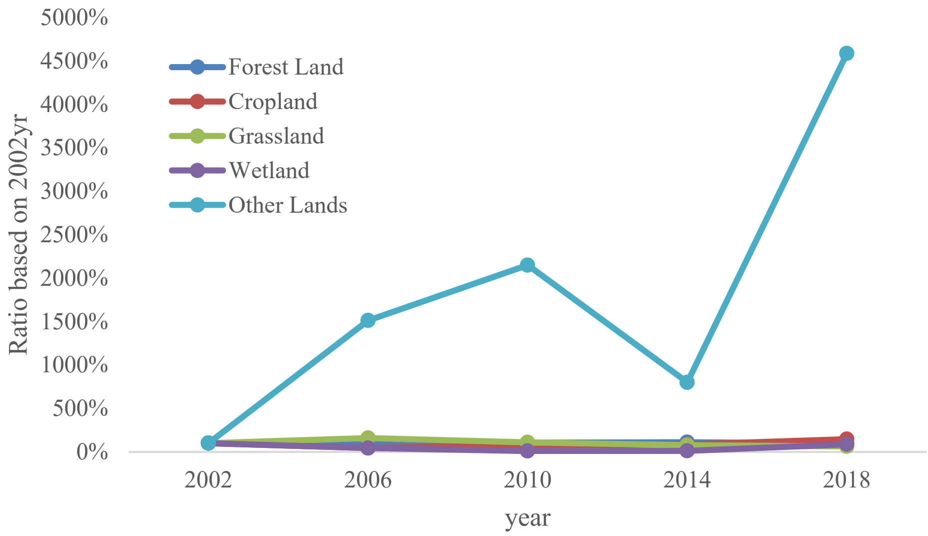

Figure 2.1.5 Fluctuation of area by Land Cover / Land Use classification in Plantations

Figure 2.1.6 shows the fluctuation of the Forest Land area by each county based on 2002. Of the 47 counties, 3 counties (orange line) showed an increase in all periods, while 17 counties (blue line) showed a decrease in all periods. In addition, counties with less forest area (green line) tended to have a larger range of increase/decrease rates. Figure 2.1.7 shows the area of the Land Cover / Land Use classification by each county.

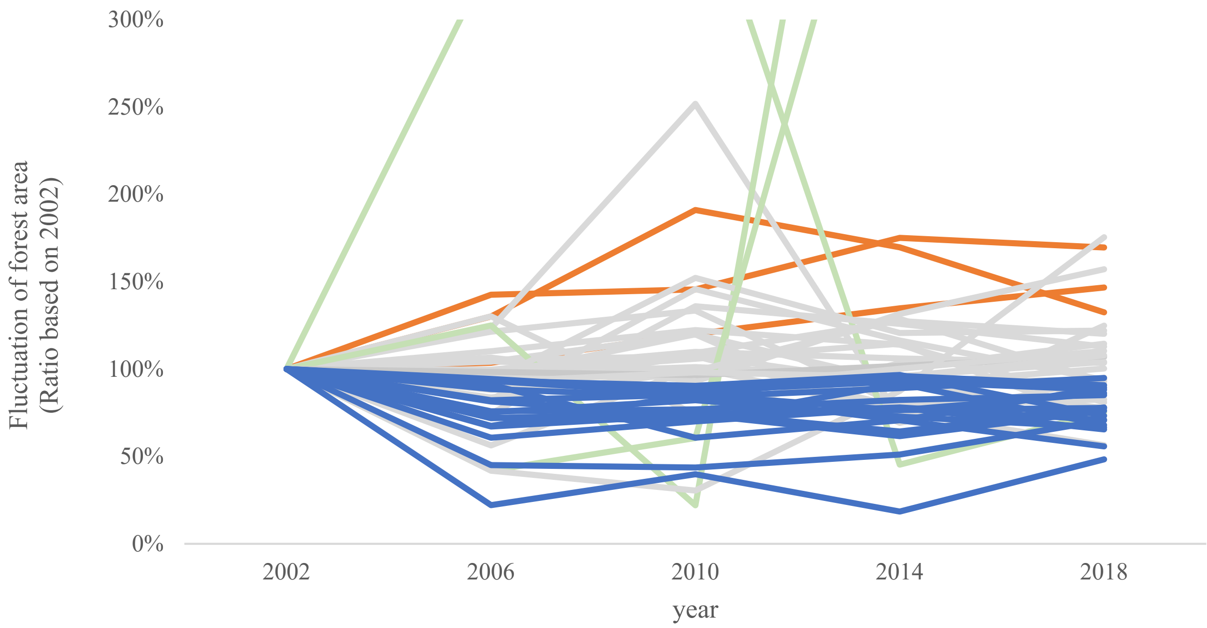

Figure 2.1.6 Fluctuation of forest area by each county

Figure 3.1.2 shows the fluctuation of Forest Land and Cropland area by each county (Appendix shows the data of all Land Cover / Land Use classification area by each county).

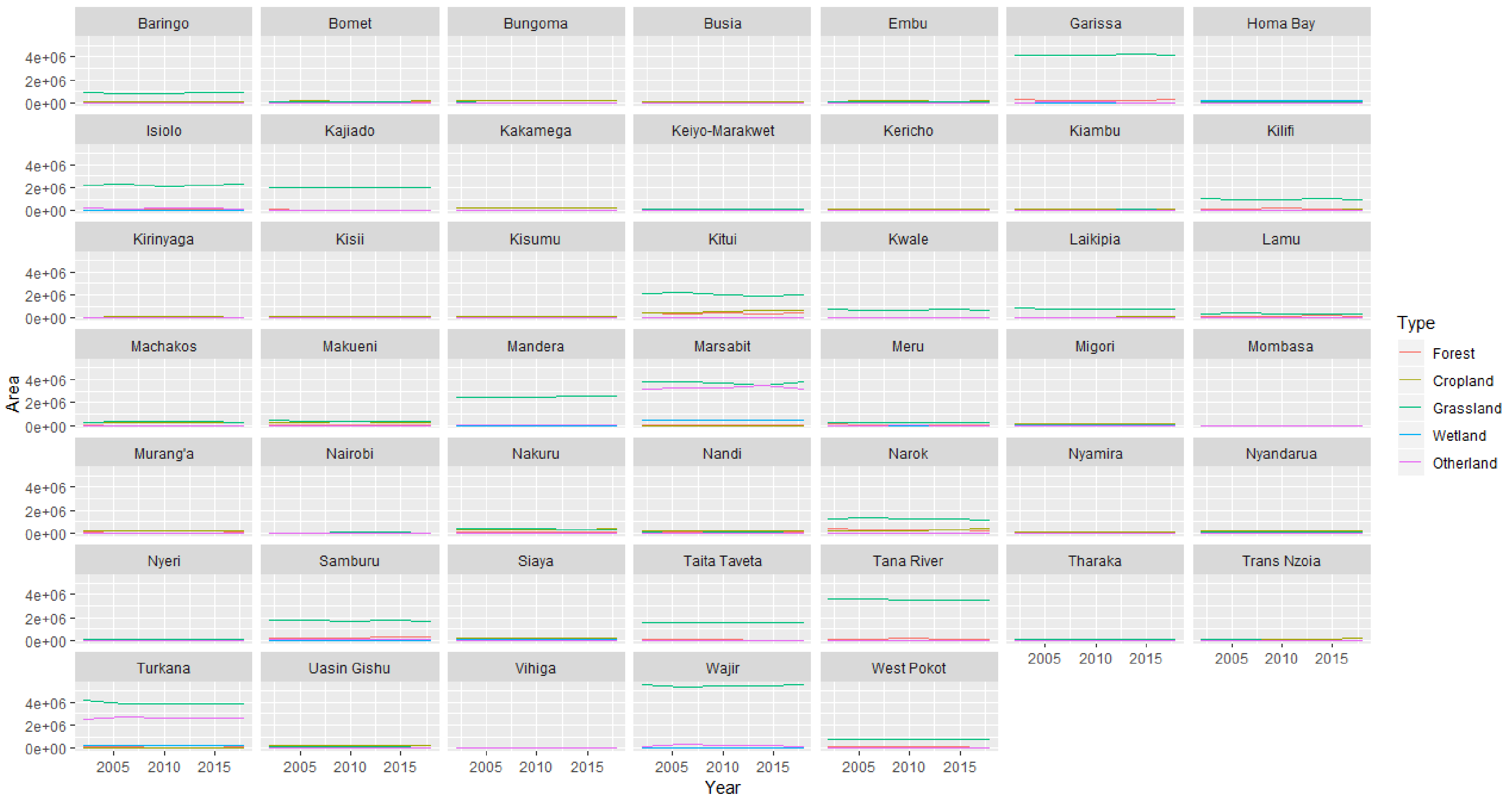

Figure 2.1.7 Fluctuation of Land Cover / Land Use classification area by each county

2.2. Land Cover / Land Use Change

Figure 2.2.1 - Figure 2.2.4 shows the Land Cover / Land Use Change map of each period. Throughout the period 2002-2018, the maps present the following characteristics: (1) The areas where Land Cover / Land Use Changes related to the forest were detected, are located especially in the southern part of Kenya, (2) Many of the areas that are maintained as large forest are forest reserves (Green), and (3) The area which were detected as Enhancement (Yellow green) and Degradation (Orange) are small compared to the area of No Change (Green) in Forest Land.

By period, in 2002-2006, there are the conversion between Grassland and Forest Land in D Forest (Figure 2.2.1, (a)). In addition, the change from Cropland to Forest Land can be detected in M&W Forests (Figure 2.2.1, (b)). In 2006-2010, the change from Grassland to Forest in D Forest and the change from Cropland to Forest Land were confirmed (Figure 2.2.2, (a) and (b)). In 2010-2014, the change from Grassland to Forest Land and the change from Cropland to Forest Land were confirmed. In 2014-2018, the change from Forest Land to Grassland and the change from Cropland to Forest Land were confirmed (Figure 2.2.4, (a) and (b)). In addition, Forest (Degradation) appeared in M&C Forest (Figure 2.2.4, (c)).

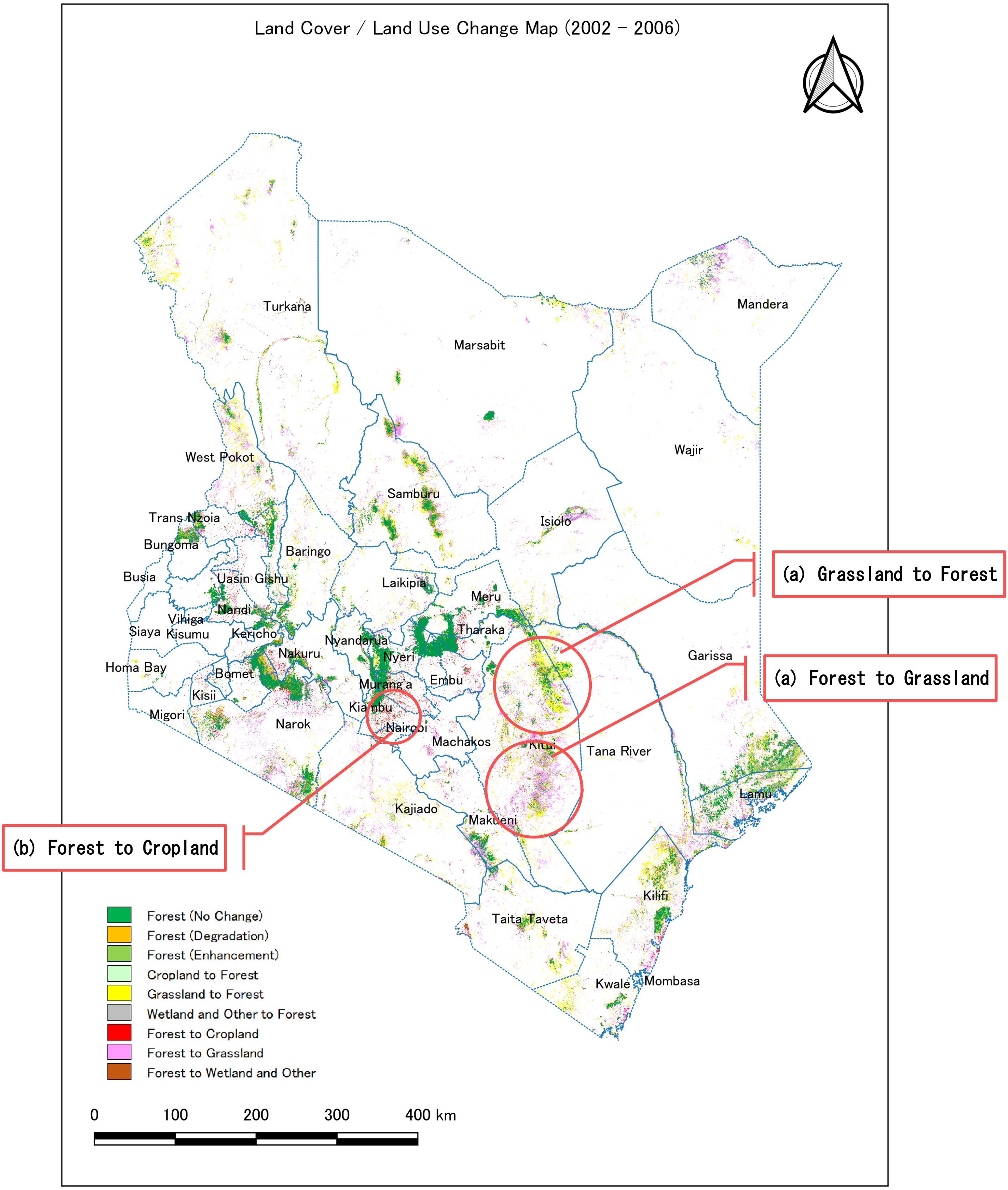

Figure 2.2.1 Land Cover / Land Use Change map (2002-2006)

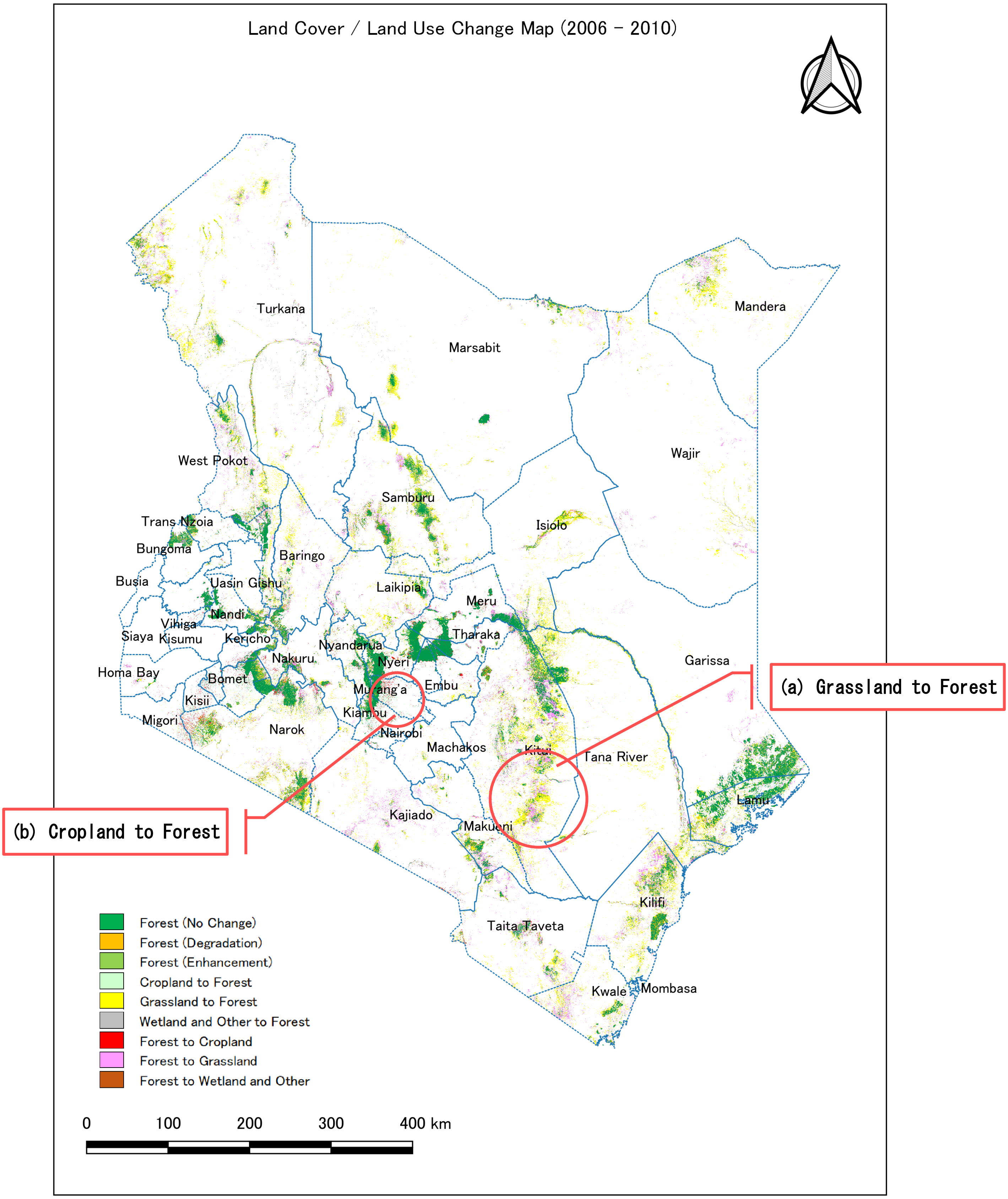

Figure 2.2.2 Land Cover / Land Use Change map (2006-2010)

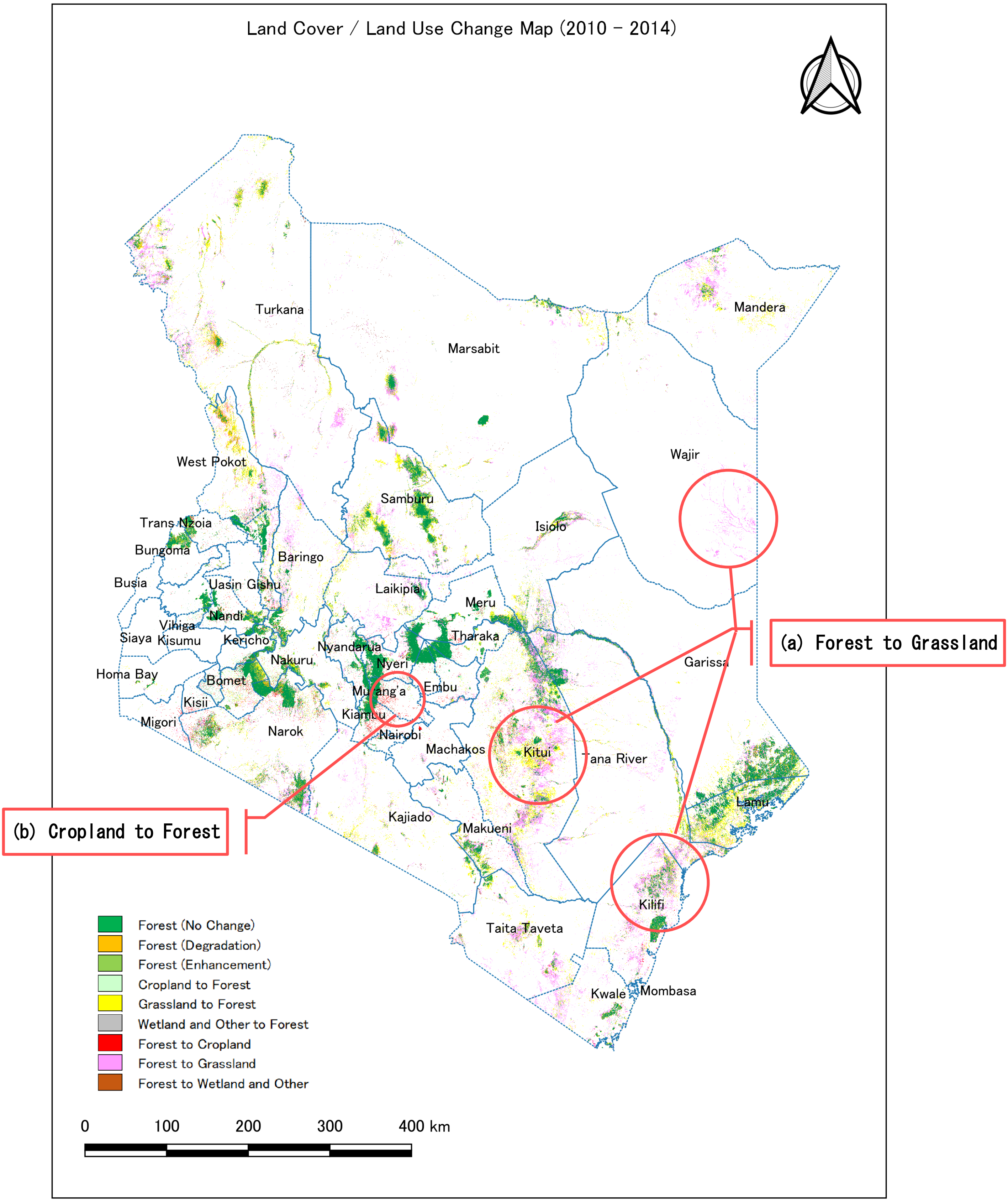

Figure 2.2.3 Land Cover / Land Use Change map (2010-2014)

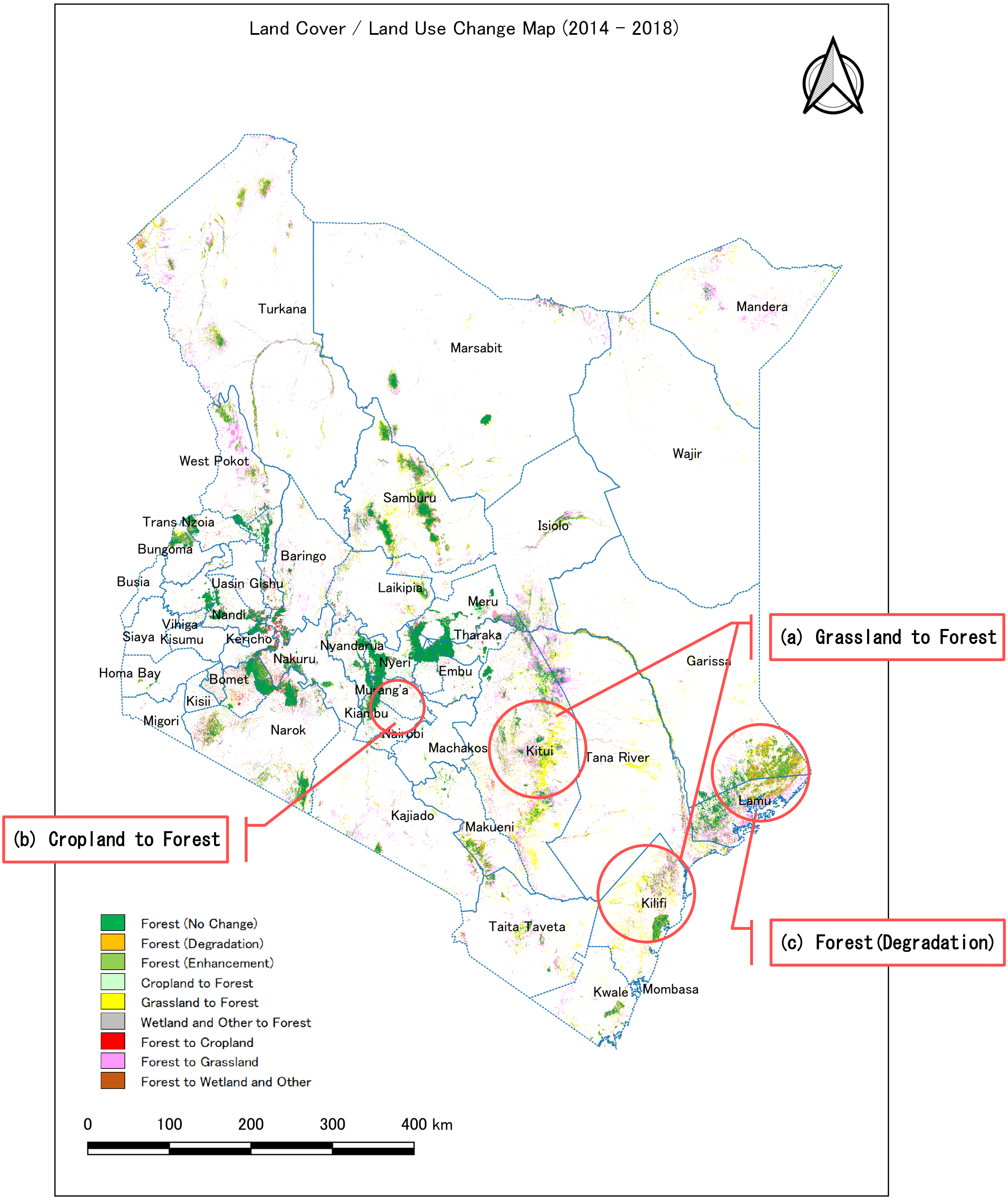

Figure 2.2.4 Land Cover / Land Use Change map (2014-2018)

In addition, Figure 2.2.5 shows area of the Land Cover / Land Use Change. In each period, Forest (No change) area showed the largest value, followed by Grassland to Forest or Forest to Grassland. In 2002- 2014, Forest (Enhancement) exceeded the value of Forest (Degradation), while in 2014-2018, Forest (Degradation) exceeded the value of Forest (Enhancement). In the forest area of about 3,500~3,800 thousand ha of Land Cover/Land Use classification, about 1,000 thousand ha of Forest Land changed from Grassland to Forest Land, and about 1,000 thousand ha changed from Forest Land to Grassland in each period.

Figure 2.2.6 shows the area of Land Cover / Land Use Change classification by Forest strata. The Figures indicate the most conversion between Grassland and Forest Land occurred in D forest. The area of deforestation occurred in M&W Forest more than other Forest strata.

The area of Dense, Moderate and Open Forest which changed from Grassland to Forest Land in D Forest was 343 thousand ha; 132 thousand ha and 229 thousand ha respectively in 2002 - 2006; 486 thousand ha, 230 thousand ha and 277 thousand ha respectively in 2006 – 2010; 386 thousand ha, 135 thousand ha and 168 thousand ha respectively in 2010 – 2014; and 378 thousand ha, 208 thousand ha and 158 thousand ha respectively in 2014 - 2018. Dense showed the highest value in all period (Please refer to the Appendix).

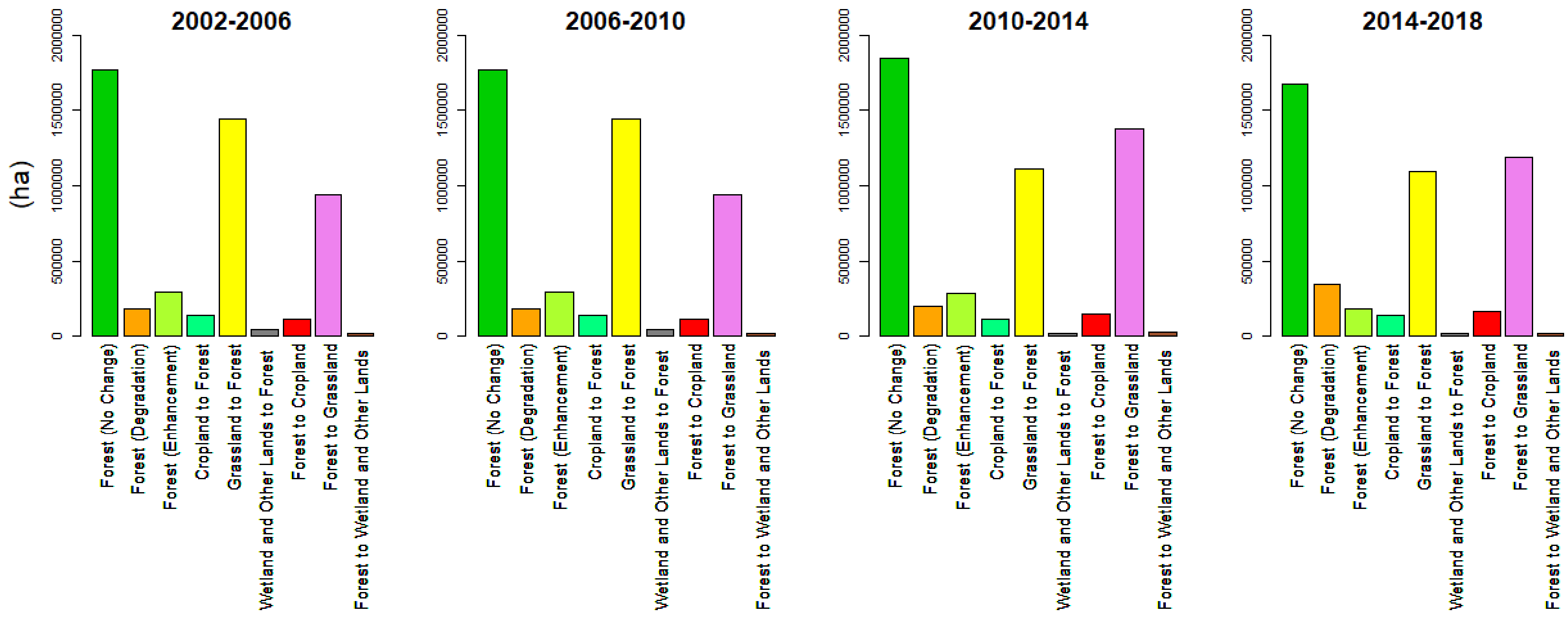

Figure 2.2.5 Area of Land Cover / Land Use Change classification

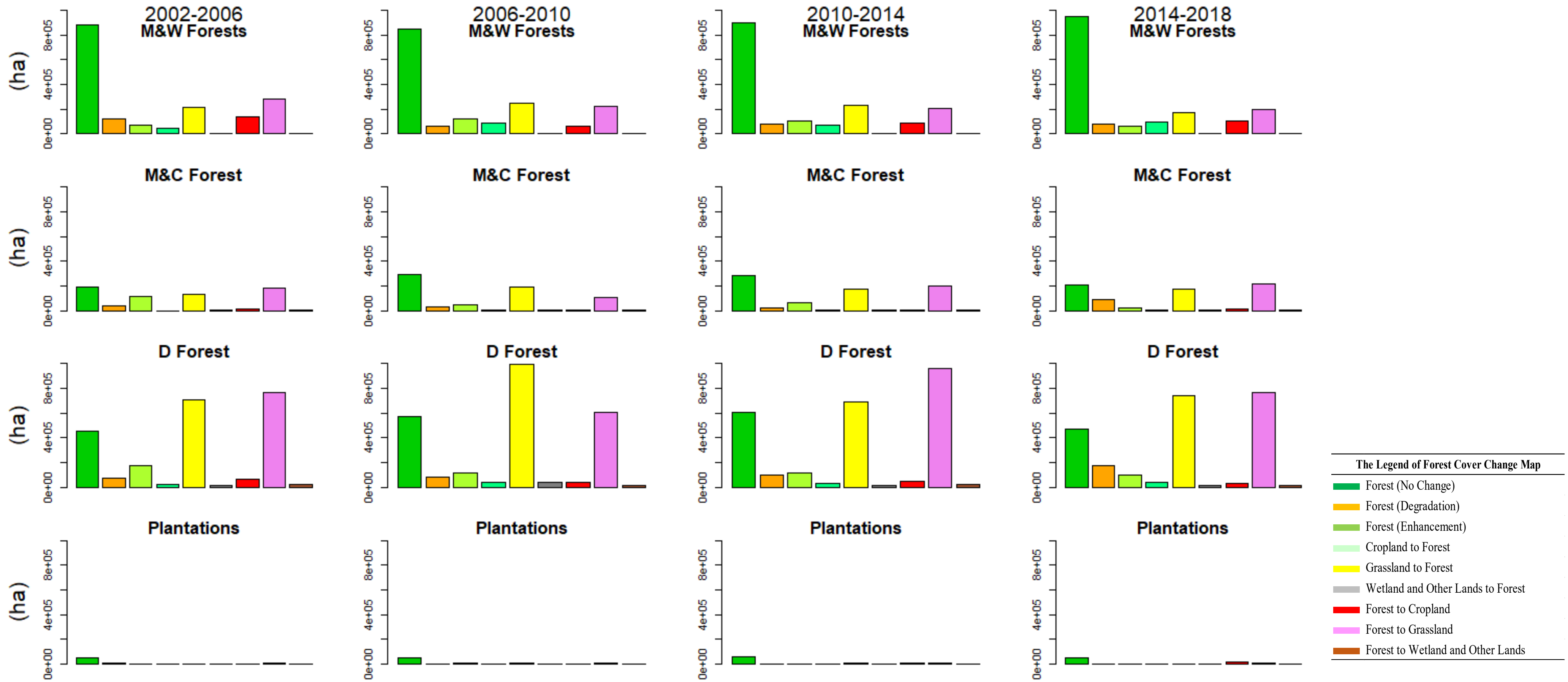

Figure 2.2.6 Area of Land Cover / Land Use Change classification by Forest strata

In addition to the extraction of general change, Figure 2.2.7 and Figure 2.2.8 show the details of the change in order to identify more characteristics of land cover / land use change. In M&W Forests, there were many changes between Forest Land and Cropland, and two kinds of trend were confirmed in this change. First, the change between Forest Land and Cropland is found in a group form in a small area, and the change occurs reversibly, and the Land Cover / Land Use Change is very fluid (Figure 2.2.7). Second is the change to Cropland from a large-scale Forest Land seen in Nakuru and Narok counties. This change has never been reverted to Forest again after conversion to the Cropland.

In D Forest, large-scale changes between Forest and Grassland were confirmed in many cases (Figure 2.2.8). In this change,　a case where the change occurs reversibly and another where Forest disappears unilaterally were confirmed.

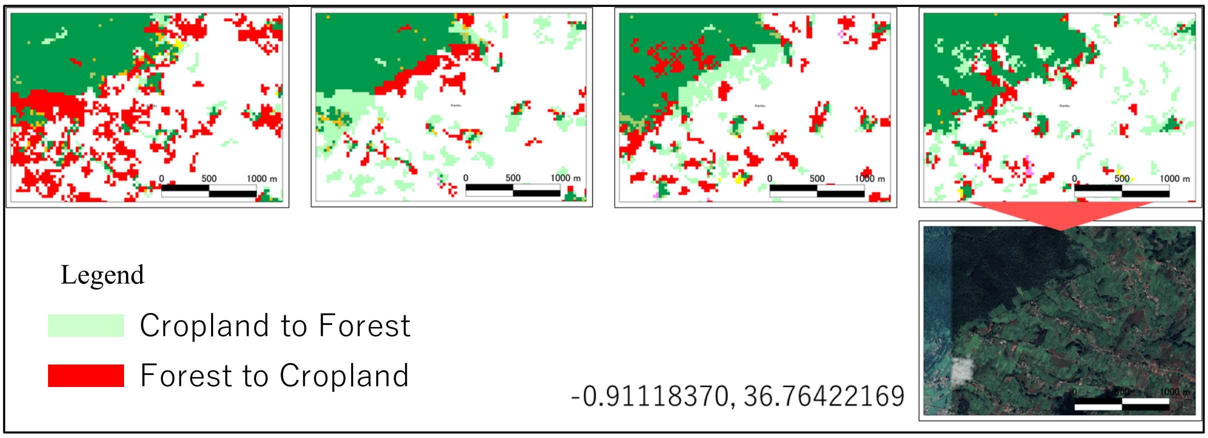

Figure 2.2.7 Detail of Land Cover / Land Use Change 1：between Forest（M&W Forests）to Cropland

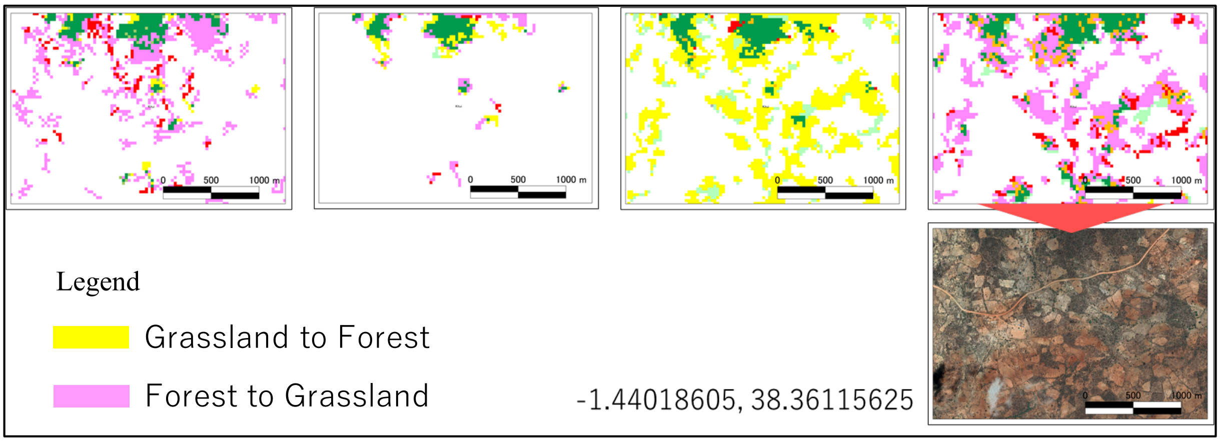

Figure 2.2.8 Detail of Land Cover / Land Use Change 2 : between Forest (D Forest) to Grassland

3. Discussion

3.1. Conversion of Forest to Cropland

From fluctuation of the area of each Land Cover / Land use classification, Cropland has the highest growth rate since 1990 in Kenya (Figure 2.1.1). The area under Annual Crops is larger compared to that under Perennial Crops in Cropland (Table 2.1.1), and many of Croplands are presumed to be used for the food self-sufficiency crops such as maize and cassava. In developing countries, the increase in demand for food and firewood materials (household fuels) due to population growth has led to the conversion of Forest to Cropland and excessive consumption of firewood, and is feared to lead to deforestation and forest degradation. Population trends and human activities in Kenya seem to be one of the factors of the Land Cover / Land Use Change [Ministry of Forestry and Wildlife, 2013]. Figure 3.1.1 shows the population density of Kenya (*3*). From this figure, it is possible to confirm that the population in Kenya is concentrated in some regions. The region where the population is concentrated can be divided into three parts: the central part including capital Nairobi, the western part including Kisii and Vihiga counties and the southeastern part including Mombasa county.

In the Land Cover / Land Use classification (Figure 1.5.1), all of the central part and a section of the western part where the population concentrates are included in M&W Forests, and the southeastern part is included in M&C Forest (the rest of the western part is included in D Forest).

Regarding the Land Cover / Land Use Change, the change from Forest Land to Cropland is high in M&W Forests as shown in Figure 2.2.6. A geographical relationship with a population concentration area is considered as one of the factors generating a lot of Cropland conversion in M&W Forests. In M&W Forests, changes between Forest Land and Cropland have been confirmed to repeat (Figure 2.2.1 - Figure 2.2.4). Therefore, in M&W Forests, it is necessary to predict whether the forest will be recovered after it is converted to the cropland. Figure 3.1.2 shows Forest Land area and Cropland area for each county based on Figure 2.1.7. In some counties, the area under Cropland is higher compared with that under Forest Land (e.g. Nakuru, Nandi and Uasin Gishu). This means that a lot of conversion of Cropland may have already been completed in these counties. On the other hand, there are some counties in which there is no significant difference between the area under Cropland and that under Forest Land e.g., Bomet, Narok and Nyeri counties. In these counties, there is a high risk that forests will be converted to Cropland in the future Therefore, close monitoring is needed in M&W Forest areas.

As shown in Figure 3.1.3, the trend shows the population of Kenya is increasing [World Bank]. Since it is thought that conversion of forest to the cropland increases to secure the food source for the increasing population in the future, it is necessary to watch the trend of the Land Cover / Land Use Change especially in the region where the population concentrates. Moreover, it is important to consider a measure to conversion of forest to cropland in the future REDD+ activity based on the medium and long-term plan by cooperation with not only the forestry department but also the related ministries.

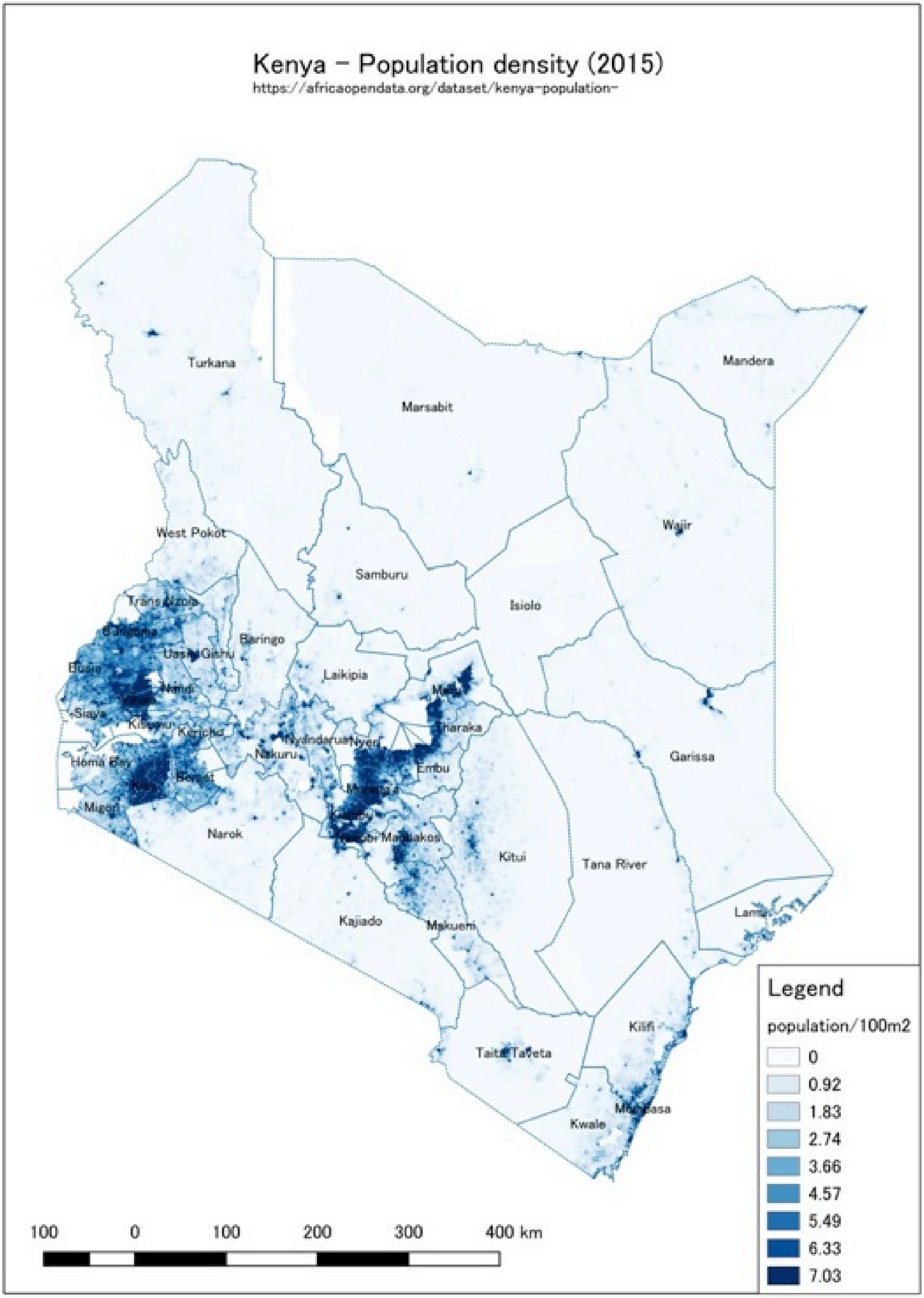

Figure 3.1.1 Population density of Kenya

Figure 3.1.2 Fluctuation of Forest Land and Cropland area by each county

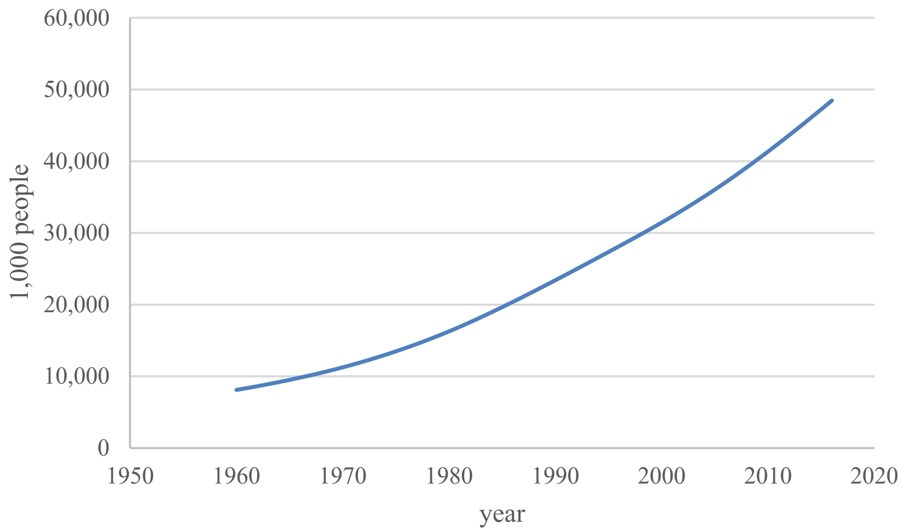

Figure 3.1.3 Population trend of Kenya

Regarding the southeastern part where the population concentrates, in which includes M&C Forest, the change between Forest and Cropland as seen in M&C Forest is smaller than in M&W Forests (Figure 2.1.7). Although it is difficult to identify the cause at the present why the conversion of Forest to Cropland is small in C&M Forest where the population concentrates, it is presumed that there is an influence of growth pattern of the population, geographical relation of cropland and forest, etc.

3.2. Large-scale deforestation other than cropland conversion

In D Forest, a relatively large-scale change occurs between forest and grassland (For example, in Wajir, Garissa, Kitui and Machakos counties). In D Forest especially in the counties where large-scale changes occurred in the past, activities to prevent deforestation are important such as regularly monitoring forest area where currently forest exists. It is also important to investigate the causes of the large-scale deforestation that have occurred so far to help devise measures to be put in place in future.

As a result (2.2 Land Cover / Land Use Change), most of Forest Land in Kenya has changed from Forest Land to Grassland or from Grassland to Forest Land in each period, and the majority of this Land Cover / Land Use Change occurred in D Forest (Figure 2.2.6). In D Forest, many of the forests that changed from Grassland are classified into Dense Forest (Appendix). The growth of forest is expected to take a long time, but this trend was confirmed in all terms for a short time of four years. At present, it is difficult to explain in detail the process that Grassland changes to Dense Forest in D Forest. In the future, it is important to examine the process of the change through the monitoring investigation and the survey of the forest utilization and conservation by the local population, and examine the necessary conditions leading to the change.

3.3. Examination on the analysis method of the Land Cover / Land Use Change

This analysis is able to grasp the trend of land cover change in Kenya, but it is difficult to understand the details of some changes at present. The Land Cover / Land Use Change map was developed by use of the change in the Land Cover / Land Use classification extracted by comparison of the Land Cover / Land Use map at the starting point and the ending point of the period. However, there is no standard criterion for extraction of change through the whole period from 2002 to 2018, and it is not advisable to consider the change simply the same at each period. In the future, it is necessary to improve the accuracy of analysis by examining the improvement of the method to develop the Land Cover / Land Use Change map.

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List of Appendix

Appendix: Area of Land Cover/Land Use change in each reference periods (ha) (AD)

Appendix: Area of Land Cover / Land Use change in each reference period (ha)（AD）

2002 - 2006

			2006															
			Montane and Western Rain Forests			Mangroves and Costal Forest			Dryland Forest			Plantations			Cropland	Grassland	Wetland	Settlements & Other Lands
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open				
2002	Montane and Western Rain Forests	Dense	773,672	75,916	27,963										110,685	127,283	251	445
		Moderate	36,857	75,670	14,739										17,071	71,895	154	248
		Open	25,105	10,533	27,186										8,333	82,848	18	267
	Mangroves and Costal Forest	Dense				114,602	11,053	3,190							2,458	36,401	490	623
		Moderate				100,716	77,558	22,429							9,195	130,990	431	1,039
		Open				12,055	4,378	1,861							1,509	18,267	22	128
	Dryland Forest	Dense							303,805	32,124	21,397				38,529	301,166	1,933	2,465
		Moderate							107,414	84,438	21,236				17,244	220,465	2,309	1,868
		Open							43,048	22,420	62,831				8,668	248,377	1,452	10,672
	Plantations	Dense										51,349	5,080	1,300	3,681	9,685	9	4
		Moderate										2,469	1,227	338	443	2,580	0	3
		Open										367	57	105	123	357	0	2
	Cropland		37,067	3,719	2,655	300	583	102	16,223	1,679	5,441	5,024	374	122				
	Grassland		103,916	73,048	33,153	52,514	41,374	40,874	343,099	132,028	228,734	4,614	487	414				
	Wetland		205	61	23	513	576	368	2,229	1,768	1,835	9	1	0				
	Settlements & Other lands		462	64	48	266	156	115	1,707	1,360	4,005	4	0	0				

2006 - 2010

			2010															
			Montane and Western Rain Forests			Mangroves and Costal Forest			Dryland Forest			Plantations			Cropland	Grassland	Wetland	Settlements & Other Lands
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense	Modera te	Open				
2006	Montane and Western Rain Forests	Dense	749,295	38,797	18,012										57,504	111,178	256	2,243
		Moderate	74,676	79,707	9,679										4,647	70,133	44	125
		Open	29,698	13,517	20,443										4,500	37,492	16	101
	Mangroves and Costal Forest	Dense				215,356	29,039	333							713	34,769	581	176
		Moderate				19,875	77,651	1,166							521	35,589	726	149
		Open				3,352	27,627	1,329							205	35,722	473	230
	Dryland Forest	Dense							425,505	39,428	26,851				28,583	291,829	2,881	2,449
		Moderate							62,214	76,621	17,783				3,653	112,795	1,870	881
		Open							28,938	28,669	68,159				9,935	200,598	2,053	7,129
	Plantations	Dense										50,136	3,089	374	3,734	6,492	11	0
		Moderate										4,738	1,055	80	319	1,033	0	0
		Open										1,377	230	103	125	444	0	0
	Cropland		67,138	8,536	8,401	2,485	2,573	298	27,969	4,497	12,733	3,319	453	47				
	Grassland		132,713	78,280	40,850	59,719	122,443	9,292	485,917	230,353	276,515	10,046	1,615	310				
	Wetland		222	39	28	402	552	18	2,850	1,283	1,359	16	1	0				
	Settlements & Other lands		882	962	138	507	945	185	4,230	21,324	10,939	12	1	0				

2010 - 2014

		2014															
		Montane and Western Rain Forests			Mangroves and Costal Forest			Dryland Forest			Plantations			Cropland	Grassland	Wetland	Settlements & Other Lands
		Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open				
2010: Montane and Western Rain Forests	Dense	811,460	35,478	29,991										67,820	109,131	215	529
	Moderate	70,180	76,226	10,964										8,986	53,130	107	244
	Open	20,994	12,731	13,395										8,378	41,885	43	123
2010: Mangroves and Costal Forest	Dense				221,815	20,895	768							1,186	55,669	460	902
	Moderate				59,002	59,199	1,835							4,427	135,127	912	327
	Open				623	926	646							978	9,361	15	72
2010: Dryland Forest	Dense							450,388	48,329	26,540				31,316	475,519	2,748	2,782
	Moderate							68,735	78,685	23,421				4,150	220,502	1,454	5,230
	Open							31,273	17,404	75,590				11,696	268,363	1,887	8,126
2010: Plantations	Dense										57,205	1,078	364	5,245	5,732	12	8
	Moderate										4,670	363	90	491	829	0	1
	Open										578	27	8	154	147	0	0
2010: Cropland		62,635	6,649	3,452	2,606	460	15	28,717	4,707	3,493	4,933	108	68				
2010: Grassland		118,181	70,500	46,412	137,075	37,087	2,216	385,810	134,613	168,121	10,772	800	415				
2010: Wetland		330	11	10	1,126	344	2	4,112	1,266	412	14	0	0				
2010: Settlements & Other lands		1,938	128	239	368	194	3	2,708	1,202	6,554	11	0	0				

2014 - 2018

			2018															
			Montane and Western Rain Forests			Mangroves and Costal Forest			Dryland Forest			Plantations			Cropland	Grassland	Wetland	Settlements & Other Lands
			Dense	Moderate	Open	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
	Mangroves and Costal Forest	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 Forest	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
	Plantations	Dense										52,713	1,218	598	16,947	6,661	24	22
		Moderate										925	278	61	673	438	1	0
		Open										427	27	69	259	163	0	0
	Cropland		78,641	8,156	6,568	1,689	2,567	438	21,204	9,163	10,163	3,611	131	144				
	Grassland		85,367	48,885	38,956	76,856	82,563	13,417	377,850	207,559	158,441	4,147	403	284				
	Wetland		267	176	12	343	316	38	1,648	1,083	1,877	9	4	1				
	Settlements & Other lands		866	107	1,702	398	470	15	1,667	2,424	3,279	6	0	0				

Carbon stock calculations for Additional Pilot Forest Inventory in Kenya

Capacity Development Project for Sustainable Forest Management
JICA REDD+ Readiness component

The 8th May, 2017

Table of content

1. Introduction

Goal of additional pilot forest inventory

The REDD+ Readiness component (hereinafter referred to as "the Component") of Capacity Development Project for Sustainable Forest Management (CADEP-SFM) implemented additional pilot forest inventory survey from February to March 2017. Objectives of the survey are 1) to set temporary EF without reliability in Tier 2 level for FRL from KFS original DATA (EF with reliability can be obtained from NFI only), 2) to establish pre-inventory data as basal data for National Forest Inventory (NFI) plot sampling by step-wise approach.

2. Method

2.1. (Additional pilot forest inventory)

Gap research for additional pilot forest inventory

In order to acquire the Kenyan country pre-Forest Inventory data, the Component found gaps in the previous research. The way of thinking through that gap in research is the following explanation. For setting the expected number of plots to be surveyed in additional pilot forest inventory which is called the gap/the difference, firstly, former the Improving Capacity in Forest Resources Assessment in Kenya (ICFRA) forest inventory data was probed to find the level of existing available data of plots survey by this forest inventory. Only the data matching with forest classification of Activity Data (12 forest types) can be used as existing available data. Secondly, the level of required number of surveyed plots was set. For pre-inventory, required data for each stratification is 5 to 10plots (Kataoka 1959). If number of plots is less than number of NFI, the data is not reliable as NFI. On CADEP-SFM, the survey for NFI cannot be implemented. However, the acquired data will be reliable to find enough plots number for future NFI at the Tier 2. Finally, the calculation of distraction from the level of required number of survey plots and the level of existing available data of plots survey by ICFRA forest inventory resulted in the gap, that is , the expected number of plots to be surveyed in additional pilot forest inventory survey (Figure 1.).

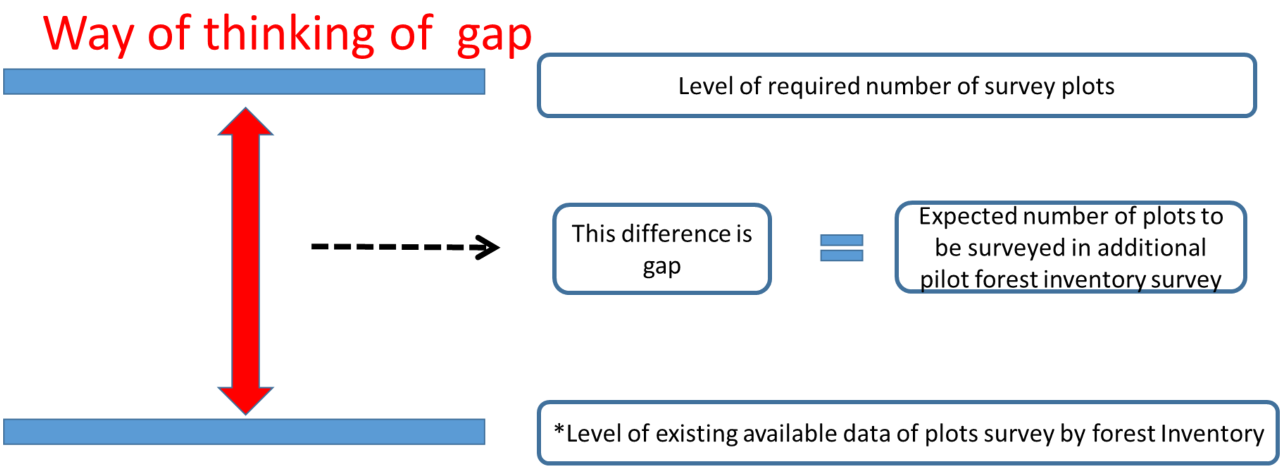

Figure 1. The way of thinking on gap for survey

The level of existing available data on plots survey by forest inventory is shown below in Table 1. And also, the expected number of plots to be surveyed in additional pilot forest inventory survey is shown below in Table 2 and 3.

Required data for each stratification is 5 to 10 plots[1] for pre-inventory. The number of plots in the Table 2. shows the gap. And also, this survey aimed to set 6 forest type classes in order to prepare to change forest type classification in the future, such as Montane forest, Western Rain Forest, Coastal Forest, Mangrove Forest, Dryland Forest and Plantation, while Kenya currently classifies forest type classes into four for REDD+ as shown below. For the 6 forest type classes, Western Rain Forest data could not be surveyed due to time and budget limitation. Further, in order to obtain country data on cropland, the data of Perennial cropland (Agro-forest) was only surveyed for setting EF. Other classification could not be surveyed due to lack of the survey method.

Table 1. Number of plots in each 12 forest type class from the ICFRA pilot Forest inventory Data

Class	Dense	Moderate	Open	Total
Montane Forest & Western Rain Forest	4	4	0	8
Coastal Forest & Mangrove Forest	10	2	3	15
Dryland Forest	2	2	7	11
Plantation	23	6	0	29
Total				63

Table 2.Number of plots for planning research in each 12 forest type class

Class	Dense	Moderate	Open	Total
Montane Forest	3	3	7	13
Coastal forest	7	7	7	21
Mangrove Forest	-	4	4	8
Dryland Forest	5	6	-	11
Plantation	-	-	7	7
Total				60

Table 3.Number of plots for planning research in Agro-forestry

Class	Number
* (Agro-forestry)	7
Total	7

*The class of Agro-forestry has been considered to apply for setting FRL.

Implementation of additional pilot forest inventory

The additional survey was implemented from 15th February, 2017 to 14th March, 2017. Survey areas were; Nyeri (Plantations and Montane forest), Embu (Perennial crop land – Agro-forest), Kibwezi (Dryland forest), Kilifi and Kwale (Coastal forest) and Gazi and Kwale (Mangrove forest).

Sampling method, plot design and measurement design

Non random sampling was applied. And plot shape type was taken by concentric plot (Figure 2.). The size of concentric plot was set as same as ICFRA pilot forest inventory due to data setting. Then, according to the ICFRA field manual, the measurement design was planned and implemented.

[1] Mr. Kataoka, Hideo described that the plots are required from 5 to 10 plots in pre-inventory by his publication (in Japanese) in 1959.

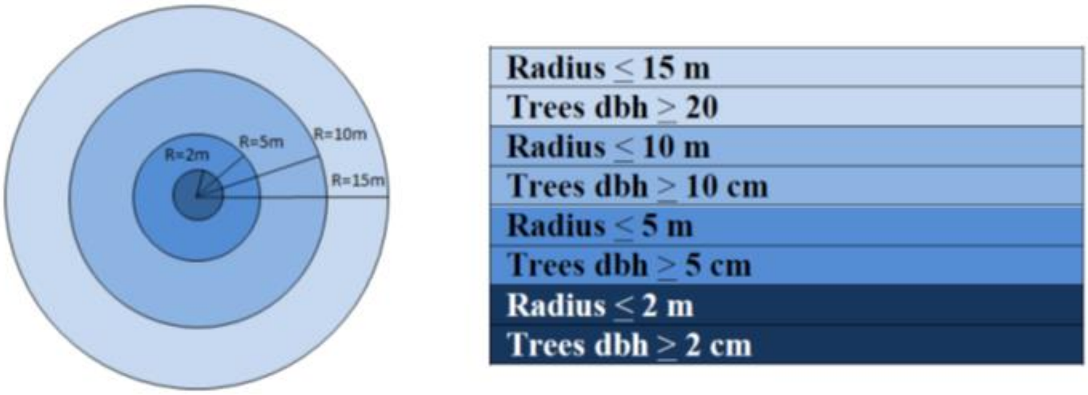

Figure 2. Concentric sample plots used in the pilot inventory

DATA collection

Tough pads were used which are a special kind of field computers made for hash conditions for data collection. Open Foris Collect software (a free open source software developed by FAO) was installed and forest survey form was designed. Following instructions in the ICFRA field manual, plot measurements were taken and recorded in the tough pad. Measurement of tree heights, DBH, plot gradient, tree directions, canopy coverage and species identification were taken. In the plot level, the results of measurement of tree, bamboo, climber deadwood and stump measurement were recorded in the Open Foris Collect. At the end of every week's forest survey, each team was to clean their data and make a backup. The survey team was composed of two teams as described in the ICFRA field Manual.

2.2 Calculation

DATA analysis

The field data from each team was combined using Open Foris Collect and exported in CSV file format. The CSV files are then imported to "R" statistical soft-ware (R) for volume and Above Ground Biomass (AGB) computation. The values of volume and AGB in each plot is written out of "R" as CSV File which was then converted to excel format for other calculations.

Using the plot result, Below Ground Biomass (BGB) was calculated with the Root/Shoot ratio, while carbon stock were calculated using carbon fraction (CF). All the equation applied in this work is as shown below;

Method of Calculation

- Calculation of volume - using equation of volume calculation

A common equation of Volume (Henry et al. 2011) is as shown below:

$$\text{Volume} = \pi \times (DBH/200)^2 \times H \times 0.5$$

- Calculation of AGB – using equation for AGB calculation

a) An equation was used for calculation of AGB for common trees, *Acacia spp*., plantation species, such as *Pinus patula*, *Eucalyptus* and *Cupressus* (Chave et al. 2009, 2014). The equation was used for calculation of EF for UNFCCC submission in Uganda.

The equation is as follows:

$$AGB=0.0673*(0.598*D^2H)^{0.976} \text{ (kg)}$$

b) An equation of $AGB_{Rhizophora}$ (Fromard et al. 1998, Komiyama et al. 2008) is as follows:

$$AGB = 0.128 \times DBH^{2.60}$$

c) An equation for Agro-forest (Henry et al. 2009) is as follows:

$$AGB_{Agro\text{-}forest}=e^{(0.93*\log((d^{\wedge}2*h))-2.97)}$$

- Calculation of BGB – using the Root/Shoot ratio

The below ground biomass was estimated with the Root/Shoot ratio of BGB to AGB (IPCC 2006).The area was set by the FAO Global ecological zones.

- Montane Forest: 0.27
- Coastal forest: 0.20 (AGB ≤ 125 (ton/ha)), 0.24 (AGB＞125 (ton/ha))
- Mangrove Forest: 0.37 and 0.20 (AGB ≤ 125 (ton/ha)), 0.24 (AGB＞125 (ton/ha))
- Dryland Forest: 0.40 (Kibwezi), 0.27 (Baringo)
- Plantation: 0.27

- Calculation of AGB Carbon stocks

- The carbon stocks of AGB are calculated by using Carbon fraction: CF of AGB for forest, such as default value (IPCC 2006).
- The CF for AGB for forest is 0.47 (tonne C (tonne d.m.)$^{-1}$).
- The carbon stocks are equal to the value which the AGB multiplies with the CF.

- Calculation of BGB Carbon stocks

- The carbon stocks of BGB are calculated by using Carbon fraction: CF of AGB for forest (FFPRI 2012).
- The CF for BGB for forest is 0.50 (tonne C (tonne d.m.)$^{-1}$).
- The carbon stocks are equal to the value which the BGB multiplies with the CF.

3. Result

3.1 Additional pilot forest inventory

The survey was implemented in 76 plots. Though, available total plots number was 74. The results of number of additional pilot forest inventory in forest types and perennial cropland is shown as below in Table 4 and 5.

Table 4.Number of plots for the results of the survey in each 12 forest type class

Class	Dense	Moderate	Open	Total
Montane Forest & Western Rain Forest	5	3	6	14
Coastal Forest & Mangrove Forest	8	10	13	31
Dryland Forest	6	6	0	12
Plantation	0	0	7	7
Total				64

Table 5.Number of plots for the results of the survey in Agro-forestry

Class	Number
＊(Agro-forestry)	10
Total	10

*The class of Agro-forestry has been considered to apply for setting FRL.

And also, total number of ICFRA available data and additional survey plots was shown as below in Table 6.

Table 6. Total number of plots in each 12 forest type class

Class	Dense	Moderate	Open	Total
Montane Forest & Western Rain Forest	9	7	6	22
Coastal Forest & Mangrove Forest	18	12	16	46
Dryland Forest	8	8	7	23
Plantation	23	6	7	36
Total				127

3.2 The result of Calculation

According to the method indicated above, Volume, Biomass and Carbon stock were calculated. Table 7. shows the results of Volume, Biomass stock and Carbon stock of each forest type. In Table 8, forest type of Coastal forest & Mangrove forest was divided into the two classes, such as Coastal forest and Mangrove forest for calculations to be performed separately. For comparison of the results, the default data of IPCC (2006) was attached in the Appendix.

Table 7. Volume (m^3/ha), Biomass stock (ton/ha) and Carbon stock (ton/ha) of each forest type class

Class	Canopy coverage	Volume**	AGB		BGB		TOTAL	
			Biomass stock	Carbon stock	Biomass stock	Carbon stock	Biomass stock	Carbon stock
Montane Forest & Western Rain Forest	Dense	437.86	344.75	162.03	93.08	46.54	437.83	208.57
	Moderate	69.59	58.36	27.43	15.76	7.88	74.12	35.31
	Open	26.23	23.02	10.82	6.22	3.11	29.23	13.93
Coastal forest & Mangrove forest	Dense	97.35	92.82	43.62	27.39	13.70	120.21	57.32
	Moderate	64.53	60.45	28.41	13.64	6.82	74.09	35.23
	Open	41.92	35.24	16.57	7.48	3.74	42.72	20.30
Dryland Forest	Dense	98.55	79.27	37.26	31.29	15.64	110.56	52.90
	Moderate	38.74	33.83	15.90	12.72	6.36	46.55	22.26
	Open	16.00	14.26	6.70	3.85	1.93	18.12	8.63
Plantation	Dense	539.23	436.68	205.24	117.90	58.95	554.58	264.19
	Moderate	137.79	113.54	53.36	30.66	15.33	144.20	68.69
	Open	174.54	138.22	64.96	37.32	18.66	175.54	83.62
＊(Agro-forestry)		106.98	74.23	34.89	20.04	10.02	94.27	44.91

* The class of Agro-forestry has been considered to apply for setting FRL. **Volume does not include volume of Climber.

Table 8. Volume (m^3/ha), Biomass stock (ton/ha) and Carbon stock (ton/ha) of each forest type class

Class	Canopy coverage	Volume	AGB		BGB		TOTAL	
			Biomass stock	Carbon stock	Biomass stock	Carbon stock	Biomass stock	Carbon stock
Montane Forest	Dense	437.86	344.75	162.03	93.08	46.54	437.83	208.57
	Moderate	69.59	58.36	27.43	15.76	7.88	74.12	35.31
	Open	26.23	23.02	10.82	6.22	3.11	29.23	13.93
Coastal forest	Dense	125.32	105.13	49.41	23.26	11.63	128.39	61.04
	Moderate	67.87	56.60	26.60	11.32	5.66	67.92	32.26
	Open	61.40	50.65	23.80	10.13	5.06	60.78	28.87
Mangrove Forest	Dense	74.98	80.31	37.75	29.71	14.86	110.02	52.60
	Moderate	59.86	65.84	30.94	16.89	8.44	82.73	39.39
	Open	16.87	15.44	7.26	4.07	2.04	19.52	9.29
Dryland Forest	Dense	98.55	79.27	37.26	31.29	15.64	110.56	52.90
	Moderate	38.74	33.83	15.90	12.72	6.36	46.55	22.26
	Open	16.00	14.26	6.70	3.85	1.93	18.12	8.63
Plantation	Dense	539.23	436.68	205.24	117.90	58.95	554.58	264.19
	Moderate	137.79	113.54	53.36	30.66	15.33	144.20	68.69
	Open	174.54	138.22	64.96	37.32	18.66	175.54	83.62
Perennial Cropland	Agro-forest	106.98	74.23	34.89	20.04	10.02	94.27	44.91

* The class of Agro-forestry has been considered to apply for setting FRL. **Volume does not include volume of Climber.

Appendix

Appendix Table 1. Above-Ground Biomass data in forests from 2006 IPCC and 2003 IPCC Guideline

Class	Canopy coverage	IPCC Ecological zone	Biomass stock (ton/ha)	Carbon stock (ton/ha)	Remarks
Montane Forest	Dense	Tropical mountain systems	40–190	18.8–89.3	Nyeri
	Moderate				
	Open				
Coastal forest	Dense	Tropical moist deciduous forest	260 (160–430)	122.2 (75.2–202.1)	Kilifi, Kwale
	Moderate				
	Open				
Mangrove Forest	Dense	Tropical rain forest	310 (130–510)	145.7 (61.1–239.7)	Gazi
	Moderate	Tropical moist deciduous forest	260 (160–430)	122.2 (75.2–202.1)	Kwale
	Open				
Dryland Forest	Dense	Tropical shrubland	70 (20–200)	32.9 (9.4–94)	Kibwezi
	Moderate				
	Open				
Plantation	Dense	Tropical mountain systems	40–190	18.8–89.3	Nyeri
	Moderate	Values from AGB in Forests			
	Open				
Plantation	Dense	Tropical mountain systems			
	Moderate	Values from AGB in Forest Plantations			
	Open	Africa broad leaf > 20 y	60–150	28.2–70.5	Nyeri
		Africa broad leaf ≤ 20 y	40–100	18.8–47	
		Africa Pinus sp. > 20 y	30–100	14.1–47	
		Africa Pinus sp. ≤ 20 y	10–40	4.7–18.8	
*(Agro-forestry)		Cropland (Agro-forest) C to C	41 (29–53)	19.27 (13.63–24.91)	Embu

* The class of Agro-forestry has been considered to apply for setting FRL.

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Recommendation for Soil carbon pool

Suggestion

In the IPCC Guideline 2006, the estimating total change in soil carbon stocks is shown as annual change in carbons stocks. The annual change of organic carbon stocks in mineral soils and annual loss of carbon from drained organic soils are the elements to calculate annual change in carbons stocks. For using the default value of IPCC Guideline 2006 as Tier 1 level, estimation of annual change in carbon stocks in soil requires to set Stock change factors. The Stock change factors consist of a land-use factor (FLU), a management factor (FMG), an input factor (FI). The factors need to be decided by several information. It is required further research for the soil organic carbon in Kenya to set EF in the soil carbon pool, even if the default values of soil carbon estimation is used for Tier 1 level. Therefore, it is recommendable to cancel the soil carbon pool at the first submission of FRL to UNFCCC and to take step-wise approach as including the soil carbon pool with further research of soil when Kenya renew or update the FRL in the future. The reason of the recommendation is described as follows.

Background

According to the REDD+ definition, forest ecosystems are regarded as consisting of five carbon pools. On the Capacity Development Project for Sustainable Forest Management (CADEP-SFM) REDD+ Readiness component, it is aimed to set EF for the 3 pools such as AGB, BGB, and Soil. However, there is few case about submission of FRL on Soil carbon pool for UNFCCC. Therefore, it should be considered to set the soil carbon pool for setting EF and FRL.

Soil carbon stocks

Due to IPCC Guideline 2006, the estimating total change in soil carbon stocks is shown as annual change in carbons stocks. Data as Tier 1 is available from IPCC Guideline 2006, though it needs other information, such as climate region, soil type and level to decide the default value of stock change factor, except Forestland remained forest. As for land converted to other land, estimation of annual change in carbon stocks in soil requires to set stock change factor.

Stock Change Factor

The stock change factors are very broadly defined and include: a land-use factor (FLU), a management factor (FMG), an input factor (FI). For using the default values of stock change factor, the factors will be decided by several information, such as climate region, soil type and level. For setting these information, specifically, information of level is difficult to set. The information is needed from land use level information in the whole country. For example crop land, the condition of using land with area information is required, such as Tillage Full, Tillage Reduced etc. In the future plan, these research would be implemented in Kenya. From the results of the researches, Tier 1 default data can be applicable. Recommendation is to take step-wise approach in the soil carbon pool in the future.

The Second National Communication

As for the Second National Communication final version (SNC), there is description including soil in the carbon pools. However, there is not enough research for the soil organic carbon in Kenya for setting EF in the soil carbon pool. In addition, it is explained in the SNC that the further research of the soil including the method is expected. For estimation, the accurate value of annual carbon stock change are requisite to submit to UNFCCC. Meanwhile, in this communication, it was also written that the details of method was explained in "the Kenya's 2010 Greenhouse Gas Inventory Report".

Kenya's Climate Change Action Plan: Mitigation Chapter 2: Preliminary Greenhouse Gas Inventory (2012) as "Kenya's 2010 Greenhouse Gas Inventory Report"

In this report, it was written that the method to make Table 2.13 was used by the PATH model. From those information, it was also described that the data of soil carbon stock is available to use. Those data describes the data of Soil carbon stock or Soil organic carbon stock on land areas. However, there is no explanation how they analyse the relation between land cover data and soil carbon stocks. It could not show the certain evidence of relationship related with Soil carbon stock and land cover data to use for estimation of annual carbon stock change.

In the case of Chile, they use the Harmonized World Soil Database by the FAO for calculation of soil carbon stock. However, TA shows that there are no explanation of the rate of change in first submission. The results of Chile show only the carbon stock. The rate of change is regarded as the annual stock change. In this reason, calculation of carbon stock does not show exactly the value of annual carbon stock change. Finally, in the modified submission, Chile dropped the soil carbon pool.

Due to 2006 IPCC Guideline, annual change of carbon stock is required as value for submission of FRL. On this purpose, it is requisite to calculate the annual change of organic carbon stocks in mineral soils and annual loss of carbon from drained organic soils.

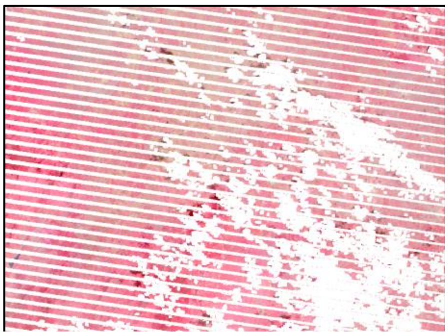
Reference Time Period and AD Adjustment with Forest Definition

1. Reference Time Period

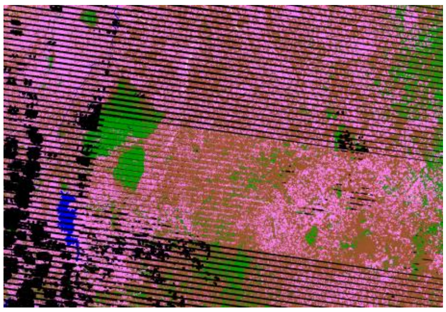
It was decided that the map of the Activity Data (AD) utilizes the Land Cover / Land Use Map created by the technical remote sensing team through SLEEK project. This map had been assessed by the Component 3 in the first year and the result was sufficient for the classification accuracy of land cover and land use class as the AD.

The SLEEK project had produced time series maps based on the same methodology and process. For the utilization of AD as necessary reference year, the time series maps of all years were assessed for quality of LANDSAT imagery as resource data of Land Cover / Land Use Map since there were variations of the classification results of forest cover percentage. The classification result depends on the quality of utilized imagery. The time series maps are available for 1990, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012 and 2013. For those maps, LANDSAT imagery data was screened for the image quality such as cloud cover area as NO-DATA area and strip gap.

The utilized LANDSAT 7 imageries for 2004 to 2009 were not good quality data due to failure of LANDSAT 7's scan line corrector since end of May 2003 known as the Scan Line Corrector anomaly. Therefore those imageries should not be utilized. The following figures are example of strip imagery and classification result. This strip imagery is defective in the sense that it has stripes or gaps and affected the classification result.
Note: Technical remote sensing team selected possible best imageries for each years based on less than 20 percent cloud coverage.



Strip gap on the satellite imagery



Classification result

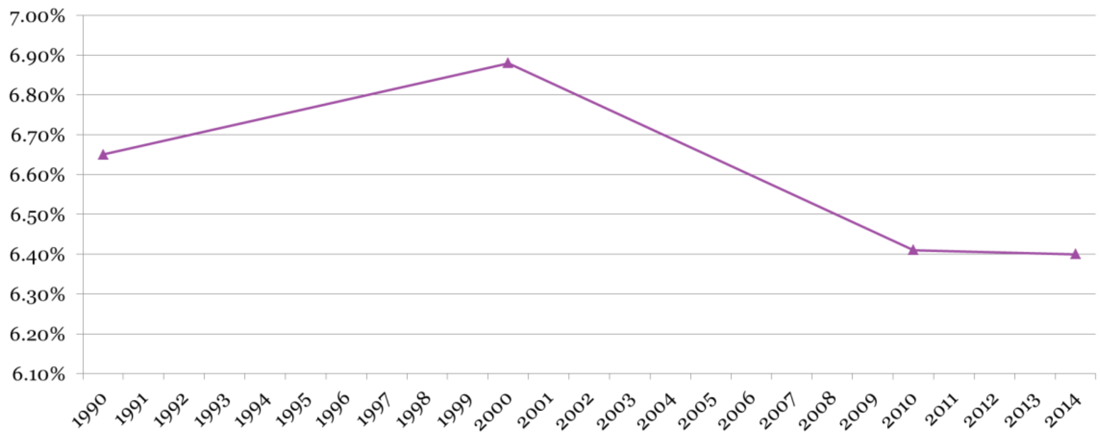
For the data screening, it was considered cloud cover ratio as well. The cloud cover area affected the classification result as unclassified area. The result of data screening is presented in the following table. The highlighted years as shown in green color utilized LANDSAT imagery of good quality with small NO-DATA cover ratio. The highlighted years as shown in yellow color utilized LANDSAT imagery of good quality with slightly higher NO-DATA cover ratio, moderate quality with small NO-DATA cover ratio or moderate quality with little higher NO-DATA cover ratio.

	1990	1995	2000	2002	2003	2004	2005	2006
No DATA (%)	10.59%	14.35%	6.50%	6.53%	8.56%	23.77%	20.86%	23.13%
LANDSAT4 (scene)	26	0	0	0	0	0	0	0
LANDSAT5 (scene)	8	34	0	0	0	0	0	0
LANDSAT7 (scene)	0	0	34	34	34	34	34	34
Missing scenes	0	0	0	0	0	0	0	0
LANDSAT8 (scene)	0	0	0	0	0	0	0	0
Stripping Effect (scene)	0	0	0	0	0	34	34	34
Ratio of Stripping Effect (%)	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**100.00%**	**100.00%**	**100.00%**

	2007	2008	2009	2010	2011	2012	2013	2014
No DATA (%)	26.14%	28.00%	15.85%	6.81%	12.51%	20.85%	16.98%	3.75%
LANDSAT4 (scene)	0	0	0	0	0	0	0	0
LANDSAT5 (scene)	0	0	11	24	15	0	0	0
LANDSAT7 (scene)	34	34	23	9	19	34	13	0
Missing scenes	0	0	0	1	0	0	0	0
LANDSAT8 (scene)	0	0	0	0	0	0	21	34
Stripping Effect (scene)	34	34	23	9	19	34	13	0
Ratio of Stripping Effect (%)	**100.00%**	**100.00%**	**64.60%**	**26.50%**	**55.90%**	**100.00%**	**38.20%**	**0.00%**

The result of data screening

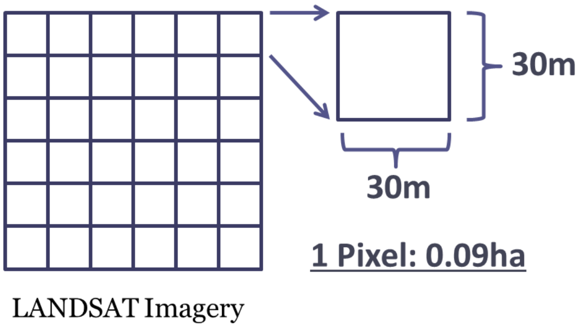
The Technical Working Group (TWG) meeting considered above results of data screening and interval period as reference year, and then 1990, 2000, 2010 and 2014 were selected as 10 years interval and recent reference year for the AD. The following figure shows forest cover percentage of Land Cover / Land Use Map on each year.



Change of Forest Cover Percentage (1990 – 2014)

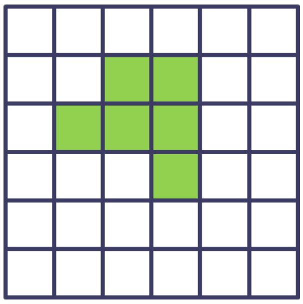
2. AD Adjustment with Forest Definition

The TWG meeting discussed how to meet the forest definition on the pixel based Land Cover / Land Use Map. Pixel size of LANDSAT imagery is 30m x 30m as shown in the following figure. The area size of one pixel of forest class is 0.09ha.



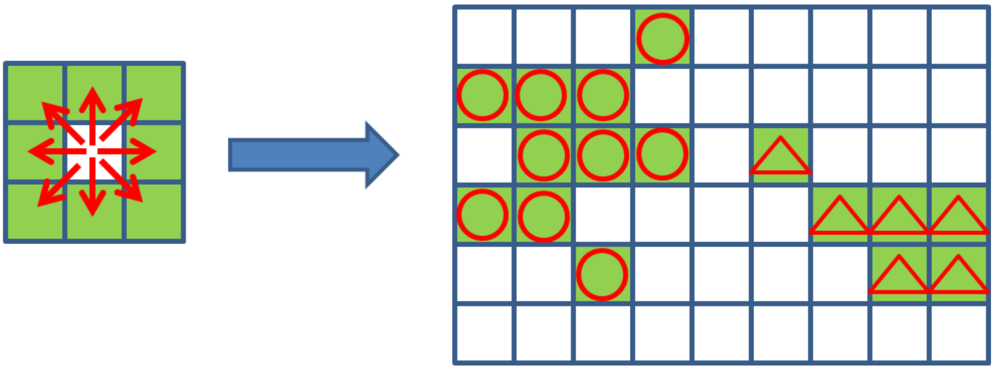
Pixel size of LANDSAT Imagery

The forest definition defines at least 15 percentage canopy cover with 0.5ha size. Therefore, in order to fulfilling the forest definition, the continuously connected forest class pixel has to be constituted at least from 6 pixels as shown in the following figure. The area size of 6 pixels is totally 0.54ha.



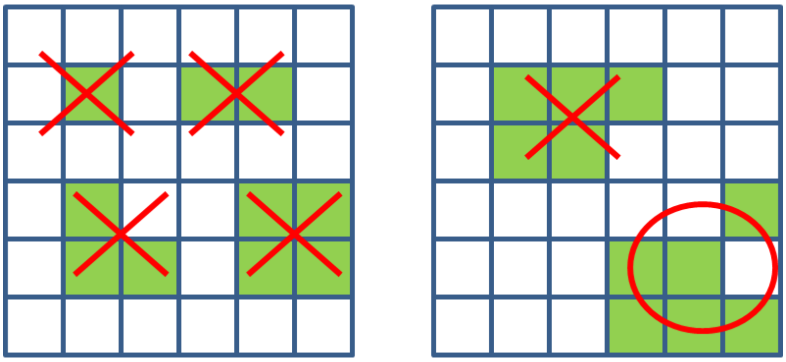
Number of minimum pixels according to the forest definition

In the SLEEK project, it did not consider pixel based forest definition as above mentioned and apply to the Land Cover / Land Use Map. In order to fulfilling the forest definition, the forest areas which are less than 0.5ha have to be removed. Therefore, the Component has considered developing the filtering function for removal of forest pixel groups which are constituted less than 6 pixels. The case of continuously connected forest class pixel was discussed through the TWG meeting. And then connected direction as grouping was decided which is 8 neighbor searching as shown in the following figure.



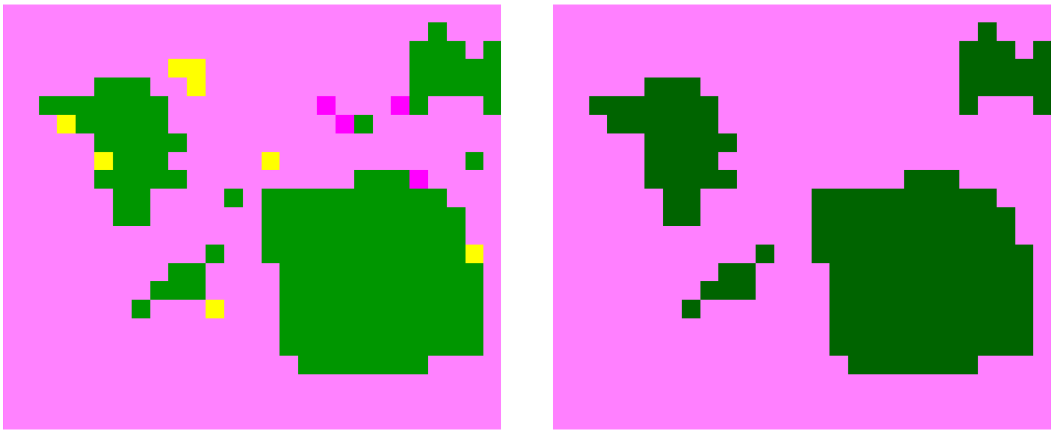
Example of 8 neighbor grouping

The following figure is showing the example of removal for less than 6 pixels.



The example of removal for less than 6 pixels

The example of filtered the Land Cover / Land Use Map is shown in the following figures.



Recommendation for EF setting

Summary of recommendation

For choosing Emission Factor (EF) in order to setting Forest Reference Level (FRL), there are the two way of selection of EF (Figure 1.). One is to use the country data which is combined with the Improving Capacity in Forest Resources Assessment in Kenya (ICFRA) data and additional pilot-forest inventory data by the Japan International Cooperation Agency (JICA) project. And another way is to use the default value of 2006 IPCC Guideline. However, according to the FRL documents submitted by other countries to the United Nations Framework convention on Climate Change (UNFCCC), National Forest Inventory (NFI) is required to set the enough plot number as a country data for Tier 2 level. For setting FRL, the Kenya's country data is applicable without reliability as same as NFI level data. However, these two data sets show a good opportunity to compare figures with better condition of FRL setting. There are two options to set EF. Option 1 shows setting EF to get more credit. Meanwhile, Option 2 shows setting EF as conservative estimation. Choosing one of options and comparing the data are important to obtain carbon stocks for FRL.

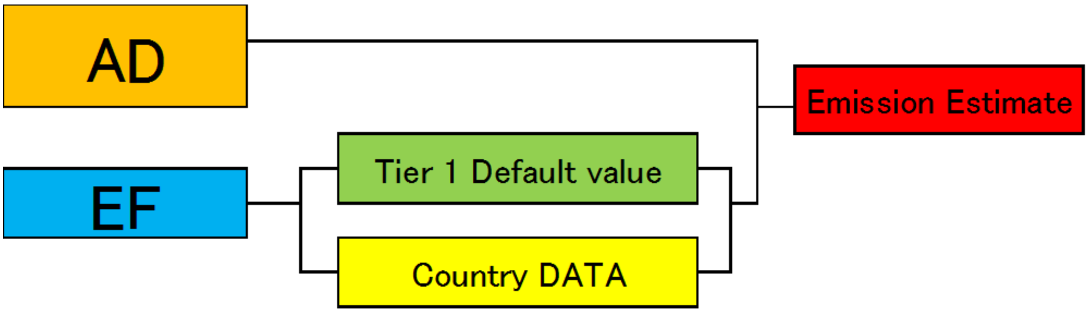


Figure 1. Flow chart for Emission estimate

Background of EF setting, regard to the submission of FRL report:

Until now, more than 20 countries submitted FRL report to UNFCCC. The value of EF for AGB is required enough number of plots as NFI level. The number of plots mentioned in the FRL documents submitted to UNFCCC, such as country DATA, is almost more than 1000 plots. And also, it is required that the permissible error of the data with t-statistic reliability and Standard deviation of each forest types is set for NFI plot setting with necessary numbers. Taking into consideration of these context, we should discuss how to set the EF in Kenya.

The way of setting Emission Factor

According to the discussion of Work shop and REDD+ TWG meeting, the two data which includes the country data and Tier 1 Default value were shown. There are the results of calculation as shown below.

The result of Calculation and the default data of 2006 IPCC Guideline

According to the methodology for calculation of the country data, the value of Volume, Biomass and Carbon stock was calculated. Table 1 shows the results of Volume, Biomass stock and Carbon stock of each forest type. Further, the default data of IPCC (2006) was attached on Table 2. In Kenya, the species of Plantation includes *Pinus patula*, *Eucalyptus* and *Cupressus.* The default values can be applicable for *Pinus spp*. and broad leaf species (Table 2). In Table 2, the default value of plantation is described as two ways. However, the default value cannot cover whole plantation species. Therefore, firstly, the default value of natural forest same as IPCC ecological zone was applied (Table 2). The default value is used from that of the mountain system's IPCC Ecological zone as natural forest. Secondly, the default value is used that of plantation forest in the mountain system's IPCC Ecological zone except *Cupressus* (Table 2). In this case, the default value of *Cupressus* should be considered to choose from other default value.

Table 1. Volume (m^3/ha), Biomass stock (ton/ha) and Carbon stock (ton/ha) of each forest type class

Class	Canopy coverage	Volume	AGB		BGB		TOTAL	
			Biomass stock	Carbon stock	Biomass stock	Carbon stock	Biomass stock	Carbon stock
Montane Forest & Western Rain Forest	Dense	441.99	345.99	162.62	93.42	46.71	439.41	209.32
	Moderate	70.92	58.43	27.46	15.78	7.89	74.21	35.35
	Open	26.44	23.13	10.87	6.25	3.12	29.38	14.00
Coastal forest & Mangrove forest	Dense	99.57	94.09	44.22	27.65	13.82	121.74	58.05
	Moderate	64.53	60.45	28.41	13.64	6.82	74.09	35.23
	Open	42.14	35.37	16.62	7.50	3.75	42.88	20.38
Dryland Forest	Dense	100.42	80.36	37.77	31.72	15.86	112.09	53.63
	Moderate	39.88	34.50	16.21	12.99	6.49	47.48	22.71
	Open	16.00	14.26	6.70	3.85	1.93	18.12	8.63
Plantation	Dense	541.32	437.34	205.55	118.08	59.04	555.42	264.59
	Moderate	142.54	116.07	54.56	31.34	15.67	147.42	70.23
	Open	174.54	138.22	64.96	37.32	18.66	175.54	83.62
*(Agro-forestry)		106.98	74.23	34.89	20.04	10.02	94.27	44.91

* The class of Agro-forestry has been considered to apply for setting FRL.

Table 2. Above-Ground Biomass data in forests from 2006 IPCC and 2003 IPCC Guideline

Class	Canopy coverage	IPCC Ecological zone	Biomass stock (ton/ha)	Carbon stock (ton/ha)	Remarks
Montane Forest	Dense	Tropical mountain systems	40–190	18.8–89.3	Nyeri
	Moderate				
	Open				
Coastal forest	Dense	Tropical moist deciduous forest	260 (160–430)	122.2 (75.2–202.1)	Kilifi, Kwale
	Moderate				
	Open				
Mangrove Forest	Dense	Tropical rain forest	310 (130–510)	145.7 (61.1–239.7)	Gazi
	Moderate	Tropical moist deciduous forest	260 (160–430)	122.2 (75.2–202.1)	Kwale
	Open				
Dryland Forest	Dense	Tropical shrubland	70 (20–200)	32.9 (9.4–94)	Kibwezi
	Moderate				
	Open				
Plantation	Dense	Tropical mountain systems	40–190	18.8–89.3	Nyeri
	Moderate	Values from AGB in Forests			
	Open				
Plantation	Dense	Tropical mountain systems			
	Moderate	Values from AGB in Forest Plantations			
	Open	Africa broad leaf > 20 y	60–150	28.2–70.5	Nyeri
		Africa broad leaf ≤ 20 y	40–100	18.8–47	
		Africa Pinus sp. > 20 y	30–100	14.1–47	
		Africa Pinus sp. ≤ 20 y	10–40	4.7–18.8	
*(Agro-forestry)		Cropland (Agro-forest) C to C	41 (29–53)	19.27 (13.63–24.91)	Embu

* The class of Agro-forestry has been considered to apply for setting FRL.

Considering choice of Carbon stocks for EF

For choosing EF for setting FRL, there are two ways. Firstly, there is the one way to use the country data. According to the FRL documents submitted by other countries to UNFCCC, National Forest Inventory (NFI) is required to set the enough plot number with statistical accuracy as a country data for Tier 2 level. That is the reason why it was mentioned that the country data is not enough number to set as the reliable EF. Secondly, there is another way using the default value of 2006 IPCC Guideline for calculation. The value was shown below in Table 9.

To choose the value from these two method, it is recommendable to compare with the two data each other and to recognize data, such as the conservative estimation or not. The idea is following.

- Option 1 Setting EF to get more credit

  - Case 1 – Choice Country data

    Country data > Tier 1 default value (conservative estimation)

  - Case2 – Choice Tier 1 default value

    Tier 1 default value > Country data (conservative estimation)

- Option 2 Setting EF as conservative value

  - Case 1 – Choice Country data

    Country data (conservative estimation) < Tier 1 default value

  - Case 2 – Choice Tier 1 default value

    Tier 1 default value (conservative estimation) < Country data

For choosing an option shown above, it is recommendable to decide to use conservative estimation or not. Option 1 shows setting EF to get more credit. Then, Option 2 shows setting EF as conservative value. Choosing one of options and comparing the data are important to obtain the carbon stock data which is intended as the result of forest reference level. Also, the data choice affects FRL values.

Option 1

In Case 1, the country data is greater than Tier 1 default value. In this case, the country data would be used for EF setting. However, because of not enough plot number, probably the submitter would be to get Technical Assessment (TA) by UNFCCC pointed that value is not enough reliability of EF. And also, TA would advise to calculate again EF using the default value of IPCC Guideline for modified document.

In Case 2, Tier 1 default value is greater than the country data. In this case, Tier 1 default data would be used for EF setting. However, the default value does not have any classification of canopy coverage. Therefore, each forest type represent only showing own forest classes without that. This means that SLEEK stratification cannot be completely used.

Option 2

In Case 1, the country data is smaller than Tier 1 default value. In this case, the country data would be used for EF setting as conservative estimation. And also, there is possibility to be recognized by TA in that point although the country data is not based on the enough number of plots. Furthermore, TA would identify the country data in line with the Step-wise approach's condition.

In Case 2, Tier 1 default value is smaller than the country data. In this case, Tier 1 default data would be used for EF setting as conservative estimation. However, the default value does not have any classification of canopy coverage. Therefore, each forest type represent only showing forest classes without that.

Republic of Kenya

Ministry of Environment and Natural Resources

National Forest Reference Level for REDD+ Implementation

For

Submission to UNFCCC for Technical Assessment

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List of Acronyms

AD	Activity Data
AGB	Above Ground Biomass
BGB	Below Ground Biomass
CBD	Convention on Biological Diversity
CF	Carbon Fraction
EF	Emission Factor
FAO	Food and Agriculture Organization of the United Nations
FLEGT	Forest Law Enforcement, Governance and Trade
FPP	Forest Preservation Program
FRA	Forest Resources Assessment
REL	Reference Emission Level
FRL	Forest Reference Level
GFOI MGD	Global Forest Observation Initiative Methods and Guidance Document
GHG	Green House Gases
IPCC	Intergovernmental Panel on Climate Change
ITTA	International Tropical Timber Agreement
JICA	Japan International Cooperation Agency
KEFRI	Kenya Forestry Research Institute
KFS	Kenya Forest Service
LCC	Land Cover Change Mapping
MENR	Ministry of Environment and Natural Resources
MMU	Minimum Mapping Unit
NCCRS	National Climate Change Response Strategy
NDC	Nationally Determined Contribution
NFI	National Forest Inventory
REDD+	Reducing Emissions from Deforestation and Forest Degradation, and the role of Conservation, Sustainable management of forests and Enhancement of forest carbon stock.
SDG	Sustainable Development Goals
SLEEK	System for Land-based Emissions Estimation in Kenya
SNC	Second National Communication
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change

Summary

Kenya is a low forest cover country with a total forest area of 3,488,765 ha or about 6.1% of the total land area. The government of Kenya has a goal of enhancing and maintaining forest cover at a minimum of 10 % of the land area by 2030. As a party to the UNFCCC, Kenya has also made a commitment to contribute to global climate change mitigation and adaptation. The forest sector has been identified as key to the realization of the national goals due to its comparatively high abatement potential. Based on data collected as part of this process, the deforestation rate is estimated to be 0.46 % or 16,235 ha per year

Kenya has decided to establish a Forest Reference Level to exploit opportunities for reducing current emissions arising from deforestation and forest degradation, and has identified opportunities for afforestation, reforestation and restoration of degraded forest areas. Based on available data, Kenya proposes a FRL of -7,471,382 t CO_2/year. This FRL is derived from average annual historical emission from deforestation and forest degradation and emission removals from sustainable management of forests, afforestation and reforestation activities in the country.

The various building blocks for establishing the Forest Reference Level (FRL) were comprehensively discussed and agreed by a Technical Working Group that was established purposely to offer technical guidance for FRL development. An overview of the decisions is as follows:

- Forest definition: a minimum 15% canopy cover; minimum land area of 0.5 ha and minimum height of 2 meters.
- Scale: National
- Scope: REDD+ Activities include Reducing emissions from deforestation, Reducing emissions from forest degradation, Sustainable management of forest and Enhancement of forest carbon stocks.;
- Gases: covers only CO_2.;
- Pools: Above Ground Biomass (AGB) and Below Ground Biomass (BGB).
- Construction method: Historical Average method between 2000 and 2014 using average annual historical emission and removals

The Activity Data (AD) shows declining forest area in Kenya between 2000 and 2014. The Emission Factors (EF) for estimating emissions and removals are based on forest inventory data in the country spread across the various forest strata (127 plots in the forest areas). The EF shows that Carbon stocks in Plantation forest, and Montane forest and Western Rain Forest have larger values than Coastal forests and Mangrove forests, and Dryland forest. Annual emissions from the identified REDD+ activities were 20,206,141 (tCO_2/year) and 2,864,442 (tCO_2/year) for deforestation and forest degradation respectively. Sustainable management of forest and enhancement of forest carbon stocks hada corresponding emission removal of 1,127,606 (tCO_2/year) and 29,414,359 (tCO_2/year)

respectively. Therefore, values of net emissions are -7,471,382 (tCO_2/year) in the period 2000-2014.

1. Introduction

1.1 Relevance

In response to decision 1/CP.16 paragraph 71 (b) and decision 12/CP.17 paragraph 8 and 10, Kenya wishes to voluntarily submit to the United Nations Framework Convention on Climate Change (UNFCCC) the proposed National Forest Reference Level (FRL) for contribution to mitigation actions in the forest sector. In this context, this submission is premised on the consideration that the submission is subject to a technical assessment in accordance with decision 13/CP.19; decision 14/CP.19; and decision 12/CP.17. In preparing the FRL, Kenya has used a stepwise approach consistent with decision 12/CP.19; on the modalities for FRELs and FRLs; including the right to make adjustments to the proposed FRELs/FRLs based on national circumstances. This stepwise approach is strongly informed by availability of data, financial resources and capacities within the country for establishing the FRL.

The National Context

Country Profile

Kenya is located on the eastern part of Africa. It lies across the equator at latitude of 4° North to 4° South and Longitude 34° East to 41° East. The country is bordered by South Sudan and Ethiopia in the north, Somalia to the east, Indian Ocean to the south-east, Tanzania to the south and Uganda to the west (Fig. 1). The country has a total area of 582,650 km^2 including 13,400 km^2 of inland water and a 536km coastline.

Kenya's geography is diverse and varied. The terrain of the country gradually changes from the low-lying coastal plains to the Kenyan highlands. The highest point of the country lies in Mount Kenya, which is 5,199m above sea level. The Great Rift Valley located in the central and western part of the country basically dissects the Kenyan highlands into east and west. The highlands have a cool climate and are known for their fertile soil, forming one of the major agricultural regions of the country. There are also a number of lakes and rivers; most of them in the Rift Valley.

Kenya is divided into seven agro-climatic zones ranging from humid to very arid. Less than 20% of the land is suitable for cultivation, of which only 12% is classified as high potential (adequate rainfall) agricultural land and about 8% is medium potential land. The rest of the land is arid or semi-arid.

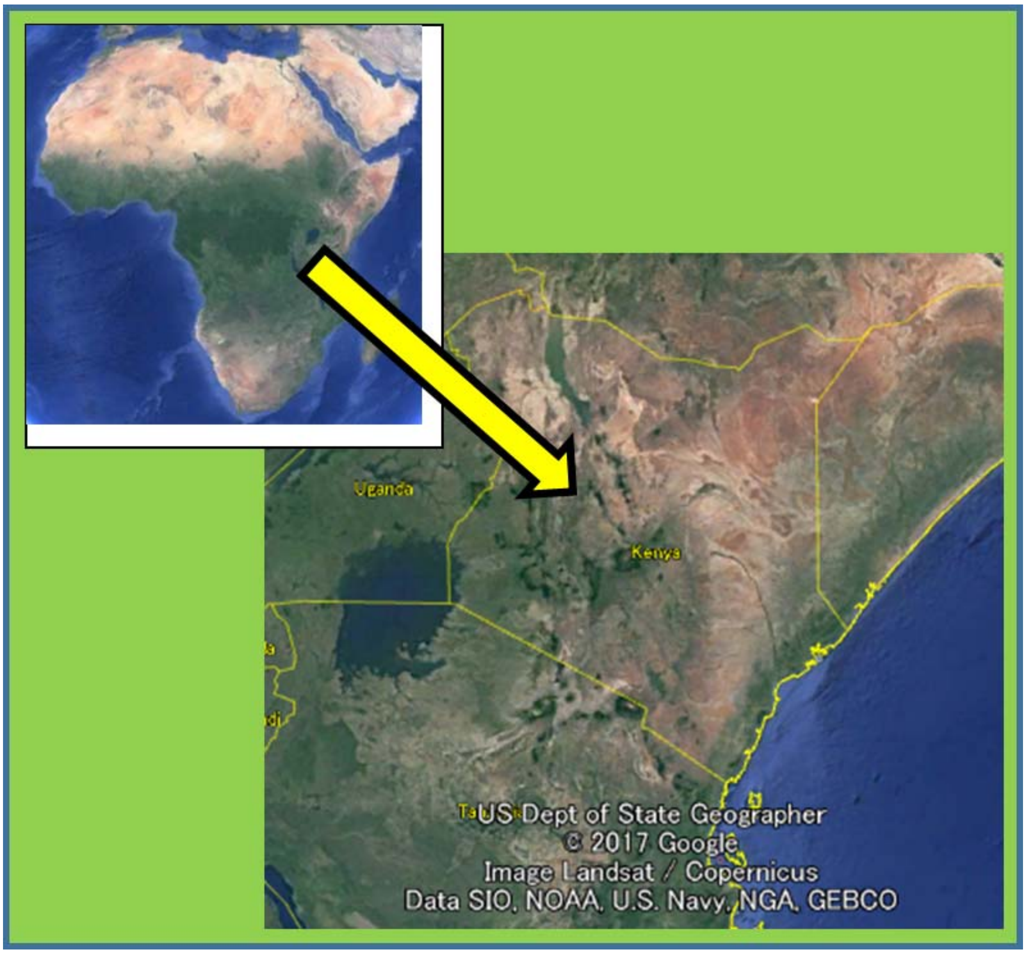

Figure. 1 Map of Africa/Kenya (Google earth. 2017)

Kenya is a low forest cover country with about 6.1 % of the total land area under forests. Enhancing forest cover to a minimum of 10% is a key priority of the Government of Kenya. The Constitution obliges the government to work and achieve forest cover of at least 10% while the national development plan (Vision 2030) and the National Climate Change Response Strategy (NCCRS) aim to achieve this goal by 2030, which amounts to an estimated increase of 2.4 million hectares over the next 13 years. As a party to the UNFCCC, Kenya has committed herself to contribute effectively to global climate change mitigation and adaptation efforts including a renewed resolve to conserve all available carbon storehouses and enhancing its forest carbon. The country has signed the **Paris Agreement** and developed a **Nationally Determined Contribution (NDC)** to global climate change efforts. The success of the NDC will strongly be influenced by the forest sector due to its comparatively high abatement potential.

At the national level, Climate **Change Policy** and Act have been enacted to guide and strengthen country efforts in climate change mitigation and adaptation responses. The **Forest Act** has also been reviewed to further strengthen the country responses to protect forested landscapes and to provide opportunities for increasing the forest cover in line with national development aspirations. The land agriculture and energy policies and supporting legislation have also been developed.

All these policy documents refer to the forestry sector as one of the six priority areas to move Kenya towards a low-carbon, climate-resilient development pathway. In support of the national climate change response process, and in response to a global call for action contained in the **New York Declaration of forests, the Bonn Challenge and the Africa 100 million ha of forests (AFR100) commitment**, the Government has committed to restore 5.1 million ha by 2030 equivalent to an average of 392,000 ha per year. The opportunities for restoration have been identified and current discussions revolve around the best strategies for restoration and funding.

The Forest Sector

Kenya's economy has very strong dependence on the natural environment and in particular, forestry resources. Forestry supports most sectors, including agriculture, horticulture, tourism, wildlife and the energy. Maintenance of forests in water catchment areas (water towers) is critical to Kenya's water supply. In some rural areas, forests contribute over 75% of the cash income and provide virtually all of household's energy requirements. The water towers and forests are estimated to contribute more than 3.6 per cent of GDP, and economic benefits of forest ecosystem services are estimated at more than four times higher than the short-term gains of deforestation and forest degradation.

In spite of these important functions, deforestation and forest degradation has continued to pose challenges driven by among others pressure for conversion to agriculture, settlements and other developments, unsustainable utilization of forest resources, inadequate forest governance and forest fires. The country is exploring a wide range of options, including policy reforms and investments, to protect the existing forests and to substantially restore forest ecosystems across the country.

The Constitution of Kenya and the National Development Plan (Vision 2030) identify forestry as one of the key areas of focus and have made commitments to protect all forests, and to increase the forest cover to a minimum 10 % through aggressive afforestation and reforestation and rehabilitation programs.

Forests in Kenya are managed under three tenure systems: public, community and private. Public forests managed by both national government agencies (mainly Kenya Forest Service and Kenya Wildlife Service) and County governments are manly managed for provision of environmental services but they also contain a belt that is managed for timber, poles and fuelwood. Community forests are found on community land in the expansive arid and semi-arid lands and whose management objective is mainly livestock grazing. Private forests are found on private land. The Kenya Forest Service remains the foremost institution charged with the responsibility and mandate to ensure all forests in the country are sustainable management

REDD+ in Kenya

Past attempts to increase forest cover and address the problem of deforestation and forest degradation in the country have not been very successful undermined by among others increasing demand for land for agriculture, settlement and other developments, high energy demand and inadequate funding to support investments in the forestry sector. Unresponsive policy and poor governance in the forestry sector have often in the past compounded these problems.

Kenya has developed a consultative REDD+ readiness proposal which has identified priorities in the REDD+ implementation process. It is noted that REDD+ presents a great opportunity to reverse the negative trends of forest loss by providing innovative approaches, including incentives from carbon finance, that support implementation of a comprehensive strategy that effectively supports sustainable management and conservation of forests and at the same time reduce carbon emissions. In Kenya, REDD+ is evolving as an attractive means to reduce forest sector carbon emissions. Kenya's participation in REDD+ is premised on the conviction that the process holds great potential in supporting:

- Realization of vision 2030 objectives of increasing forest cover to a minimum of 10%;
- Access to international climate finance to support investments in the forestry sector;
- Government efforts in designing policies and measures to protect and improve its remaining forest resources in ways that improve local livelihoods and conserve biodiversity;
- Realization of the National Climate Change Response Strategy (NCCRS) goals.
- Contribution to global climate change mitigation and adaptation efforts.

Priority areas of focus in REDD+ include the following:

- Reducing pressure to clear forests for agriculture, settlements and other land uses;
- Promoting sustainable utilization of forests by promoting efficiency, energy conservation;
- Improving governance in the forest sector by strengthening national capacity for FLEG, advocacy and awareness;
- Enhancement of carbon stocks through afforestation /Reforestation, and fire prevention and control.

2. Development of the Forest Reference Level

2.1 Objectives of developing a national FRL

Kenya is establishing a Forest Reference Level as an objective benchmark for assessing performance of REDD+ activities. The FRL has been established in consistency with the country's greenhouse gas inventory process guided by the UNFCCC reporting principles of Transparency, Accuracy, Consistency and Comparability.. In this report, Kenya focuses on four REDD+ activities; reducing emissions from deforestation, reducing emissions from forest degradation, sustainable management of forests and Enhancement of forest carbon stocks.

2.2 The Building Blocks of the Forest Reference Level

2.2.1 Forest definition

A national forest definition for REDD+ Kenya has been agreed through a broad stakeholder consensus as a minimum 15% canopy cover; minimum land area of 0.5 hectares and potential to reach a minimum height of 2 meters at maturity in situ. This definition was informed by four basic considerations;

- Opportunity for as many as possible 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 have a variety of characteristics but are a priority for conservation by Kenya's national development programmes
- Support by available technology for establishing the reference level and for monitoring of performance;
- Need to balance the costs of implementation and monitoring and the result-based incentives
- Consistency with the national forest agenda to optimize, manage and conserve Kenya's forests.

While the Second National Communication (SNC) used the FAO forest definition to provide information on forest cover in the country (FAO, 2015), it has since been agreed that the third National Communication to UNFCCC will be harmonized with the Forest definition which is used for setting this FRL. This definition will also be used to inform monitoring of forest sector performance (including the proposed National Forest Monitoring System) and reporting to other international treaties and protocols to which Kenya has subscribed.

Perennial tree crops like coffee, tea and fruit trees are not considered as forests under this definition irrespective of whether they meet the definition of forests.

2.2.2 Forest stratification

The following broad forest strata have been agreed to support the mapping work in the country for purposes of generating activity data, emission factors and GHG emission and removal statistics.

a. Natural forest with further stratification into;

i. Montane forest/Western forest/Bamboo

ii. Mangrove and Coastal forest

iii. Dryland forest

b. Plantation forest;

Further stratification on each of the above strata was done on the basis of canopy closure into three canopy classes: 15-40 %, 40-65 %, and above 65 %.

Further clarification of the various classification (Table 1) was provided as follows:

Table 1 Classification of Land Cover/Land Use in Kenya

Forest	Montane forest/ western rain forest/ Bamboo	Dense
		Moderate
		Open
	Mangrove and coastal forest	Dense
		Moderate
		Open
	Dryland forest	Dense
		Moderate
		Open
	Plantation forest	Dense
		Moderate
		Open
Non Forest	Cropland	
	Grassland	
	Wetland	
	Settlement and Other land	

(1) Montane forest, Western rain forests and Bamboo

a) Montane forest

These are forests in high altitude regions of Kenya (above 1,500 m). They have been described as water towers due to their support to water catchments. They include the Mau, Mt. Kenya, Aberdares, Cherangany and Mt. Elgon forest ecosystems, as well as Leroghi, Marsabit, Ndotos, the Matthews Range, Mt, Kulal, Loita Hills, Chyulu Hills and Taita Hills. These forests differ in species composition from other forests in the country due to climate and altitude. The moist broad-leaved forests occur on the windward sides of the highlands while the drier coniferous mixed forests are found on the leeward sides. At higher altitudes thick stands of the highland bamboo (*Yushania alpina*) dominates.

b) Western rain forests

These are forests with characteristics of the Guineo-Congolean forests and include Kakamega forest, North and South Nandi forest and Nyakweri forest in Transmara Sub-County. The trees are significantly taller and larger as compared to the other forests of Kenya. Due to the relatively small forest area, western rainforests have been categorized together with montane forests.

(2) Mangrove and Coastal forest

a) Mangrove

Mangrove are trees 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 *Rhyzophora mucronata*, then *Bruguiera gymnorrhiza*, *Ceriop stagal*, *Avicennia marina*, *Lumnitzera racemose* and *Heritiera litoralis* respectively. However, the mangrove forests occupy a very insignificant area of Kenya's forests and are classified together with coastal forests

b) Coastal forest

These are the forests found in the coastal region of Kenya within a 30 km strip from shoreline. 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 area biodiversity hotspots.

(3) Dryland forest

Dryland forests are found in the expansive arid and semi-arid regions of Kenya where they exist in patches. Tree composition of this forest is dominated by *Acacia-Commiphora* species but also include *Combretum*, *Platycephelium voense*, *Manilkara*, *Lannea*, *Balanites aegyptiaca*, *Melia volkensii*. *Euphorabia candelabrum* and *Adansonia digitata*. The category also includes riverine forest in dry areas. Their carbon stocks may differ from that of other forests due to leaf shedding, elongated rooting systems and high specific wood density.

(4) Plantation forests

Plantation forests are even aged monocultures of *cypress, pines and eucalyptus* managed for commercial purposes. Their boundaries in public forests (forests on public lands) are clearly defined and it is possible to delineate them from natural forest. The trees are specifically grown for commercial wood production and are subjected to periodic clear felling and a series of silvicultural activities like pruning and thinning which affect their carbon stocks. In public forests, exotic plantation species include *Cupressus lusitancia*, *Eucalyptus sp.* And several pine species (*P. patula* in montane areas and, *P. carribbeae* in coastal forests). Due to their management practices, it is possible to estimate carbon emissions and sinking activities due to various silvicultural treatments.

(5) Non Forest areas

Non forest areas refer to Cropland, Grassland, Wetland, Settlement and Other land. These classifications correspond to Intergovernmental Panel on Climate Change (IPCC) guidelines' on consistent representation of lands for monitoring GHG fluxes.

2.3 Scope

2.3.1 REDD+ Activities

Kenya has decided on the following scope of REDD+ activities with its definitions:

- Reducing emissions from deforestation (Deforestation)
- Deforestation is taken to mean conversion of Forest to Non-Forest land use across all management systems. Deforestation does not include planned and periodic felling of plantation forests and associated carbon stock fluxes. Kenya has the necessary data and technical capacity to provide information to support inclusion of this activity in its submission. In this submission, the short-term fluxes cannot be judged by the unique scientific data as Activity Data. In future however, more details of these fluxes can be researched through a stepwise approach.

- Reducing emissions from forest degradation (Forest Degradation)

Forest degradation is taken to refer to carbon stock changes associated with forest canopy changes from dense canopy coverage to moderate and low canopy coverage in Natural forests (Montane forest, western rain forests, Mangrove and coastal forest, and Dryland forest).

- Sustainable management of forest

This refers to carbon stock changes within the public Plantation Forests managed by Kenya Forest Service (KFS), including changing the forest stratifications between different canopy coverages within Plantation Forest, and also including the forest changes from Plantation Forests to Non Forest and from Non Forest to Plantation Forests. The justification for this is based on a backlog in replanting these forest areas since 1990s resulting to extensive non forests within government forest plantation zones and a failed sustainable management programme. In addition, poor stocking due to failure of the implementation of silvicultural treatments of the existing plantation forests resulted to open plantation forests but these areas provide an opportunity for enhancing production on a sustainable management programme. There has also been uptake of afforestation programmes by private investors in areas that were non forested and formerly marginal areas.

- Enhancement of forest carbon stocks

This refers to activities that increase carbon stocks within natural forests through rehabilitation of degraded areas and those that result in new forests from reforestation and afforestation efforts within the country.

The matrix below (Table 2) provides an explanation how each REDD+ Activities will be accounted for while setting the FRL. Kenya has decided to measure its REDD+ Activities changes in the whole forest land.

Table 2 Monitoring Land Cover/Land Use Changes of REDD+ Activities in Kenya

Area in 20XX			Area in 20XX+(X)													
			Forest												Non Forest	
			Montane Forest/ Western Rain Forest/ Bamboo			Costal Forest and Mangroves			Dryland Forest			Plantation Forest			Grass land	Other Non-forest
			D	M	O	D	M	O	D	M	O	D	M	O		
Forest	Montane Forest/ Western Rain Forest/ Bamboo	D	n	dg	dg										df	df
		M	e	n	dg										df	df
		O	e	e	n										df	df
	Costal Forest and Mangroves	D				n	dg	dg							df	df
		M				e	n	dg							df	df
		O				e	e	n							df	df
	Dryand Forest	D							n	dg	dg				df	df
		M							e	n	dg				df	df
		O							e	e	n				df	df
	Plantation Forest	D										n	s	s	s	s
		M										s	n	s	s	s
		O										s	s	n	s	s
Non Forest	Grass land		e	e	e	e	e	e	e	e	e	s	s	s		
	Other non Forest		e	e	e	e	e	e	e	e	e	s	s	s		

df Deforestation (F→NF)
dg Forest Degradation (F→F(Degraded))
e Enhancement (F→F(Improved) ,NF→F)
n No Change (F→F)
s Sustainable Management of Forest (F→F, F→NF, NF→F)

2.3.2 Carbon pools

Kenya selected the carbon pool as follows:

- Above-ground biomass
- Below-ground biomass

The carbon pools shown below are not considered when establishing the FRL:

- Soil organic carbon
- Litter
- Deadwood
- Harvested wood products

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

a) Soil organic carbon

Kenya notes the requirements for Tier 1 reporting of the soil carbon stocks (2006 IPCC Guidelines) which require a land-use factor (FLU), a management factor (FMG) an input factor (FI), all that require a variety of information which is lacking in Kenya. The technical working group agreed to omit this carbon pool during the current process. This is in line with the stepwise approach which will allow the country to undertake further necessary research of soil, to support an update is of the FRL in future.

b) Litter

There is minimal research data in the country to support inclusion of this carbon pool. Kenya does not also have enough information on this carbon pool. In future, this pool will be researched further to support a more accurate estimation based on a stepwise approach.

c) Deadwood

There has not been enough research on the deadwood carbon pool. However, Kenya has tried to get some information for this carbon pool through a pilot forest inventory but the results are inconclusive. Further research and collection of the accurate data has been proposed to support its inclusion. In future submission, this pool is expected to be included.

2.4 Scale

Kenya has chosen to establish a national FRL. This decision is informed by current forest management practices and evolving policies, legislation and institutional frameworks for forest sector reforms which have a national approach. There is broad consensus that REDD+ will be implemented through strong policies and other measures by the national government through county governments. Kenya's decision was also informed by the need to provide broad sectoral technical guidance and monitoring framework to support jurisdictional and project-level REDD+ activities.

2.5 Green House Gases (GHG)

Kenya's FRL only covers Carbon dioxide gas (CO_2) as the only GHG for reference. Non-CO_2 emission Gas such as Methane (CH_4), Carbon Monoxide (CO) and Nitrous Oxide (N_2O) are not considered because Kenya does not have quantitative spatial data for Non-CO_2 emission Gases (such as emissions from forest fires and emissions from forests in wetlands). It is recognized however that forest fires and mangroves are major sources on non- CO_2 gases and should be considered in subsequent estimation.

2.6 Activity Data Generation

In Kenya, different institutions and programs have in the past taken initiatives to develop wall to wall Land Cover / Land Use Maps. For example, FAO Africover program produced Land Cover / Land Use Map for 1999 based onLANDSAT4 and 5 satellite images. The Forest Preservation Program (FPP), a grant aid program financed by the Japan Government, produced Land Cover / Land Use Map for 1990, 2000 and 2010 based on imageries of LANDSAT4, 5, 7 and ALOS . The FPP mapping process used object based methodology by manual digitizing for the three epochs which was time consuming and non-consistent with developing technologies.

In 2013, Kenya launched the System for Land-Based Emission Estimation in Kenya (SLEEK) programme to support the National GHG inventory process. The SLEEK did an extensive mapping using a semi-automated method and produced the Land Cover / Land Use Map for the year 1990, 1995, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010,, 2011, 2012, 2013 and 2014 based on imagery of LANDSAT4, 5, 7 and 8.

The map production methodology applied by SLEEK was pixel based – supervised classification using Random forest algorithm. The SLEEK Land Cover Change Mapping (LCC) Program aimed to create a consistent, sustainable and technically rigorous process for providing land cover and change information required for national land based greenhouse gas (GHG) estimation. In addition to supporting SLEEK, the maps and statistics produced by the program are recognized as official Government documents for informing Government processes across the land sector – such as land use planning, tracking deforestation, and landscape restoration. These are the maps adopted to support the REDD+ process in construction of the Forest Reference Level and the National Forest Monitoring System.

The methodology employed for the SLEEK process allows creation of Land Cover / Land Use Map in a short period at low cost without requiring manual interpretation and editing. The site training data for supervised classification was extracted through a rigorous ground truth survey complemented by Google Earth in areas with poor accessibility. The minimum mapping unit (MMU) of Land Cover / Use class was 0.09ha due to pixel basis image classification methodology and a 6 pixel filtering process was applied to ensure that forest mapping met the forest definition (0.5ha) as agreed in the country.

For the development of FRL, the Land Cover / Land Use Maps for 2000 and 2014 were selected based on LANDSAT imagery quality and cloud cover ratio (Fig. 2 and Table 3). And it was divided by individual forest type of ecological zone, such as Montane Forest/Western Rain Forest/Bamboo, Costal Forest and Mangroves, Dryland Forest and Plantation. The details of forest types' definition are described on Annex 1 and 2. The detailed methodology and screening of LANDSAT imagery for selection of the Land Cover / Land Use Map is described in Annex 1. The matrices of area of land Cover/Land use change is shown in Table 4 with individual forest types. The time periods for assessing land cover/ land use change of each matrix is 2000 – 2014.

Table 3 Land Cover/Land Use statistics from 2000 and 2014

		2000		2014	
		Area in Ha	Percentage	Area in Ha	Percentage
Montane Forest/ Western Rain forest / Bamboo	Dense (above 65%)	958,824.36	1.6%	1,085,866.29	1.8%
	Moderate (40% - 65%	246,815.82	0.4%	201,829.14	0.3%
	Open (15% - 65%)	130,944.87	0.2%	104,391.72	0.2%
Sub Total		**1,336,585.05**	**2.3%**	**1,392,087.15**	**2.4%**
Coastal Forest and Mangroves	Dense (above 65%)	177,554.61	0.3%	421,461.18	0.7%
	Moderate (40% - 65%	373,599.54	0.6%	125,032.32	0.2%
	Open (15% - 65%)	22,956.57	0.0%	6,241.41	0.0%
Sub Total		**574,110.72**	**1.0%**	**552,734.91**	**0.9%**
Dryland Forest	Dense (above 65%)	971,411.85	1.6%	970,205.40	1.6%
	Moderate (40% - 65%	532,503.90	0.9%	286,968.33	0.5%
	Open (15% - 65%)	333,839.79	0.6%	305,131.68	0.5%
Sub Total		**1,837,755.54**	**3.1%**	**1,562,305.41**	**2.6%**
Plantation	Dense (above 65%)	60,817.23	0.1%	78,319.08	0.1%
	Moderate (40% - 65%	4,866.66	0.0%	2,371.77	0.0%
	Open (15% - 65%)	1,933.29	0.0%	946.35	0.0%
Sub Total		**67,617.18**	**0.00**	**81,637.20**	**0.00**
Forest Total Area		**3,816,068.49**	**6.4%**	**3,588,764.67**	**6.1%**
Cropland		4,450,229.19	7.5%	6,199,777.26	10.5%
Grassland		43,012,653.03	72.7%	41,200,817.04	69.6%
Water Body		1,236,114.99	2.1%	1,263,078.81	2.1%
Otherland and Settlements		6,685,673.22	11.3%	6,948,302.49	11.7%
Total		59,200,738.92	100.0%	59,200,740.27	100.0%

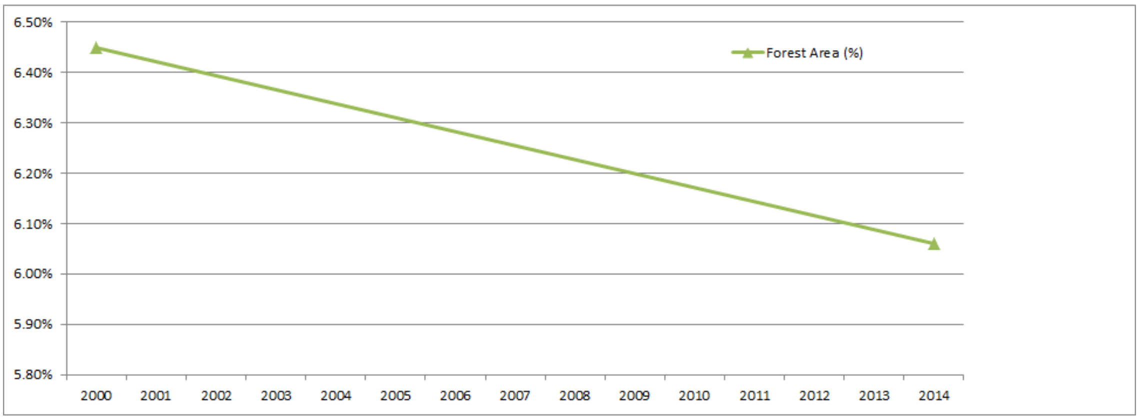

Figure. 2 Change of forest cover percentage from 2000 to 2014

Table 4 Area of Land Cover/Land Use change in each reference periods (ha)

			2014															
			Montane Forest / Western Rain Forest / Bamboo			Costal Forest and Mangroves			Dryland Forest			Plantation			Cropland	Grassland	Wetland	Settlement and Other land
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open				
2000	Montane Forest / Western Rain Forest / Bamboo	Dense	764,212	32,274	11,406										75,352	74,634	312	634
		Moderate	80,651	75,942	13,003										18,195	58,395	540	89
		Open	28,207	12,440	24,809										15,817	49,464	30	177
	Costal Forest and Mangroves	Dense				130,627	14,832	662							1,164	29,471	259	539
		Moderate				149,599	70,438	2,636							7,748	141,963	377	838
		Open				2,185	2,034	255							1,410	16,942	14	116
	Dryland Forest	Dense							332,473	35,597	21,645				68,784	509,509	1,881	1,523
		Moderate							117,224	64,691	25,926				28,461	291,851	1,618	2,734
		Open							33,921	31,761	50,164				11,168	200,725	1,432	4,669
	Plantation	Dense										46,713	1,029	525	6,578	5,959	8	6
		Moderate										3,392	302	47	381	737	5	2.25
		Open										1,403	53	7	202	268	0.09	0.36
	Cropland		47,186	4,175	1,804	2,304	303	18	16,270	1,756	421	6,557	134	74				
	Grassland		164,906	76,748	53,075	134,762	36,753	2,624	462,145	148,928	194,297	20,137	853	293				
	Wetland		254	13	6	1,209	476	42	3,577	1,359	843	0	0	0				
	Settlement and Other land		450	236	289	775	196	4	4,597	2,877	11,836	109	0.90	0.27				

* Public plantation forest areas cover 136,890 ha. The changing areas from non-forest to non-forest in KFS plantation sites amount 41,115 ha within the total non-forest to non-forest areas. These areas are defined as forest areas with no stocks and will placed under sustainable management during REDD+ implementation.

2.7 Emission Factors (EF)

Kenya has decided to use available country specific data for setting the Emission Factors. The EF were obtained from pilot forest inventory data.

The EF used in this submission are based on Land Cover Classification that is consistent with the Activity Data. The classifications of the AD are divided into Dense Forest, Moderate Forest, Open Forest, and Non Forest. Forest land is divided into four forest class: Montane and western rain forest and Bamboo, Mangroves and coastal forest, Dryland forest and Plantation forest as shown in Table 1. In total, there are 12 forest type classes. Non Forest land class consists of Cropland, Grassland, Wetland, Settlement and Other land. The details of the results in each forest types are explained in the Annex 3.

Kenya has never conducted a comprehensive National Forest Inventory (NFI) that would have effectively supported the establishment of emission factors. According to the step-wise approach, it is expected that the NFI whose guidelines and manuals have already been approved will be implemented in the future. Therefore, data from the pilot inventory that covered all the forest types was used. The data was collected from a total of 127 plots.

The EF were estimated by the following process. Firstly, the values of AGB in each plot are computed (Table 5), using the forest inventory data with allometoric equations as shown in Table 6. The values of BGB are calculated by applying the R/S ratio (IPCC 2006). The plots' data and the equations with Carbon Fraction (CF) applied in this work are shown in Table 6. The carbon stock values are calculated on the basis of the AGB and BGB data. Finally, Emission Factors are estimated by calculation of the carbon stocks changes per unit area at two points in time.

Besides the above, the values of Non Forest land class are referred from 2006 IPCC Guidelines as shown in Table 7. The related details of EF setting are described in Annex 3.

Table 5 Volume (m^3/ha), Biomass stock (ton/ha), Carbon stock (ton/ha) and CO_2 amount (ton/ha) of each forest type class

Class	Canopy coverage	AGB				BGB			TOTAL		
		Volume*	Biomass stock	Carbon stock**	CO_2 amount	Biomass stock***	Carbon stock****	CO_2 amount	Biomass stock	Carbon stock	CO_2 amount
Montane Forest & Western Rain Forest	Dense	437.86	344.97	162.14	594.50	93.14	46.57	170.76	438.11	208.71	765.26
	Moderate	69.59	58.43	27.46	100.70	15.78	7.89	28.92	74.21	35.35	129.62
	Open	26.23	23.26	10.93	40.09	6.28	3.14	11.52	29.54	14.07	51.61
Coastal forest & Mangrove forest	Dense	97.35	94.63	44.47	163.07	27.76	13.88	50.89	122.38	58.35	213.96
	Moderate	64.53	60.45	28.41	104.17	13.64	6.82	25.01	74.09	35.23	129.18
	Open	41.92	35.47	16.67	61.14	7.53	3.76	13.80	43.00	20.44	74.93
Dryland Forest	Dense	98.55	80.32	37.75	138.42	31.71	15.85	58.13	112.03	53.61	196.56
	Moderate	38.74	34.52	16.23	59.49	13.00	6.50	23.83	47.52	22.72	83.32
	Open	16.00	14.26	6.70	24.58	3.85	1.93	7.06	18.12	8.63	31.64
Plantation Forest	Dense	539.23	436.68	205.24	752.54	117.90	58.95	216.15	554.58	264.19	968.69
	Moderate	137.79	113.54	53.36	195.67	30.66	15.33	56.20	144.20	68.69	251.87
	Open	174.54	138.22	64.96	238.20	37.32	18.66	68.42	175.54	83.62	306.62

* Volume does not include volume of Climber.
** The values were calculated by CF(0.47) (IPCC 2006).
*** The values were calculated by R/S ratio in Table. 7.
****The values were calculated by CF(0.5) (Hirata et al 2012).

Table 6 List of allometoric equation and References

Type	Volume (m^3)	Reference	AGB (kg)	Reference	BGB (Kg)	Reference
Common	$\pi\times(DBH/200)^2\times H\times 0.5$	Henry et al. 2011	$0.0673*(0.598*D^2H)^{0.976}$	Chave et al. 2009, 2014	0.27 (Montane Forest, Plantation) 0.20 (AGB ≤ 125 (ton/ha)), 0.24 (AGB＞125 (ton/ha)) (Coastal forest) 0.40 (Kibwezi), 0.27 (Baringo)(Dryland Forest)	IPCC. 2006
Rhizophora sp.	$\pi\times(DBH/200)^2\times H\times 0.5$	Henry et al. 2011	$0.128\times DBH^{2.60}$	Fromard et al. 1998, Komiyama et al. 2008	0.37 and 0.20 (AGB ≤ 125 (ton/ha)), 0.24 (AGB＞125 (ton/ha)) (Mangrove Forest)	IPCC. 2006
Bamboo	$d^2-(d*0.7)^2/4*\pi*h*0.8$	Dan et al. 2007	$1.04+0.06*d*GW_{bamboo}$ $GW_{bamboo}=1.11+0.36*d^2$ (bamboo diameter > 3 cm) $GW_{bamboo}=1.11+0.36*3.1^2$ (bamboo diameter ≤ 3 cm)	Muchiri and Muga. 2013	0.27 (Montane Forest)	IPCC. 2006
Climber	-	-	$e^{(-1.484+2.657*\ln(DBH))}$	Schnitzer et al. 2006	0.27 (Montane Forest, Plantation) 0.20 (AGB ≤ 125 (ton/ha)), 0.24 (AGB＞125 (ton/ha)) (Coastal forest) 0.40 (Kibwezi), 0.27 (Baringo)(Dryland Forest)	IPCC. 2006

* Volume does not include volume of Climber.

Table 7 Default values of Biomass stock and Carbon stock of land cover classes

Class	Biomass stock (ton/ha)	Carbon stock (ton/ha)	CO_2 amount (ton/ha)	References
Cropland	0	0	0	IPCC Guideline2006
Grassland	8.7*	4.35**	15.95	IPCC Guideline2006
Wetland	0	0	0	–
Settlement and Other land	0	0	0	IPCC Guideline2006

* The data is included AGB and BGB. ** CF=0.5 (Hirata et al. 2012)

2.8 National circumstances

2.8.1 Qualitative analysis

This section describes how the national circumstances are likely to influence future forest sector emissions and removals. The national circumstances considered include current and evolving institutional arrangements for forest management and administration, implementation of policies and legislation, national and international forest commitments, and national development strategies likely to impact on future forest resources management and conservation.

The importance of the forest sector in Kenya has been emphasized since early 1900s when most of the major forest blocks were reserved as forest areas and the development of the first forest policy in 1957 to support protection of the forest estate, ensure sustainable exploitation, promote afforestation, and management forests for public amenity, recreation and as a habitat for wildlife.

The forest sector is today a critical asset for economic growth, environmental sustainability, and provision of social and cultural values. For instance, about 50,000 people are directly employed in the forest sector while about 300,000–600,000 are indirectly employed depending on the sector, (FAO, 2014; KFS 2015b). Further, over 530,000 households within 5 kilo meters from forest areas have significant dependency on the forest services and products which include, cultivation, grazing, fishing, fuel, food, honey, herbal medicines, water and other benefits.

Forest Sector Governance

The management of land resources in Kenya including forestry are enshrined in Chapter 5 of the Constitution. Under the Constitution, forest resources are governed under government, community and private tenure systems. Public forests are managed by national government through its agencies and County governments. Transfer of public forests to county governments has yet to be realized due to lack of human capacity to manage such resources. The Constitution has however expressly stated the desire to[1] achieve and maintain at least 10% forest cover of the total national land area. The Forest Policy also recognizes the critical role played by the forests in ensuring ecological balance and providing various social, cultural and economic benefits, compelling the need for properly structured governance framework. Further, the Forest Conservation and Management Act, 2016 categorises Kenyan forests into public, community and private forests to ensure sustainable development and management of all forest resources.

The other key policies and legislation that have a bearing on the forest management include; National Wildlife Conservation and Management Act, 2013, supporting management of forest areas in significant wildlife habitats; The Land Act, 2012 and the County Government Act, 2013 which requires engagements of the local communities in the planning and management of forest resources

[1] The Constitution states that "land in Kenya shall be held, used and managed in a manner that is equitable, efficient, productive and sustainable," and entrenches "sound conservation and protection of ecologically sensitive areas."

to ensure sustainable and strategic environmental, ecological, social, cultural and economic benefit sharing. Other important policy and legislation include Environmental Management and Coordination (Amendment) Act, 2015; The Energy Act, 2006; Agriculture, Fisheries and Food Authority Act, 2013; The Water Act, 2002; National Museums and Heritage Act, 2006; and the Climate change Act, 2016.

The country recognizes the forest sector as a key sector in her national development strategies and plans which include the Kenya Vision 2030, the national Climate Change Response Strategy (2010), , and the Kenya Green Economy Strategy and Implementation Plan (2017) which recognises the critical role of the forest sector in meeting the climate change mitigation and adaptation obligations. Kenya has already developed a National Determined Contribution (NDC) in line with her commitment to the global climate change goals under the Paris climate agreement.

Governance challenges

The main challenge in the management of the forest resources is that of providing environmental, economic, social, and cultural benefit while ensuring resource use efficiency, equity and adequate incentives to encourage conservation and growth of forest cover. The governance challenges result from the increasing population and associated increased demand for forest products and services, overlapping policies and institutional mandates, Policy conflicts, inadequate land tenure policies, and inadequate collaboration among forest conservation agencies. Governance and enforcement of forest management policies and legislation is poorly coordinated and has inadequate provision for effective participation of Stakeholders. Inadequate regulation of grazing in the semi- arid and arid lands woodland and Dryland forests has resulted to overstocking and overgrazing leading to wide spread deforestation and degradation of forests. Despite the presence of policies and legislation that govern the management of forest resources., these challenges still manifest and have continued to cause significant deforestation and forest degradation.

Socio-Economic profile

Kenya has experienced significant growth in population in the recent past. The current population of about 48 million has a very high positive relationship on forest cover and the rates of deforestation and forest degradation The government has proposed drastic measures to boost food production, including increased acreages under irrigation and provision of subsidies for agricultural inputs. There is rapid urbanization in the country as a result of growth in population and enabling economic environment in the country. The expansion of cities and towns will continue to cause deforestation and forest degradation by encroaching into the forest areas and causing increased demand of forest products for construction and energy. Both rural and urban populations are highly dependent on biomass energy especially the use charcoal accounting for 60% energy of demand.

There are a number of challenges that affect the economical and efficient exploitation and management of the forest resources and these include; bureaucracy obstructing competitiveness of businesses, inadequate knowledge of forest-based enterprise, poverty, high prices for agriculture products, subsidized fertilizer, tax exemption for certain agricultural machinery resulting in unhealthy competition for land and overdependence on rain-fed agriculture.

Infrastructural, and industrial developments

Kenya has an aggressive Infrastructural, commercial and industrial development programme based on the vision 2030. this development is likely to result in clearing of large areas of previously forested landscapes. The surrounding forest areas are also more likely to be converted to settlements leading to deforestation and forest degradation. It has been pointed out that the current and planned developments are concentrated in the fragile ecosystems including the dryland forest and woodland areas adversely affecting the forest cover in the country. The current and planned developments that are expected to lead to planned deforestation and forest degradation include Konza technology city, Isiolo Port, Lamu port, LAPSET Project, comprising of a road, rail and pipeline connecting Kenya to South Sudan and Ethiopia, The Northern Corridor Transport Project, Construction of a standard gauge railway line from Mombasa to Kisumu, Creation of a one-million-ha irrigation scheme in the Tana Delta.

Development Priorities and commitments

There are different development priorities recognized in the country due to the set national development agenda, agreements within regional economic blocks, international treaties and multilateral agreements. Most of these agreements have identified forests and woodlands as important resources for economic growth and poverty reduction, especially with regard to energy, food, and timber. There are also other non-timber forest products and environmental services that underpin ecosystem functions in support of agricultural productivity and sustainability" (IIED, 2014c. p. 39). Important development priorities affecting the forest sector include; SDG Targets, UNFCCC, Convention on Biological Diversity (CBD), Forest Law Enforcement, Governance and Trade (FLEGT), International Tropical Timber Agreement 2006 (ITTA), Reducing Emissions From Deforestation and Forest Degradation (REDD+ mechanisms) and the United Nations Convention to Combat Desertification (UNCCD)

The Sustainable Development Goals (SDG) which recognize multiple functions of forests including ensuring conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems, the need to mobilize resources for forest management, protecting forest catchments area in line with obligations under international agreements (SDG15.1, SDG15.2, SDG15b, SDG6.6) by year 2020. Under the United Nations Framework Convention on Climate Change (UNFCCC), through the Nationally Determined Contribution (NDC) the government has committed to contribute to the mitigation and adaptation to climate change by using the forest sector as the main sink for GHG

Emissions.

While significant changes in policy and Legislation has been undertaken over the last decade that seeks to strengthen sustainable forest management and conservation, the country's forest resources continue to experience severe pressure from the expanding agricultural frontier, settlements and other developments. There are genuine concerns that commitments to national and international forest goals may not be realized if the current challenges are not addressed. There is expectation however that improved governance of the sector arising from the devolution and public participation in management may reverse the current negative practices. This is however expected to take some time as capacities within county governments are strengthened to assume expanded responsibilities.

Projections of FRL

No modelling studies have so far been carried out to understand how various land use and land resources policies implementation will manifest in future against the challenges of competing land claims by key economic sectors, increasing population and increased demand for forest resources and food insecurity.

In view of the above, it is proposed that the FRL will be projected based on the historical data in accordance with the recommended stepwise approach to forest reference level construction. Kenya will however invest resources to ensure the subsequent reference level will rely more strongly on models generated locally.

2.9 Construction method

Kenya has used the Historical average method to develop the projection. The process of developing the reference years and the average emissions are described in section 2.3-2.7 of this

3. Forest Reference Level

AD were analyzed on the basis of the Land cover/Land use change maps. The attribution of AD and EF was used as the basis for estimating historical trends of emissions from forestlands of Kenya. In this submission, the proposed FRL's value is the value using average annual historical emission.

3.1 Historical average and the proposed FRL value

The values of Emission estimates of each REDD+ activity are shown in the Table 8 and 9 (See, also Annex 4). The value of Net emission is calculated as the sum of emissions arising from deforestation and forest degradation and emission removals from afforestation, reforestation and forest rehabilitation activities. The calculations done have indicated a net removal of -7,471,382 tCO_2/year in the period of 2000-2014. In terms of REDD+ activities (Table 9), Deforestation is currently responsible for annual emissions of 20,206,141 tCO2. Forest degradation has an annual emission of 2,864,442 tCO2. Sustainable management of forest has a net removal of 1,127,606 tCO2.

Enhancements arising from restoration efforts have been shown to generate annual removals of 29,414,359 tCO2. Based on the various calculations, the proposed FRL value is -7,471,382 tCO_2/year as shown in Table 10, Fig. 3, 4, 5.

Table 8 Emission estimates (tCO_2/year)

Period	2000-2014
Net Emisssion	-7,471,382
Gross Emission	24,039,316
Gross Removal	-31,510,697

Table 9 Total emissions/removals for each REDD+ activity (tCO_2/year)

Period	2000-2014
Deforestation	20,206,141
Degradation	2,864,442
Sustainable management of forest	-1,127,606
Enhancement	-29,414,359
Total (Emission estimates (Net))	-7,471,382

Table 10 Table. Forest Reference Level (tCO_2/year)

Period	2000-2014
FRL	-7,471,382

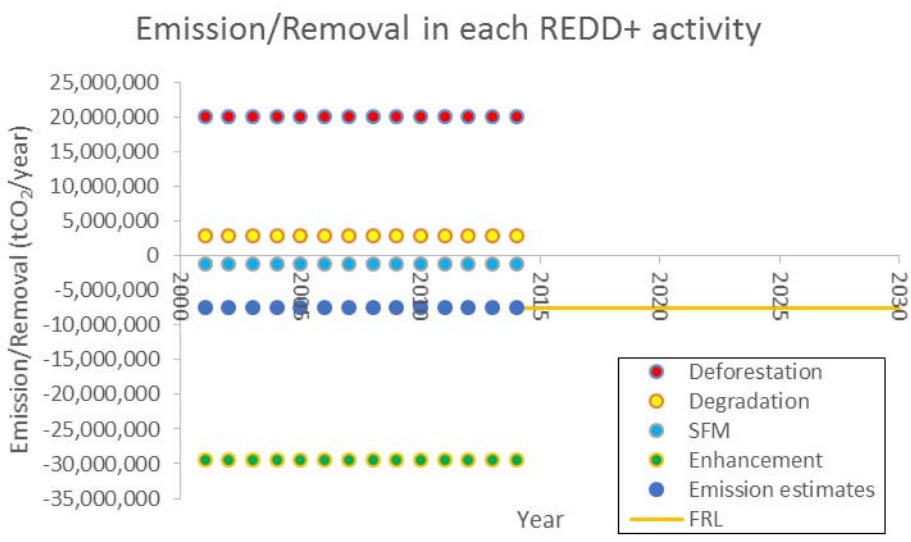

Figure. 3FRL liner projection, and Emission and Removal in each REDD+ activity

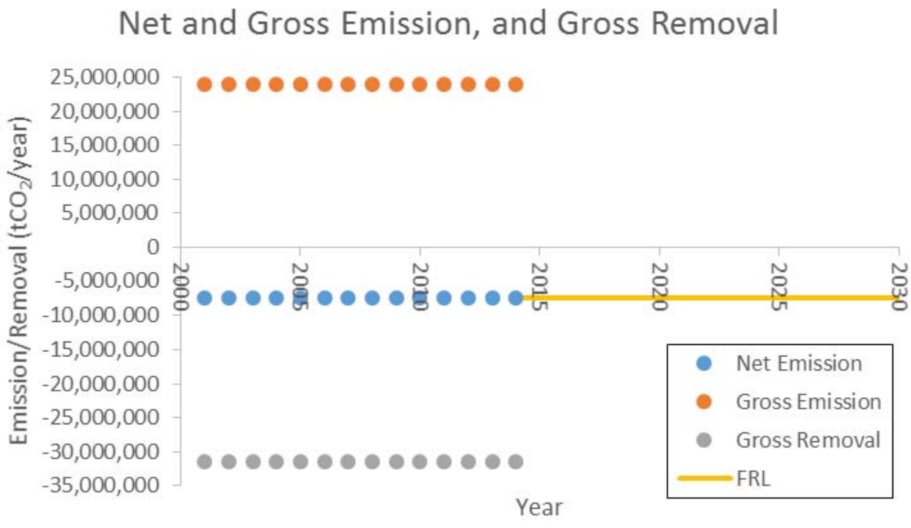

Figure. 4 FRL liner projection, Net and Gross Emission, and Gross Removal

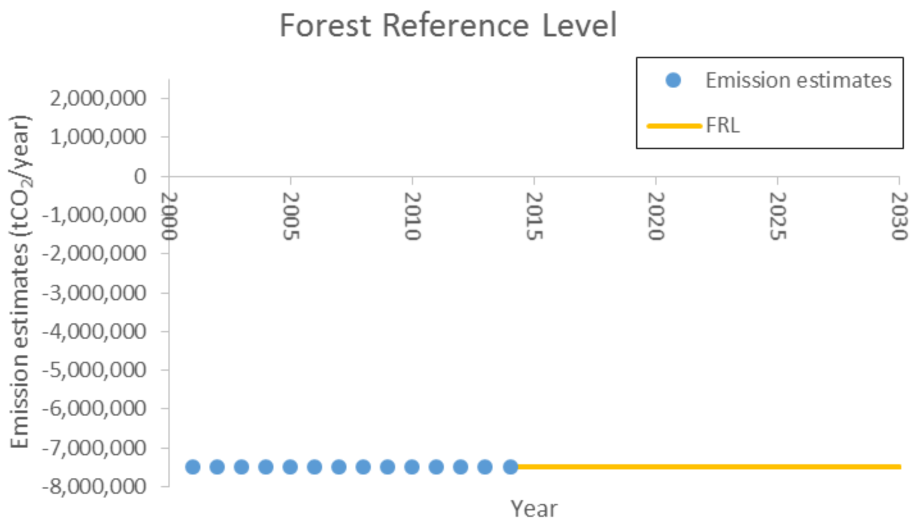

Figure. 5 FRL liner projection and Emission estimates in each year

4. Accuracy

4.1 Accuracy of AD

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. Statistically robust and transparent approaches are critical to ensure the integrity of land change information. The steps followed were as recommended by Global Forest Observation Initiative Methods and Guidance

Document (GFOI MGD).

The most common approach for accuracy assessment is to conduct ground referencing where each pixel in the land cover map is verified. However, field work is normally expensive and time consuming and therefore sampling methods were used to generate representative classes for field verification.

Randomly generated ground reference points were prepared for the 2014 map as the land cover map verification exercise. . A total of 1894 field sample points were visited for ground trothing. Based on accessibility, and security situation in Kenya another 1905 sample were independently interpreted using Google Earth as high resolution imagery.

The classification accuracy was achieved by comparing the classification result with presumably correction information (ground truth) which was indicated by field verification survey and Google Earth collection. The accuracy assessment results was 75.1 % for the 2014 map. The following tables illustrate the accuracy of mapping the various land cover types in the 2014 map. Table 11 correct ness of the 2014 map and Table 12 error matrix of the 2014 map.

Table 11 Correctness of the 2014 map

Class Name	Land Cover / Land Use	Number of correct	Accuracy Ratio
Dense Forest	312	239	76.6%
Moderate Forest	221	152	68.8%
Open Forest	150	97	64.7%
Cropland	1194	913	76.5%
Grassland	1565	1167	74.6%
Water Body	142	110	77.5%
Other Land	215	174	80.9%
TOTAL	3799	2852	75.1%

Table 12 Error Matrix of the 2014 map

Classified Data	Dense Forest	Moderate Forest	Open Forest	Grassland	Cropland	Water Body	Other land	Total
Dense Forest	239	13	7	21	31	1	0	312
Moderate Forest	12	153	4	28	23	1	0	221
Open Forest	5	4	97	31	12	1	0	150
Grassland	20	23	20	1273	188	16	25	1565
Cropland	31	13	8	151	968	13	10	1194
Water Body	1	2	3	11	12	111	2	142
Other land	0	0	1	31	8	1	174	215
Total	**308**	**208**	**140**	**1546**	**1242**	**144**	**211**	**3799**

4.2 Accuracy of EF

In Kenya, a full national forest inventory has never been implemented. The number of plots in the pilot forest Inventory which was done for EF setting is limited (127 plots in total). Coefficient of Variation (CV) for those forest inventory data ranges from 43.47 % to 138.47 % which is significantly high. In addition, the data was compared with other independently carried out research in the specific forests of Kenya (e.g. Kinyanjui et al 2014, Glenday, 2006 and KAiro, 2009) to identify comparability. In general there is a great variation in carbon and biomass values in different forest types of Kenya and thus, an NFI using the nationally approved methodology will be expected to be implemented in the future to provide accurate values of EF for the variety of forests.

5. Improvements

Kenya will develop its FRL according to a stepwise approach informed by available data, expertise and technologies. There are proposed improvements in the future FRL setting.

- Carbon pool

Currently, only AGB and BGB have been considered. In future, dead wood, litter and soils should be measured and included as significant carbon pools in subsequent FRL estimation.

- GHG

In the latest report, CO_2 is the only gas considered. It is proposed that further research should be done to allow for inclusion of CH_4 and N_2O gases.

- NFI

For the development of EF, a full NFI will have to be implemented.

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Annex

Annex 1 Methodology for Land Cover / Land Use Map and data screening for time series maps

1. Classes for Land Cover / Land Use Map

The categorized classes for Land Cover / Land Use Map was 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 were adopted from IPCC where these classes were further subcategorized. The IPCC classes are:

- Forestland,
- Cropland,
- Grassland,
- Settlement,
- Wetlands and
- Other lands.

The subcategorized classes were based on local definitions of land cover and land use. Forest and forest conversion were of high importance in terms of carbon stocks and emissions. The forestland was subcategorized based on national forest definition which is canopy density not less than 15%, and was divided into three categories: Open, moderate and dense. The cropland was divided into two categories: annual crops, and perennial crops. The grassland had also been classified into wooded grass (shrubs and grasses) and open glass. The wetland had been mapped as two categories: water body and vegetated wetland. And the other land was included barren land, rocks, soils and beaches. However the settlement was not classified due to required alternative methodology other than Satellite Imagery Remote Sensing.

For the subcategorized forestland by forest definition, it was mixed type of forest e.g. plantation and dryland forest. The subcategorized forestland i.e. open, moderate and dense had been zoned by ancillary data which was classified by forest strata definitions in Kenya. The forest strata definitions are described in Annex 2. The table below show sub categorization of forestland.

Table 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 • Dense Forest (above 65% Canopy) • Moderate Forest (40% - 65%) • Open Forest (15% ≤ 40%)	Mangrove and Coastal forests Dryland forests Montane and Western rain forests
	➢ Plantation	Plantation
Grassland	➢ Wooded Grassland	

	➢ Open Grassland	
Cropland	➢ Perennial Cropland ➢ Annual Cropland	
Wetland	➢ Vegetated Wetland ➢ Open Water	
Other Land	➢ Settlement	

2. Methodology for preparation of Land Cover / Land Use Map

The Land Cover / Land Use Maps 2014 were created based on the following process steps using Landsat Imagery as show in Figure1. The best available Landsat images for each year were selected from the USGS archive which provided a complete cloud-free (threshold 20% cloud cover) coverage of Kenya. Cloud cover was a major consideration. Dry season images are preferred for classification purposes as these allow for better discrimination between trees and grasses or crops.

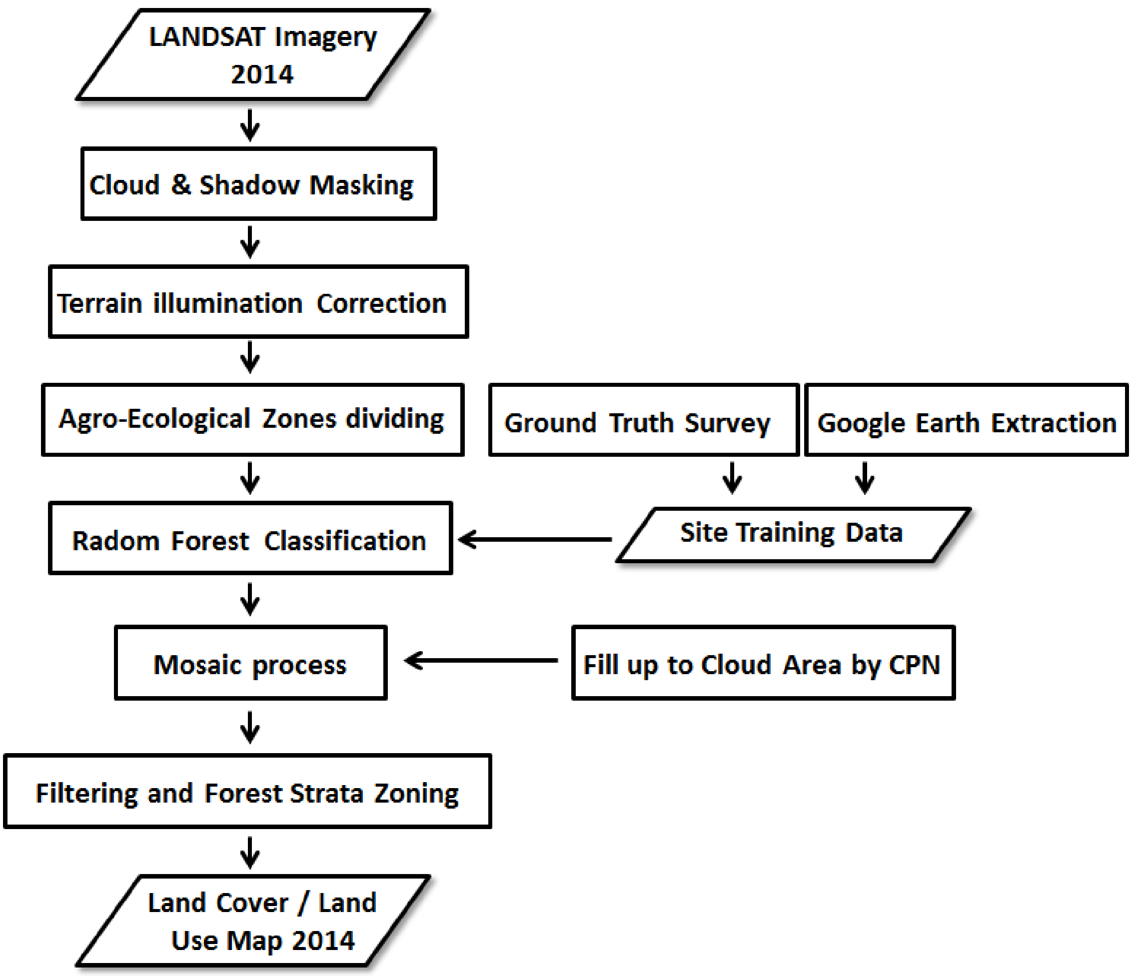

Figure 1 Flow chart for preparation of Land Cover / Land Use Map 2014

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 have 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 was 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 were initially based on Kenya's Agro-Ecological Zones.

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

For image classification method, supervised (Maximum Likelihood Classifier) and Random Forest classification had been tested. As a result of the test, The Random Forest classification has better accuracies than supervised classification. The Random Forest classification had been selected as method for preparation of Land Cover / Land Use Map.

Training sites were 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 represented the full range spectral variation of that class in the zone for that scene, and 'balanced' with respect to the different spectral colors for that class. The set of training data contained enough pixels. The prepared site training data was applied to individual terrain-corrected and masked images which had been processed as Random Forest classification process. And this process was applied separately to each stratification zone within the image.

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

The mosaic process was required due to the application of Random Forest classification was applied to individual images. Individual images were mosaicked as one classified image map. Figure 2 shows mosaicked individual classification result for a single scene from 2014.

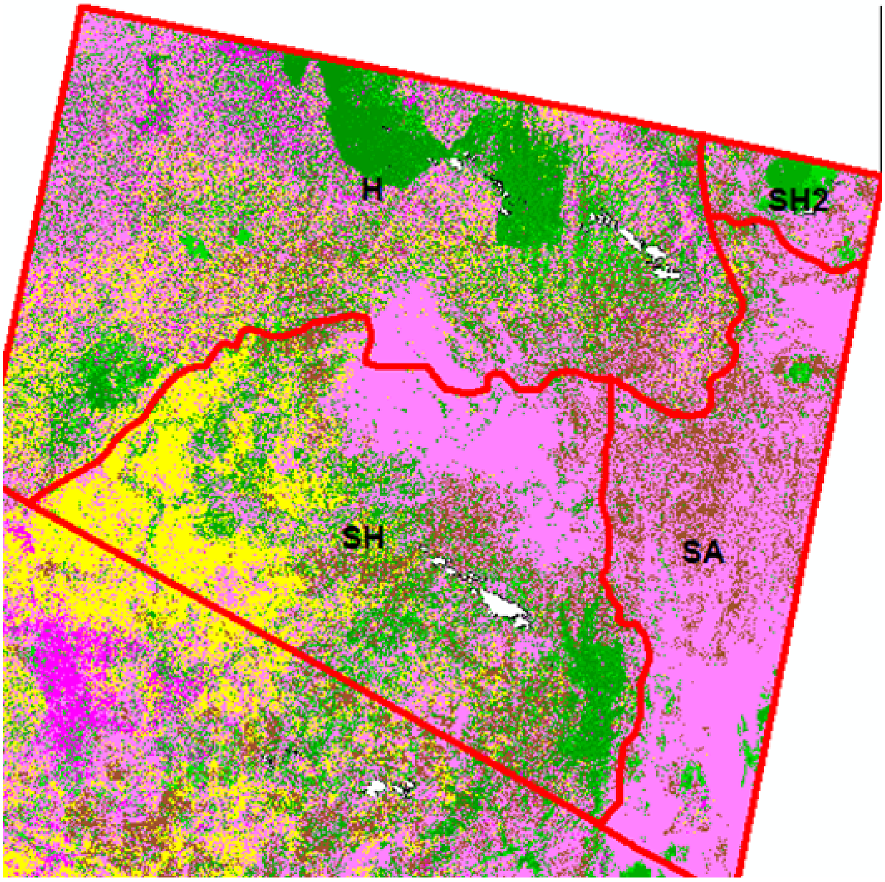

Figure 2 Mosaicked individual classification result for a single scene from 2014

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

The multi-temporal processing was 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 was utilized to filling up the gap area.

6) Filtering and Forest Strata Zoning

The mosaicked and filled up image map was 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) neighbors filtering method was preferred and used for mapping. The eight (8) neighbors filtering used eight (8) direction searching and clumping as one connected forest as shown in Figure 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.

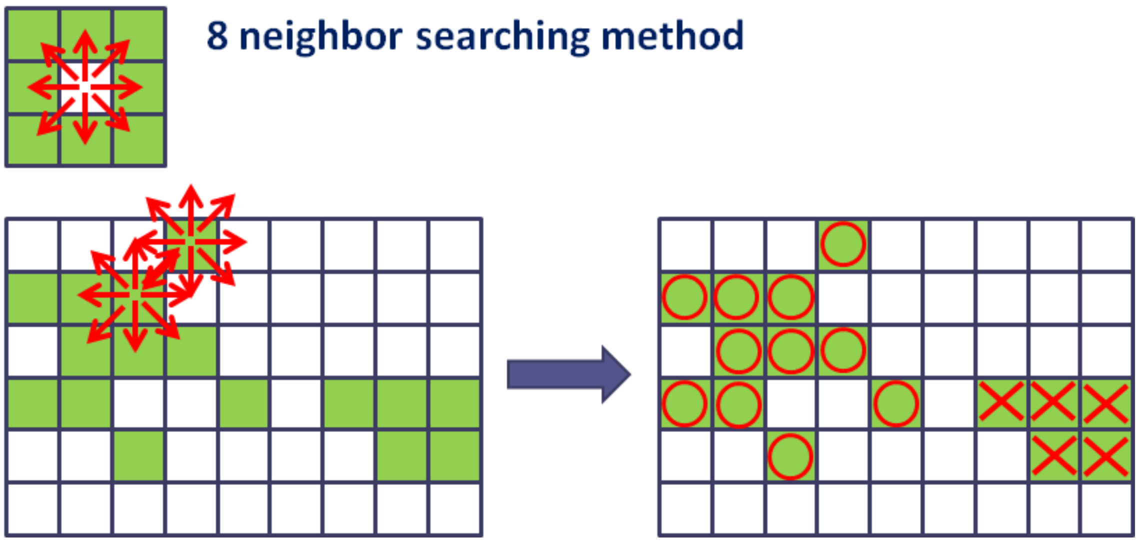

Figure 3 Eight (8) neighbors filtering

The filtered classification result map was zoned by forest strata zoning. This forest strata zoning information was generated by the forest strata definition as shown in Figure 4. The forest strata definitions are described in Annex 2

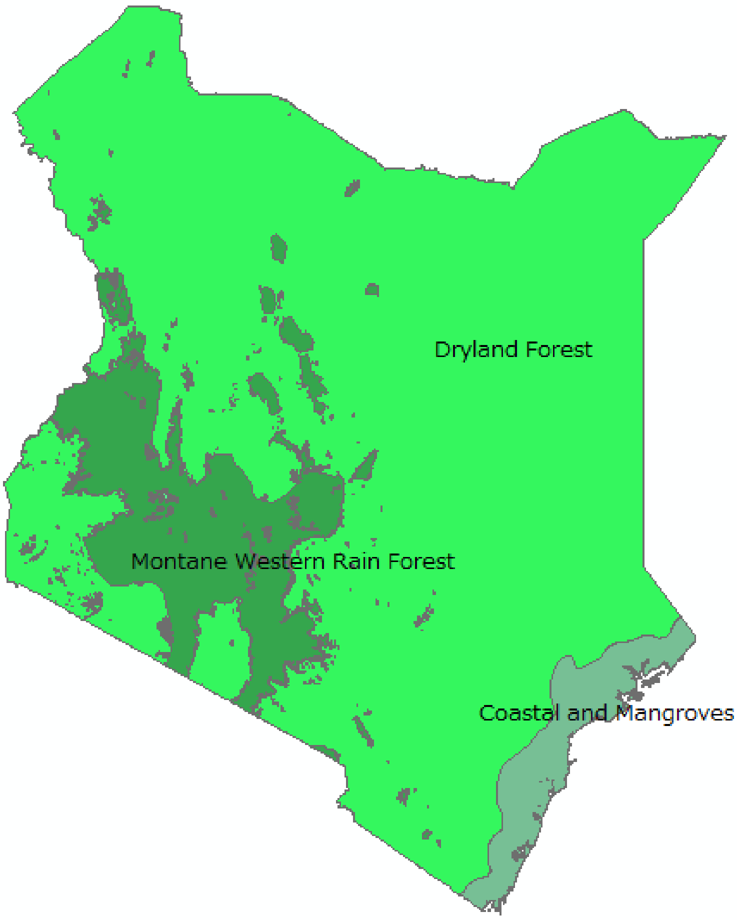

Figure 4 Forest Strata Zone Image

As explained above, the process steps for the Land Cover / Land Use Map were applied to other the past years which are 1990, 1995, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012 and 2013.

3. Data Screening

The Land Cover/Land Use Maps for the year 1990, 1995, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012 and 2013 were developed using the same methodology as of the year 2014. The statistical trend for all the epochs indicated significant fluctuations which led to further examination of the data used. These maps were subjected to further analysis to examine the quality of the LANDSAT imagery data used especially the striping effect, the cloud cover percentage and the sensor used.

The result of the examination shown that the data from 2004 to 2009, 2011 and 2012 was clarified as not good quality data hence could not be used. This was due to Landsat 7 sensor that failed at the end of May 2003.The failure led to stripping effect in the images having No-Data in the stripped areas as shown in figure 5. After the classification as shown in figure 6, the effect is seen significantly.

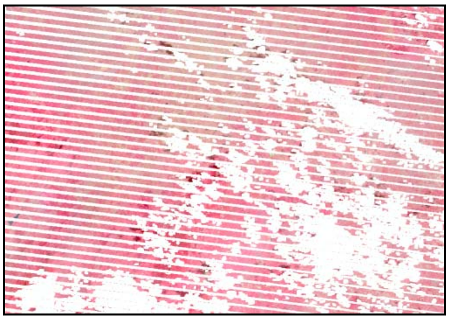

Figure. 5 LANDSAT imagery by stripping effect

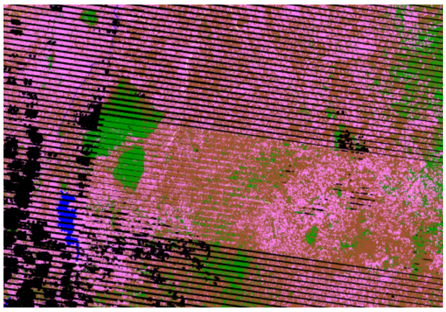

Figure. 6 The result of the classified stripping imagery

The recommendable reference time period as candidate, year 1990, 2000, 2002, 2003 and 2014 were selected. This was based on the Landsat data screening results for the image quality such as cloud cover area as NO-DATA area and strip gap as presented in Table 2. The highlighted years as shown in green color utilized LANDSAT imagery of good quality evaluated by stripping effect with small NO-DATA cover ratio while the ones shown in yellow color utilized LANDSAT imagery of good quality with slightly higher NO-DATA cover ratio, moderate quality with small NO-DATA cover ratio or moderate quality with little higher NO-DATA cover ratio.

Table 2 The result of data screening

	1990	1995	2000	2002	2003	2004	2005	2006
No DATA (%)	10.59%	14.35%	6.50%	6.53%	8.56%	23.77%	20.86%	23.13%
LANDSAT4 (scene)	26	0	0	0	0	0	0	0
LANDSAT5 (scene)	8	34	0	0	0	0	0	0
LANDSAT7 (scene)	0	0	34	34	34	34	34	34
Missing scenes	0	0	0	0	0	0	0	0
LANDSAT8 (scene)	0	0	0	0	0	0	0	0
Stripping Effect (scene)	0	0	0	0	0	34	34	34
Ratio of Stripping Effect (%)	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	100.00%	100.00%
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
No DATA (%)	26.14%	28.00%	15.85%	6.81%	12.51%	20.85%	16.98%	3.75%
LANDSAT4 (scene)	0	0	0	0	0	0	0	0
LANDSAT5 (scene)	0	0	11	24	15	0	0	0
LANDSAT7 (scene)	34	34	23	9	19	34	13	0
Missing scenes	0	0	0	1	0	0	0	0
LANDSAT8 (scene)	0	0	0	0	0	0	21	34
Stripping Effect (scene)	34	34	23	9	19	34	13	0
Ratio of Stripping Effect (%)	100.00%	100.00%	64.60%	26.50%	55.90%	100.00%	38.20%	0.00%

{ TA ¥l "**Annex 1 Methodology for Land Cover / Land Use Map and data screening for time series maps**" ¥s "Annex 1 Methodology for Land Cover / Land Use Map and data screening for time series maps" ¥c 1 }**Annex 2 Forest Strata Definitions (Excerpt from SLEEK Forest Biomass EWG Paper)**{ TA ¥l "**Annex 2 Forest Strata Definitions (Excerpt from SLEEK Forest Biomass EWG Paper)**" ¥s "Annex 2 Forest Strata Definitions (Excerpt from SLEEK Forest Biomass EWG Paper)" ¥c 1 }

Forest Strata Definitions and Supporting Descriptions

1. **Plantation forest land:** Refers to areas with even aged monocultures and would therefore have a unique spectral characteristics that can allow separation from other vegetation types by remote sensing. Their boundaries in public forests (Government owned forests) are also clearly defined 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. In public forests, exotic plantation species include *Cupressus lusitanica, Eucalyptus sp.* and several pine species (*P. patula* in montane areas and, *P. carribeae* in coastal forests). In the private forests, Eucalypts are the main plantation species in the montane areas, with *Melia volkensii* in many dryland areas, and *Casuarina equisetifolia* dominating at the coast. Since these varied plantation species may not be easily separated by remote sensing, ancillary data will be used for sub categorization by species. Similarly these plantations exist in different age classes which imply different carbon stocks. Information on the age class of the plantations is available with the managers of specific forests (e.g. the inventory section of KFS).

2. **Mangroves and coastal forests**
    a. 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 mucranata*, 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*. Shapefiles of the mangrove zones which will be used for sub categorization are available at KFS.
    b. **The coastal forests:** These are the forests found in the coastal region of Kenya within a 30km strip from shoreline. 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. This class was defined as unique by the KIFCON in Wass (1994) and the shapefiles of the forests are available at KFS.

3. **The montane and western rain forests:**
   a. **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 differ in species composition due to climate and altitude. 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 highland bamboo (*Yushania alpina*) predominates.
   b. **The 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. The trees are significantly taller and larger as compared to the other forests of Kenya. The shapefile describing these forests developed by KIFCON is available at KFS.

4. **The 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. Their carbon stocks may differ from that of other forests due to leaf shedding, elongated rooting systems and high specific wood density.

Categorization of these forests will be done using the shapefiles developed by KIFCON (1994) which are based on climate and altitude. These shapefiles are available at Kenya Forest Service

Annex 3 Additional explanations of EF setting{ TA ¥l "Annex 3 Additional explanations of EF setting" ¥s "Annex 3 Additional explanations of EF setting" ¥c 1 }

In this Annex, additional explanations for setting EF are described. Firstly, there are details of descriptions of plots number of each forest type. Secondly, the trend of AGB values in each forest type are described with its values. Finally, the calculation's method of quantifing CO_2 to EF for FRL setting is described. This explanation clarifies how the values of CO_2 are calculated for coordination with AD. Emission estimates are provided by multiplying AD and EF which are based on CO_2 amount (tCO_2/ha).

A) The number of the plots in forest classification

The number of the plots in forest classification is shown in Table. 1. The classification is consist of Dense Forest, Moderate Forest, Open Forest, and Non Forestland. Also, Forest land was divided into four forest classes, such as Montane and western rain forest, Mangroves and coastal forest, Dryland forest and Plantation forest. Non Forest land class consists of Cropland, Grassland, Perennial Cropland, Wetland, Settlement and Other land. The numbers of the plots surveyed by two pilot forest inventory are shown below in Table 1.

Table 1 Total number of plots in each 12 forest type classes

Class	Dense	Moderate	Open	Total
Montane Forest & Western Rain Forest	9	7	6	22
Coastal Forest & Mangrove Forest	18	12	16	46
Dryland Forest	8	8	7	23
Plantation Forest	23	6	7	36
Total				127

B) The values of AGB in each forest types

- Montane forest, Western rain forests and Bamboo

The values have tendency to be decline due to the change in canopy coverage: the value of AGB in the Dense, Moderate and Open canopy coverage are 344.97, 58.43 and 23.26 (ton/ha), respectively.

- Mangrove and coastal forest

The values have tendency to be decline due to the canopy coverage. The values of AGB in each canopy coverages Dense, Moderate and Open are 94.63, 60.45 and 35.47 (ton/ha), respectively.

- Dryland forest

The values have tendency to be decline due to the canopy coverage. The values of AGB in the Dense, Moderate and Open canopy coverage are 80.32, 34.52 and 14.26 (ton/ha), respectively.

- Plantation forest

The AGB values of the dense canopy coverage are largest among the canopy coverages. However, the value of AGB in the Open canopy coverage is larger than that of the Moderate. This is the reason why that the researched area of Open canopy coverage is selected due to the AD classification and the tree of the Open Canopy coverage areas have larger volumes due to its old growth stand after thinning. The value of AGB in each canopy coverages Dense, Moderate and Open are 436.68, 113.54 and 138.22 (ton/ha), respectively.

C) Calculation's method of CO_2 amount related EF for FRL setting

For setting FRL, EF is estimated by the values of Carbon stocks at two points in time. In this work, firstly the values of Carbon stocks are converted to the CO_2 amount, then the changes at two points in time are calculated, such as the values of Carbon stock (tC/ha) is converted to CO_2 amount by calculation as following:

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

And also, the values of CO_2 changed from forestland to forestland at two points in time will be calculated by the equation as shown below:

CO_2 amount (Forestland change to Forestland) = CO_2 amount (Forestland) - CO_2 amount (Forestland)

Further, the values of CO_2 for non-forest land changed from forestland to non-forestland (deforestation) was shown in the Table 2. The values which changed from forestland to non-forestland (deforestation) will be calculated by the equation as shown below:

CO_2 amount (Forestland change to Non-forestland) = CO_2 amount (Forestland) - CO_2 amount (Non-forestland)

Moreover, the values of CO_2 for forest land changed from non-forestland to forestland (enhancement) was shown in the Table 2. The values which changed from non-forestland to forestland (enhancement) will be calculated by the equation as shown below:

CO_2 amount (Non-forestland change to Forestland) = CO_2 amount (Non-forestland) - CO_2 amount (Forestland)

Table 2 Matrix of EF setting for Country data (Forest) with Default data (Non forest) CO_2(ton/ha) Emission

			The end year of the period															
			Montane Forest/Western Rain Forest/Bamboo			Coastal Forest and Mangroves			Dryland Forest			Plantation			Cropland	Grassland	Wetland	Settlement and Other land
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open				
The beginning year of the period	Mountane Forest /Western Rain Forest/Bamboo	Dense	0	635.64	713.66										765.26	749.31	765.26	765.26
		Moderate	−635.64	0	78.02										129.62	113.67	129.62	129.62
		Open	−713.66	−78.02	0										51.61	35.66	51.61	51.61
	Coastal Forest and Mangroves	Dense				0	84.78	139.03							213.96	198.01	213.96	213.96
		Moderate				−84.78	0	54.25							129.18	113.23	129.18	129.18
		Open				−139.03	−54.25	0							74.93	58.98	74.93	74.93
	Dryland Forest	Dense							0	113.24	164.91				196.56	180.61	196.56	196.56
		Moderate							−113.24	0	51.68				83.32	67.37	83.32	83.32
		Open							−164.91	−51.68	0				31.64	15.69	31.64	31.64
	Plantation	Dense										0	716.82	662.07	968.69	952.74	968.69	968.69
		Moderate										−716.82	0	−54.75	251.87	235.92	251.87	251.87
		Open										−662.07	54.75	0	306.62	290.67	306.62	306.62
	Cropland		−765.26	−129.62	−51.61	−213.96	−129.18	−74.93	−196.56	−83.32	−31.64	−968.69	−251.87	−306.62	0			
	Grassland		−749.31	−113.67	−35.66	−198.01	−113.23	−58.98	−180.61	−67.37	−15.69	−952.74	−235.92	−290.67		0		
	Wetland		−765.26	−129.62	−51.61	−213.96	−129.18	−74.93	−196.56	−83.32	−31.64	−968.69	−251.87	−306.62			0	
	Settlement and Other land		−765.26	−129.62	−51.61	−213.96	−129.18	−74.93	−196.56	−83.32	−31.64	−968.69	−251.87	−306.62				0

Annex 4 Matrix for Emission estimates Calculation{ TA ¥l "**Annex 4 Matrix for Emission estimates Calculation**" ¥s "Annex 4 Matrix for Emission estimates Calculation" ¥c 1 }

Table 1 The value of Multiplication of AD and EF in the reference period (tCO_2/14 year)

			2014															
			Montane Forest / Western Rain Forest / Bamboo			Costal Forest and Mangroves			Dryland Forest			Plantation			Cropland	Grassland	Wetland	Settlement and Other land
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open				
2000	Montane Forest / Western Rain Forest / Bamboo	Dense	0	20,514,964	8,140,090	–	–	–	–	–	–	–	–	–	57,664,330	55,924,102	238,647	485,009
		Moderate	−51,265,071	0	1,014,428	–	–	–	–	–	–	–	–	–	2,358,513	6,637,946	70,020	11,549
		Open	−20,130,464	−970,508	0	–	–	–	–	–	–	–	–	–	816,247	1,763,688	1,565	9,136
	Costal Forest and Mangroves	Dense	–	–	–	0	1,257,445	92,079	–	–	–	–	–	–	249,042	5,835,443	55,400	115,403
		Moderate	–	–	–	−12,682,673	0	142,987	–	–	–	–	–	–	1,000,922	16,074,723	48,703	108,229
		Open	–	–	–	−303,777	−110,368	0	–	–	–	–	–	–	105,670	999,272	1,066	8,659
	Dryland Forest	Dense	–	–	–	–	–	–	0	4,030,849	3,569,564	–	–	–	13,519,989	92,020,778	369,741	299,423
		Moderate	–	–	–	–	–	–	−13,273,936	0	1,339,788	–	–	–	2,371,370	19,662,222	134,800	227,823
		Open	–	–	–	–	–	–	−5,594,010	−1,641,319	0	–	–	–	353,401	3,150,080	45,327	147,733
	Plantation	Dense	–	–	–	–	–	–	–	–	–	0	737,266	347,626	6,372,412	5,676,949	7,323	6,190
		Moderate	–	–	–	–	–	–	–	–	–	−2,431,790	0	−2,548	95,841	173,939	1,292	567
		Open	–	–	–	–	–	–	–	–	–	−928,710	2,902	0	62,008	77,802	28	110
	Cropsland		−36,109,674	−541,130	−93,072	−493,039	−39,146	−1,369	−3,197,948	−146,288	−13,311	−6,351,575	−33,798	−22,794				
	Grassland		−123,566,003	−8,724,210	−1,892,434	−26,683,996	−4,161,597	−154,777	−83,466,477	−10,033,410	−3,049,198	−19,185,148	−201,159	−85,153				
	Wetland		−194,293	−1,727	−316	−258,612	−61,457	−3,143	−703,129	−113,241	−26,685	0	0	0				
	Settlement and Other land		−344,644	−30,600	−14,918	−165,739	−25,287	−290	−903,505	−239,702	−374,538	−105,752	−227	−83				

Republic of Kenya

Ministry of Environment and Forestry

The National Forest Reference Level for REDD+ Implementation

December 2019

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LIST OF ACRONYMS

AD	Activity Data
AGB	Above Ground Biomass
BGB	Below Ground Biomass
CBD	Convention on Biological Diversity
CF	Carbon Fraction
CO_2	Carbon Dioxide
EF	Emission Factor
EMCA	environmental Management and Conservation Act
FAO	Food and Agriculture Organization of the United Nations
FLEGT	Forest Law Enforcement, Governance and Trade
FPP	Forest Preservation Program
FRA	Forest Resources Assessment
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
GFOI MGD	Global Forest Observation Initiative Methods and Guidance Document
GHG	Green House Gases
IPCC	Intergovernmental Panel on Climate Change
ITTA	International Tropical Timber Agreement
JICA	Japan International Cooperation Agency
KEFRI	Kenya Forestry Research Institute
KFS	Kenya Forest Service
LAPSSET	Lamu Port South Sudan Ethiopia Transport Corridor
LCC	Land Cover Change Mapping
MEF	Ministry of Environment and Forestry
MMU	Minimum Mapping Unit
NCCRS	National Climate Change Response Strategy
NDC	Nationally Determined Contribution
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NIR	National Inventory Report
NRS	National REDD+ Strategy
REDD+	Reducing Emissions from Deforestation and Forest Degradation, and the role of Conservation, Sustainable management of forests and Enhancement of forest carbon stock.

SDG	Sustainable Development Goals
SIS	Safeguard Information System
SLEEK	System for Land-based Emissions Estimation in Kenya
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change

EXECUTIVE SUMMARY

Kenya is a low forest cover country with a total forest area of 3,462,536 ha or about 5.9% of the total national area. The government of Kenya has a goal of enhancing forest cover to a minimum of 10 % of the National area by 2030. As a party to the UNFCCC, Kenya has committed to contribute to Global climate change mitigation and adaptation and has submitted its Nationally Determined Contribution (NDC) in line with the requirements of the Paris Climate change Agreement. The forest sector was identified as key to the realization of the national goals due to its comparatively high abatement potential. Based on data collected as part of this process, deforestation in the country is estimated at 103,368 ha per year (0.17% of the national area) but conservation efforts achieve about 90,477ha of reforestation annually (0.15% of national area).

Kenya is establishing a Forest Reference Level (FRL) for REDD+ to; 1) exploit opportunities for reducing current emissions arising from deforestation and forest degradation, and 2) take advantage of opportunities for enhancement of carbon stock arising from afforestation, reforestation and restoration of degraded forest areas. The various building blocks for establishing the FRL were comprehensively discussed and agreed by a Technical Working Group that was established purposely to offer technical guidance for FRL development. An overview of the decisions is as follows:

- Forest definition: a minimum 15% canopy cover; minimum land area of 0.5 ha and minimum height of 2 meters.
- Scale: National
- Scope: REDD+ Activities include Reducing emissions from deforestation, Reducing emissions from forest degradation, Sustainable management of forest and Enhancement of forest carbon stocks.;
- Gases: covers only CO_2.
- Pools: Above Ground Biomass (AGB) and Below Ground Biomass (BGB).
- Reference period: 2002-2018
- Construction method: Historical Average of emissions and removals between 2002 and 2018, monitored at 4 year intervals

Using an approach 3 mapping and a combination of local and IPCC defaults, Kenya proposes a FRL of 52,204,059 t CO_2/year. This FRL is derived from average annual historical emissions from deforestation, forest degradation, sustainable management of forests, and enhancement of forest carbon stocks in the period 2002-2018 monitored at 4 year intervals. The FRL for each of the REDD+ Activities has been calculated as 48,166,940 t CO_2/year for Deforestation, 10,885,950 t CO_2/year for forest degradation, 2,681,433 t CO_2/year for sustainable management of forests and -9,530,264 t CO_2/year for enhancement of carbon stocks.

Based on national circumstances, the projected future Emissions are based on an extrapolation of the average trend from the historical analysis for the net Emissions and for each of the REDD+ Activities. Since Kenya is in the process of developing a National REDD+ Strategy, the FRL provides an opportunity to monitor emission reductions based on the proposed Policies and Measures and their specific interventions.

The FRL process identifies a number of improvements for the future which include; enhancing the land cover mapping process to improve accuracy of Activity data, implementing an NFI to improve on Emission Factors and research to capture the variety of non CO_2 emissions from REDD+ activities and involve more pools.

1. INTRODUCTION

1.1. Relevance

In response to UNFCCC decision 1/CP.16 paragraph 71 (b) and decision 12/CP.17 paragraph 8 and 10, Kenya wishes to voluntarily submit to the United Nations Framework Convention on Climate Change (UNFCCC) the proposed National Forest Reference Level (FRL) for contribution to mitigation actions in the forest sector. In this context, this submission is premised on the consideration that the submission is subject to a technical assessment in accordance with decision 13/CP.19; decision 14/CP.19; and decision 12/CP.17. In preparing the FRL, Kenya has used a stepwise approach consistent with decision 12/CP.19; on the modalities for FRLs and FRELs; including the right to make adjustments to the proposed FRLs/FRELs based on national circumstances. This stepwise approach is strongly informed by availability of data, financial resources and capacities within the country for establishing the FRL.

1.2. The National Context

1.2.1. Country Profile

Kenya is one of the East African countries lying across the equator at latitude of 4° North to 4° South and Longitude 34° East to 41° East. The country is bordered by South Sudan and Ethiopia in the north, Somalia to the east, Indian Ocean to the south-east, Tanzania to the south and Uganda to the west (Fig. 1). The country has a total area of 592,038. km^2 including 13,400 km^2 of inland water and a 536km coastline.

Kenya's geography is diverse and varied. The terrain gradually changes from the low-lying coastal plains to the Kenyan highlands reaching a peak of 5,199m above sea level at Mt Kenya. The Great Rift Valley located in the central and western part of the country basically dissects the Kenyan highlands into east and west. Further west, the altitude decreases towards Lake Victoria while northwards, there are vast drylands which are gradually being colonized to support livelihoods for the pastoralist communities and game ranchers. Kenya has six drainage patterns based on the direction of the waters and the majority of inland water bodies are found in the Rift Valley.

Kenya is divided into seven agro-climatic zones ranging from humid to very arid. Less than 20% of the land is suitable for cultivation, of which only 12% is classified as high potential (adequate rainfall) agricultural land and about 8% is medium potential land. The rest of the land is arid or semi-arid.

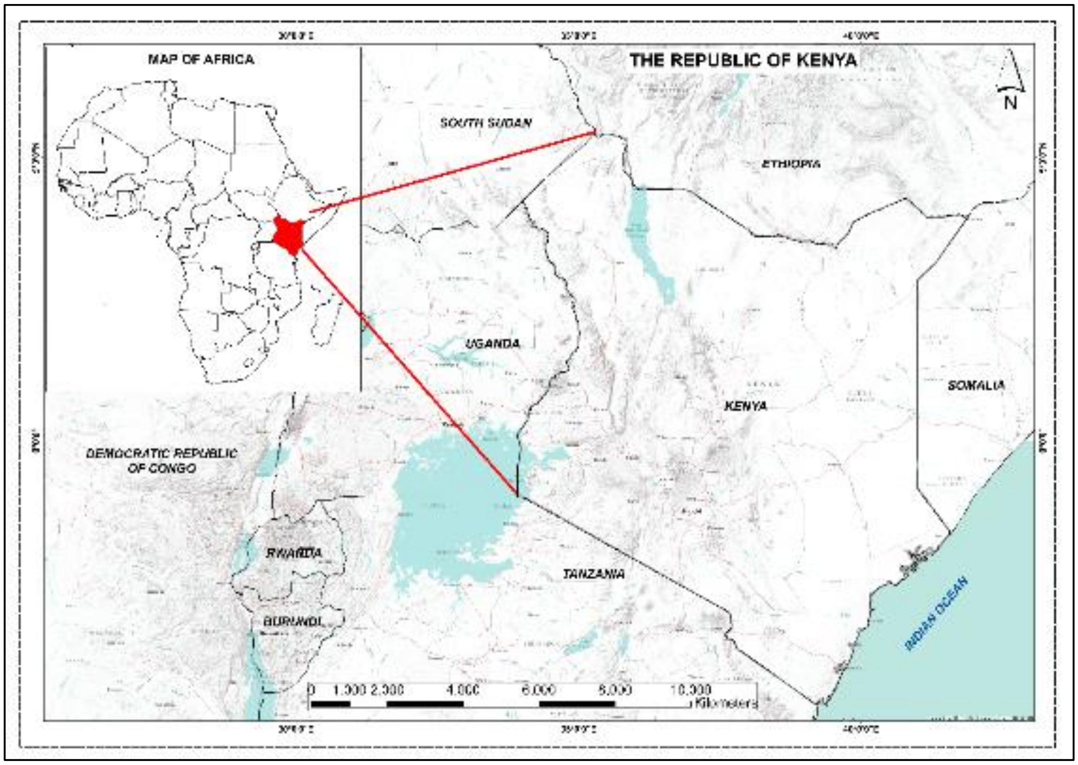

Figure 1: Location Map of Kenya

Kenya is a low forest cover country. The 2018 Land cover mapping shows a forest cover of 3,462,536 ha or about 5.9% of the country's total area, which has slightly declined from about 6.2% in the year 2002. Enhancing forest cover to a minimum of 10% is a key priority of the Government of Kenya. The Constitution (GoK, 2010) obliges the government to work and achieve a forest cover of at least 10% while the national development blueprint (Vision 2030) and the National Climate Change Response Strategy (NCCRS) aim to achieve this goal by 2030. As a party to the UNFCCC, Kenya has committed herself to contribute effectively to global climate change mitigation and adaptation efforts including a renewed resolve to conserve all available carbons stocks and enhancing its forest carbon. The country has signed the **Paris Agreement** and developed a **Nationally Determined Contribution (NDC)** to global climate change efforts. The success of the NDC will strongly be influenced by the forest sector due to its comparatively high abatement potential.

A Climate Change Strategy was developed in 2010 and this has led to the passing of the Climate Change Act in 2016. The Climate Change Act defines an institutional arrangement under the Ministry in charge of Environment to spearhead implementation of climate change activities and recognizes the need to mainstream climate change issues in all developmental programmes in the country. In addition, Climate Change Action Plans have been developed for the period 2013-2017 and also 2018-2022 to support implementation of pertinent and upcoming issues regarding climate change. The **Forest Act** of 2005 has also been reviewed into the Forest Conservation and Management Act of 2016 (GoK, 2016) to further strengthen the country's responses to protect forested landscapes and to provide opportunities for increasing the forest cover in line with national development aspirations. In mainstreaming Climate change in various sectors, additional policies in the land, agriculture and energy sectors have also been developed. In addition to this, Kenya has a National Development Plan which seeks to achieve the Vision 2030 targets through aggressive afforestation and reforestation and rehabilitation programs.

All these policy documents and Specifically the NDC regard the forestry sector as a priority area to move Kenya towards a low-carbon, climate-resilient development pathway. Specifically, in response to a global call for action contained in the **New York Declaration of forests, the Bonn Challenge and the Africa 100 million ha of forests (AFR100) commitment**, the Government of Kenya has committed to restore 5.1 million ha by 2030 equivalent to an average of 392,000 ha per year. The opportunities for restoration have been identified and current discussions revolve around the best strategies for restoration.

1.2.2. The Forest Sector

Kenya's economy is strongly dependent on natural resources including forestry. The Forest sector is the backbone of Kenya's Tourism since forests provide habitats for wild animals, offer dry season grazing grounds and protect catchments that provide water downstream. Forests maintain water catchments (defined as water towers) which support agriculture, industry, horticulture, and energy sectors contribute more than 3.6 per cent of GDP. In some rural areas, forests contribute over 75% of the cash income and provide virtually all of household's energy requirements. It is estimated that economic benefits of forest ecosystem services exceed the short-term gains of deforestation and forest degradation and therefore justify the need to conserve the forests.

In spite of these important functions, deforestation and forest degradation have continued to pose challenges driven by among others pressure for conversion to agriculture, urbanization and other developments, unsustainable utilization of forest resources, inadequate forest governance and forest fires. The country is exploring a wide range of options, including policy reforms and investments, to protect the existing forests and to substantially restore forest ecosystems across the country.

Forests in Kenya are managed under three tenure systems: public, community and private. Public forests are managed by both national government agencies (mainly Kenya Forest Service and

Kenya Wildlife Service) and County Governments. Public forests are mainly managed for provision of environmental goods and services but they also contain a belt that is managed for timber, poles and fuelwood. Community forests are owned by communities or held in trust by county governments and where forest management rights and responsibilities are transferred from the Public Administration to local communities through long-term leases or management agreements. Private forests are owned or managed by individuals, institutions or corporate entities as freehold or leasehold. The Kenya Forest Service remains the foremost institution charged with the responsibility and mandate to ensure all forests in the country are sustainably managed.

1.3. REDD+ in Kenya

Past attempts to increase forest cover and address the problem of deforestation and forest degradation in the country have not been very successful. This can be attributed to among other factors; increasing demand for land for agriculture, urbanization and other developments, high energy demand and inadequate funding to support investments in the forestry sector. Unresponsive policy and poor governance in the forestry sector have often in the past compounded these problems.

In the year 2012, Kenya developed a consultative REDD+ readiness proposal which identified priorities in the National REDD+ implementation process. The National REDD+ strategy is currently being developed. It is noted that REDD+ presents a great opportunity to reverse the negative trends of forest loss by providing innovative approaches, including incentives from carbon finance that support implementation of a comprehensive strategy that effectively supports sustainable management and conservation of forests and at the same time reduce carbon emissions. In Kenya, REDD+ is evolving as an attractive means to reduce forest sector carbon emissions. Kenya's participation in REDD+ is premised on the conviction that the process holds great potential in supporting:

- Realization of constitutional requirement and vision 2030 objectives of increasing forest cover to a minimum of 10%;
- Government efforts in designing policies and measures to protect and improve its remaining forest resources in ways that improve local livelihoods and conserve biodiversity;
- Access to international climate finance to support investments in the forestry sector;
- Realization of the National Climate Change Response Strategy (NCCRS) goals.
- Contribution to global climate change mitigation and adaptation efforts as illustrated in Kenya's NDC.

Priority areas of focus in REDD+ include the following:

- Reducing pressure to clear forests for agriculture, settlements and other land uses;
- Promoting sustainable utilization of forests by promoting efficiency and energy conservation;
- Improving governance in the forest sector -by strengthening national capacity for Forest Law Enforcement, Governance (FLEG)- advocacy and awareness;
- Enhancement of carbon stocks through afforestation /Reforestation, and fire prevention and control.

2. THE FOREST REFERENCE LEVEL

2.1. Objectives of developing a National FRL

Kenya is establishing a Forest Reference Level as an objective benchmark for assessing performance of REDD+ activities. The FRL has been established in consistence with the country's greenhouse gas inventory process guided by the IPCC reporting principles of Transparency, Accuracy, Consistency and Comparability. In this report, Kenya focuses on four REDD+ activities; reducing emissions from deforestation, reducing emissions from forest degradation, sustainable management of forests and enhancement of forest carbon stocks.

2.2. The Building Blocks of the Forest Reference Level

2.2.1. Forest definition

A national forest definition for REDD+ has been agreed through a broad stakeholder consensus as a minimum 15% canopy cover; minimum land area of 0.5 ha and potential to reach a minimum height of 2 meters at maturity in situ. Perennial tree crops like coffee and tea are 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 have been constrained by ecological conditions but are a priority for conservation by Kenya's national development programmes;
- Possibility of providing consistent data for establishing the reference level and for monitoring of performance based on available technology;
- Need to balance the costs of implementation and monitoring and the result-based incentives
- Consistency with the national forest agenda to optimize, manage and conserve Kenya's forests.

While the Second National Communication (SNC) to the UNFCCC used the FAO forest definition to provide information on forest cover in the country, it has since been agreed that the Third National Communication will be harmonized with the forest definition which is used for setting this FRL. This definition will also be used to inform monitoring of forest sector performance and reporting to other international treaties and protocols to which Kenya has subscribed.

2.2.2. Identification of REDD+ Activities

Kenya has classified forests in the country based on four strata (Figure 2). Three strata (Montane and Western rain. Coastal and Mangrove and Dryland) are based on Kenya's broad ecological zones based on climate and altitude. They define the major biomes/ecological zones in which forests grow and align to the IPCC ecological zones[1] The 4th strata is a management zone and covers the public plantation forests which are managed by the Kenya Forest Service. These strata were used to define the scope of REDD+ Activities.

Kenya has decided on the following scope of REDD+ activities with their definitions:

- Reducing emissions from deforestation (Deforestation)

Deforestation is defined as the conversion of Forest to Non-Forest land use across all management systems in Montane and Western rain, Mangrove and coastal, and Dryland forest strata. Deforestation does not include planned and periodic felling of public plantation forests and associated carbon stock fluxes.

- Reducing emissions from forest degradation (Forest Degradation)

Forest degradation is defined as the degradation of forest canopy which changes from dense canopy coverage to moderate and open canopy coverage and from moderate to open canopy coverage in Montane and Western rain, Mangrove and Coastal, and Dryland forest strata.

- Sustainable management of forests

Sustainable management of forests which is limited to the public Plantation Forests managed by Kenya Forest Service (KFS), is defined as the conversion of non-planted forest area to planted forest area. This is based on a backlog in replanting of areas designated for public commercial plantations. Kenya notes that any variations in canopy cover among plantation forests may not be associated to degradation and enhancement and adopted a single canopy cover for plantation forests. Sustainable management of forests aims at ensuring a balance between harvests and replanting activities of the public plantation forests in which case the net emissions will be equal to zero.

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[1] Table 4.4. of the 2006 IPCC guidelines for GHGI. Volume 4: Agriculture, Forestry and Other Land Use

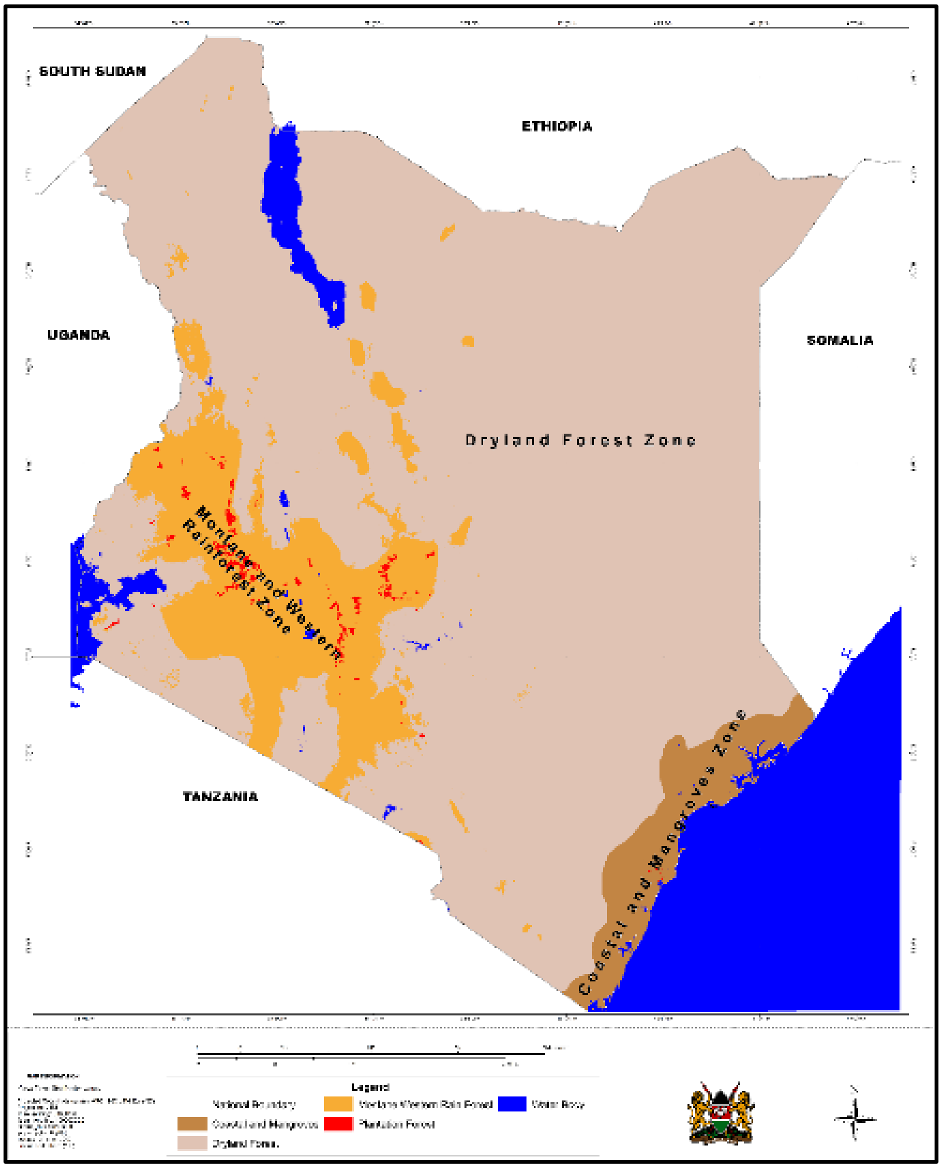

Figure 2: The Ecozones used to create forest strata

- Enhancement of forest carbon stocks

This refers to activities that increase carbon stocks in Montane and Western rain, Coastal and Mangrove, and Dryland forest strata through rehabilitation of degraded areas, reforestation and afforestation efforts.

2.2.3. Carbon pools

Kenya selected the carbon pools as follows:

- Above-ground biomass
- Below-ground biomass

The carbon pools shown below were not considered when establishing the FRL:

- Soil organic carbon
- Litter
- Deadwood

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

a) Soil organic carbon

Kenya notes the requirements for Tier 1 reporting of the soil carbon stocks (2006 IPCC Guidelines) which require a land-use factor (FLU), a management factor (FMG) an input factor (FI), all that require a variety of information which is lacking in Kenya. In line with the stepwise approach and based on data availability, this pool can be included in Kenya's monitoring of GHGs from the forest sector in future.

b) Litter

There is limited information and research data in Kenya to support inclusion of this carbon pool. In the future, this pool will be researched further to support a more accurate estimation based on a stepwise approach.

c) Deadwood

There has not been enough research on the deadwood carbon pool. Data from a pilot forest inventory showed inconclusive results. Further research and collection of more data has been proposed to support its inclusion in future.

2.2.4. Scale

Kenya has chosen to establish a national FRL. This decision is informed by current forest management practices and evolving policies, legislation and institutional frameworks for forest sector reforms. There is broad consensus that REDD+ will be implemented through strong policies and other measures by the national government and county governments. Kenya's decision was also informed by the need to provide broad sectoral technical guidance and monitoring framework to support jurisdictional and project-level REDD+ activities.

2.2.5. Green House Gases (GHG)

Kenya's FRL only covers Carbon dioxide gas (CO_2). Non-CO_2 emission Gas such as Methane (CH_4), Carbon Monoxide (CO) and Nitrous Oxide (N_2O) have not been considered because Kenya does not have quantitative spatial data for Non-CO_2 emission Gases (such as emissions from forest fires and emissions from forests in wetlands). Nethertheless, forest fires and mangrove forests are major sources of non- CO_2 gases and may be considered in subsequent estimation.

2.3. Selection of Reference Period

The forest sector in Kenya has undergone a number of changes over the historical period. It started during the colonization of Kenya where white highlands were created and areas of forest plantation established from existing natural forests (Ochieng *et al.,* 1992). In 1957 under the then CAP 385 Laws of Kenya, a National Forest Policy was published to support the management of forests. The policy was further revised in 1968 with the objective of enhancing biodiversity conservation. However, the suspension of the "Shamba" system[2] in the 1980s and 1990s due to an increasing forest adjacent community, massive excisions of public forests and poor enforcement of conservation recorded large scale destruction of forests. In the year 2001, a partial implementation of the proposed excision of 167,000 ha of forests was done taking away 71,000 ha of forests mainly in the Mau Forest Complex, and converting it into agricultural land (Ministry of Lands, 2001).

The Kenya Indigenous Forest conservation Programme (KIFCON) of 1990-1994 (Wass, 1995) provided a first glimpse of the situation of forests in Kenya, illustrated poor stocking in natural forests due to massive human encroachment. Agitation for revision of the Forest Act started in 2002 culminating in enactment of the Forest Act 2005 which has further been revised to the Forest Conservation and Management Act of 2016. The First National Land cover maps were actualized under the Forest Preservation Program (FPP) (KFS, 2013) which produced Land Cover / Land Use Map for 1990, 2000 and 2010 based on imageries of LANDSAT4, 5, 7 and ALOS. The maps illustrated a declining forest cover in the period 1990- 2000 and then a slight increase in the forest cover past year 2000 corresponding to improved forest policies. However, an improvement in forest policies of conservation may have favored only the forests of the white highlands (in this report described as Montane and Western Rain forests exposing the other forests to further degradation.

[2] Under the Shamba system, communities were allowed to reside inside forests and they actively participated in supporting forest plantation programmes

2.3.1. Aligning Reference period to changes in the Forest Sector

Policy has advised the selection of the reference period as **the period 2002 – 2018**. Such policies have been detailed in the introductory chapter of this document and are summarized below

1. The implementation of recent forest Acts i.e. Forest Act 2005 and Forest Conservation and Management Act of 2016 is expected to affect forest area changes positively. The agitation for a change in the forest act peaked in the year 2002 when a new government was elected and there was a general consensus that governance of forests should change. The forest act brought changes on management including community participation and made forest excisions more difficult than they were previously. The year 2002 is just after major excisions of montane forests that were done in 2001 (Ministry of Lands 2001) and no further excisions have been done. It implies a period of clearance of the excised forests but also a recovery of degraded forests next to excisions.

2. The coming of a new government in the year 2002 brought in planning of large scale development under the Vision 2030 targets. This came with urbanization and infrastructural growth, improved access into formerly pristine vegetation which exposes the dryland forests. By 2010, a new constitution was enacted and governance structures under devolved governments instituted. These changes have affected management and conservation of forests both positively and negatively. For example, proposals to increase agricultural land encroaches into former marginal lands where dryland forests existed. Similarly, developmental targets in the construction industry expose forests to further degradation because they are a major source of construction material

3. The period after the year 2002 has experienced enactment of many environmentally friendly policies that may favour forest conservation. The climate change related policies include The National Climate Change Strategy of 2010, Kenya Climate Change Act 2016, National Climate Change Framework Policy 2016 and Climate Change Action Plan 2018 among others. Land related polices include the Kenya Land Registration Act of 2012, The National Land Use policy of 2016 and the Kenya Land Act of 2016. Similarly, the Farm Forestry Rules of 2009, the gazettement of the Kenya Water Towers Agency in 2012 and the Enactment of the Wildlife Conservation and Management Act 2016 are some of the recent policies that favour forest conservation.

2.3.2. Selecting a Reference period based on mapping tools

Activity data for Estimating Green House Gases from the Land sector which has been used in the National Inventory Report for 2019 and the FRL is based on Wall to Wall land cover mapping using LANDSAT imagery. The detailed procedures used to develop the maps are explained in chapter three of this report. To develop a time series set of maps, the 34 LANDSAT images that make a wall-to-wall map of Kenya were available for the period 1990 to 2018. The land cover products are available for the years 1990, 1995, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015 and 2018. However, analyzing land cover change associated with each available epoch e.g. on annual basis is a complex process. Under the System for Landbased Emission Estimation for Kenya (SLEEK) programme that supported the development of the land cover maps, an Integration Tool (FLINT) is proposed to provide an annual monitoring of emissions from the Land sector based on annual land cover maps. However, the integration tool is still under development.

It is noted that the National Inventory Report for Kenya's 3rd NC has adopted the period 1995 – 2015 due to availability of data from other sectors while the FRL has adopted the period 2002 – 2018 to capture the period of implementation of recent forest sector policy decisions. The NIR adopted a 5 year interval of monitoring emissions (1990-2000, 2000-2005, 2005-2010 and 2010-2015). To harmonise emissions from the two processes and allow comparability, the FRL has adopted 4 year intervals in the period 2002-2018 (2002-2006, 2006-2010, 2010-2014 and 2014-2018).

3. ACTIVITY DATA AND EMISSION FACTORS

3.1. Activity data

3.1.1. Kenya's Land Cover mapping programme

In 2013, Kenya launched the System for Land-Based Emission Estimation in Kenya (SLEEK) programme to support the National GHG inventory process. The SLEEK has done an extensive mapping using a semi-automated method and produced the Land Cover / Land Use Map for the year 1990, 1995, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015 and 2018 based on imagery of LANDSAT4, 5, 7 and 8.

The map production methodology applied by SLEEK is pixel based – supervised classification using Random forest algorithm. The SLEEK Land Cover Change Mapping (LCC) Process aims to create a consistent, sustainable and technically rigorous process for providing land cover and change information required for national land based greenhouse gas (GHG) estimation. The programme seeks to provide a nationwide, time series consistent land cover maps for Kenya. These maps allow analysis of land cover and cover change through time based on IPCC land cover categories and their subtypes based on local requirements. In addition to supporting SLEEK, the maps and statistics generated by the program are recognized as official Government documents for informing Government processes across the land sector – such as land use planning, tracking deforestation, and landscape restoration. These maps have also been used to support the REDD+ process in construction of the Forest Reference Level and the National Forest Monitoring System.

The methodology employed for the SLEEK mapping process and which is described in Annex 1 allows creation of Land Cover / Land Use Map in a short period at low cost without requiring manual interpretation and editing. The site training data for supervised classification was extracted through a ground truth survey supplemented by Google Earth in areas with poor accessibility. The minimum mapping unit (MMU) of Land Cover / Use class was 0.09ha due to pixel basis image classification methodology. However, filtering process was applied to ensure that forest mapping met the forest definition (0.5ha as minimum area) as agreed in the country. The detailed process of developing these maps is available in a Technical Manual (SLEEK, 2018). An illustration of the map products from this process is shown in Figure

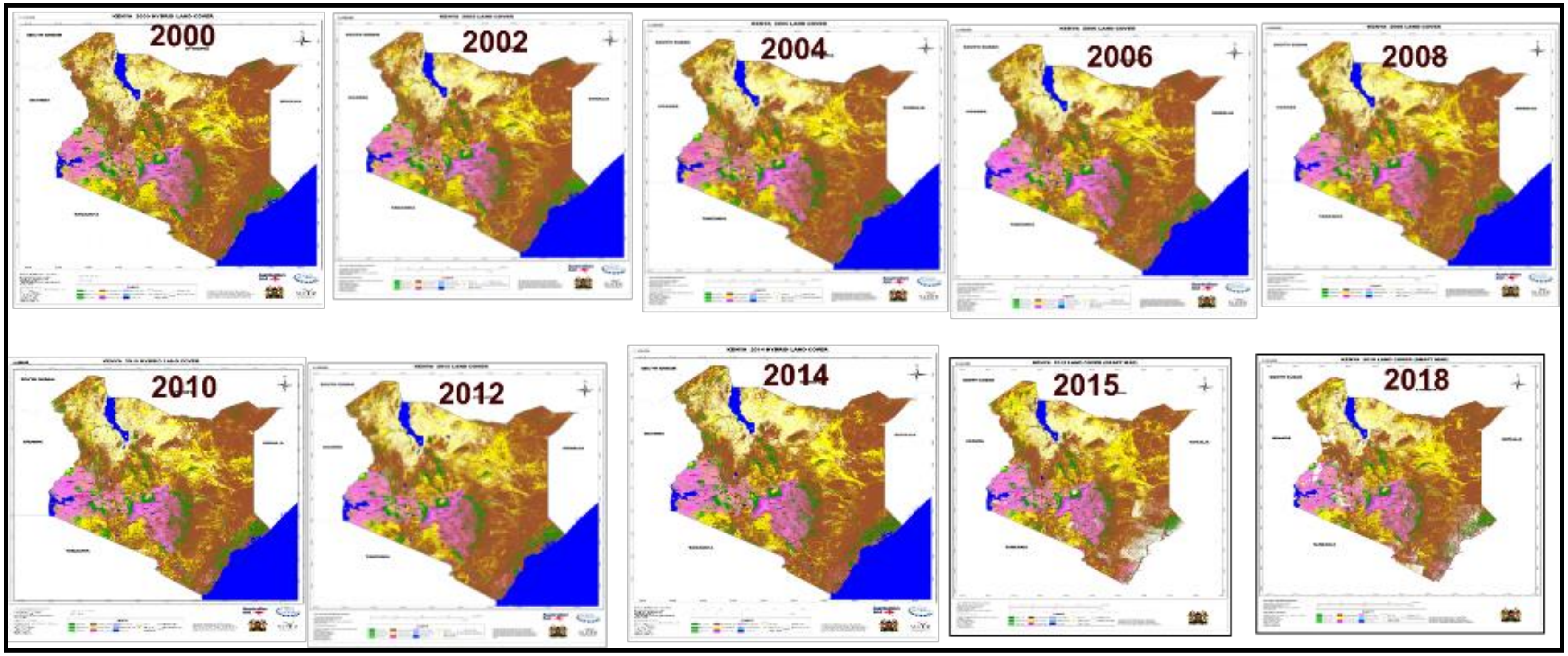

Figure 3: Some of the Wall-Wall time series Landcover maps from the SLEEK programme

Based on the complete time series mapping, the trend of forest cover for the period 2002-2018 is shown in percentages in Figure4. The figure shows a decline in forest cover from 6.2% (3,669,768 ha) in 2002 to 5.9% (3,462,536 ha) in 2018.

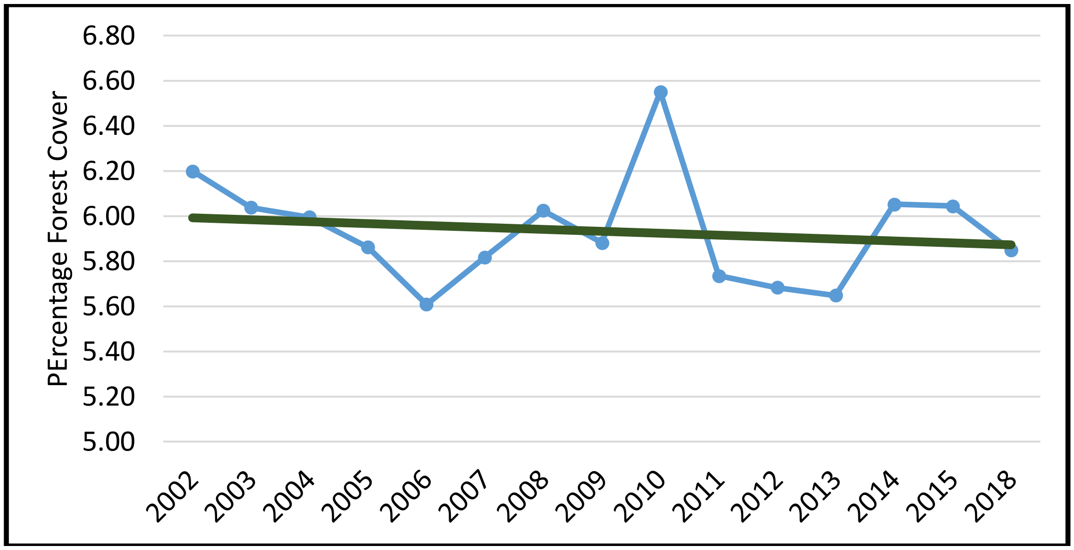

Figure 4: The Trend of forest cover change (%) (2002 – 2018) (SLEEK maps)

3.1.2. Stratification of forests

The land cover maps stratify forests into four strata (Figure 2) which have been adopted for assigning emission factors to different forest types. These strata are described in Chapter 2 of this report and follow the three forest ecozones of Kenya (Dryland forest areas, Montane & Western Rain forest areas and Coastal & Mangrove forest areas) defined by altitude and climate (Wass, 1995). The specific characteristics of the forests in each stratum are described in Annex 2. The fourth stratum is a management stratum comprising of commercial plantation forest areas managed by Kenya Forest Service (KFS), which spread across the ecozones. Non forest areas refer to Cropland, Grassland, Wetland, Settlement and Other land corresponding to the IPCC guidelines[3].

A second level stratification on the three strata based on ecozones (Dryland forest areas, Montane & Western Rain forest areas and Coastal & Mangrove forest areas) was done on the basis of canopy closure. The resultant canopy classes are: 15-40 % (Open), 40-65 % (Moderate), and

[3] Note that the SLEEK mapping system has not allowed separation of settlement (built up areas) and Otherlands as described by the IPCC guidelines

above 65 % (Dense). However, for the Plantation forest category managed by Kenya Forest Service (KFS), no subdivisions were done by canopy closure. This results to a total of 10 forest strata (Table 1). A conversion of a forest in a lower canopy class (e.g. open forest) to a higher canopy class (e.g. dense forest) results to Enhancement of Carbon stocks. Similarly a conversion of higher canopy forest to a lower canopy forest results to reduction in carbon stocks and is a forest degradation activity.

Table 1: Classification of Land Cover/Land uses for mapping under SLEEK

Land Category	First level stratification	Second level stratification
Forest	Montane/western rainforest/bamboo	Dense (canopy cover ≥65%)
		Moderate (Canopy cover 40-65%)
		Open (Canopy cover 15-40%)
	Coastal and Mangrove forests	Dense (canopy cover ≥65%)
		Moderate (Canopy cover 40-65%)
		Open (Canopy cover 15-40%)
	Dryland forest	Dense (canopy cover ≥65%)
		Moderate (Canopy cover 40-65%)
		Open (Canopy cover 15-40%)
	Plantation forest	Plantation forest
Non forest	Cropland	
	Grassland	
	Wetland	
	Settlement and Other lands[4]	

Table 2 below shows a product of the mapping process. It illustrates the specific areas of land uses mapped for the years 2002 and 2018. The table gives an illustration of the coverage of the various land uses identified in Table 2. Forestlands comprise a small percentage of the total land area of Kenya at approximately 6% (ranging from 6.2% in 2002 to 5.9% in 2018) while grasslands dominate at about 70% of the total land cover in Kenya. Croplands show a slight increasing trend from 8.9% to 11.4% in the years 2002 and 2018 respectively. These numbers are important because they describe Kenya's national circumstances affecting the forest cover and how this is expected to change over time. A decline in forest cover in the period 2002 – 2018 provides an opportunity for REDD+ implementation not only to reverse this trend but also to increase the forest cover towards the constitutional target of 10%. Similarly, an expansion in the Cropland area may be attributed to decreasing grasslands and forestlands and is one of the challenges

[4] The SLEEK land cover automated mapping does not separate Settlements and otherlands. Settlements are manually digitized on each maps based on ancillary data

affecting conservation of forestlands.

Table 2 also shows that most of the forests in Kenya are found in the dryland areas and the Montane forest areas. Each of these strata is faced by different drivers of deforestation but in spite of this, there is potential for enhancement of carbon stocks. The plantation forests managed by Kenya Forest Service (KFS) have the least area among the four strata and the areas have decreased over time. However, the area of plantation forests presented in Table 2 is only half of what is set aside for plantation forestry in Kenya[5] and this provides an opportunity for increasing the forest cover within the plantation zones.

[5] KFS maps show the area set aside for public plantation forestry as approximately 137,000 ha

Table 2: Land Cover statistics generated for each year used in the reference period

	2002		2006		2010		2014		2018	
Land Use Strata	**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**	**59,203,788**	**100**	**59,203,788**	**100**	**59,203,788**	**100**	**59,203,788**	**100**

3.1.2. Mapping land use transitions

The process of mapping land use transitions involved comparing change in maps from 2 time periods sequentially (e.g. 2002 vs 2006, 2006 vs 2010, 2010 vs 2014, and 2014 vs 2018). This resulted in a change map with areas remaining in the same land use type and areas changed to different land use types between 2-time periods (e.g. as shown in Figure 5) for the specific REDD+ activities. The process was repeated for each of the 4 time intervals (epochs) to generate activity data which was used to calculate emissions.

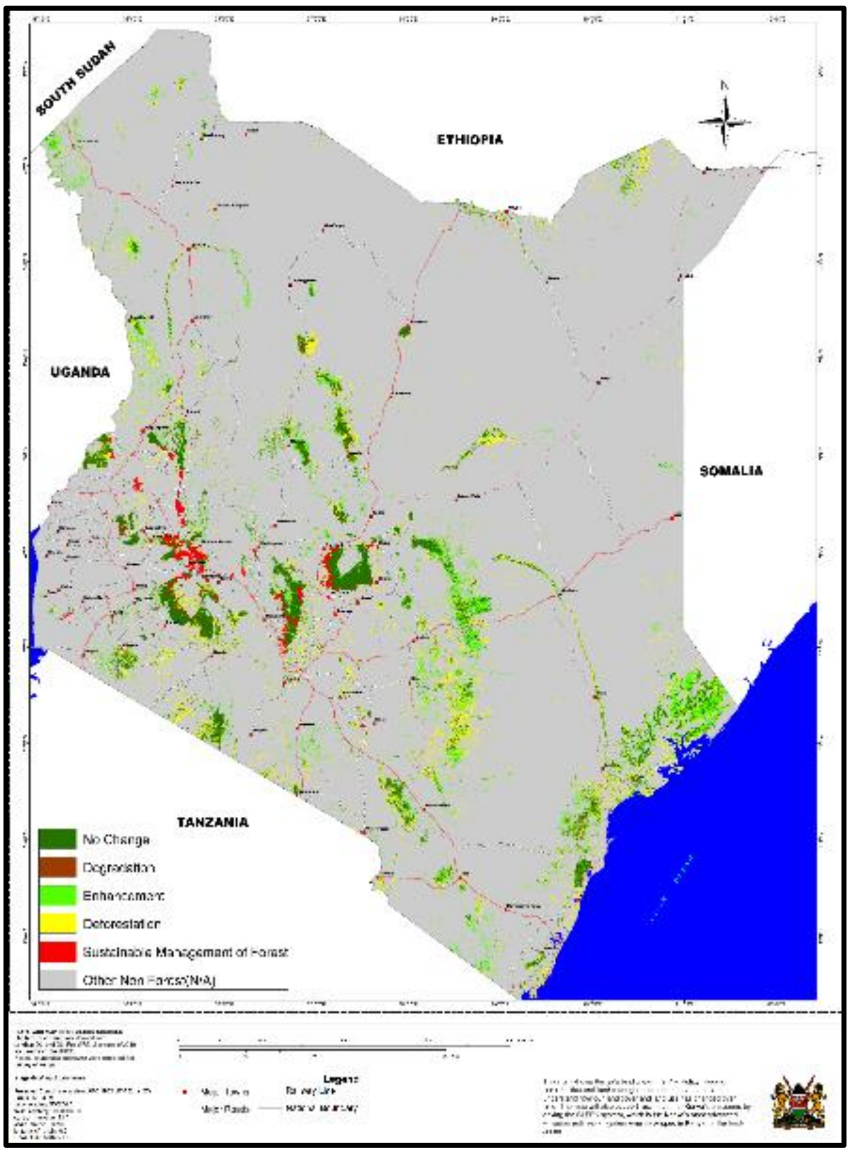

Figure 5: A Change maps (for year 2002-2006) used to generate activity data

3.1.3. Assigning Activity Data to REDD+ Activities

Based on the identified forest strata, Activity data on land use changes were assigned to each REDD+ activity to allow calculation of area change. A matrix was prepared to facilitate assigning the REDD+ activities to the different land use transitions, identify the specific areas of transition, with their specific Emission Factors and facilitate calculation of the overall emissions. The matrix below (Table 3) provides an explanation how each REDD+ Activities will be accounted for while setting the FRL. This information is summarized below

1. Deforestation is conversion of Forests to Non forests in all canopy classes of Montane/Western Rain forest, Coastal and mangrove forests and Dryland forests and is indicated by Red colour
2. Degradation is conversion of a forest from a higher canopy class to a lower canopy class for all forests in the strata/ecozones of Montane/Western Rain forests, Coastal and mangrove forests and Dryland forests and is indicated by yellow colour
3. Enhancement of Carbon stocks is the conversion of Non forests into forests (afforestation and reforestation) and the improvement of forests from a lower canopy class to a higher canopy class in the strata/ecozones of Montane/Western Rain forests, Coastal and mangrove forests and Dryland forests and is indicated by green colour.
4. Sustainable management of forests is the conversion of non-forests into forests and sustainable harvesting (forests into non forests) in public plantation forest areas managed by Kenya Forest Service (KFS) and is indicated by blue colour. This aims at reducing backlogs by replanting and increasing productivity of the public plantation forests.
5. Forestlands remaining forestland in the strata/ecozones of Montane/Western Rain forests, Coastal and mangrove forests, Dryland forests and Public Plantation Forests, which were mapped with a canopy remaining in the same canopy level in the two mapping years (e.g. 2002 and 2006) do not imply any carbon stock changes and have not been assigned any colour.
6. Conversions among non-forests e.g. cropland converted to wetland do not imply any emissions and have not been assigned any colour.

Table 3: Matrix for Allocating REDD+ activities to land use changes

Area in 20XX			Area in 20XX+(X)													
			Forest										Non Forest			
			Montane Forest/ Western Rain Forest/ Bamboo			Costal Forest and Mangroves			Dryland Forest			Plantation Forest	Crop Land	Grass land	Wet land	Settlement and Other land
			D	M	O	D	M	O	D	M	O					
Forest	Montane Forest/ Western Rain Forest/ Bamboo	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 Forest and Mangroves	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
	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 and Other land		e	e	e	e	e	e	e	e	e	s	NA	NA	NA	NA

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

3.1.4. Land cover change areas between years

The proposed land cover change matrix was populated with data based on the proposed epochs; 2002 - 2006, 2006 -2010, 2010 -2014, and 2014-2018 as illustrated in Table 4. Calculations of area change are based on aforementioned strata (Montane & Western Rain forest areas, Coastal and mangrove forest areas, Dryland forest areas and Plantation forest zones) and their specific canopy classes (for Montane & Western Rain forests, Coastal and mangrove forests and Dryland forests). The area of each land use transition is illustrated and the colour on the table used to assign each change to a REDD+ activity as described in Table 3.

3.1.5. Transitions of forests based on land cover change matrices

A summary of land over transitions affecting the forest sector illustrates that

1. Most of the forests of Kenya are found in the Montane and Western Rain forest strata
2. The Montane dense forests are stable and have been increasing over the time series from 773,672ha in 2002 to 834,862 ha in 2018. This is unlike the dryland dense forests that have large fluctuations from 303,805ha in 2006, 425,505ha in 2010, 450,388ha in 2014 and 344,985ha in 2018
3. The largest conversions of forests occur in the dryland forest strata and the conversion is mainly from forests into grasslands and the reverse
4. The plantation forest has not exceeded 65,000ha in all the years implying that the plantation forests occupy only half of the designated public plantation forest areas

Table 4: Land use Change (No of ha) for each forest strata in the 2002-2006 epoch

Forest strata			2006													
			Montane & Western Rain Forest			Costal & Mangrove Forest			Dryland Forest			Plantation forest	Cropland	Grassland	Wetland	Settlement & Otherland
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open					
2002	Montane Forest & Western Rain Forest /	Dense	773,672	75,916	27,963								110,685	127,283	251	445
		Moderate	36,857	75,670	14,739								17,071	71,895	154	248
		Open	25,105	10,533	27,186								8,333	82,848	18	267
	Costal & Mangrove Forests	Dense				114,602	11,053	3,190					2,458	36,401	490	623
		Moderate				100,716	77,558	22,429					9,195	130,990	431	1,039
		Open				12,055	4,378	1,861					1,509	18,267	22	128
	Dryland Forest	Dense							303,805	32,124	21,397		38,529	301,166	1,933	2,465
		Moderate							107,414	84,438	21,236		17,244	220,465	2,309	1,868
		Open							43,048	22,420	62,831		8,668	248,377	1,452	10,672
	Plantation forest											62,292	4,248	12,622	9	9
	Cropland		37,067	3,719	2,655	300	583	102	16,223	1,679	5,441	5,520				
	Grassland		103,916	73,048	33,153	52,514	41,374	40,874	343,099	132,028	228,734	5,515				
	Wetland		205	61	23	513	576	368	2,229	1,768	1,835	10				
	Settlement & Other land		462	64	48	266	156	115	1,707	1,360	4,005	4				

Table 5: Land use Change (No of ha) for each forest strata in the 2006-2010 epoch

Forest strata			2010													
			Montane & Western Rain Forest			Costal & Mangrove Forest			Dryland Forest			Plantation forest	Cropland	Grassland	Wetland	Settlement & Otherland
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open					
2006	Montane Forest & Western Rain Forest /	Dense	749,295	38,797	18,012								57,504	111,178	256	2,243
		Moderate	74,676	79,707	9,679								4,647	70,133	44	125
		Open	29,698	13,517	20,443								4,500	37,492	16	101
	Costal & Mangrove Forests	Dense				215,356	29,039	333					713	34,769	581	176
		Moderate				19,875	77,651	1,166					521	35,589	726	149
		Open				3,352	27,627	1,329					205	35,722	473	230
	Dryland Forest	Dense							425,505	39,428	26,851		28,583	291,829	2,881	2,449
		Moderate							62,214	76,621	17,783		3,653	112,795	1,870	881
		Open							28,938	28,669	68,159		9,935	200,598	2,053	7,129
	Plantation forest											61,183	4,178	7,968	11	0
	Cropland		67,138	8,536	8,401	2,485	2,573	298	27,969	4,497	12,733	3,819				
	Grassland		132,713	78,280	40,850	59,719	122,443	9,292	485,917	230,353	276,515	11,970				
	Wetland		222	39	28	402	552	18	2,850	1,283	1,359	17				
	Settlement & Other land		882	962	138	507	945	185	4,230	21,324	10,939	13				

Table 6: Land use Change (No of ha) for each forest strata in the 2010-2014 epoch

Forest strata			2014													
			Montane & Western Rain Forest			Costal & Mangrove Forest			Dryland Forest			Plantation forest	Cropland	Grassland	Wetland	Settlement & Otherland
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open					
2010	Montane Forest & Western Rain Forest /	Dense	811,460	35,478	29,991								67,820	109,131	215	529
		Moderate	70,180	76,226	10,964								8,986	53,130	107	244
		Open	20,994	12,731	13,395								8,378	41,885	43	123
	Costal & Mangrove Forests	Dense				221,815	20,895	768					1,186	55,669	460	902
		Moderate				59,002	59,199	1,835					4,427	135,127	912	327
		Open				623	926	646					978	9,361	15	72
	Dryland Forest	Dense							450,388	48,329	26,540		31,316	475,519	2,748	2,782
		Moderate							68,735	78,685	23,421		4,150	220,502	1,454	5,230
		Open							31,273	17,404	75,590		11,696	268,363	1,887	8,126
	Plantation forest											64,384	5,889	6,707	12	9
	Cropland		62,635	6,649	3,452	2,606	460	15	28,717	4,707	3,493	5,109				
	Grassland		118,181	70,500	46,412	137,075	37,087	2,216	385,810	134,613	168,121	11,987				
	Wetland		330	11	10	1,126	344	2	4,112	1,266	412	15				
	Settlement & Other land		1,938	128	239	368	194	3	2,708	1,202	6,554	11				

Table 7: Land use Change (No of ha) for each forest strata in the 2014-2018 epoch

Forest strata			2018													
			Montane & Western Rain Forest			Costal & Mangrove Forest			Dryland Forest			Plantation forest	Cropland	Grassland	Wetland	Settlement & Otherland
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open					
2014	Montane Forest & Western Rain Forest /	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
	Costal & 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 Forest	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 forest											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				

3.1.6. Annual and percentage areas of change

The tables 8-12 illustrate annual areas of change for each stratum based on the land use change matrices presented in tables 4-7. Figure 4 compares the contribution of the forest strata to deforestation

1. Table 8 shows that the area of deforestation in Kenya (average 338,863ha) has slightly exceeded the area of reforestation (average 326,794ha) and therefore there has been a net loss of forests. The greatest transition of forests to non forests and the reverse occurs in the dryland forest strata. A REDD+ programme to reduce deforestation is expected to reverse this trend
2. Table 9 shows that the process of degradation of forests is slightly less than that of canopy improvement at 59,736ha versus 69,813ha. This implies that afforestation programmes have been on an improvement trend. A continuous improvement of the planted forests enhances their stocks and justifies this as a REDD+ activity
3. Table 10 shows that in public plantation forest areas, the process of harvesting forests has slightly exceeded the process of planting implying that the plantation forests have more planting backlogs and their forest area has been reducing. A sustainable management programme is expected to reverse this trend.
4. Table 11 gives the average deforestation rate in Kenya as 0.58% of the total land area which implies an area of 9.27% of the total land area was deforested in the 2002-2018 reference period. This is against an afforestation area of 8.83% of the total land area. In effect a net area of 0.44% of Kenya's total land area was deforested in the reference period. Figure 6 shows the specific deforestation areas among strata in the different mapping epochs
5. Table 12 illustrates the rates of forest degradation and enhancement of forest canopy in conserved areas. The table shows that the areas under canopy improvement are slightly more (at 0.12% of the national land area) than the areas undergoing forest degradation (at 0.1% of the national land area).

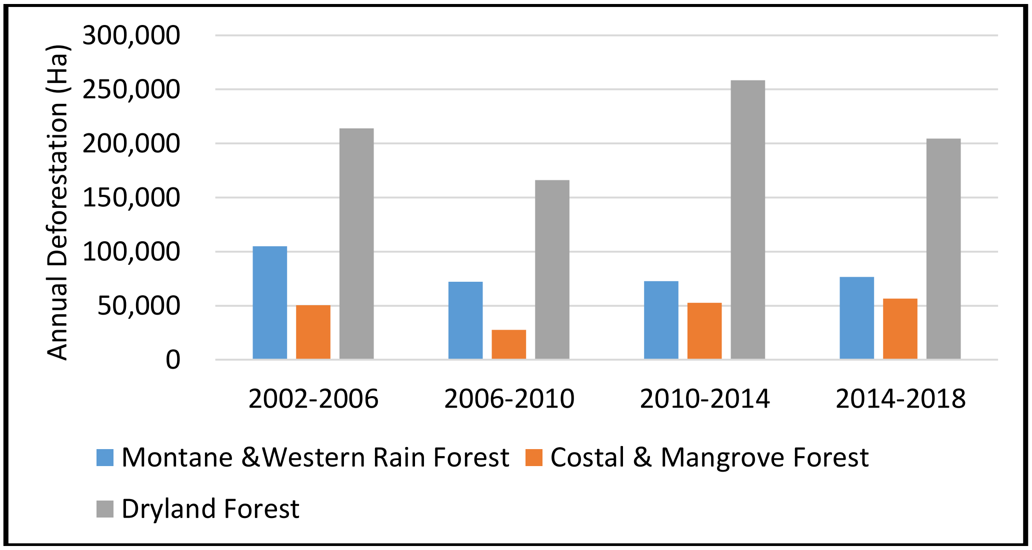

Figure 6: The contribution of strata to the annual deforestation in the reference period

Table 8: Annual transitions (No of ha); Deforestation and Afforestation among forest strata

Forest strata	Area (ha/yr) of Deforestation					Area (ha/yr) of Afforestation				
	2002-2006	2006-2010	2010-2014	2014-2018	Average	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	104,874	72,059	72,648	76,322	81,476	63,605	84,547	77,621	67,426	73,300
Costal & Mangrove Forest	50,388	27,463	52,359	56,664	46,719	34,435	49,855	45,374	44,777	43,610
Dryland Forest	213,787	166,164	258,443	204,279	210,668	185,027	269,992	185,429	199,089	209,884
Total	369,049	265,687	383,450	337,265	338,863	283,068	404,394	308,424	311,292	326,794

Table 9: Annual transitions (No of ha); Forest degradation and Canopy improvement

Forest strata	Area (ha/yr) of Forest Degradation					Area (ha/yr) of Forest enhancement by Canopy improvement				
	2002-2006	2006-2010	2010-2014	2014-2018	Average	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	29,655	16,622	19,108	20,461	21,461	18,124	29,473	25,976	15,104	22,169
Costal & Mangrove Forest	9,168	7,634	5,874	22,830	11,377	29,287	12,714	15,138	6,032	15,793
Dryland Forest	18,689	21,016	24,572	43,316	26,898	43,220	29,955	29,353	24,878	31,852
Total	57,512	45,272	49,555	86,607	59,736	90,631	72,142	70,467	46,013	69,813

Table 10: Annual transitions for sustainable management in public Plantation forests

Forest strata	Area (ha/yr) of Sustainable Management of forests				
	2002-2006	2006-2010	2010-2014	2014-2018	Average
Harvested area	4,222	3,039	3,155	6,298	4,178
Afforested area	2,762	3,955	4,280	2,185	3,296
Net (Deficit/backlog)	-1,460	916	1,125	-4,113	-882

Table 11: Annual transitions (% of national area); Deforestation and Afforestation

Forest strata	Percentage of national area Deforested					Percentage of national area Afforested				
	2002-2006	2006-2010	2010-2014	2014-2018	Average	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	0.18	0.12	0.12	0.13	0.14	0.11	0.14	0.13	0.11	0.12
Costal & Mangrove Forest	0.09	0.05	0.09	0.10	0.08	0.06	0.08	0.08	0.08	0.07
Dryland Forest	0.36	0.28	0.44	0.35	0.36	0.31	0.46	0.31	0.34	0.35
Total	0.63	0.45	0.65	0.58	0.58	0.48	0.68	0.52	0.53	0.55

Table 12: Annual transitions (% of national area); Forest degradation and Canopy improvement

Forest strata	Percentage of national area with Forest Degradation					Percentage of national area with Canopy improvement				
	2002-2006	2006-2010	2010-2014	2014-2018	Average	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	0.05	0.03	0.03	0.03	0.04	0.03	0.05	0.04	0.03	0.04
Costal & Mangrove Forest	0.02	0.01	0.01	0.04	0.02	0.05	0.02	0.03	0.01	0.03
Dryland Forest	0.03	0.04	0.04	0.07	0.05	0.07	0.05	0.05	0.04	0.05
Total	0.10	0.08	0.08	0.15	0.10	0.15	0.12	0.12	0.08	0.12

Table 13: Area of forestland remaining forestland in the reference period

Forest strata	Area (ha) of Forestland that remained forestland					Percentage of forestland (based on national land area) that remained forestland				
	2002-2006	2006-2010	2010-2014	2014-2018	Average	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	1,067,639	1,033,823	1,081,420	1,086,615	1,067,374	1.80	1.75	1.83	1.84	1.80
Costal & Mangrove Forest	347,841	375,728	365,710	320,549	352,457	0.59	0.63	0.62	0.54	0.60
Dryland Forest	698,714	774,168	820,364	744,965	759,553	1.18	1.31	1.39	1.26	1.28
Plantation	62,292	61,183	64,384	56,315	61,044	0.11	0.10	0.11	0.10	0.10
Total	**2,176,487**	**2,244,903**	**2,331,878**	**2,208,444**	**2,240,428**	**3.68**	**3.79**	**3.94**	**3.73**	**3.78**

3.1.7. Area of stable forests

The area of forests that remained forests between two mapping years is shown in table 13. An area of slightly over 2 million hectares has remained forest in the reference period and averages at 2,240,428ha. The Montane and Western Rain forest stratum has the biggest contribution to the stable forest maintaining an area slightly over 1 million hectares (average 1,067,374ha) in the reference period. The Dryland forests and the Coastal and Mangrove strata have also significantly stable forests. The table shows that an area of 3.78% of Kenya's land area has remained forestland in the reference period. This area of stable forests and the area that underwent afforestation and the reduction of areas that have been undergoing deforestation contribute towards meeting the country's target of 10% forest cover.

3.1. Emission Factors (EF)

Two sets of data were used to generate Emission Factors; stock change and growth rates.

3.2.1. Emission factors from stock change

Emission Factors for changes in forest carbon stocks were based on 1st level and 2nd level stratification of forests described in Table 1 above. Stratified sampling was used and forest stock data collected in a Pilot Forest Inventory by ICFRA (KFS, 2016) and CADEP-SFM (JICA, 2017) was used to assign biomass stock to each strata and sub strata. It is noted that Kenya has not conducted a comprehensive National Forest Inventory (NFI) that would have effectively supported the establishment of emission factors. According to the step-wise approach, it is expected that the NFI will be implemented in future[6]. Therefore, data from the pilot inventory that covered all the forest strata was used. The data was collected from a total of 121 plots and is illustrated in Annex 3. A simple average of the field data for each stratum was used as the Biomass stock for each sub strata.

The EFs were estimated for Deforestation (conversion of forests into non forests) by the following process. Firstly, the values of AGB in each plot were computed (Table 14), using the forest inventory data described above and locally acceptable allometric equations (Table 15). The values of BGB were calculated by applying the R/S ratio per forest strata based on IPCC 2006 guidelines for each stratum (Table 16). Forest biomass calculated as the sum of AGB and BGB was converted into Carbon using the IPCC carbon fraction of 0.47. Further, the conversion to CO_2 is based on the ratio of molecular weights (44/12) (IPCC 2006). Finally, Emission Factors were estimated as the differences in carbon stocks in an area at two points in time (e.g. 2002 and 2006).

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[6] The ICFRA project developed technical manuals for Biophysical assessment of Forest resources and also developed a design for an NFI. However, the NFI has not been implemented

In conversions of forests into non-forests, the Carbons stocks were assumed to go through immediate oxidation and IPCC 2006 guidelines used for Tier 1 default factors[7] used in calculating stock changes.

3.2.2. Emission Factors due to forest growth

Emission Factors due to forest growth were classified into two as shown below

3.2.2.1. Conversion of non-forests into forests

The EFs due to afforestation (conversion of a non-forest into a forest) shown in Table 17 were calculated using a growth rate for each of the forest strata for trees < 20yr, because in the 4 year change period such the forests have not attained 20 years. Choice of EF was based on the fact that a forest undergoes a process of growth after planting and does not immediately achieve the carbon stock of the forest it is mapped into but attains a carbon stock value described by its growth rate and the number of years of growth. The growth rates were calculated based on IPCC 2006 guidelines as shown in Table 17.

3.2.2.2. Improvement of forest stock due to canopy enhancement

The EFs for Enhancement (improvement of Carbon stocks where a canopy improvement was noted between two years of mapping are shown in Table 18. They were calculated using a growth rate associated to each of the forest strata for trees >=20 yr. The >=20 yr is selected on the basis that these are already grown forests which had previously been degraded and are undergoing stock enhancement. Choice of EF was based on the fact that a forest undergoes a process of growth after conservation measures are initiated and a canopy improvement (as in the case of an open forest converting to a dense forest) does not result to the carbon stock of the forest it is mapped into, but attains a carbon stock value described by its growth rate and the number of years of growth typical to such a forest stratum.

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[7] Table 4.7of vol 4 chapter 4 of IPCC 2006 guidelines

Table 14: Emission Factors from NFI for forest type class

Forest strata	Canopy Cover	ABG	BGB	TOTAL		
		Biomass Tonnes/ha)[8]	Biomass Tonnes/ha)[9]	Biomass (Tonnes/ha)[10]	Carbon (Tonnes/ha)[11]	CO_2 (Tonnes/ha)[12]
Montane & Western Rain	Dense	244.80	90.57	335.37	157.62	577.95
	Moderate	58.43	21.62	80.05	37.62	137.96
	Open	18.31	6.77	25.08	11.79	43.23
Coastal & Mangrove	Dense	94.63	18.93	113.55	53.37	195.69
	Moderate	52.75	10.55	63.30	29.75	109.08
	Open	24.01	4.80	28.81	13.54	49.64
Dryland	Dense	42.43	11.88	54.31	25.53	93.60
	Moderate	34.52	9.67	44.19	20.77	76.15
	Open	14.26	3.99	18.26	8.58	31.47
Plantation		324.79	87.69	412.48	193.87	710.84
Cropland Wetland &Settlements/ Otheralands		0	0	0	0[13]	0
Grassland				8.7[14]	4.09	14.99

[8] Stock obtained from Pilot NFI and allometric equations as simple average of plot data for each stratum
[9] Calculated using the IPCC root/shoot Ratio shown in table 9
[10] Sum of ABG and BGB
[11] Calculated using Carbon fraction of 0.47
[12] Calculated using CO_2 molecular formula of 44/12
[13] The Cropland Carbon Factor obtained from IPCC default values for tier 1 reporting: 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4: Chapter 5 (Cropland) Table 5.8: Default Biomass Stocks Present On Cropland , After Conversion From Forestland
[14] The Grassland Carbon Factor obtained from IPCC default values for Tropical Dry Grasslands: 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4: Chapter 6 (Grassland) Table 6.4: Default Biomass Stocks Present On Grassland , After Conversion From Other Land Use

Table 15: List of allometric equations used for AGB Estimation

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	$1.04+0.06*d*GW_{bamboo}$ $GW_{bamboo}=1.11+0.36*d^2$ (bamboo diameter > 3 cm) $GW_{bamboo}=1.11+0.36*3.1^2$ (bamboo diameter ≤ 3 cm)	Muchiri and Muga. 2013
Climbers in natural forests	-	-	$e^{(-1.484+2.657*\ln(DBH))}$	Schnitzer et al. 2006

Table 16: Specific Shoot/Root ratios for the different strata

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

Table 17: Emission factors for calculating forest growth due to afforestation

Forest strata	Biomass gain (Tonnes/ha)			Carbon from Biomass	CO_2 sequestered (Tonnes/ha)		Reference AGB value from IPCC V4.4
	AGB value	BGB[15]	Total		One year	4 years	
Montane and Western rain	10	3.70	13.70	6.44	23.61	94.44	Table 4.9 for Africa tropical rain forests for forests <20 yrs
Dryland	2.4	0.67	3.07	1.44	5.29	21.16	Table 4.9 for Africa tropical dry forests for forests< 20 yrs
Coastal and Mangrove	5	1.00	6.00	2.82	10.34	41.36	Table 4.9 for Africa tropical moist deciduous forests for forests < 20 yrs
Public Plantation	10	2.70	12.70	5.97	21.89	87.56	Table 4.10 for Africa Tropical mountain systems plantation forests

[15] EF used as in table 16 for shoot/root rations

Table 18: Emission factors used for calculating forest growth due to enhancement

Forest strata	Biomass gain (Tonnes/ha)			Carbon from Biomass	CO_2 sequestered (Tonnes/ha)		Reference AGB value from IPCC V4.4
	AGB value	BGB[16]	Total		One year	4 years	
Montane and Western rain	3.1	1.15	4.25	2.00	7.32	29.28	Table 4.9 for Africa tropical rain forests for forests >20 yrs
Dryland	1.8	0.50	2.30	1.08	3.97	15.88	Table 4.9 for Africa tropical dry forests for forests > 20 yrs
Coastal and Mangrove	1.3	0.26	1.56	0.73	2.69	10.76	Table 4.9 for Africa tropical moist deciduous forests for forests > 20 yrs
Public Plantation	10	2.70	12.70	5.97	21.89	87.56	Table 4.10 for Africa Tropical mountain systems plantation forests

[16] EF used as in table 16 for shoot/root rations

3.2.3. Generating Emission factors from land use transitions

Using Carbon stock data (Tables 14 to 18), the EF associated with each land use transition, were calculated and assigned to each REDD+ activity as illustrated in Table 19. These calculations were done as follows

1. Deforestation which is conversion of a forest to a non-forest in Montane &Western Rain forests, Coastal & mangrove forests and Dryland forests;
    a. Instantaneous Oxidation[17] was assumed for all deforestation. Therefore, the EF is the difference between the CO_2 value of the initial forest strata/canopy class and the CO_2 value of the non-forest
    b. All forest conversions into Croplands, Wetlands and Settlements& Otherlands attain a CO_2 value of Zero after conversion. The EF is the difference between the CO_2 of the former forest and zero
    c. All forest conversions into Grasslands attain a CO_2 value of 14.99 Tonnes/ha after conversion. The EF is the difference between the CO_2 of the former forest and 14.99 Tonnes/ha
2. Forest Degradation which is the conversion of a forest from a higher canopy class to a lower canopy class in Montane &Western Rain forests, Coastal & mangrove forests and Dryland forests
    a. Instantaneous Oxidation was assumed for all degradation[18]. Therefore, the EF is the difference between the CO_2 value of the initial forest canopy class and the CO_2 value of the new forest canopy class within a stratum
3. Enhancement of Carbon stocks due to conversion of non-forests into forests in Montane & Western Rain forests, Coastal & mangrove forests and Dryland forests was calculated as follows
    a. A growth factor was adopted for each stratum (Table 17) to give the amount of CO_2 gained in a planted/young forest (in this case a forest that is less than 20 years) in the 4 year period. In case the calculation of growth results to a stock which is more than the stock factor of the specific canopy class, a capping was done to retain the stock of the specific canopy class.
    b. The EF for conversion of Croplands, Wetlands and Settlements & Otherlands into forestlands was the difference between zero and the CO_2 value after growth of 4

17.There is no data on harvested wood products. Most of the activities that convert forests to non-forests in the specified strata may result to instantaneous oxidation

18.Data on drivers of degradation is not reliable enough to estimate emissions as shown in a preliminary study to this work - Options for Estimating GHG Emissions/Sinks from Forest Degradation, Forest Fires and Forest Revegetation. A Report To Support Establishment of Kenya's Forest Reference Level years

c. The EF for conversion of grasslands into Forestlands was the difference between a CO_2 value of 14.99 Tonnes/ha and the CO_2 value of the forest after 4 years of growth

4. Enhancement of Carbon stocks due to improvement of Canopy in forests from a lower canopy class to a higher canopy class in Montane and Western Rain forests, Coastal and mangrove forests and Dryland forests was calculated as follows
   a. A growth factor was adopted for each stratum (Table 18) to give the amount of CO_2 gained in an existing forest (in this case a forest that is more than 20 years[19]) in the 4 year period
   b. The EF was calculated as the difference between the previous CO_2 value (for the starting year) and the new CO_2 value after forest enhancement (end year). In case the calculation of growth results to a stock which is more than the stock factor of the specific canopy class, a capping was done to retain the stock of the specific canopy class.
5. In Sustainable management of forest which is the conversion of non-forests into forestlands in areas designated as Plantation zones[20], EF were calculated as follows
   a. A stock change method was applied and the EF calculated as the difference between the CO_2 value of the previous non-forest to the CO_2 value of a plantation based on growth rate (Table 16).
   b. A Conversion of a Cropland, Wetland and Settlements & Otherlands into a forestland changes carbon stocks from a zero CO_2 value to a CO_2 value to 87.56 Tonnes/ha
   c. A conversion of a grassland to a forestland changes carbon stocks from a CO_2 value of 14.99 Tonnes/ha to a CO_2 value of 87.56 Tonnes/ha

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19 IPCC Table 4.9 classifies forests into less than 20 years or more than 20 years to determine Growth rate Factors

20 NB: future Definitions of sustainable management of forests may include plantation forests remaining plantations where stock improvement is considered. This requires periodic inventories

Table 19: Matrix of EF setting for various land use changes and REDD+ activities

	Forest strata		End Year													
			Montane & Western Rain Forest			Coastal & Mangroves Forest			Dryland Forest			Plantation	Cropland	Grassland	Wetland	Settlement & Other land
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open					
Start year	Montane & Western Rain Forest	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 & Mangroves 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 Forest	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											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. EMISSIONS FROM LAND USE CHANGE

4.1. Emission Estimates

Activity data for land use change conversions (Table 4) and the Emission Factors calculated for the specific land use conversions (Table 19) were used to calculate CO_2 emissions associated with each land use change for each epoch. This is shown in Tables 20-23.

The largest emissions occurred when dense montane forests were converted into either Croplands, Wetlands or Settlement and Otherlands resulting to a net emission of 577.95 Tonnes of CO_2 per ha. The reverse however, does not sequester the equivalent of emitted GHG because the forest is still in a recovery mode at age 4.

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Table 20: Emissions (CO_2 Tonnes) calculated for land use changes (2002 to 2006)

Forest strata			2006													
			Montane &Western Rain Forest			Coastal & Mangroves Forest			Dryland Forest			Plantation	Cropland	Grassland	Wetland	Settlement & Other land
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense				
2002	Montane &Western Rain Forest	Dense	0	33,402,790	14,952,439	0	0	0	0	0	0	0	63,970,436	71,655,345	144,916	256,958
		Moderate	-1,079,014	0	1,396,195	0	0	0	0	0	0	0	2,355,007	8,840,448	21,194	34,144
		Open	-734,972	-308,355	0	0	0	0	0	0	0	0	360,219	2,339,276	759	11,540
	Coastal & Mangroves Forest	Dense	0	0	0	0	957,251	465,807	0	0	0	0	480,910	6,577,554	95,791	121,980
		Moderate	0	0	0	-1,083,064	0	1,333,070	0	0	0	0	1,002,960	12,324,488	47,025	113,301
		Open	0	0	0	-129,630	-47,079	0	0	0	0	0	74,933	632,966	1,072	6,353
	Dryland Forest	Dense	0	0	0	0	0	0	0	560,352	1,329,447	0	3,606,220	23,672,823	180,967	230,717
		Moderate	0	0	0	0	0	0	-1,705,968	0	948,998	0	1,313,196	13,483,713	175,828	142,251
		Open	0	0	0	0	0	0	-683,703	-356,075	0	0	272,758	4,091,434	45,693	335,808
	Plantation			0	0	0	0	0	0	0	0	0	3,019,518	8,782,822	6,589	6,398
	Cropland		-3,500,587	-351,190	-114,753	-12,418	-24,117	-4,203	-343,535	-35,565	-115,221	-483,208		0	0	0
	Grassland		-8,255,667	-5,803,365	-936,099	-1,384,632	-1,090,906	-1,077,714	-2,121,493	-816,374	-1,414,338	-400,154		0	0	0
	Wetland		-19,387	-5,729	-1,004	-21,221	-23,838	-15,210	-47,195	-37,433	-38,861	-890		0	0	0
	Settlement & Other land		-43,653	-6,077	-2,081	-10,996	-6,455	-4,761	-36,156	-28,809	-84,815	-347		0	0	0

Table 21: Emissions (CO_2 Tonnes) calculated for land use changes (2006 to 2010)

			2010													
			Montane &Western Rain Forest			Coastal & Mangroves Forest			Dryland Forest			Plantation	Cropland	Grassland	Wetland	Settlement & Other land
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense				
2006	Montane &Western Rain Forest	Dense	0	17,070,483	9,631,385	0	0	0	0	0	0	0	33,234,376	62,588,594	147,829	1,296,129
		Moderate	-2,186,221	0	916,880	0	0	0	0	0	0	0	641,058	8,623,860	6,009	17,258
		Open	-869,436	-395,724	0	0	0	0	0	0	0	0	194,514	1,058,624	704	4,357
	Coastal & Mangroves Forest	Dense	0	0	0	0	2,514,938	48,646	0	0	0	0	139,539	6,282,487	113,702	34,396
		Moderate	0	0	0	-213,728	0	69,327	0	0	0	0	56,881	3,348,489	79,186	16,287
		Open	0	0	0	-36,046	-297,093	0	0	0	0	0	10,178	1,237,805	23,475	11,411
	Dryland Forest	Dense	0	0	0	0	0	0	0	687,757	1,668,294	0	2,675,256	22,938,859	269,626	229,252
		Moderate	0	0	0	0	0	0	-988,102	0	794,694	0	278,196	6,898,571	142,429	67,092
		Open	0	0	0	0	0	0	-459,594	-455,333	0	0	312,609	3,304,391	64,602	224,316
	Plantation			0	0	0	0	0	0	0	0	0	2,969,681	5,544,797	7,997	192
	Cropland		-6,340,425	-806,099	-363,176	-102,764	-106,401	-12,314	-592,272	-95,234	-269,644	-334,294		0	0	0
	Grassland		-10,543,466	-6,219,016	-1,153,433	-1,574,598	-3,228,446	-245,011	-3,004,578	-1,424,344	-1,709,779	-868,478		0	0	0
	Wetland		-21,011	-3,680	-1,194	-16,609	-22,848	-759	-60,353	-27,178	-28,782	-1,521		0	0	0
	Settlement & Other land		-83,329	-90,817	-5,957	-20,950	-39,100	-7,668	-89,580	-451,569	-231,643	-1,127		0	0	0

Table 22: Emissions (CO_2 Tonnes) calculated for land use changes (2010 to 2014)

			2014													
			Montane &Western Rain Forest			Coastal & Mangroves Forest			Dryland Forest			Plantation	Cropland	Grassland	Wetland	Settlement & Other land
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense				
2010	Montane &Western Rain Forest	Dense	0	15,610,247	16,036,988	0	0	0	0	0	0	0	39,197,047	61,436,643	124,214	305,593
		Moderate	-2,054,576	0	1,038,642	0	0	0	0	0	0	0	1,239,653	6,533,103	14,763	33,623
		Open	-614,621	-372,719	0	0	0	0	0	0	0	0	362,152	1,182,669	1,879	5,334
	Coastal & Mangroves Forest	Dense	0	0	0	0	1,809,649	112,104	0	0	0	0	232,125	10,059,001	89,979	176,559
		Moderate	0	0	0	-634,485	0	109,077	0	0	0	0	482,940	12,713,774	99,468	35,646
		Open	0	0	0	-6,702	-9,963	0	0	0	0	0	48,549	324,386	742	3,570
	Dryland Forest	Dense	0	0	0	0	0	0	0	843,032	1,648,963	0	2,931,093	37,377,617	257,218	260,428
		Moderate	0	0	0	0	0	0	-1,091,665	0	1,046,613	0	316,036	13,485,959	110,723	398,281
		Open	0	0	0	0	0	0	-496,680	-276,412	0	0	368,015	4,420,666	59,385	255,702
	Plantation			0	0	0	0	0	0	0	0	0	4,186,177	4,667,342	8,765	6,653
	Cropland		-5,915,120	-627,891	-149,208	-107,782	-19,014	-614	-608,119	-99,679	-73,974	-447,272		0	0	0
	Grassland		-9,388,981	-5,600,946	-1,310,483	-3,614,253	-977,878	-58,429	-2,385,584	-832,356	-1,039,548	-869,672		0	0	0
	Wetland		-31,185	-1,054	-432	-46,590	-14,223	-63	-87,077	-26,814	-8,727	-1,276		0	0	0
	Settlement & Other land		-183,019	-12,069	-10,341	-15,202	-8,029	-127	-57,351	-25,447	-138,787	-977		0	0	0

Table 23: Emissions (CO_2 Tonnes) calculated for land use changes (2014 to 2018)

			2018													
			Montane &Western Rain Forest			Coastal & Mangroves Forest			Dryland Forest			Plantation	Cropland	Grassland	Wetland	Settlement & Other land
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense				
2014	Montane &Western Rain Forest	Dense	0	21,651,842	10,552,404	0	0	0	0	0	0	0	51,342,310	51,702,465	240,417	474,592
		Moderate	-1,178,313	0	1,221,932	0	0	0	0	0	0	0	1,573,535	6,618,484	10,728	4,507
		Open	-288,162	-302,242	0	0	0	0	0	0	0	0	278,178	1,456,014	436	1,093
	Coastal & Mangroves Forest	Dense	0	0	0	0	7,614,288	199,091	0	0	0	0	1,256,626	28,942,580	319,374	161,431
		Moderate	0	0	0	-236,831	0	121,268	0	0	0	0	388,871	4,743,776	50,009	25,466
		Open	0	0	0	-11,996	-10,637	0	0	0	0	0	5,469	96,905	469	572
	Dryland Forest	Dense	0	0	0	0	0	0	0	1,708,213	2,620,098	0	2,298,665	35,836,894	362,633	215,951
		Moderate	0	0	0	0	0	0	-919,222	0	1,482,003	0	362,697	7,824,389	93,596	77,496
		Open	0	0	0	0	0	0	-337,031	-324,191	0	0	126,249	3,060,342	45,466	134,488
	Plantation			0	0	0	0	0	0	0	0	0	12,709,896	5,053,745	18,233	16,058
	Cropland		-7,426,718	-770,231	-283,940	-69,858	-106,163	-18,121	-449,021	-194,042	-215,215	-340,227		0	0	0
	Grassland		-6,782,015	-3,883,689	-1,099,942	-2,026,449	-2,176,942	-353,769	-2,336,368	-1,283,405	-979,692	-350,685		0	0	0
	Wetland		-25,201	-16,642	-537	-14,167	-13,066	-1,582	-34,902	-22,924	-39,737	-1,245		0	0	0
	Settlement & Other land		-81,816	-10,063	-73,567	-16,442	-19,446	-614	-35,299	-51,327	-69,442	-567		0	0	0

4.2. Emissions Estimates per REDD+ Activities

The Emissions were calculated for each of the selected REDD+ activities and also the net emissions for the Country. Calculation of emissions per REDD+ activity allows the identification of REDD+ policies and measures that can address the drivers of emissions in the selected activities

4.2.1. Emissions from Deforestation

Table 24 illustrates that deforestation has an average annual emission of 48,166,940 Tonnes of CO_2 in the reference period implying that a total of 770,671,037 Tonnes of CO_2 were emitted in the period 2002-2018. The greatest emissions came from the Montane and western Rain forests with an annual average of 30,121,437 Tonnes of CO_2. Though larger in area, the dryland strata did not present as high emissions due to the smaller forest area here and also their associated lower Emission Factors. Historically, the period 2002-2006 had the greatest emissions at 54,755,246 Tonnes of CO_2. However, Figure 7 shows that after a dip in emissions in the year 2010, there has been a gradual increase in emissions post year 2010. Though very minimal, there is an overall decrease in the emissions due to deforestation in the Reference period.

Table 24: Historical Annual CO_2 Emissions from Deforestation

Forest strata	Emissions (Tonnes of CO_2)				
	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	37,497,560	26,953,329	27,609,168	28,425,689	30,121,437
Costal & Mangrove Forest	5,369,833	2,838,459	6,066,685	8,997,887	5,818,216
Dryland Forest	11,887,852	9,351,299	15,060,281	12,609,716	12,227,287
Total	54,755,246	39,143,087	48,736,134	50,033,292	48,166,940

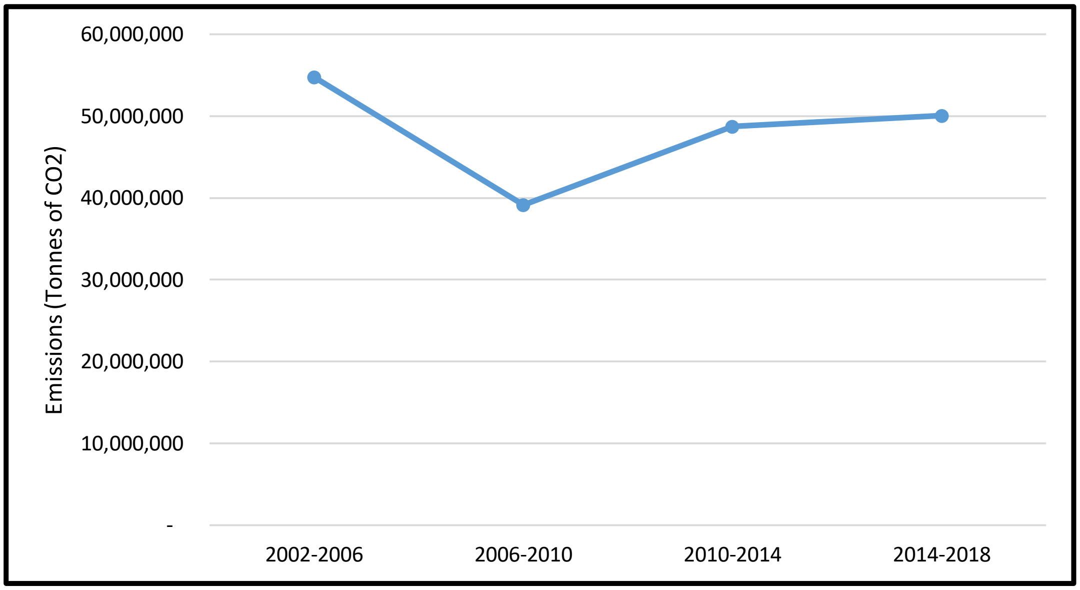

Figure 7: The Trend of Emissions due to Deforestation in the period 2002-2018

4.2.2. Emissions from Forest Degradation

Table 25 illustrates that forest degradation has an average annual emission of 10,885,950 Tonnes of CO_2 in the reference period implying a total of 174,175,207 Tonnes of CO_2 were emitted in the period 2002-2018. About 82% of emissions due to forest degradation came from the Montane and Western Rain forests with an annual average of 8,967,639 Tonnes of CO_2. Historically, the period 2002-2006 had the greatest emissions at 13,836,587 Tonnes of CO_2 and the trend of emissions from this REDD+ activity decreases with time (Figure 8).

Table 25: Historical Annual CO_2 Emissions from Forest Degradation

Forest strata	Emissions (Tonnes of CO_2)				
	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	12,437,856	6,904,687	8,171,469	8,356,545	8,967,639
Costal & Mangrove Forest	689,032	658,228	507,708	1,983,662	959,657
Dryland Forest	709,699	787,686	884,652	1,452,579	958,654
Total	13,836,587	8,350,601	9,563,829	11,792,785	10,885,950

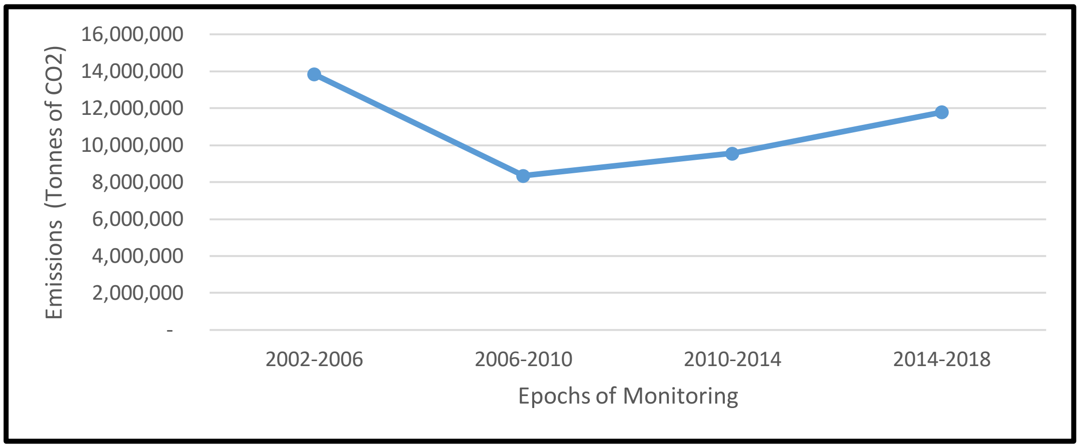

Figure 8: The Trend of Emissions due to Forest Degradation in the period 2002-2018

4.2.3. CO_2 Sinks due to Afforestation (Enhancement of Carbon)

Table 26 shows the CO_2 sinks due to afforestation activities. There was an annual removal of 8,205,540 Tonnes of CO_2 from the atmosphere in the reference period implying a total of 131,288,638 Tonnes of CO_2 were sequestered from the atmosphere due to afforestation activities in the period 2002-2018. About 67% of the sequestered CO2 was achieved in the Montane and Western Rain forests with an annual average of 5,522,268 Tonnes of CO_2. Historically, Sequestration of CO_2 due to afforestation programmes has been increasing in the reference period because a negative gradient illustrates the trend of increasing sequestration volumes (Figure 9).

Table 26: Historical Annual CO_2 sinks from Afforestation

Forest strata	Emissions (Tonnes of CO_2)				
	2002-2006	2006-2010	2010-2014	2014-2018	average
Montane &Western Rain Forest	-4,759,898	-6,407,901	-5,807,682	-5,113,591	-5,522,268
Costal & Mangrove Forest	-919,118	-1,344,367	-1,215,551	-1,204,155	-1,170,798
Dryland Forest	-1,279,949	-1,996,239	-1,345,866	-1,427,843	-1,512,474
Total	**-6,958,965**	**-9,748,507**	**-8,369,099**	**-7,745,589**	**-8,205,540**

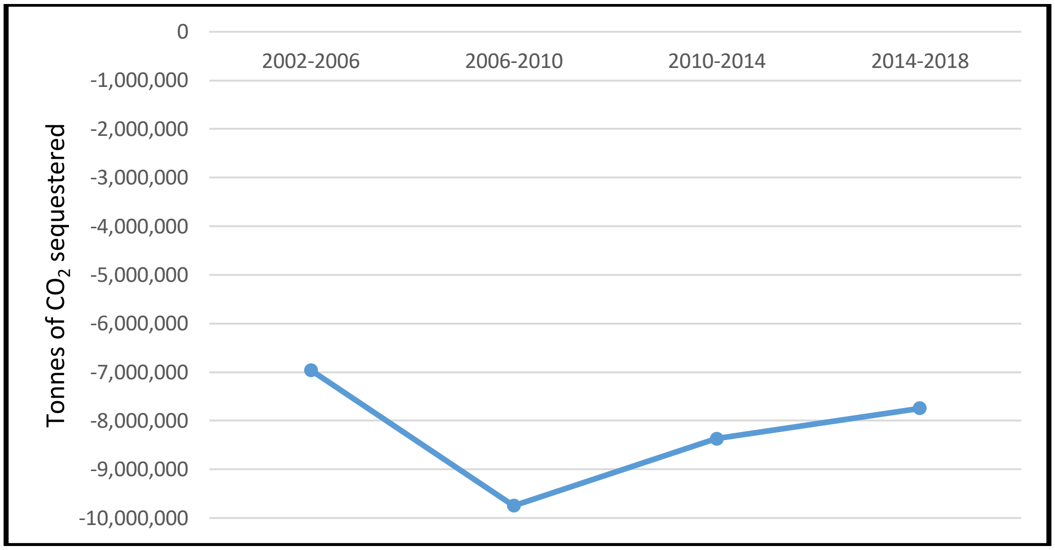

Figure 9: The Trend of CO_2 sequestration due to afforestation

4.2.4. CO_2 Sinks due to Canopy improvement (Enhancement of Carbon)

Table 27 shows the CO_2 sinks due to canopy improvement. There was an annual removal of 1,324,724 Tonnes of CO_2 from the atmosphere in the reference period implying a total of -21,195,588 Tonnes of CO_2 were sequestered from the atmosphere due to forest conservation and canopy improvement activities in the period 2002-2018. All the strata have a significant contribution to the sequestered CO_2 implying that this is an activity that should be prioritized in all the strata. Historically, Sequestration of CO_2 due to forest conservation and canopy improvement have been on a decrease in the reference period with 1,531,965 Tonnes of CO_2 sequestered in the period 2002-2006 as compared to 902,157 Tonnes of CO_2 sequestered in the period 2014-2018 (Figure 10).

Table 27: Historical Annual CO_2 sinks from Canopy improvement

Forest strata	Emissions (Tonnes of CO_2)				
	2002-2006	2006-2010	2010-2014	2014-2018	average
Montane &Western Rain Forest	-530,585	-862,845	-760,479	-442,179	-649,022
Costal & Mangrove Forest	-314,943	-136,717	-162,788	-64,866	-169,828
Dryland Forest	-686,437	-475,757	-466,189	-395,111	-505,874
Total	**-1,531,965**	**-1,475,319**	**-1,389,456**	**-902,157**	**-1,324,724**

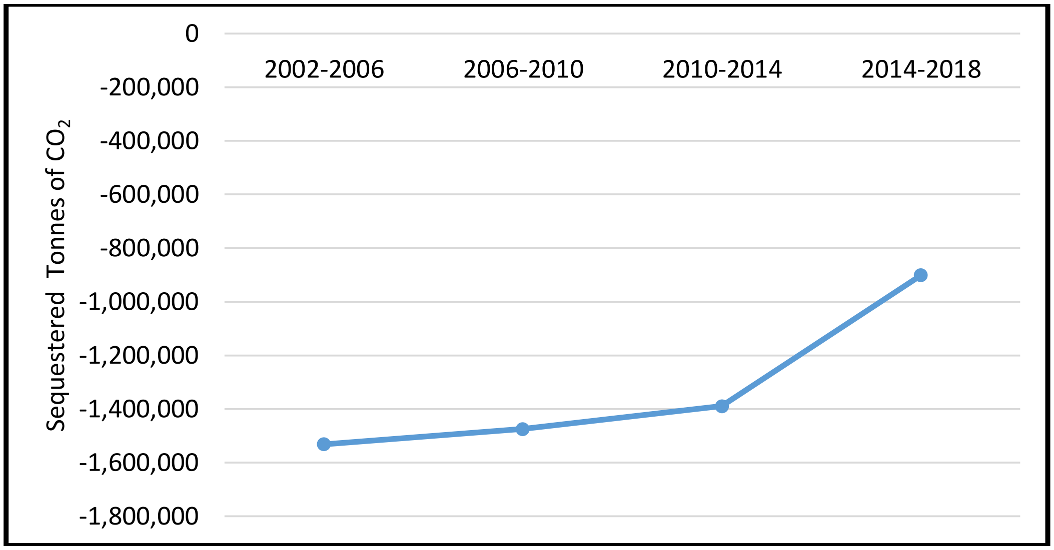

Figure 10: The Trend of CO_2 sequestration due to Canopy improvement

4.2.5. Emissions of CO_2 due to sustainable management of forests

Table 28 shows the CO_2 sinks due to sustainable management of forests. A backlog in the replanting programme of the public plantation forests of Kenya, has resulted in a net emission of CO_2 from the public plantation forests with an average emission of 2,681,433 Tonnes of CO_2 implying a total of 42,902,925 Tonnes of CO_2 were emitted in the period 2002-2018. Historically, Emissions from this stratum have an increasing trend (Figure 11).

Table 28: Historical Annual CO_2 Emissions from public forest plantations

Forest strata	Emissions (Tonnes of CO_2)				
	2002-2006	2006-2010	2010-2014	2014-2018	Average
Harvesting	2,953,832	2,130,667	2,217,234	4,449,483	2,937,804
Replanting	-221,150	-301,355	-329,799	-173,181	-256,371
Net	**2,732,682**	**1,829,312**	**1,887,435**	**4,276,302**	**2,681,433**

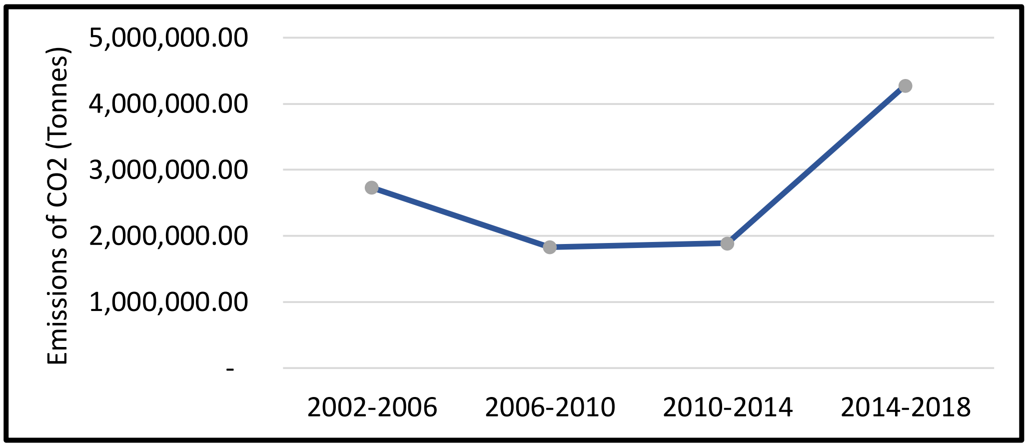

Figure 11: The Trend of CO_2 Emissions in the public plantation forests

4.2.6. Net National Emissions

The Reference period provides a net Emissions of CO_2 at the national Level. Table 29 illustrates that Kenya has an average annual emission of 52,204,059 Tonnes of CO_2 in the reference period implying a total Net emission of 835,264,942.23 Tonnes of CO_2 in the period 2002-2018. The dip in emissions in the period 2006-2010 (Figure 12) does not comprise an outlier based on 2 standard deviations from the mean (at 95% CI, the emissions range from 30,829,478 to 84,208,165 Tonnes of CO_2). Figure 10 shows that in the reference period, Kenya has attained a minimal decline in Emissions from the forest sector. This minimal decline of Emissions is associated with activities like a decline in deforestation, a decline in forest degradation, an improvement in the conservation activities which enhance forest canopy and an enhanced afforestation programme.

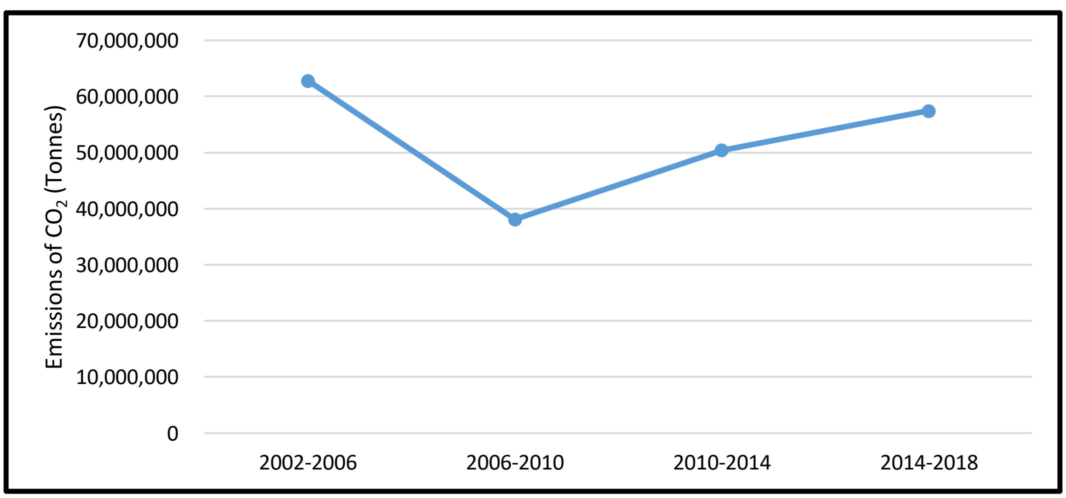

Figure 12: The Trend of Net Emissions in the period 2002-2018

Table 29: Historical Annual CO_2 Net Emissions classified by forest strata

Forest Strata	Emissions (Tonnes of CO_2)				
	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	44,644,932	26,587,270	29,212,476	31,226,464	32,917,786
Costal & Mangrove Forest	4,824,805	2,015,603	5,196,054	9,712,528	5,437,247
Dryland Forest	10,631,166	7,666,989	14,132,878	12,239,340	11,167,593
Public Plantations	2,732,682	1,829,312	1,887,435	4,276,302	2,681,433
Total	**62,833,585**	**38,099,174**	**50,428,843**	**57,454,634**	**52,204,059**

The greatest emissions came from the Montane and Western Rain forests with an annual average of 32,917,786 Tonnes of CO_2 (Table 29 and Figure 13). The annual emissions for the Dryland forest strata, the Coastal and Mangrove strata and the Public Plantation forest strata were 11,167,593 Tonnes of CO_2, 5,437,247 Tonnes of CO_2 and 2,681,433 Tonnes of CO_2 respectively. Historically, the period 2002-2006 had the greatest emissions at 62,833,585 Tonnes of CO_2.

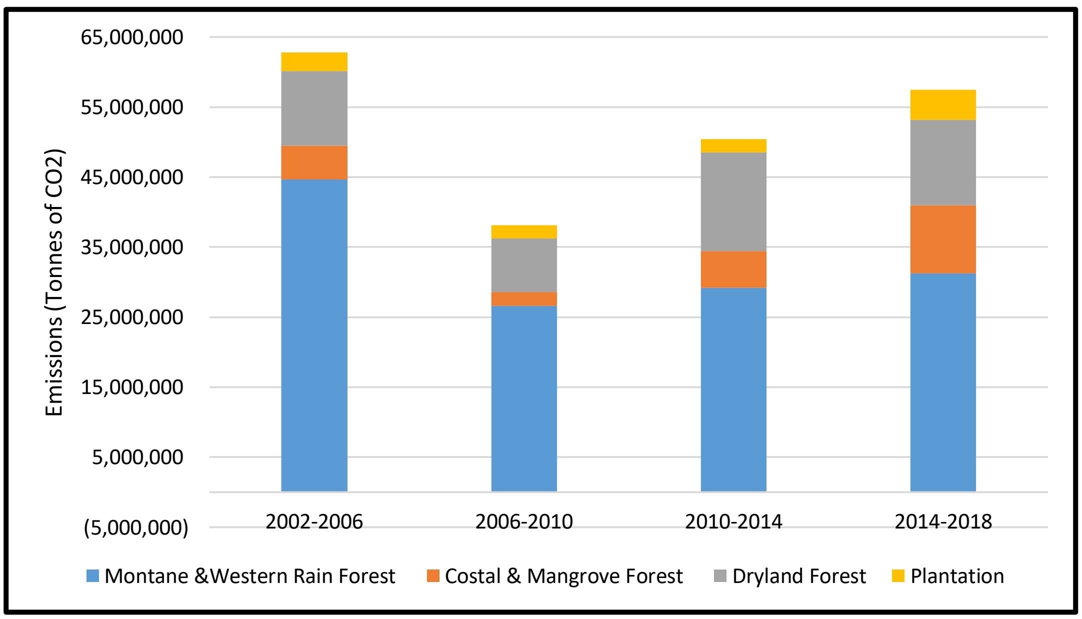

Figure 13: A cumulative bar graph to compare emissions among the forest strata of Kenya

The summary of the statistics associated with emissions from the specific REDD+ activities is shown in table 30 and Figure 14. Deforestation has the biggest contribution to national emissions with an average of 48,166,940 Tonnes of CO2. A key Category Analysis shows that Deforestation contributes over 68% of the national CO_2 sources and sinks and is therefore a main activity to be addressed in Reducing Emissions for REDD+. Similarly, Emissions from Forest degradation and Enhancement of carbon stocks are significant activities for Kenya's REDD+ programme. Though a key Category Analysis identifies that public plantation forests of Kenya are not a Key source of Emissions for the REDD+ programme (3.76%), these forests supply material for wood based industries and therefore support livelihoods and economic development and qualify as an important REDD+ activity.

Table 30: Historical Annual CO_2 Net Emissions classified by REDD+ Activity

REDD+ Activity	Emissions (Tonnes of CO_2)					KCA
	2002-2006	2006-2010	2010-2014	2014-2018	Average	
Deforestation	54,755,246	39,143,087	48,736,134	50,033,292	48,166,940	67.59
Degradation	13,836,587	8,350,601	9,563,829	11,792,785	10,885,950	15.28
Sustainable management of forest	2,732,682	1,829,312	1,887,435	4,276,302	2,681,433	3.76
Enhancement	-8,490,930	-11,223,826	-9,758,555	-8,647,746	-9,530,264	13.37
Total (Emission estimates (Net)	**62,833,585**	**38,099,174**	**50,428,843**	**57,454,634**	**52,204,059**	

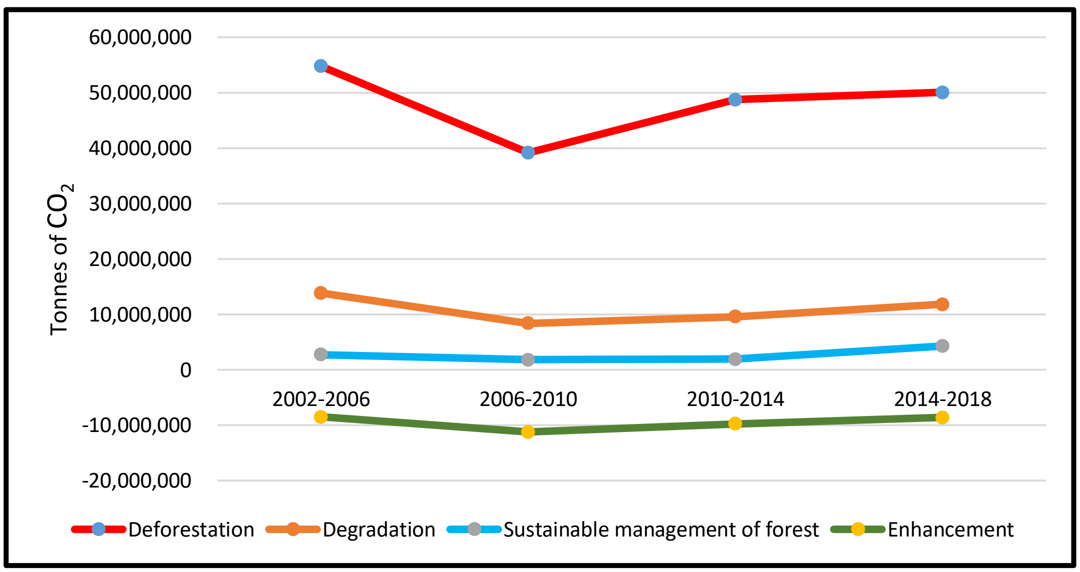

Figure 14: Comparison of Annual Emissions from REDD+ Activities in the reference period

5. NATIONAL CIRCUMSTANCES

5.1. Qualitative analysis

This section describes how the national circumstances are likely to influence future forest sector emissions and removals. The national circumstances considered include current and evolving institutional arrangements for forest management and administration, implementation of policies and legislation, national and international forest commitments, and national development strategies likely to impact on future forest resources management and conservation.

The forest sector is today a critical asset for economic growth, environmental sustainability, and provision of social and cultural values. For instance, about 50,000 people are directly employed in the forest sector while about 300,000–600,000 are indirectly employed depending on the sector, (FAO, 2015). Further, over 2 million households within 5 kilometers from forest edges have significant dependency on the forest services and products which include, cultivation, grazing, fishing, fuel, food, honey, herbal medicines, water and other benefits.

The results of emissions classified by strata show that Montane forests have historically (In the reference period) accounted for the largest source of emissions and this may be attributed to encroachment of forests and their conversion to agriculture specifically before enactment of the Forest Act 2005 and its subsequent revisions. Another major source of emissions is identified as the dryland forests where agriculture is actively converting former dryland forests into arable land (Drigo et al., 2015). Poor management of plantation forests has resulted to backlogs as illustrated by reduced forest cover in the plantation zones and this stratum has become a source of emissions.

5.2. Socio-Economic profile

Kenya has experienced significant growth in population in the recent past. As Kenya seeks to transit from a Least Developed country to a middle-income economy [21] a number of developmental activities have been proposed for implementation. Such activities target industrial development and development of service industries but also note the need to enhance conservation of environment and natural resources including forests.

The current population of about 50 million (Figure 15) has a very high positive relationship with forest cover and the rates of deforestation and forest degradation The government has proposed drastic measures to boost food production, including increased acreages under irrigation and provision of subsidies for agricultural inputs. There is rapid urbanization in the country as a result of growth in population and an enabling economic environment in the country. The expansion of cities and towns will continue to cause deforestation and forest degradation by encroaching into the forest areas and causing increased demand of forest products for construction and energy. Both rural and urban population is highly dependent on biomass energy especially the use of charcoal accounting for 60% energy demand (Drigo et al., 2015).

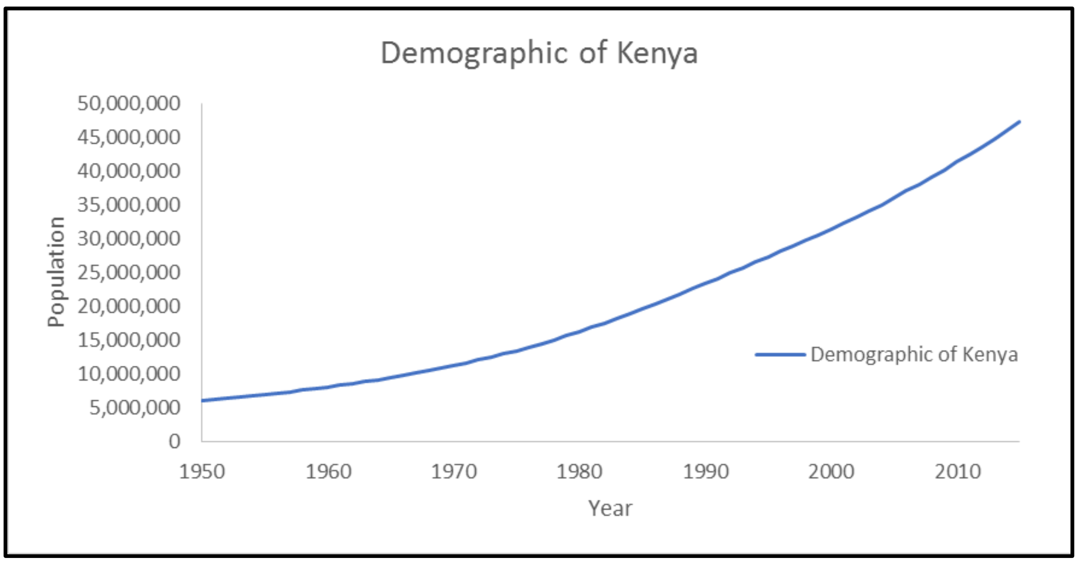

Figure 15: Kenya's Demographic trend (UN 2019)

5.3. Infrastructural, and industrial developments

Kenya has an aggressive infrastructural, commercial and industrial development programme based on the vision 2030. This development is likely to result in clearing of large areas of previously forested landscapes. The surrounding forest areas are also more likely to be converted

[21] Vision 2030 targets

to settlements leading to deforestation and forest degradation. It has been pointed out that the current and planned developments are concentrated in the fragile ecosystems including the dryland forest and woodland areas which will adversely affect the forest cover in the country. The current and planned developments that are expected to lead to planned deforestation and forest degradation include Konza technology city, Isiolo Port, Lamu port, LAPSSET Project, comprising of a road, rail and pipeline connecting Kenya to South Sudan and Ethiopia, The Northern Corridor Transport Project, Construction of a standard gauge railway line from Mombasa to Kisumu, Creation of a one-million-ha irrigation scheme in the Tana Delta.

5.4. Development Priorities and commitments

There are different development priorities recognized in the country due to the set national development agenda, agreements within regional economic blocks, international treaties and multilateral agreements. Most of these agreements have identified forests and woodlands as important resources for economic growth and poverty reduction, especially with regard to energy, food, and timber. There are also other non-timber forest products and environmental services that underpin ecosystem functions in support of agricultural productivity and sustainability". Important development priorities affecting the forest sector include; SDG Targets, UNFCCC, Convention on Biological Diversity (CBD), Forest Law Enforcement and Governance (FLEG), International Tropical Timber Agreement 2006 (ITTA), Reducing Emissions from Deforestation and Forest Degradation (REDD+ mechanisms) and the United Nations Convention to Combat Desertification (UNCCD)

The Sustainable Development Goals (SDG) which recognize multiple functions of forests including ensuring conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems, the need to mobilize resources for forest management, protecting forest catchments area in line with obligations under international agreements (SDG15.1, SDG15.2, SDG15b, SDG6.6) by year 2020. Under the United Nations Framework Convention on Climate Change (UNFCCC), through the Nationally Determined Contribution (NDC) the government has committed to contribute to the mitigation and adaptation to climate change by using the forest sector as the main sink for GHG Emissions.

While significant changes in policy and Legislation have been undertaken over the last decade that seeks to strengthen sustainable forest management and conservation, the country's forest resources continue to experience severe pressure from the expanding agricultural frontier, settlements and other developments. There are genuine concerns that commitments to national and international forest goals may not be realized if the current challenges are not addressed. There is expectation, however, that improved governance of the sector arising from the devolution and public participation in management may reverse the current negative practices. This is, however, expected to take some time as capacities within county governments are strengthened to assume expanded responsibilities. Figure 16 illustrates the historical trend of areas under agriculture and cropland in the reference period based on the mapping programme that was used to develop this FRL. It can be noted that the area of grasslands has been decreasing while that of cropland has been increasing.

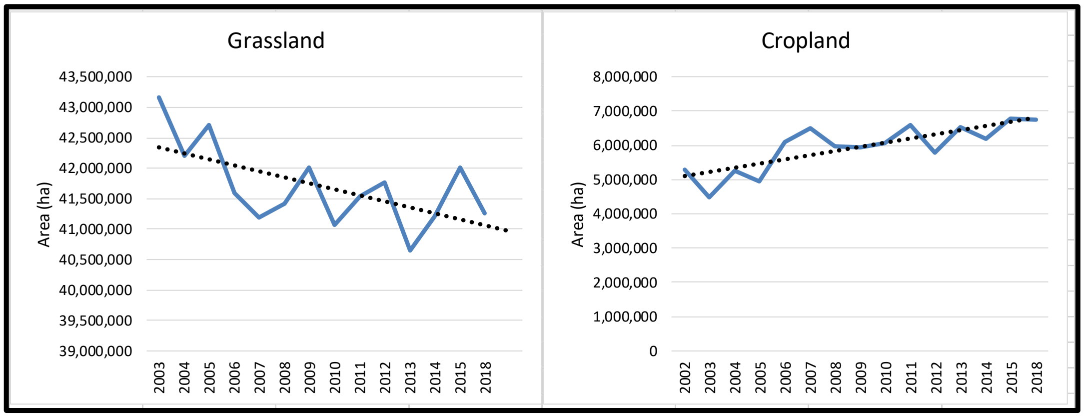

Figure 16: Historical Trends of Grassland and Cropland (SLEEK maps)

5.5. Forest Sector Governance

As described in the introductory part, Kenya has policies and legislation for sustaining its resources and ecosystems. According to the Constitution and Vision 2030[22], Kenya desires to achieve and maintain at least 10% forest cover of the total national land area by the year 2030. Further, the Forest Conservation and Management Act, 2016 identifies all the forest tenure systems of Kenya (Public, community and private forests) as potential for reforestation towards meeting the constitutional requirements of the 10% forest cover. The Forest Landscape Restoration Project for Kenya[23] identified a potential of afforesting up to 5.1 million ha in the different strata of Kenya which would double the current forest area and therefore exceed the 10% forest cover target.

The other key policies and legislation that have a bearing on the forest management include; National Wildlife Conservation and Management Act, 2013, supporting management of forest areas in significant wildlife habitats; The Land Act, 2012 and the County Government Act, 2013

[22] The Constitution states that "land in Kenya shall be held, used and managed in a manner that is equitable, efficient, productive and sustainable," and entrenches "sound conservation and protection of ecologically sensitive areas."
[23] http://www.kenyaforestservice.org/index.php/2016-04-25-20-08-29/news/437-forests-and-landscape-restoration-a-key-component-of-climate-change-mitigation-and-adaptation

which requires engagements of the local communities in the planning and management of forest resources to ensure sustainable and strategic environmental, ecological, social, cultural and economic benefit sharing. Other important policy and legislation include Environmental Management and Coordination (Amendment) Act, 2015; The Energy Policy 2014; Agriculture, Fisheries and Food Authority Act, 2013; The Water Act, 2012; National Museums and Heritage Act, 2006; and the Climate change Act, 2016.

The country recognizes the forest sector as a key sector in her national development strategies and plans which include the national Climate Change Response Strategy (2010), and the Kenya Green Economy Strategy and Implementation Plan (2017) which recognizes the critical role of the forest sector in meeting the climate change mitigation and adaptation obligations.

Kenya has already developed a National Determined Contribution (NDC) in line with her commitment to the global climate change goals under the Paris climate agreement in which it identifies forests as a significant sector in reducing emissions and meeting the NDC targets.

Figure 17 is a projection of the forest cover increase that would allow Kenya to meet the Vision 2030 requirement of 10% forest cover. This graph is developed based on the forest cover recorded in year 2018.

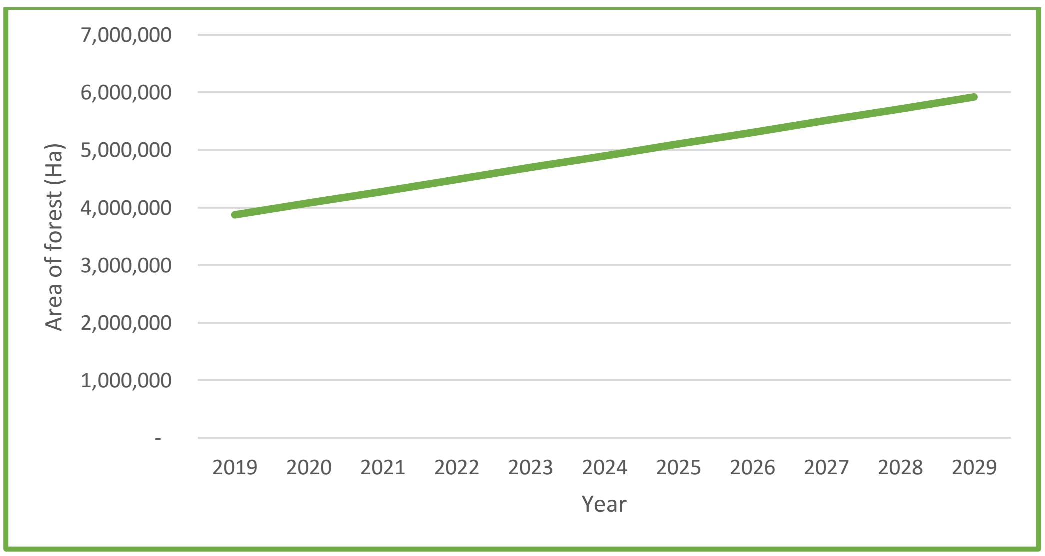

Figure 17: Projected forest cover towards 10% by year 2030[24]

[24] Estimated at afforesting/increasing forest cover by 204,727ha per year

5.6. Governance challenges

A few challenges manifest and have continued to cause significant deforestation and forest degradation in Kenya. The main challenge in the management of the forest resources is the increasing population and associated increased demand for forest products and services. Though the government has clear policies to support conservation of forests, a spiralling population poses pressure on the forest resource and calls for enhanced awareness in supporting conservation measures. It is noted that the ongoing development of the Forest strategy has noted these challenges and seeks to create an all-inclusive strategy that will support forest conservation.

Historically poor enforcement of forest regulations has been a challenge to forest conservation. This is exacerbated by the dwindling funding for conservation activities in Kenya and the small human resource capacity within the Kenya Forest Service (MENR 2016). A continuous improvement in the functions of the Kenya Forest Service and the involvement of communities through Community forest Associations is expected to enhance enforcement though successful community management of forests in Kenya has only been actualised in communities with harmonised cultural characteristics (KWTA, 2014). It is hoped that an all-encompassing REDD+ strategy will enhance awareness of conservation, involvement of more stakeholders and a campaign towards environmental protection.

Overlapping policies and institutional mandates, Policy conflicts, inadequate land tenure policies, and inadequate collaboration among forest conservation agencies are identified as other governance challenge affecting forest conservation (FAO, 2017). It is noted that the Environmental Management and Coordination Act (EMCA) (NEMA, 2018) is the supreme environmental law and seeks to enhance forest conservation and biodiversity conservation. However implementation of the EMCA is still a challenge. Other challenges including Inadequate regulation of grazing in the semi- arid and arid lands woodland and Dryland forests that has resulted to overstocking and overgrazing leading to wide spread deforestation and degradation of forests which needs to be addressed through programmes that support development of marginal areas.

5.7. Factors influencing future Emissions

No modelling studies have so far been carried out to understand how various land use and land resources policies implementation will manifest in future against the challenges of competing land claims by key economic sectors, increasing population and increased demand for forest resources and food insecurity. As discussed in chapter 2, it is proposed that the FRL will be projected based on the historical average of emissions using the 2002-2018 data. The foregoing discussion has illustrated two major factors that will influence emissions in Kenya. Population growth and increased demands for developmental needs, has historically put pressure on the forests. With the projected population growth of 2.5% in 2018[25] an equivalent increase in emissions would increase CO_2 Emissions in the four REDD+ activities from the current annual average of 52,204,059 Tonnes of CO_2. Noting that population increase is not the only factor influencing forests of Kenya, a Business as Usual scenario under the current forest product consumption rates would increase CO_2 emissions from the forest sector unless efforts are put in place to integrate emission reductions in developmental activities.

On the conservation front, Kenya's vision 2030 targets an increase in forests from the current 5.85% in 2018 to 10% in 2030. This translates to an increase of the current forest cover by 0.3458% per year which is equivalent to 207,213 ha per year for the period 2019 to 2030. Such a planting and conservation rate if implemented would reverse Kenya's emission status from the current state of net emission to a net sink.

The ongoing discussion therefore proposes that a projection of the future emissions for Kenya would preferably use a historical average to represent a business as usual scenario. A decrease in emissions in the future would therefore illustrate an extra effort by the country to deviate from the Business As Usual scenario towards reducing emissions

[25] Obtained from Kenya Population (LIVE). Yearly Population Grentity_medium growth Rate (%).https://www.worldometers.info/world-population/kenya-population/

6. PROJECTIONS OF THE FRL

6.1. Historical average projected into the future

The values of Emission estimates of each REDD+ activity are shown in the Tables 29 and 30. The value of Net emission is calculated as the sum of emissions arising from the four REDD+ activities (Deforestation, Forest degradation, Sustainable Management of Forests and Enhancement) and also classified by forest strata (Montane and western Rain forests, Coastal and Mangrove forests, Dryland forests and Public plantation forests). It is also hoped that emissions in the future will be monitored at 4 year intervals because Kenya is continuously improving its land cover mapping programme. There are also plans to implement a National Forest Inventory based on the designs that have already been developed.

The process of projection adopted an average of the historical emissions. It was noted that the linear relationship developed from the 4 point data (2002-2006, 2006-2010, 2010-2014 and 2014-2018) had a weak Coefficient of Determination (R^2) which explains that the trend of emissions is not accurately defined by the time series monitoring. A historical average therefore explains that a Business as Usual scenario is assumed in projecting emissions into the future and the assumptions for this are clearly explained in the Chapter on National Circumstances. The Chapter on National Circumstances did not identify any need to create an adjustment of the average emissions because there are no specific development and human livelihood activities prioritized by the government that may result to a reversal of the ongoing conservation activities.

6.2. Projected Net National Emissions

A projection of Emissions using the Business as Usual Scenario is an extension of the average emissions into the future (Figure 18 and table 31). The table presents the averages calculated for the historical period and their projection into the future which implies that the same historical numbers have been projected into the future.

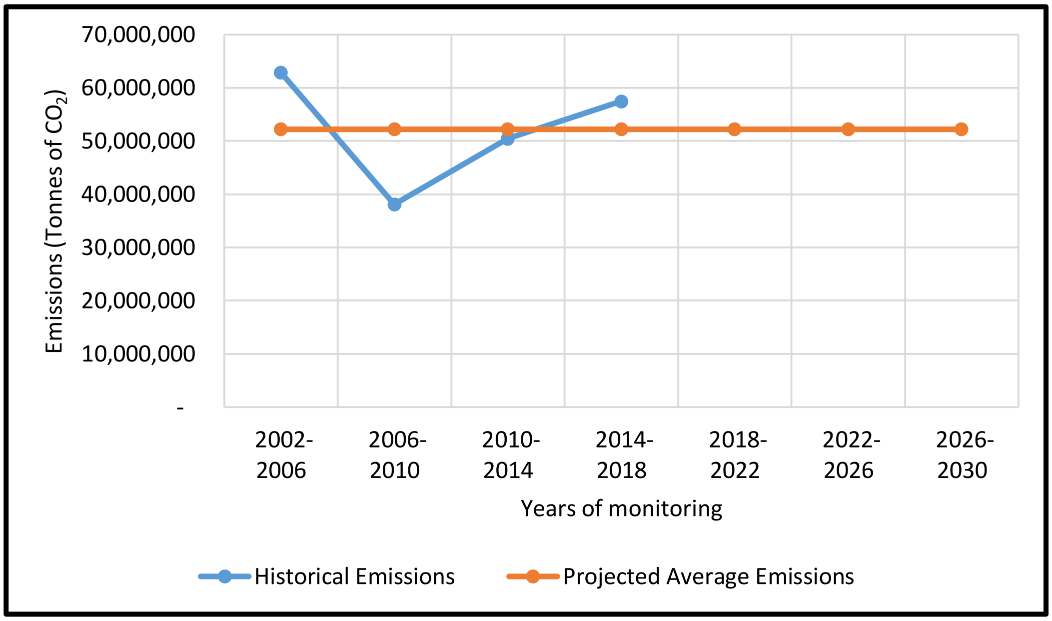

Figure 18: Projections of Net Emissions

6.3. Projected emissions from REDD+ activities

Projected emissions for the various REDD+ activities and based on the historical average emissions for each REDD+ activity are shown in Figure 19 and table 31. The table presents the averages calculated for the historical period and their projection into the future which implies that the same historical numbers have been projected into the future.

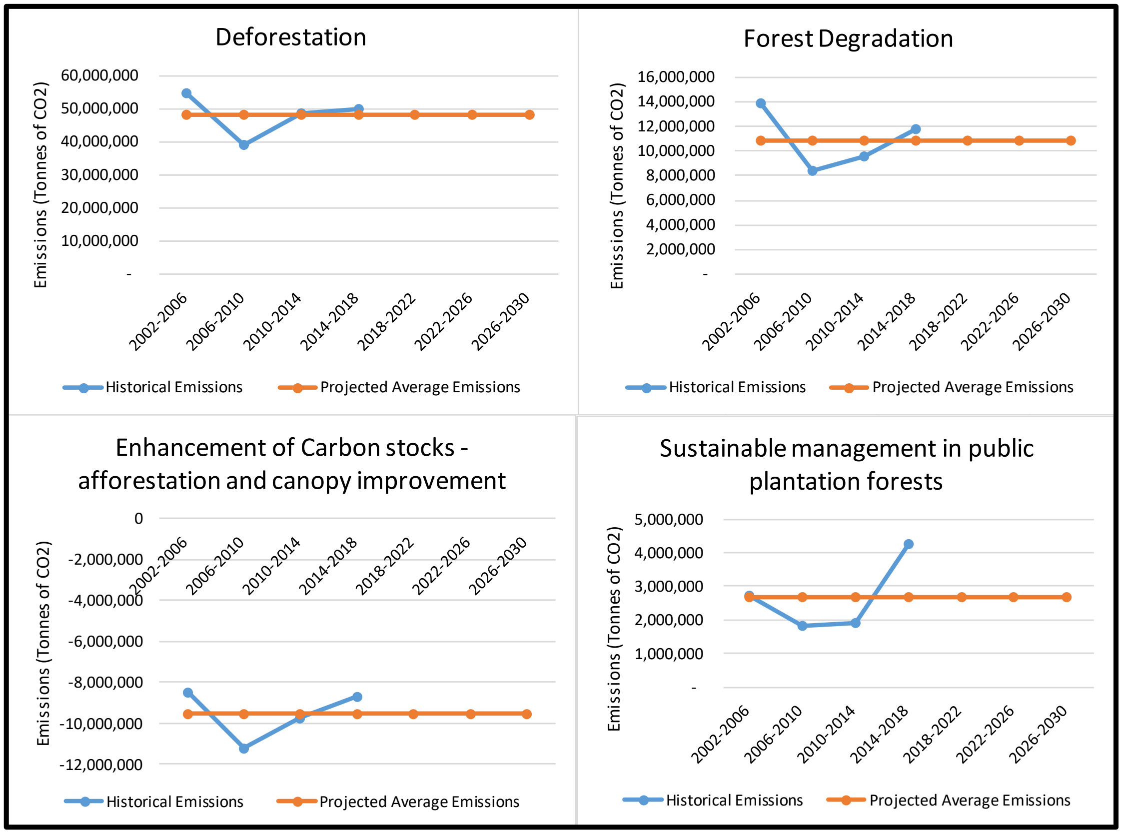

Figure 19: Projections of Annual Emissions from the selected REDD+ Activities

Table 31: Projected Annual CO_2 Emissions based on historical averages

REDD+ Activity	2002-2006	2006-2010	2010-2014	2014-2018	2018-2022	2022-2026	2026-2030
Deforestation	48,166,940	48,166,940	48,166,940	48,166,940	48,166,940	48,166,940	48,166,940
Degradation	10,885,950	10,885,950	10,885,950	10,885,950	10,885,950	10,885,950	10,885,950
Sustainable management of forest	2,681,433	2,681,433	2,681,433	2,681,433	2,681,433	2,681,433	2,681,433
Enhancement	-9,530,264	-9,530,264	-9,530,264	-9,530,264	-9,530,264	-9,530,264	-9,530,264
Total (Emission estimates)	**52,204,059**	**52,204,059**	**52,204,059**	**52,204,059**	**52,204,059**	**52,204,059**	**52,204,059**

7. UNCERTAINTY OF THE FRL

7.1 Uncertainty of AD

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. Statistically robust and transparent approaches are critical to ensure the integrity of land use change information. The steps followed were as recommended by Global Forest Observation Initiative Methods and Guidance Document [26]. The most common approach for accuracy assessment is to conduct ground referencing where each pixel in the land cover map is verified. However, field work is normally expensive and time consuming and therefore sampling methods were used to generate representative classes for field verification.

7.1.1. Uncertainty of individual land cover maps

The 2018 map was developed during the same year and allowed ground truthing. A total of 1894 field sample points were visited for ground truthing done based on accessibility, and security situation in Kenya. Another 1905 sample were independently interpreted using Google Earth as high resolution imagery. Since no ground truthing would be done for historical maps, ground truthing was done using Google Earth imagery.

The classification accuracy was calculated by comparing the classification result with presumably correct information (ground truth) as indicated by either field verification and/or Google Earth imagery. The accuracy assessment results illustrated in Table 32 show values for all the years and highlight the years that were used for the FRL. Table 33 shows the correctness of each of the landcover classes. In all the years used for developing the FRL, the accuracy of the maps is within acceptable limits and have over 70% agreement.

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[26] Methods and Guidance from the Global Forest Observations Initiative Version 2: Integration of remote-sensing and ground-based observations for estimation of emissions and removals of greenhouse gases in forests

Table 32: Kappa Coefficients of the time series Land cover maps

S/No	Year	Overall Accuracy %	Kappa Coefficient		S/No	Year	Overall Accuracy %	Kappa Coefficient
1	2000	83.018	0.743		9	2009	89.485	0.851
2	2002	87.030	0.815		10	2010	82.392	0.748
3	2003	83.931	0.738		11	2011	81.818	0.727
4	2004	81.611	0.705		12	2012	77.526	0.705
5	2005	82.258	0.749		13	2013	83.139	0.764
6	2006	88.713	0.828		14	2014	75.635	0.7025
7	2007	78.227	0.697		15	2015	78.870	0.727
8	2008	78.001	0.688		16	2018	76.021	0.705

Table 33: Correctness of the 2018 land cover map by land cover classes

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%			

7.1.2. Uncertainty of change Maps (Activity Data)

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. The results of uncertainty are presented in Table 34.

$$S(\hat{p}_{\cdot j}) = \sqrt{\sum_{i=1}^{q} W_i^2 \frac{\frac{n_{ij}}{n_{i\cdot}}\left(1 - \frac{n_{ij}}{n_{i\cdot}}\right)}{n_{i\cdot} - 1}}.$$

Table 34: Uncertainty of Activity Data

Uncertainty (%) of Change map 2002-2006	
Overall Accuracy	41.05
Overall Uncertainty	4.94
Limits	41.05%±4.94%
Uncertainty (%) of Change map 2006-2010	
Overall Accuracy	51.9
Overall Uncertainty	4.03
Limits	51.9%±4.03%
Uncertainty (%) of Change map 2010-2014	
Overall Accuracy	35.75
Overall Uncertainty	2.17
Limits	35.75%±2.17%
Uncertainty (%) of Change map 2014-2018	
Overall Accuracy	30.01
Overall Uncertainty	2.15
Limits	30.01%±2.15%

Noting that 4 intervals were used for the AD, an average of the uncertainties for the 4 epochs was used to calculate the overall uncertainty of AD as illustrated below,

$$\frac{4.94}{4} + \frac{4.03}{4} + \frac{2.17}{4} + \frac{2.15}{4} = 3.32$$

Therefore the average uncertainty of the maps is 3.32%.

The mean accuracy of the Activity data was calculated using the same method from data for the four epochs and gives a mean of 39.68%

$$\frac{41.05}{4} + \frac{51.9}{4} + \frac{35.75}{4} + \frac{30.01}{4} = 39.68$$

7.2. Uncertainty of EF

In Kenya, a full national forest inventory has never been implemented. The number of plots in the pilot forest Inventory which was done for EF setting was limited to only 121 plots distributed among the 10 strata described in Table 2. An analysis of the data shows high uncertainty of the mean (Table 35) which is attributed to the small sample size. The standard deviations are extremely high illustrating a need for creating substrata within all the selected strata. A comparison of the data with other independently carried out research in the specific forests of Kenya (e.g. Kinyanjui *et al* 2014, Glenday, 2006 and Kairo, 2009) also showed a great variation in carbon and biomass values within strata of Kenya and thus, an NFI using the nationally approved methodology will be expected to be implemented in the future to provide more accurate values of EF for the variety of forests. This may necessitate creating further substrata within the current ones.

Table 35: Uncertainty of the Field data

Strata	Canopy Class	Mean (Tonnes of AGB)	Std Dev	No Samples	Uncertainty	Uncertainty of mean
Montane & Western Rain Forest	Dense	244.80	157.94	8	126.46	44.71
	Moderate	58.43	34.64	7	116.20	43.92
	Open	23.26	13.64	6	114.94	46.92
Coastal & Mangrove forest	Dense	94.63	45.03	18	93.27	21.98
	Moderate	60.45	31.90	12	103.43	29.86
	Open	35.47	34.03	16	188.04	47.01
Dryland Forest	Dense	42.43	32.11	8	148.33	52.44
	Moderate	34.52	15.01	8	85.22	30.13
	Open	14.26	6.89	7	94.70	35.79
Plantation	Plantatio n	324.79	249.38	36	150.49	25.08

Due to the limitations in the EF data, a Bootstrap simulation according to the 2006 IPCC Guidelines[27] (Volume 1 Chapter 3) was used to calculate the Uncertainty of the EF. The Bootstrap simulation helps to obtain the confidence interval of the mean in cases where of the uncertainty of the mean is not a symmetric distribution. The results of the bootstrap analysis describes the ranges of 95 % Probability of the confidence interval. Then, the 2.5 Percentile and the 97.5

[27] Volume 1 chapter 3of the 2006 IPCC guidelines. Uncertainty

Percentile are 142.34 and 228.95, respectively. The mean EF is 183.51 and the uncertainty of the EF was calculated as 24.8%

7.2. Uncertainty of FRL

Olofsson, et al, (2013) have explained that the error of the estimated Green House Gas emission is a product of the AD and EF and provide the following formula for estimating the error propagation

$$SD\,CO_2 = \sqrt{\overline{Total_{carbon}}_{1\to2}^{2}\left[\left(\frac{SD^2_{Emissions_{factor}}}{\overline{Emissions_{factor}}_{1\to2}^{2}}\right)+\left(\frac{SD^2_{Activity_{data}}}{\overline{Activity_{data}}_{1\to2}^{2}}\right)\right]}$$

The uncertainty of AD and uncertainty of EF were 2.9 % and 24.8 % respectively. The total CO_2 calculated for the FRL was 52,204,059. Therefore the uncertainty of the FRL was calculated as

$$\textit{Uncertainty of the FRL} = \sqrt{52{,}204{,}059^2 * [(24.8^2/183.51^2) + (3.32^2/39.68^2)]}$$

The Uncertainty of this Submission is ± 8,299,540. This implies that the FRL is 52,204,059 ± 8,299,540 t CO2/year which is equivalent to 16%:

8. FUTURE IMPROVEMENTS

Kenya will develop its FRL according to a stepwise approach informed by available data, expertise and technologies. There are proposed improvements in the future FRL setting. Listed as follows

8.1. National Forest Inventory

The Emission factors presented in this FRL are based on a very small sample size representing the different forest strata of Kenya. As noted in the accuracy assessment section, better accuracy of this EF would be achieved when a wider data set is considered. Similarly, the wide variations in the collected data within strata calls for creation of sub strata to enhance accuracy. It is noted that within the current strata there exists some sub strata which may require sub sampling. For example, within the Montane and Western rain forest strata, Montane forests can be separated from Bamboo forests and Western rain forests to create three strata. Similarly, separation of Mangrove forests from Coastal forests would enhance accuracy noting the great variation in the tree characteristics and biomass components (Kairo et al., 2009).

An NFI should develop permanent sample plots which will provide better information on stock changes and growth rates. This FRL has adopted IPCC default values for growth rates and these might not be very accurate at the strata specific level. For example growth rates for the Montane and western rain forests have been adopted from the Tropical rain forests of the world. However Kenya's Montane forest have slightly less stocking (Kinyanjui et al., 2014) and growth rates compared to the tropical rain forests, but they can also not be classified as mountain ecosystems under the IPCC classification system because the mountain ecosystems of Kenya have dwarf vegetation that is slow growing.

8.2. Land cover mapping

The SLEEK land cover mapping programme has generated 18 maps using Approach 3 of the IPCC guidelines[28]. From this time series set of land cover maps, five maps were selected to develop this FRL. An improvement in the accuracy of the maps would have made it possible to select more maps and shorter time intervals would have been adopted to create a more realistic scenario for the FRL. Though the use of 4 year intervals to describe land cover changes and historical emissions was used, the future reporting of Biennial Update Reports may require doing monitoring at 2 or 1 year intervals. This implies a need for capacity building to enhance the accuracy of the maps so that they may provide accurate estimates of Emission trends

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[28] 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Chapter 3: Consistent Representation of Lands

The land cover maps used in the FRL have 7 land cover classes. It is noted that settlements and other lands have been mapped as a single category and this can be a source of errors. An improvement in the mapping programme would enhance accuracy moving from a Tier 1 reporting towards a Tier 3 reporting.

8.3. Carbon pools

Currently, only AGB and BGB have been considered. In future, dead wood, litter, soil organic matter and harvested wood products should be measured and included in subsequent FRL estimation. It is noted that immediate oxidation for all deforestation as presented in this FRL may not be the case on the ground.

8.4. Non CO_2 emissions

In this FRL, CO_2 is the only gas considered. Noting that emissions from the forest sector include other non CO_2 emissions, it is proposed that further research should be done to allow inclusion of CH_4 and N_2O gases.

8.5. Stock change vs Gain loss method

The FRL has been developed using a gain loss method that uses land cover changes to inform changes in the forest stocks. However, all deforestation has assumed instantaneous oxidation but this is not the case for harvested wood products. Similarly the method provided here assumes that forest degradation is fully captured when a forest canopy degrades from a superior to an inferior canopy. A more realistic method would have analyzed data for harvested wood products. However, such data which changes over time is not available and there is not accurate method of estimating it. A mechanism for collecting such data should be put in place to allow better estimation of Emissions from the forest sector

8.6. Calculation of emissions into the future

The future monitoring of emissions based on the FRL projections will be done in short time epochs. Therefore, lands converted to forestlands will be assigned the growth factors based on their forest strata and sub strata. However, such lands should be isolated so that they do not exaggerate emissions from deforestation in the subsequent change map. This activity is not included in the current land cover change analysis. A model that has been tested in Kenya under the SLEEK programme requires further testing because its efficient use would greatly enhance emission estimation into the future. This model has been used to do an external validation of this FRL.

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ANNEXES

Annex 1 Methodology for Land Cover / Land Use Mapping

1. Classes for Land Cover / Land Use Map

The categorized classes for Land Cover / Land Use Map was 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 were adopted from IPCC where these classes were further subcategorized. The IPCC classes are:

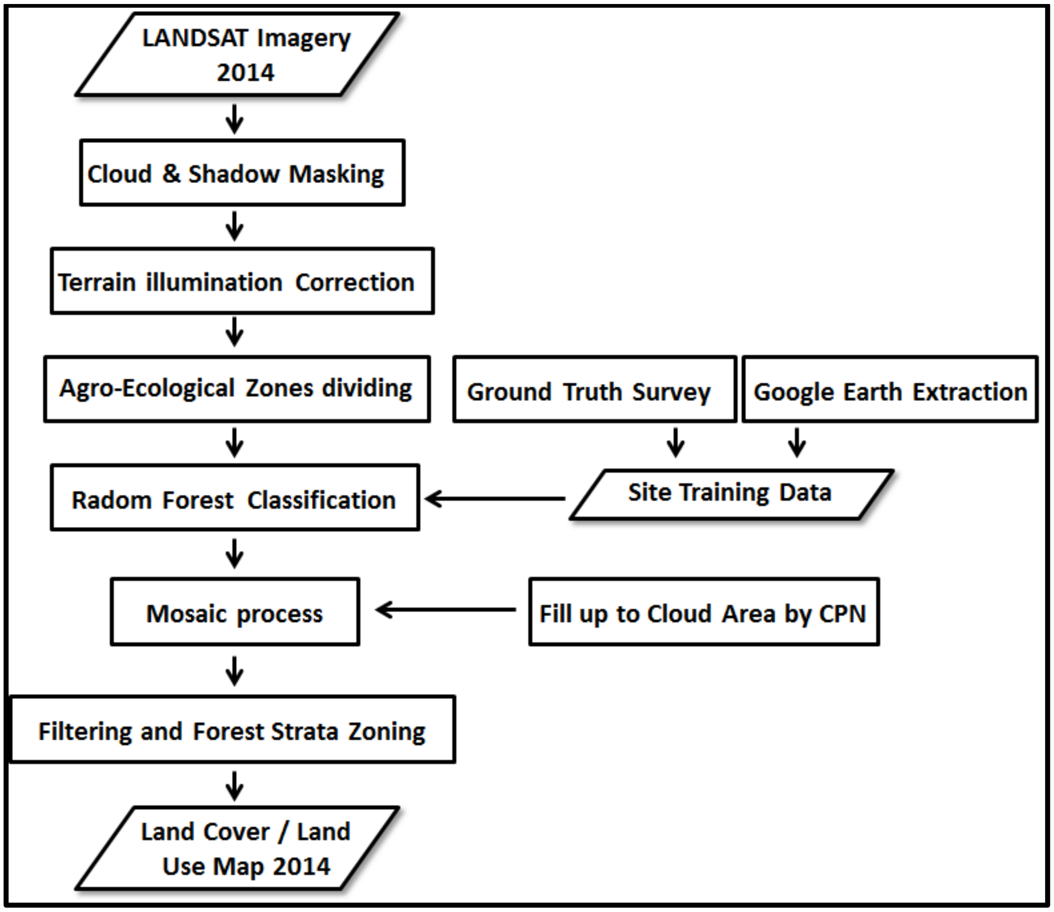
- Forestland,
- Cropland,
- Grassland,
- Settlement,
- Wetlands and
- Other lands.

The subcategorized classes were based on local definitions of land cover and land use. Forest and forest conversion were of high importance in terms of carbon stocks and emissions. The forestland was subcategorized based on national forest definition which is canopy density not less than 15%, and was divided into three categories: Open, moderate and dense. The cropland was divided into two categories: annual crops, and perennial crops. The grassland had also been classified into wooded grass (shrubs and grasses) and open glass. The wetland had been mapped as two categories: water body and vegetated wetland. And the other land was included barren land, rocks, soils and beaches. However, the settlement was not classified due to required alternative methodology other than Satellite Imagery Remote Sensing.

For the subcategorized forestland by forest definition, it was mixed type of forest e.g. plantation and dryland forest. The subcategorized forestland i.e. open, moderate and dense had been zoned by ancillary data which was classified by forest strata definitions in Kenya. The forest strata definitions are described in Annex 2. The table 2 in the report show sub categorization of forestland.

2. Methodology for preparation of Land Cover / Land Use Map

The Land Cover / Land Use Maps were created based on the following process steps using Landsat Imagery as show in the Figure below. The best available Landsat images for each year were selected from the USGS archive which provided a complete cloud-free (threshold 20% cloud cover) coverage of Kenya. Cloud cover was a major consideration. Dry season images are preferred for classification purposes as these allow for better discrimination between trees and grasses or crops.



Flow chart for preparation of Land Cover / Land Use Map 2014

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 have 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 was divided into 'spectral stratification zones' (SSZ). 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 were initially based on Kenya's Agro-Ecological Zones.

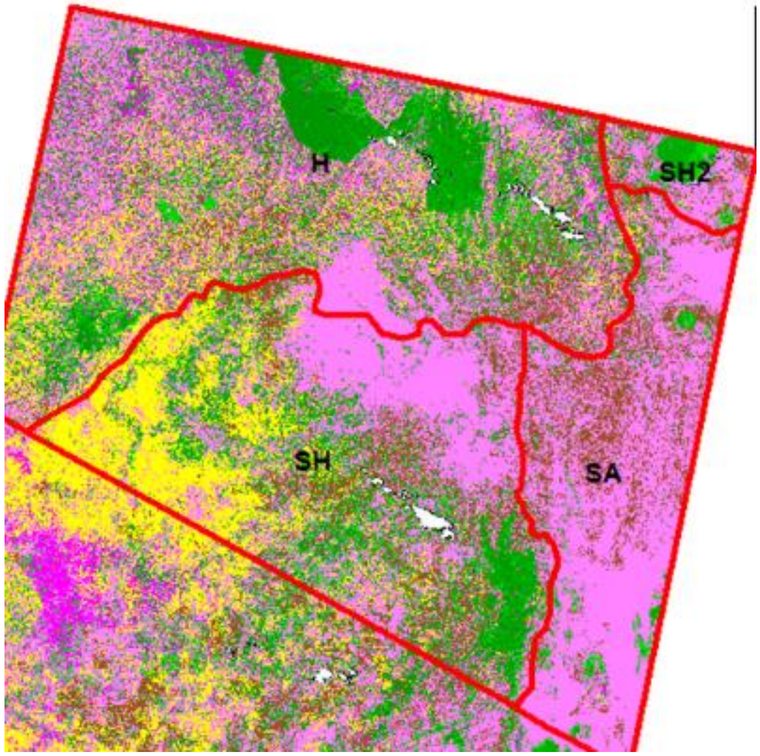
4) Random Forest classification with training data (ground truth survey and Google Earth)

For image classification method, supervised (Maximum Likelihood Classifier) and Random Forest classification had been tested. As a result of the test, The Random Forest classification has better accuracies than supervised classification. The Random Forest classification had been selected as method for preparation of Land Cover / Land Use Map.

Training sites were 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 represented the full range spectral variation of that class in the zone for that scene, and 'balanced' with respect to the different spectral colors for that class. The set of training data contained enough pixels. The prepared site training data was applied to individual terrain-corrected and masked images which had been processed as Random Forest classification process. And this process was applied separately to each stratification zone within the image.

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

The mosaic process was required due to the application of Random Forest classification to individual images. Individual images were mosaicked as one classified image map. The Figure below shows mosaicked individual classification result for a single scene from 2014.



Mosaicked individual classification result for a single scene from 2014

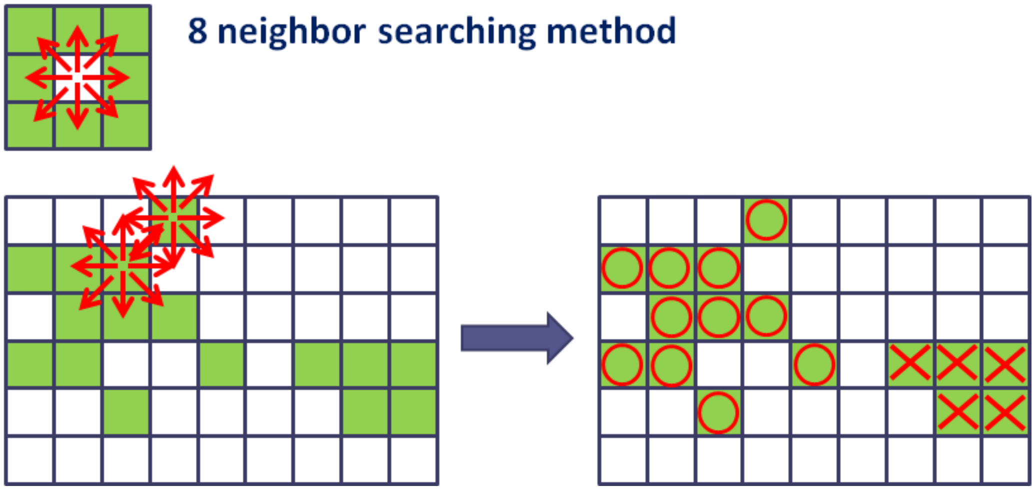
The mosaicked classification result has gap area as cloud masked image. To fill up to the gap area, replacement image was generated by the multi-temporal processing. Therefore, the mosaicked maps for all years were modified in the multi-temporal processing.

The multi-temporal processing was 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 was utilized to fill up the gap area.

6) Filtering and Forest Strata Zoning

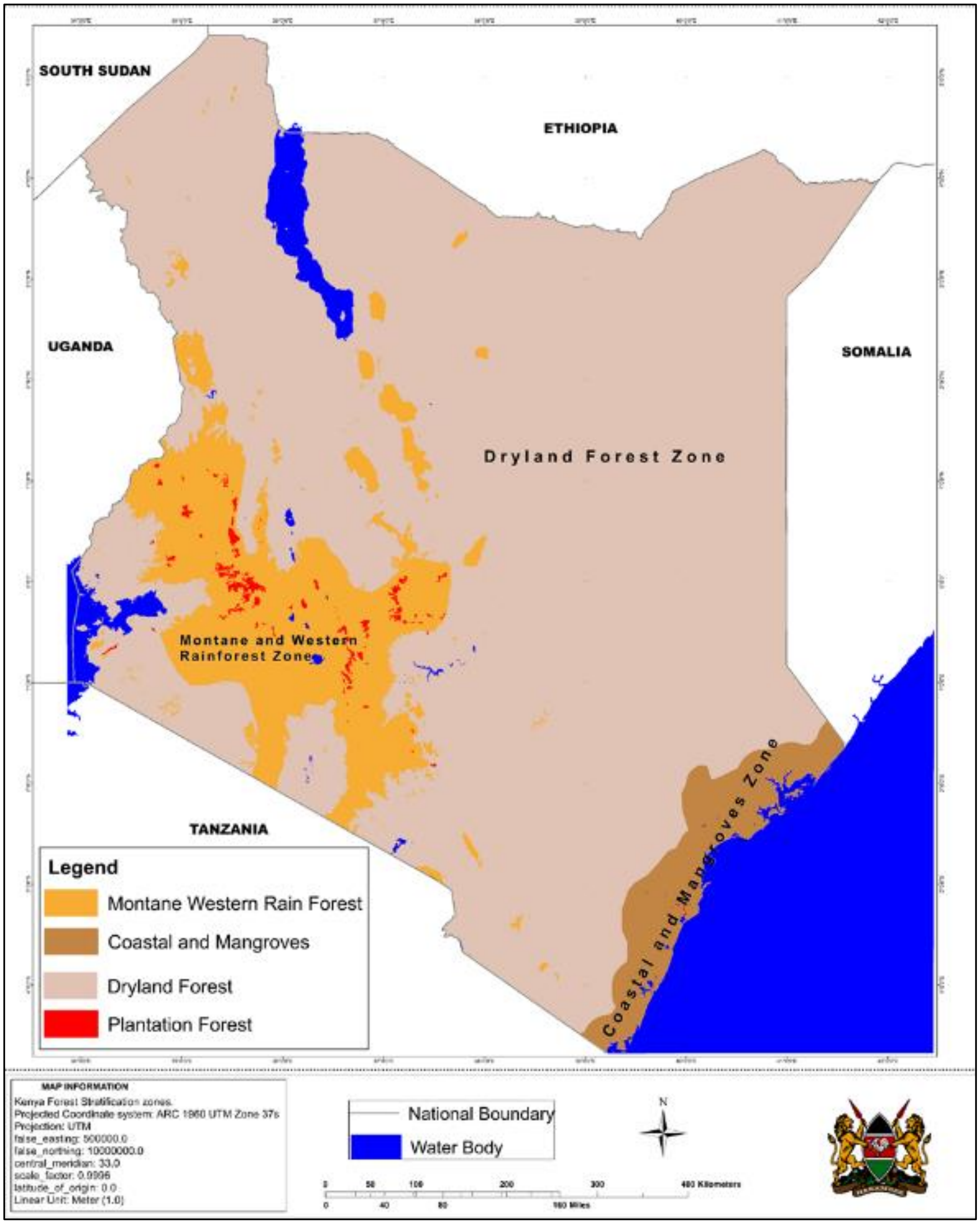
The mosaicked and filled up image map was subjected to a filtering process to obtain the minimum mappable area and to meet the agreed forest definition for Kenya. To meet the forest definition, eight (8) neighbors filtering method was preferred and used for mapping. The eight (8) neighbors filtering method used eight (8) direction searching and clumping as one connected forest as shown in the Figure below. 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.



Eight (8) neighbors filtering

The filtered classification result map was zoned by forest strata zoning. This forest strata zoning information was generated by the forest strata definition as shown in the Figure below.



Forest Strata Zone Image

As explained above, the process steps for the Land Cover / Land Use Map were applied to all years: 1990, 1995, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015 and 2018.

Annex 2: Forest Strata Definitions and Supporting Descriptions

1. **Plantation forest land:** Refers to areas with even aged monocultures and would therefore have a unique spectral characteristics that can allow separation from other vegetation types by remote sensing. Their boundaries in public forests (Government owned forests) are also clearly defined 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. In public forests, exotic plantation species include *Cupressus lusitanica, Eucalyptus sp.* and several pine species (*P. patula* in montane areas and, *P. carribeae* in coastal forests). In the private forests, Eucalypts are the main plantation species in the montane areas, with *Melia volkensii* in many dryland areas, and *Casuarina equisetifolia* dominating at the coast. Since these varied plantation species may not be easily separated by remote sensing, ancillary data will be used for sub categorization by species. Similarly these plantations exist in different age classes which imply different carbon stocks. Information on the age class of the plantations is available with the managers of specific forests (e.g. the inventory section of KFS).

2. **Mangroves and coastal forests**
    a. 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 mucranata*, 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*. Shapefiles of the mangrove zones which will be used for sub categorization are available at KFS.
    b. **The coastal forests:** These are the forests found in the coastal region of Kenya within a 30km strip from shoreline. 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. This class was defined as unique by the KIFCON in Wass (1994) and the shapefiles of the forests are available at KFS.
3. **The montane and western rain forests and bamboo:**

a. **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 differ in species composition due to climate and altitude. 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 highland bamboo (*Yushania alpina*) predominates.
b. **The 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. The trees are significantly taller and larger as compared to the other forests of Kenya. The shapefile describing these forests developed by KIFCON is available at KFS.

4. **The 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. Their carbon stocks may differ from that of other forests due to leaf shedding, elongated rooting systems and high specific wood density.

Categorization of these forests will be done using the shapefiles developed by KIFCON (1994) which are based on climate and altitude. These shapefiles are available at Kenya Forest Service

.

Annex 3 The Plot data form the Pilot NFI

Montane and Western rain forest Dense Canopy

Project	Cluster	Plot	Forest type	Canopy cover (%)	D/M/O	AGB Volume (m3/ha)				AGB Biomass (ton/ha)					AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Total	Tree	Bamboo	Climber	Total			
ICFRA	5999	2	Montane Forest	100.0	Dense	263.89	1.61		265.49	208.38	0.98	7.88	217.24	217.24	97.94	0.46	3.70	102.10	Nyeri	Nyeri	Tetu
ICFRA	6001	1	Montane Forest	79.2	Dense	105.90	0.00	0.00	105.90	87.87	0.00	0.00	87.87	87.87	41.30	0.00	0.00	41.30	Nyeri	Nyeri	Tetu
ICFRA	6002	4	Montane Forest	95.0	Dense	195.91	0.00		195.91	160.50	0.00	3.16	163.67	163.67	75.44	0.00	1.49	76.92	Nyeri	Nyeri	Aberdare Forest
JICA	915	2	Montane Forest	95.0	Dense	246.38	0.00	0.00	246.38	200.15	0.00	0.00	200.15	200.15	94.07	0.00	0.00	94.07	Nyeri	Nyeri	Gathiuru
JICA	9141	1	Montane Forest	98.3	Dense	361.74	0.00	0.00	361.74	288.13	0.00	0.00	288.13	288.13	135.42	0.00	0.00	135.42	Nyeri	Nyeri	Narumoru
JICA	9150	1	Montane Forest	99.2	Dense	646.28	0.00	0.00	646.28	511.25	0.00	0.00	511.25	511.25	240.29	0.00	0.00	240.29	Nyeri	Nyeri	Narumoru
JICA	9150	2	Montane Forest	99.2	Dense	532.79	0.00		532.79	427.02	0.00	2.11	429.13	429.13	200.70	0.00	0.99	201.69	Nyeri	Nyeri	Gathiuru
JICA	912	1	Montane Forest	65.0	Dense	72.25	0.00	0.00	72.25	60.93	0.00	0.00	60.93	60.93	28.63	0.00	0.00	28.63	Nyeri	Nyeri	Kabaru
	Average								303.34				244.80	244.80				115.05			
	SD												157.94					74.23			
	CV (%)												64.52					64.52			
												First Quar	144.7172								
												Third Qua	323.3808								
												IQR	178.6636								
												Q3+1.5*I(	591.3762	511.25							
												Q1-1.5*I(	-123.2782	60.93							

Montane and Western rain forest Moderate canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover	D/M/O	AGB Volume (m3/ha)				AGB Biomass (ton/ha)				AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total			
ICFRA	6002	1	Montane Forest	61.7	Moderate	39.26	0.00		39.26	33.33	0.00	1.58	34.91	15.66	0.00	0.74	16.41	Moderate	Nyeri	Nyeri
ICFRA	6002	2	Montane Forest	47.5	Moderate	40.15	0.00	0.00	40.15	34.24	0.00	0.00	34.24	16.09	0.00	0.00	16.09	Moderate	Nyeri	Nyeri
ICFRA	6002	3	Montane Forest	63.3	Moderate	52.47	0.00	0.00	52.47	44.93	0.00	0.00	44.93	21.12	0.00	0.00	21.12	Moderate	Nyeri	Nyeri
ICFRA	6162	2	Montane Forest	40.0	Moderate	135.33	0.00		135.33	108.50	0.00	3.48	111.97	50.99	0.00	1.63	52.63	Moderate	Nyeri	Nyeri
JICA	911	1	Montane Forest	44.2	Moderate	22.90	0.00	0.00	22.90	19.71	0.00	0.00	19.71	9.26	0.00	0.00	9.26	Moderate	Nyeri	Nyeri
JICA	912	2	Montane Forest	51.7	Moderate	79.36	0.00	0.00	79.36	66.89	0.00	0.00	66.89	31.44	0.00	0.00	31.44	Moderate	Nyeri	Nyeri
JICA	928	2	Montane Forest	49.2	Moderate	117.65	0.00		117.65	95.87	0.00	0.52	96.39	45.06	0.00	0.24	45.30	Moderate	Nyeri	Nyeri
	Average								69.59				58.43				27.46			
	SD												34.64				16.28			
	CV (%)												59.28				59.28			
												First Quar	34.57354							
												Third Qua	81.63634							
												IQR	47.0628							
												Q3+1.5*I(	152.2305	111.97						
												Q1-1.5*I(	-36.0207	19.71						

Montane and Western rain forest Open canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover	Canopy coverage	AGB Volume (m3/ha)				AGB Biomass (ton/ha)					AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Total	Tree	Bamboo	Climber	Total			
JICA	911	2	Montane Forest	21.7	Open	23.49	0.00	0.00	23.49	20.48	0.00	0.00	20.48	20.48	9.63	0.00	0.00	9.63	Nyeri	Nyeri	Kabaru
JICA	913	1	Montane Forest	25.0	Open	12.23	0.00	0.00	12.23	10.57	0.00	0.00	10.57	10.57	4.97	0.00	0.00	4.97	Nyeri	Nyeri	Kabaru
JICA	913	3	Montane Forest	30.8	Open	13.88	0.00	0.00	13.88	12.25	0.00	0.00	12.25	12.25	5.76	0.00	0.00	5.76	Nyeri	Nyeri	Kabaru
JICA	913	4	Montane Forest	16.7	Open	32.10	0.00	0.00	32.10	27.69	0.00	0.00	27.69	27.69	13.01	0.00	0.00	13.01	Nyeri	Nyeri	Kabaru
JICA	9120	3	Montane Forest	30.0	Open	21.45	0.00		21.45	19.05	0.00	1.51	20.56	20.56	8.95	0.00	0.71	9.66	Nyeri	Nyeri	Kabaru
	Average								20.63				18.31	18.31				8.61			
	SD												6.97					3.28			
	CV (%)												38.07					38.07			
												First Quar	12.24935								
												Third Qua	20.55853								
												IQR	8.309178								
												Q3+1.5*I(	33.02229	27.69							
												Q1-1.5*I(	-0.21442	10.57							

Coastal forest and Mangrove Dense canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover (%)	Canopy coverage	AGB Volume (m3/ha)				AGB Biomass (ton/ha)				AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total			
JICA	922	2	Coastal Forest	94.2	Dense	168.62	0.00		168.62	140.95	0.00	0.39	141.34	66.25	0.00	0.18	66.43	Kilifi	Malindi	Gede
JICA	922	3	Coastal Forest	92.5	Dense	170.55	0.00	0.00	170.55	138.68	0.00	0.00	138.68	65.18	0.00	0.00	65.18	Kilifi	Malindi	Gede
JICA	930	1	Coastal Forest	99.2	Dense	73.05	0.00		73.05	63.40	0.00	1.70	65.10	29.80	0.00	0.80	30.60	Kilifi	Malindi	Jilore
JICA	930	2	Coastal Forest	77.5	Dense	92.18	0.00		92.18	78.77	0.00	0.47	79.24	37.02	0.00	0.22	37.24	Kilifi	Malindi	Jilore
JICA	9210	2	Coastal Forest	99.2	Dense	102.77	0.00		102.77	86.45	0.00	22.52	108.98	40.63	0.00	10.59	51.22	Kilifi	Malindi	Gede
JICA	9210	4	Coastal Forest	100.0	Dense	204.43	0.00		204.43	168.15	0.00	5.79	173.94	79.03	0.00	2.72	81.75	Kilifi	Malindi	Gede
JICA	9230	2	Coastal Forest	94.2	Dense	102.87	0.00		102.87	86.60	0.00	2.80	89.40	40.70	0.00	1.32	42.02	Kilifi	Malindi	Jilore
JICA	9230	3	Coastal Forest	100.0	Dense	88.11	0.00	0.00	88.11	76.95	0.00	0.00	76.95	36.17	0.00	0.00	36.17	Kilifi	Malindi	Jilore
ICFRA	3019	1	Mangrove Forest	96.7	Dense	180.97	0.00	0.00	180.97	160.92	0.00	0.00	160.92	75.63	0.00	0.00	75.63	Kwale	Other	Other
ICFRA	3046	4	Mangrove Forest	80.8	Dense	39.40	0.00	0.00	39.40	39.64	0.00	0.00	39.64	18.63	0.00	0.00	18.63	Kwale	Other	Other
ICFRA	3047	3	Mangrove Forest	72.5	Dense	65.95	0.00	0.00	65.95	59.79	0.00	0.00	59.79	28.10	0.00	0.00	28.10	Kwale	Other	Other
ICFRA	3062	2	Mangrove Forest	95.8	Dense	67.24	0.00	0.00	67.24	87.45	0.00	0.00	87.45	41.10	0.00	0.00	41.10	Kwale	Other	Other
ICFRA	3063	1	Mangrove Forest	78.3	Dense	54.38	0.00	0.00	54.38	52.51	0.00	0.00	52.51	24.68	0.00	0.00	24.68	Kwale	Other	Other
ICFRA	3070	1	Mangrove Forest	91.7	Dense	50.63	0.00	0.00	50.63	45.91	0.00	0.00	45.91	21.58	0.00	0.00	21.58	Kwale	Other	Other
ICFRA	3070	2	Mangrove Forest	100.0	Dense	80.42	0.00	0.00	80.42	98.48	0.00	0.00	98.48	46.28	0.00	0.00	46.28	Kwale	Other	Other
ICFRA	3070	3	Mangrove Forest	89.2	Dense	51.41	0.00	0.00	51.41	78.42	0.00	0.00	78.42	36.86	0.00	0.00	36.86	Kwale	Other	Other
ICFRA	3070	4	Mangrove Forest	78.3	Dense	38.43	0.00	0.00	38.43	35.64	0.00	0.00	35.64	16.75	0.00	0.00	16.75	Kwale	Other	Other
ICFRA	3085	4	Mangrove Forest	93.3	Dense	120.94	0.00	0.00	120.94	170.89	0.00	0.00	170.89	80.32	0.00	0.00	80.32	Kwale	Other	Other
	Average								97.35				94.63				44.47			
	SD												45.03				21.16			
	CV (%)												47.59				47.59			
												First Quar	61.1206							
												Third Qua	131.2507							
												IQR	70.13013							
												Q3+1.5*I(	236.4459	173.94						
												Q1-1.5*I(	-44.0746	35.64						

Coastal forest and Mangrove Moderate canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover	Canopy coverage	AGB Volume (m3/ha)				AGB Biomass (ton/ha)					AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Total	Tree	Bamboo	Climber	Total			
JICA	921	1	Coastal Forest	60.0	Moderate	85.44	0.00	0.00	85.44	70.85	0.00	0.00	70.85	70.85	33.30	0.00	0.00	33.30	Kilifi	Malindi	Gede
JICA	923	3	Coastal Forest	49.2	Moderate	79.82	0.00	0.00	79.82	66.27	0.00	0.00	66.27	66.27	31.15	0.00	0.00	31.15	Kilifi	Malindi	Jilore
JICA	925	1	Coastal Forest	44.2	Moderate	70.79	0.00	0.00	70.79	58.25	0.00	0.00	58.25	58.25	27.38	0.00	0.00	27.38	Kwale	Kwale	Msambweni
JICA	950	1	Coastal Forest	50.8	Moderate	28.75	0.00	0.00	28.75	25.39	0.00	0.00	25.39	25.39	11.93	0.00	0.00	11.93	Kwale	Kwale	Kwale
JICA	9210	1	Coastal Forest	60.8	Moderate	63.74	0.00	0.00	63.74	53.94	0.00	0.00	53.94	53.94	25.35	0.00	0.00	25.35	Kilifi	Malindi	Gede
JICA	9230	1	Coastal Forest	63.3	Moderate	63.47	0.00	0.00	63.47	53.71	0.00	0.00	53.71	53.71	25.24	0.00	0.00	25.24	Kilifi	Malindi	Jilore
JICA	9241	3	Coastal Forest	60.0	Moderate	83.10	0.00	0.00	83.10	67.80	0.00	0.00	67.80	67.80	31.87	0.00	0.00	31.87	Kwale	Kwale	Kwale
ICFRA	3011	2	Mangrove Forest	41.7	Moderate	13.31	0.00	0.00	13.31	11.39	0.00	0.00	11.39	11.39	5.35	0.00	0.00	5.35	Kwale	Other	Other
ICFRA	3063	2	Mangrove Forest	47.5	Moderate	41.38	0.00	0.00	41.38	63.92	0.00	0.00	63.92	63.92	30.04	0.00	0.00	30.04	Kwale	Other	Other
JICA	960	1	Mangrove Forest	60.8	Moderate	62.07	0.00	0.00	62.07	53.58	0.00	0.00	53.58	53.58	25.18	0.00	0.00	25.18	Kwale	Kwale	Msambweni
JICA	961	3	Mangrove Forest	50.0	Moderate	63.67	0.00	0.00	63.67	55.12	0.00	0.00	55.12	55.12	25.91	0.00	0.00	25.91	Kwale	Kwale	Msambweni
	Average								59.59				52.75	52.75				24.79			
	SD												18.33					8.62			
	CV (%)												34.75					34.75			
												First Quar	53.64467								
												Third Qua	65.09486								
												IQR	11.45019								
												Q3+1.5*I(	82.27015	70.85							
												Q1-1.5*IQ	36.46938	11.39							

Coastal forest and Mangrove Open canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover	Canopy coverage	AGB Volume (m3/ha)				AGB Biomass (ton/ha)					AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Total	Tree	Bamboo	Climber	Total			
JICA	950	2	Coastal Forest	30.8	Open	25.95	0.00	0.00	25.95	22.97	0.00	0.00	22.97	22.97	10.80	0.00	0.00	10.80	Kwale	Kwale	Kwale
JICA	9241	1	Coastal Forest	36.7	Open	28.30	0.00	0.00	28.30	24.57	0.00	0.00	24.57	24.57	11.55	0.00	0.00	11.55	Kwale	Kwale	Kwale
JICA	9241	2	Coastal Forest	35.0	Open	48.47	0.00	0.00	48.47	40.43	0.00	0.00	40.43	40.43	19.00	0.00	0.00	19.00	Kwale	Kwale	Kwale
JICA	9290	3	Coastal Forest	36.7	Open	38.61	0.00	0.00	38.61	33.62	0.00	0.00	33.62	33.62	15.80	0.00	0.00	15.80	Kwale	Kwale	Kwale
JICA	9291	1	Coastal Forest	36.7	Open	25.05	0.00	0.00	25.05	21.68	0.00	0.00	21.68	21.68	10.19	0.00	0.00	10.19	Kwale	Kwale	Kwale
JICA	9291	2	Coastal Forest	29.2	Open	68.63	0.00	0.00	68.63	57.54	0.00	0.00	57.54	57.54	27.04	0.00	0.00	27.04	Kwale	Kwale	Kwale
JICA	9291	3	Coastal Forest	35.8	Open	31.82	0.00	0.00	31.82	27.15	0.00	0.00	27.15	27.15	12.76	0.00	0.00	12.76	Kwale	Kwale	Kwale
ICFRA	3026	3	Mangrove Forest	16.7	Open	30.30	0.00	0.00	30.30	30.08	0.00	0.00	30.08	30.08	14.14	0.00	0.00	14.14	Kwale	Other	Other
ICFRA	3046	1	Mangrove Forest	15.8	Open	2.67	0.00	0.00	2.67	2.45	0.00	0.00	2.45	2.45	1.15	0.00	0.00	1.15	Kwale	Other	Other
ICFRA	3047	1	Mangrove Forest	20.0	Open	8.45	0.00	0.00	8.45	8.01	0.00	0.00	8.01	8.01	3.76	0.00	0.00	3.76	Kwale	Other	Other
JICA	960	3	Mangrove Forest	20.0	Open	23.20	0.00	0.00	23.20	20.35	0.00	0.00	20.35	20.35	9.57	0.00	0.00	9.57	Kwale	Kwale	Kwale
JICA	960	4	Mangrove Forest	31.7	Open	7.00	0.00	0.00	7.00	6.34	0.00	0.00	6.34	6.34	2.98	0.00	0.00	2.98	Kwale	Kwale	Msambweni
JICA	961	1	Mangrove Forest	30.0	Open	23.90	0.00	0.00	23.90	20.80	0.00	0.00	20.80	20.80	9.78	0.00	0.00	9.78	Kwale	Kwale	Msambweni
JICA	961	2	Mangrove Forest	25.0	Open	22.58	0.00	0.00	22.58	20.08	0.00	0.00	20.08	20.08	9.44	0.00	0.00	9.44	Kwale	Kwale	Msambweni
	Average								27.50				24.01	24.01				11.28			
	SD												14.18					6.66			
	CV (%)												59.05					59.05			
												First Quar	20.14589								
												Third Qua	29.3473								
												IQR	9.201413								
												Q3+1.5*I(	43.14942	57.54							
												Q1-1.5*IQ	6.343772	2.45							

Dryland forest Dense canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover	D/M/O	AGB Volume (m3/ha)				AGB Biomass (ton/ha)					AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Total	Tree	Bamboo	Climber	Total			
ICFRA	1887	2	Dryland Forest	66.7	Dense	16.02	0.00	0.00	16.02	13.97	0.00	0.00	13.97	13.97	6.56	0.00	0.00	6.56	Baringo	Baringo	Marigat
ICFRA	2048	3	Dryland Forest	75.0	Dense	13.93	0.00	0.00	13.93	11.94	0.00	0.00	11.94	11.94	5.61	0.00	0.00	5.61	Baringo	Baringo	Marigat
JICA	918	1	Dryland Forest	77.5	Dense	68.66	0.00	0.00	68.66	58.04	0.00	0.00	58.04	58.04	27.28	0.00	0.00	27.28	Makueni	Makueni	Kibwezi
JICA	918	2	Dryland Forest	88.3	Dense	119.50	0.00		119.50	97.01	0.00	8.67	105.68	105.68	45.59	0.00	4.08	49.67	Makueni	Makueni	Kibwezi
JICA	920	1	Dryland Forest	67.5	Dense	33.46	0.00	0.00	33.46	29.65	0.00	0.00	29.65	29.65	13.94	0.00	0.00	13.94	Makueni	Makueni	Kibwezi
JICA	9170	2	Dryland Forest	95.0	Dense	42.00	0.00	0.00	42.00	36.18	0.00	0.00	36.18	36.18	17.00	0.00	0.00	17.00	Makueni	Makueni	Kibwezi
JICA	9170	3	Dryland Forest	93.3	Dense	49.01	0.00	0.00	49.01	41.56	0.00	0.00	41.56	41.56	19.53	0.00	0.00	19.53	Makueni	Makueni	Kibwezi
	Average								48.94				42.43	42.43				19.94			
	SD												32.11					15.09			
	CV (%)												75.68					75.68			
												First Quar	21.8098								
												Third Qua	49.80036								
												IQR	27.99056								
												Q3+1.5*I(	91.7862	105.68							
												Q1-1.5*I(	-20.1761	11.94							

Dryland forest Moderate canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover	D/M/O	AGB Volume (m3/ha)				AGB Biomass (ton/ha)				AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total			
ICFRA	1887	4	Dryland Forest	60.8	Moderate	30.92	0.00	0.00	30.92	27.57	0.00	0.00	27.57	12.96	0.00	0.00	12.96	Baringo	Baringo	Marigat
ICFRA	1888	2	Dryland Forest	56.7	Moderate	25.98	0.00	0.00	25.98	22.47	0.00	0.00	22.47	10.56	0.00	0.00	10.56	Baringo	Baringo	Marigat
JICA	918	3	Dryland Forest	42.5	Moderate	58.26	0.00	0.00	58.26	49.71	0.00	0.00	49.71	23.36	0.00	0.00	23.36	Makueni	Makueni	Kibwezi
JICA	918	4	Dryland Forest	42.5	Moderate	13.65	0.00	0.00	13.65	11.68	0.00	0.00	11.68	5.49	0.00	0.00	5.49	Makueni	Makueni	Kibwezi
JICA	9170	1	Dryland Forest	47.5	Moderate	32.74	0.00		32.74	29.17	0.00	5.06	34.23	13.71	0.00	2.38	16.09	Makueni	Makueni	Kibwezi
JICA	9190	1	Dryland Forest	58.3	Moderate	54.65	0.00	0.00	54.65	46.82	0.00	0.00	46.82	22.01	0.00	0.00	22.01	Makueni	Makueni	Kibwezi
JICA	9190	2	Dryland Forest	60.8	Moderate	62.05	0.00	0.00	62.05	55.48	0.00	0.00	55.48	26.08	0.00	0.00	26.08	Makueni	Makueni	Kibwezi
JICA	9190	3	Dryland Forest	60.8	Moderate	31.66	0.00		31.66	27.57	0.00	0.64	28.21	12.96	0.00	0.30	13.26	Makueni	Makueni	Kibwezi
	Average								38.74				34.52				16.23			
	SD												15.01				7.05			
	CV (%)												43.47				43.47			
												First Quar	26.29685							
												Third Qua	47.5431							
												IQR	21.24625							
												Q3+1.5*I(	79.41248	55.48						
												Q1-1.5*I(	-5.57252	11.68						

Dryland forest Open canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover	D/M/O	AGB Volume (m3/ha)				AGB Biomass (ton/ha)				AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total			
ICFRA	1888	1	Dryland Forest	20.0	Open	22.40	0.00	0.00	22.40	19.80	0.00	0.00	19.80	9.31	0.00	0.00	9.31	Baringo	Baringo	Marigat
ICFRA	1888	3	Dryland Forest	32.5	Open	8.74	0.00	0.00	8.74	7.72	0.00	0.00	7.72	3.63	0.00	0.00	3.63	Baringo	Baringo	Marigat
ICFRA	1888	4	Dryland Forest	26.7	Open	6.63	0.00	0.00	6.63	5.78	0.00	0.00	5.78	2.72	0.00	0.00	2.72	Baringo	Baringo	Marigat
ICFRA	2211	4	Dryland Forest	36.7	Open	11.30	0.00	0.00	11.30	10.30	0.00	0.00	10.30	4.84	0.00	0.00	4.84	Baringo	Baringo	Marigat
ICFRA	2212	1	Dryland Forest	35.0	Open	26.09	0.00	0.00	26.09	23.95	0.00	0.00	23.95	11.25	0.00	0.00	11.25	Baringo	Baringo	Marigat
ICFRA	2212	2	Dryland Forest	29.2	Open	21.59	0.00	0.00	21.59	19.51	0.00	0.00	19.51	9.17	0.00	0.00	9.17	Baringo	Baringo	Marigat
ICFRA	2370	4	Dryland Forest	37.5	Open	15.27	0.00	0.00	15.27	12.79	0.00	0.00	12.79	6.01	0.00	0.00	6.01	Baringo	Baringo	Marigat
	Average								16.00				14.26				6.70			
	SD												6.89				3.24			
	CV (%)												48.28				48.28			
												First Quar	9.009695							
												Third Qua	19.65707							
												IQR	10.64737							
												Q3+1.5*I(	35.62813	23.95						
												Q1-1.5*I(	-6.96136	5.78						

Plantation forest

Project	Cluster	Plot	Forest type	Canopy cover	D/M/O	AGB Volume (m3/ha)				AGB Biomass (ton/ha)				AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total			
ICFRA	287	1	Plantation	100.0	Dense	578.35	0.00	0.00	578.35	473.36	0.00	0.00	473.36	222.48	0.00	0.00	222.48	Kericho	Kericho	Londian
ICFRA	287	2	Plantation	100.0	Dense	646.20	0.00	0.00	646.20	527.43	0.00	0.00	527.43	247.89	0.00	0.00	247.89	Kericho	Kericho	Londian
ICFRA	288	1	Plantation	90.0	Dense	270.18	0.00	0.00	270.18	221.46	0.00	0.00	221.46	104.09	0.00	0.00	104.09	Kericho	Kericho	Londian
ICFRA	288	2	Plantation	88.3	Dense	111.99	0.00		111.99	92.84	0.00	1.65	94.49	43.63	0.00	0.78	44.41	Kericho	Kericho	Londian
ICFRA	447	1	Plantation	100.0	Dense	690.31	0.00	0.00	690.31	558.65	0.00	0.00	558.65	262.56	0.00	0.00	262.56	Kericho	Kericho	Londian
ICFRA	447	3	Plantation	89.2	Dense	311.50	0.00	0.00	311.50	252.08	0.00	0.00	252.08	118.48	0.00	0.00	118.48	Kericho	Kericho	Londian
ICFRA	447	4	Plantation	98.3	Dense	409.91	0.00	0.00	409.91	335.08	0.00	0.00	335.08	157.49	0.00	0.00	157.49	Kericho	Kericho	Londian
ICFRA	607	2	Plantation	91.7	Dense	1,078.64	0.00	0.00	1,078.64	864.66	0.00	0.00	864.66	406.39	0.00	0.00	406.39	Baringo	Koibatek	Mumberes
ICFRA	607	3	Plantation	82.5	Dense	987.63	0.00	0.00	987.63	784.27	0.00	0.00	784.27	368.61	0.00	0.00	368.61	Baringo	Koibatek	Mumberes
ICFRA	1082	1	Plantation	96.7	Dense	1,205.69	0.00	0.00	1,205.69	968.77	0.00	0.00	968.77	455.32	0.00	0.00	455.32	Baringo	Baringo	Other
ICFRA	1083	1	Plantation	79.2	Dense	836.62	0.00	0.00	836.62	675.93	0.00	0.00	675.93	317.69	0.00	0.00	317.69	Baringo	Koibatek	Eldama ravine
ICFRA	1083	2	Plantation	86.7	Dense	662.83	0.00	0.00	662.83	519.80	0.00	0.00	519.80	244.31	0.00	0.00	244.31	Baringo	Koibatek	Eldama ravine
ICFRA	1241	1	Plantation	90.0	Dense	647.91	0.00	0.00	647.91	524.72	0.00	0.00	524.72	246.62	0.00	0.00	246.62	Baringo	Koibatek	Esageri
ICFRA	1241	2	Plantation	96.7	Dense	715.18	0.00	0.00	715.18	582.32	0.00	0.00	582.32	273.69	0.00	0.00	273.69	Baringo	Koibatek	Esageri
ICFRA	1241	3	Plantation	92.5	Dense	652.09	0.00	0.00	652.09	534.50	0.00	0.00	534.50	251.22	0.00	0.00	251.22	Baringo	Koibatek	Esageri
ICFRA	1241	4	Plantation	80.0	Dense	500.59	0.00	0.00	500.59	410.79	0.00	0.00	410.79	193.07	0.00	0.00	193.07	Baringo	Koibatek	Esageri
ICFRA	1242	1	Plantation	80.0	Dense	205.15	0.00		205.15	168.42	0.00	3.21	171.63	79.16	0.00	1.51	80.67	Baringo	Koibatek	Eldama ravine
ICFRA	1242	2	Plantation	89.2	Dense	143.35	0.00		143.35	117.53	0.00	5.32	122.85	55.24	0.00	2.50	57.74	Baringo	Koibatek	Eldama ravine
ICFRA	1242	3	Plantation	100.0	Dense	473.19	0.00		473.19	386.66	0.00	1.27	387.93	181.73	0.00	0.60	182.33	Baringo	Koibatek	Eldama ravine
ICFRA	6000	4	Plantation	86.7	Dense	548.94	0.00	0.00	548.94	444.25	0.00	0.00	444.25	208.80	0.00	0.00	208.80	Nyeri	Nyeri	Tetu
ICFRA	6001	3	Plantation	75.0	Dense	299.83	0.00	0.00	299.83	242.10	0.00	0.00	242.10	113.79	0.00	0.00	113.79	Nyeri	Nyeri	Aberdare Forest
ICFRA	6161	3	Plantation	80.8	Dense	298.85	0.00		298.85	240.62	0.00	0.77	241.39	113.09	0.00	0.36	113.45	Nyeri	Nyeri	Aberdare Forest
ICFRA	6161	4	Plantation	83.3	Dense	127.41	0.00		127.41	103.69	0.00	1.37	105.06	48.74	0.00	0.64	49.38	Nyeri	Nyeri	Aberdare Forest
ICFRA	286	1	Plantation	50.0	Moderate	28.98	0.00	0.00	28.98	24.47	0.00	0.00	24.47	11.50	0.00	0.00	11.50	Kericho	Kericho	Other
ICFRA	287	4	Plantation	55.0	Moderate	60.81	0.00	0.00	60.81	52.85	0.00	0.00	52.85	24.84	0.00	0.00	24.84	Kericho	Kericho	Londian
ICFRA	6000	2	Plantation	54.2	Moderate	152.90	0.00		152.90	122.41	0.00	1.88	124.29	57.53	0.00	0.88	58.42	Nyeri	Nyeri	Tetu
ICFRA	6000	3	Plantation	51.7	Moderate	327.41	0.00	0.00	327.41	265.47	0.00	0.00	265.47	124.77	0.00	0.00	124.77	Nyeri	Nyeri	Tetu
ICFRA	6001	2	Plantation	53.3	Moderate	106.77	0.00	0.00	106.77	90.52	0.00	0.00	90.52	42.54	0.00	0.00	42.54	Nyeri	Nyeri	Aberdare Forest
ICFRA	6001	4	Plantation	59.2	Moderate	149.86	0.00	0.00	149.86	123.64	0.00	0.00	123.64	58.11	0.00	0.00	58.11	Nyeri	Nyeri	Aberdare Forest
JICA	914	3	Plantation	24.2	Open	429.01	0.00	0.00	429.01	332.00	0.00	0.00	332.00	156.04	0.00	0.00	156.04	Nyeri	Nyeri	Kabaru
JICA	928	1	Plantation	29.2	Open	91.69	0.00	0.00	91.69	74.61	0.00	0.00	74.61	35.07	0.00	0.00	35.07	Nyeri	Nyeri	Narumoru
JICA	929	1	Plantation	27.5	Open	121.34	0.00	0.00	121.34	99.14	0.00	0.00	99.14	46.60	0.00	0.00	46.60	Nyeri	Nyeri	Gathiuru
JICA	9140	4	Plantation	29.2	Open	51.24	0.00	0.00	51.24	41.46	0.00	0.00	41.46	19.49	0.00	0.00	19.49	Nyeri	Nyeri	Kabaru
JICA	9141	2	Plantation	36.7	Open	138.06	0.00	0.00	138.06	110.33	0.00	0.00	110.33	51.86	0.00	0.00	51.86	Nyeri	Nyeri	Kabaru
JICA	9141	3	Plantation	38.3	Open	276.81	0.00	0.00	276.81	218.79	0.00	0.00	218.79	102.83	0.00	0.00	102.83	Nyeri	Nyeri	Gathiuru
JICA	9141	4	Plantation	25.0	Open	113.62	0.00	0.00	113.62	91.21	0.00	0.00	91.21	42.87	0.00	0.00	42.87	Nyeri	Nyeri	Kabaru
	Average								401.41				324.79				152.65			
	SD												249.38				117.21			
	CV (%)												76.78				76.78			
												First Quar	109.01							
												Third Qua	521.03							
												IQR	412.02							
												Q3+1.5*I(	1,139.06	968.77						
												Q1-1.5*IQ	(509.01)	24.47						

United Nations
Climate Change Secretariat

Executive Secretary

Nations Unies
Secrétariat sur les changements climatiques

Secrétaire exécutive

Date: 12 March 2019
Reference: JW/aha

MESSAGE TO PARTIES

Information on the submission of proposed forest reference emission levels and/or forest reference levels by developing country Parties, on a voluntary basis, when implementing the activities referred to in decision 1/CP.16, paragraph 70, and on the technical assessments of these submitted reference levels in 2020 and 2021

Parties will recall that the COP, in its decision 12/CP.17,[1] paragraph 13, invited developing country Parties, on a voluntary basis and when deemed appropriate, to submit proposed forest reference emission levels and/or forest reference levels, in accordance with decision 1/CP.16, paragraph 71(b), when undertaking the activities referred to in paragraph 70 of that same decision. Parties will also recall that the COP, in its decision 13/CP.19, adopted the guidelines and procedures for the technical assessment of submissions from Parties on proposed forest reference emission levels and/or forest reference levels. In accordance with decision 13/CP.19, paragraphs 1 and 2, each submission shall be subject to a technical assessment and such proposed reference levels may be technically assessed in the context of results-based payments.

The secretariat, in response to the mandate set out in decision 13/CP.19, is pleased to inform Parties of the proposed **timing for the technical assessments** to be conducted in **2020** and **2021**.[2] This information is being provided to facilitate the planning for submission of reference levels by developing country Parties and to ensure the efficient and effective organization of the technical assessment sessions by the secretariat in accordance with the procedures and time frames established in the annex of that decision.

Distribution: This notification is being sent to all Parties to the United Nations Framework Convention on Climate Change (UNFCCC). It is addressed to their national focal points for climate change.

[1] All decisions mentioned in this message are available at https://unfccc.int/topics/land-use/resources/unfccc-documents-in-relation-to-reducing-emissions-from-deforestation-and-forest-degradation-in-developing-countries.

[2] Dates for 2020–2021 are indicative and the exact dates may still change in case of clashes with events which are difficult to envisage at this point of time.

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To that end, and particularly to ensure the successful organization of the technical assessment sessions, the secretariat will be taking several actions, including the following:

1. Organize assessment sessions once a year in Bonn, as mandated by paragraph 10 of the annex to decision 13/CP.19. In accordance with the same paragraph, submissions received no later than 10 weeks before a session will be assessed at that session. Parties should note that submissions received after the 10 weeks ahead of a session will be scheduled for assessment the following year;
2. Coordinate the technical assessment process;
3. Ensure a balanced representation of LULUCF experts from developing countries and developed countries, whereby each submission shall be assessed by two LULUCF experts selected from the UNFCCC roster of experts, one from a developed country and one from a developing country.

In line with point 1 above, the secretariat would appreciate an early notification from developing country Parties intending to submit their proposed reference levels for a technical assessment. In addition, the secretariat will need to receive submissions **at least ten (10) weeks** before the start of the assessment session to ensure adequate and effective logistical preparation and organization of the technical assessment (e.g. identifying, inviting and confirming relevant experts). Parties should also note that all relevant information pertaining to the submission needs to be forwarded to the assessment team of LULUCF experts **at least eight (8) weeks** before the start of the assessment session, allowing the participating LULUCF experts sufficient time to adequately prepare for the one-week centralized assessment session in Bonn. The technical assessment process itself spans approximately **forty-three (43) weeks** (including interaction time between the assessment team and Party concerned, response time by Party and the time for preparation of draft and final reports).

After careful consideration of several factors that have implications for the timing of the technical assessments, such as the timing of all technical review processes being organized under the Convention and Kyoto Protocol in any given year, the timing of UNFCCC negotiation sessions, the availability of active LULUCF experts during the year and the need for on-going fund raising to support the organization of the technical assessments, the secretariat has identified the most feasible dates for the assessment sessions in 2020 and 2021 and the corresponding submission deadlines for these sessions. The detailed steps and time frames of each technical assessment session in 2020 and 2021 are presented in the annex to this message. Submissions of forest reference emission levels and/or forest reference levels should be sent by the UNFCCC national focal point to the secretariat at secretariat@unfccc.int, with a copy to TARL@unfccc.int.

In addition to the guidance contained in decision 13/CP.19 on the organization of technical assessments, the COP invited Parties to nominate technical experts with the relevant qualifications to the UNFCCC roster of experts. Each Party should also confirm to the secretariat the names of their active LULUCF experts on the roster, and which experts will be able to participate in the technical assessment of the submitted reference levels. Parties are invited to refer to the roster at http://www4.unfccc.int/sites/roe/Pages/Home.aspx to nominate new experts and/or update the information on those already nominated.

The secretariat would also like to note in decision 13/CP.19, paragraphs 7 and 8 of decision 13/CP.19, that there are budgetary implications related to the activities undertaken by the secretariat in paragraphs 1 to 3 and the annex of the same decision. The secretariat is only able to undertake these activities subject to the availability of supplementary funding. Hence, the secretariat would like to take this opportunity to request Parties in a position to do so to support this technical assessment process, which is a critical step in developing country Parties' implementation of the Warsaw Framework for REDD-plus.

The secretariat requests the kind cooperation of Parties in meeting the time frames of the planned technical assessment sessions for 2020 and 2021 as noted above and in the annex to this message with a view to facilitating the organization and coordination of the technical assessments of submitted forest reference emission levels and/or forest reference levels and to ensuring successful outcomes.

Yours sincerely,

(Signed by)

Patricia Espinosa

Annex

Overview table on the indicative time frames of the technical assessment of reference levels in 2020 and 2021[1]

	Technical assessment 2020	**Technical assessment 2021**
Early notice to the secretariat	Latest by 1 November 2019	Latest by 30 October 2020
Deadline for reference level submission (no later than 10 weeks before the assessment session)	Latest by 6 January	Latest by 11 January
Information forwarded to assessment team (8 weeks before the assessment session)	Latest by 20 January	Latest by 25 January
Assessment session in Bonn (1 week)	**16 – 20 March 2020**	**22 – 26 March 2021**
Seeking additional clarifications from the Party (up to 1 week)	23 – 27 March	29 March – 2 April
Party to provide clarifications (8 weeks), including submission of a modified submission, if appropriate.	Latest by 25 May	Latest by 31 May
4 weeks for assessment team to consider modified reference level (applicable in the case that the Party modifies its submitted reference level)	26 May – 26 June	1 – 28 June
Assessment team to prepare draft report	Latest by 27 July	Latest by 26 July
Party to respond to draft report (12 weeks)	Latest by 19 October	Latest by 18 October
Assessment team to prepare final report within four weeks following the Party's response	Latest by 16 November	Latest by 15 November
Final report published and technical assessment completed	**7 December**	**7 December**

* For planning purposes, dates indicate the maximum time frames required in accordance with decision 13/CP.19.

[1] Dates for 2021 are indicative and the exact dates may still change in case of clashes with events which are difficult to envisage at this point of time.

Indicative timeframe for the 2020 remote technical assessment session

	Latest by:
Deadline for reference level submission (no later than 10 weeks before the assessment session)	6 January
Information forwarded to assessment team (8 weeks before the assessment session)	20 January
Remote assessment session coordinated in Bonn (Week 2)	**8–12 June 2020**
Seeking additional clarifications from the Party (up to 1 week)	15–19 June
Party to provide clarifications (8 weeks)	Latest by 17 August
4 weeks for assessment team to consider modified reference level (applicable in the case that the Party modifies its submitted reference level)	18 August–18 September
Assessment team to prepare draft report (12 [16] weeks following assessment session)	7 September [5 October]
Party to respond to draft report (12 weeks)	30 November [28 December]
Assessment team to prepare final report within four weeks following the Party's response	28 December [25 January 2021]
Final version of the report edited, approved by Party and published (estimated at least 2 weeks required for processing and finalization steps)	**12 January 2021** **[9 February 2021]**

All dates shown on the table are for the calendar year 2020-2021. Dates in brackets are the dates that apply if reference level is modified by Party.

Any delay by the Party in these time periods for providing responses/comments will result in a corresponding delay in the finalization of the report, its publication and completion of the technical assessment process.

2020 REDD+ TARL process --- Question & Answer Transcript ---**KENYA**

No.	Question	Response
1	<Forest definition> At 2.2.1. Forest Definition on page 6, several considerations are described to apply a new forest definition to REDD+ FRL from the definition Kenya used for reporting to the FAO. Could Kenya explain the rationale of the forest definition change?	The referred FAO-FRA 2015 was done at a time when Kenya had not agreed on the definition of a forest that would be used across the board. The definition used in FRL document is now the official one and has consistently been used in Kenya's National Inventory Report that will be used in the submission of the 3rd National Communications for Kenya. This definition has also been used in the recently submitted FAO FRA 2020.The same definition is illustrated in Appendix 3 of the land cover mapping manual which has been provided to the reviewers. It has been very carefully considered by stakeholders in the country and the best placed to inform REDD+ activities.
1a	Could Kenya further explain why minimum canopy cover changed from 10% to 15% and minimum tree height changed from 5 meters to 2 meters? The former is to exclude bush trees and the latter is technical improvement?	Yes. The two decisions are complementary and are within the IPCC and FAO limits for classifying forests. Kenya has vast areas of bushlands and thickets in the northern rangelands that can easily be confused with forestlands. One characteristics of these bushlands is the deciduous nature of the Acacia trees found here. Adopting a 10% forest canopy cover may include these areas into forestlands and this makes it difficult for Kenya to monitor such land cover types into the future especially if they are classified as forestlands The minimum threshold for defining forest in Kenya, was determined by the national circumstances and guided by the previously done AFRICOVER map. In the Land Cover Classification System (LCCS) of the FAO AFRICOVER mapping, a minimum threshold of 2m was considered for Woody (indistinct and/or intricate mixture of trees and shrubs) vegetation type.

No.	Question	Response
		Kenya’s Forest is highly influenced by climatic and edaphic conditions with a significant portion of the country being described as Arid and Semi-arid lands and therefore the tree growth and characterization could minimally be described using 15% canopy and the 2 meters high parameters.The two thresholds exclude bushland and was technically feasible as determined by the best previous wall-wall mapping experience in the country (AFRICOVER mapping).
2	<Tree height> How was Kenya able to identify forest areas taking into account the minimum height of 2 meters established in its forest definition?	Kenya has developed a land cover classification method and a detailed mapping manual (Which has been provided to the reviewers). Noting the difficulty in separating land cover classes by height, a preliminary ground truthing was done and areas with specific vegetation characteristics identified on the ground including height(Expert knowledge). We used this data as training data in customised Random Forest algorithm(Please see section 3.1.1 of the FRL). The same is further illustrated in the section Random Forest classification with training data on page 77 (Annex 1) under Methodology for Land Cover / Land Use Mapping. Noting the expenses associated with existing methods of mapping tree height (Lidar or RADAR) and the expansive nature of our Dry land forests where this problem persists, we note this is an area for future improvement and capacityenhancementand we would adopt an improved

No.	Question	Response
		technology which is cost effective and sustainable when such a technology is available
2a	With regards to the section highlighted in yellow in Kenya's response to question 2 above, what was the scope of the preliminary ground truthing? What was the role of expert knowledge in it?	The Scope was regional mainly targeting areas that have short trees (mainly dryland forests). Again expert knowledge based on what is known about characteristics of trees in different ecological regions of Kenya was used. Some aerial survey data done by Department of Resource Surveys and Remote Sensing (DRSRS) in developing the AFRICOVER land cover maps were used
3	<Managed land> Could Kenya please confirm what is the definition of "managed lands" used for the construction of the FREL, and how unmanaged lands have been distinguished from managed ones?	Kenya has no definition of unmanaged land. All lands in Kenyaandreferredin this FRL are classified as managed. Managed lands are those lands in Kenya that are manipulated by human beings in terms of use, protection and conservation.
4	<sustainable management of forest> On page 7 line 23, Kenya explains that "plantation forests may not be associated to degradation or enhancement and adopted a single canopy cover for plantation forests". Does this imply that all trees in plantation forests grow successfully?	In the FRL, the public Plantation Forest strata is classified under sustainable management of forests (SMF). Number 4 of Page 20 explains the objective of SMF to national priorities. SMF aims at clearing backlogs of replanted forests (where designated forest areas have not been planted for a long time) and better management of forests to ensure higher survival, proper stocking and timely harvesting schedules. This will create an overall increase in forest cover and carbon stocks in Kenya while at the same time enhancing forestry contribution to the socio-economic development of the country. It is true that all planted plantation forests do not grow successfully today. SMF will aim at improving survival rates, proper application of silviculturalprinciples and aggressive and continuous replanting in areas that have been cleared but not yet planted due to policy, governance and management failures

No.	Question	Response
		that will be further elaborated in the strategy.
4a	Based on Kenya´s response above, can it be said that the main difference between the activities SMF and enhancement of carbon stocks is that while the former happens in areas designated for plantations the latter take place in other areas?	Yes. SMF as a REDD+ activity only occurs in public plantation forests The other three REDD+ Activities (Enhancement of carbon Stocks, Reducing Emissions from Deforestation and Reducing Emissions from Forest Degradation) occur in other forest areas
4b	Does the response mean that even the unsuccessful plantation areas or plantation areas where trees are not planted for a long time are included as successful plantation? And is that correct that Kenya has no intension to differentiate successful areas and unsuccessful areas as future improvement?	All areas within the designated public plantation area whether with trees or not are classified under the SMF REDD+ activity We note that about half of these areas are currently non forested either because (1) they were not planted after harvesting (there was a historical period of no replanting in these areas due to lack of capacity/non clear management plans) (2) they are currently under farming because they were recently planted and the land is being prepared for the plantation forest planting programme Under SFM as a REDD+ activity, we want to ensure backlogs of replanting are reduced (afforestation in non-planted areas) enhanced silvicultural management to improve stocks and timely/immediate replanting after harvesting Kenya uses Landsat for land cover mapping and based on this satellite, we monitor the success of an afforestation programme during subsequent mapping years after planting
4c	While it is explained that “any variations in canopy cover among plantation forests may not be associated to degradation and enhancement and adopted a single canopy cover for plantation forests” on page 7 line 23, the spreadsheet includes information on area of canopy change in plantation forests, e.g. moderate forests to	Yes, the Activity Data shows that Plantation forests were classified into three canopy classes. However, ground data (from the pilot NFI) indicated that there was no difference in stocking among canopy classes. We therefore decided to use a

No.	Question	Response
	dense forests in plantation. It seems to lead to under- or overestimation of carbon stock unless Kenya consider canopy change plantation. Could Kenya further explain why canopy change in plantation is not reflected in estimation? Any technical issues exist?	single EF for the three canopy classes – check the formulas in the blue part of the excel tables. We noted that open plantation forests were not necessarily young forests but included mature forests with wide spacing (due to poor survival rates of the trees under a historically poor management programme) where the few mature stocks constitute a sizeable stock equivalent to that of dense forests. We also noted that Dense plantation forests also comprised young forests that have not been thinned and the cumulative stocks form these young trees were at times less than what was in open plantation forests. This justified the use of a single EF for all plantation forests We expect that this problem will be solved under the SMF REDD+ activity where we plan to introduce timely silvicultural practices
5	<REDD+ activities> On page 7, it is described that all activities except conservation of forest carbon stocks are included to develop the FRL. Could Kenya provide further information on exclusion of conservation of forest carbon stocks?	Kenya has no agreed definition of Conservation under REDD+. However, Page 8 and the calculations illustrated in page 39 describe enhancement of Carbon stocks as activities that 1. Increase carbon stocks through afforestation and reforestation 2. Increase carbon stocks through improvement of Canopy cover from an inferior canopy to a higher canopy (e.g. open forest to dense forest) The activities described in number 2 above under enhancement of carbon stocks are due partly to conservation of forests. Therefore Kenya decided to include those conservation

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		activities under enhancement of carbon stocks. Note that calculations for Activity number 2 on enhancing carbon stocks are illustrated in our calculation matrix and also in section 4.2.4 and Table 27 and therefore can easily be separated into a conservation REDD+ activity if there is need
5a	It seems that Kenya can technically extract conservation activity from enhancement activity, but can Kenya reach an agreement of the definition of conservation activity until the modified submission is completed?	We do not currently have a definition for Conservation of Carbon Stocks. We wish to remain with the 4 REDD+ activities for now/under this assessment (1) Reducing Emissions from Deforestation (2) Reducing Emissions from Forest Degradation (3) Enhancement of Carbon Stocks (4) Sustainable Management of Forests
6	<Harmonization of interval of monitoring emissions> While it is illustrated that emissions are harmonized between 3rd NC and the FRL on page 12 line 15, intervals are 5 years and 4 years respectively. Could Kenya explain how these intervals are harmonized with each other?	Kenya has not yet submitted the 3rd NC to the UNFCCC. We are in the process of developing the NIR which will form the GHG section of the 3rd NC. The land cover mapping method and Activity Data, Gases, Pools and the EF used in the FRL and the Draft NIR (LULUCF/LAND) is similar. However, the NIR calculates emissions at 5 year intervals between 1990-2015. While the FRL is based on a 2002-2018 period with emissions calculated at 4 year intervals. Therefore activity data for the two processes is borrowed from the same set of time series data. However, the fact that different years are used and different intervals per epoch means that the emissions are not exactly the same
6a	Given that Kenya´s 3rd NC has not yet been submitted to the UNFCCC, could Kenya indicate in which areas is the current FREL consistent with the latest GHG inventory submitted with its second National Communication?	The 2nd NC was done in 2015 and was done by a consultant. The methods used in the 2nd NC are not consistent with the ongoing GHGI and/or the current FRL. The methods of the 2nd NC were determined by the Consultant

No.	Question	Response
		After the submission of the 2nd NC and the enactment of the Climate Change Act, Kenya embarked on developing aninstitution for GHGI. This is the institution that has agreed on the new AD and EF which have been used in this FRL Unfortunately, the GHGI for the 3rd NC has not been completed and Kenya did not submit the 3rd NC as expected. The team doing this FRL is also the team doing the GHGI for the FOLU sector and uses AD from the same pool of land cover change datasets and the same EF
6b	This follow-up question might relate to responses of 12, 13, and 14. While the NIR being prepared for 3rd NC is applying 5-year-interval between 1990-2015, the FRL is applying 4-year-interval between 2002-2018. Even though these are using the same set of time series data, it seems that these do not have consistency. Could Kenya further explain how these are consistent?	The GHGI adopted 5 year interval data because they wanted to monitor emission trends over a longer period for all sectors The FRL adopted a 4 year period because of the following reasons (1) The period before 2002 experienced different land and forest policy issues that cannot describe the recent historical trends of emissions in the forest sector. the period 2002-2018 allows us to use the historical emissions to project future emissions (2) We adopted a 4 year period because we hope to provide REDD+ results in the Biannual Update Reports which will be done on two year basis. The 4 year period can easily identify a mid year for reporting in the BUR (3) Kenya aims to provide a biannual land cover map after the year 2018. This is good for the FRL (4) Kenya would like to use latest mapping data which is

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		2018 for assessing the historical emissions? Therefore, last year used in the ongoing GHGI that is 2015 cannot fit well to the FRL time series analysis. Due to the UNFCCC guidance on the last inventory year in reporting of NC/BUR (4 year old data), there is a likelihoodthat the GHGI that will be used to do the 3rd NC and 1st BUR will be updated to the year 2020.This will fit well with our FRL projections of emissions beyond year 2018 In terms of Consistency between GHGI and FRL, (1) We have used AD from the same pool of land cover maps (We have 18 maps for the period 1990-2018). We have done utmost effort to ensure the land cover maps are consistent over time (2) We have used same EF (3) We have used same forest strata and same forest definitions/canopy classes
7	<Forest cover trend> Figure 4 on page 15 describes the trend of forest cover change from 2002 to 2018. The plot for 2010 seems to be an outlier among other data. Could Kenya provide further explanation for this outlier, if any?	We note that year 2010 is an outlier as shown in Figure 4. We have made considerations on the effect of this data on the overall trend of forest cover. Fortunately, Kenya has data for many years (time series land cover data) allowing us to understand the forest cover trend even in circumstances of such an outlier.Statistically 2010 is not an outlier. In addition, we note that the spike in the year 2010 map does not affect the FRL historical average which is developed based on data from 5 epochs; 2002-2006, 2006-2010, 2010-2014 and 2014 -2018. Exaggerated forest increases in the period 2006-2010 are moderated by the time series mapping

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<table>
<tr><th>No.</th><th>Question</th><th>Response</th></tr>
<tr><td>7a</td><td>We understand that the forest cover trend in 2010 is not an outlier statistically and it does not affect historical average, but still we would like to know some information behind the spike. Could Kenya provide further information on whether any actual events or issues occurred to bring the spike in 2010, if any?</td><td>The 2010 map was the first map to be developed in the time series mapping 1990-2010. It was therefore part of the system testing. This map was also developed at a time when another land cover map using a different satellite image (10m ALOS 1) had been developed.</td></tr>
<tr><td>7b</td><td>Does the response to 7a mean that the spike in 2010 attributes to technical issue of map development and usage of a different satellite image?</td><td>The spike illustrates the influence of another existing map on the new map that is being developed. Technical errors may arise because technicians doing the map already have a prior knowledge of the expected product. This was a learning lesson in our mapping process. Fortunately the other maps in the time series are not affected by this influence</td></tr>
<tr><td>8</td><td><Canopy closure class>
On page 15 line 15, classes of canopy closure are defined. Could Kenya explain how these numbers are applied? Does any reference exist?</td><td>These numbers are based on Kenya’s definition of forest and are illustrated in the Forest mapping manual which has been provided.
Kenya has three forest categories
1. Open forest - 15-40 % canopy closure
2. Medium forest - 40-65 % canopy closure
3. Dense forest – above 65 % canopy closure
Please refer to the Appendix 3 of the mapping manual providedto the reviewers. This manual explains Kenya’s definition of forest and how the different canopy strata are identified and how they are mapped</td></tr>
<tr><td>8a</td><td>Thanks to the Appendix 3 of the mapping manual, we understand how canopy closure is measured, but could Kenya provide the rationale of applying the border numbers; 15%, 40%, and 65%?</td><td>The random forests algorithm was used for Kenya’s land cover mapping. A rigorous selection of adequate training sites for mapping and a rigorous QA/QC procedure ensured proper mapping of forest canopies in the three classes
1. Open forest - 15-40 % canopy closure
2. Medium forest - 40-65 % canopy closure
3. Dense forest – above 65 % canopy closure</td></tr>
</table>

No.	Question	Response
		However, the Accuracy of getting 15% or 40% or 65% is relative. This implies 40% can also be in the range of 38%-42%
8b	Based on the technical exchange on June 10, it seems that deciding 15% as a minimum thresholds has some rationale, which will be included in modified submission, however could Kenya further explain how the thresholds 40% and 65% are decided?	The thresholds 40% and 65% were considered based on studies that show that forest canopy closure in natural forests influences forest biomass/Carbon stocking, for example Kinyanjui et al 2014 (https://www.scirp.org/pdf/OJE_2014072215163971.pdf) and Glenday 2008 (https://bioone.org/journals/Journal-of-East-African-Natural-History/volume-97/issue-2/0012-8317-97.2.207/Carbon-Storage-and-Carbon-Emission-Offset-Potential-in-an-African/10.2982/0012-8317-97.2.207.short) Kinyanjui et al 2014 (https://www.scirp.org/pdf/OJE_2014072215163971.pdf) was the pilot study done by KFS with support from JICA to test the effectiveness of the 3 canopy classes. It was assumed that any forest whose canopy is more than 65% is dense and 40% is a middle point between 15% and 65% Noting that Kenya has decided to use remote sensing data (from the land cover and land cover change maps) to assess forest degradation, three canopy classes were determined as having different Biomass stocks. Therefore different EF would be applied for each Canopy class. The pilot inventory data described in this FRL confirmed that biomass stocks differ in the three different canopy classes in

No.	Question	Response
		each of the three strata of forests
8c	Past studies shown in the response to 8b does not contain the reason why 40% and 65% are thresholds for canopy closure. The study by Kinyanjui et al in 2014 is just testing the effectiveness of 40% and 65%, not explaining why they set 40% and 65% as thresholds. Since the study by Glendy in 2008 is available only its abstract for free, it is hard to regard this study as the clear response to 8b. Could Kenya further explain why 40% and 65% are chosen as thresholds for canopy cover?	The initial decision to classify forests under the three forest categories were based on the Land Cover Classification system of AFRCOVER mapping done by the FAO as explained in Question 1a above. The LCCS manual used in the AFRICOVEr mapping identified the range for i. Closed vegetation (more than 60-70 percent) – We adopted the middle value which is 65% ii. Open vegetation (70-60 percent to 40 percent) iii. Very open vegetation (40 percent to 20-10 percent)– we identified the mid point of the lower limit which is 15%referring to answer of Q 1a. iv. We identified closed vegetation as dense forest, open vegetation as moderate forest and very open vegetation as open forest.
9	<Perennial tree crops> On page 16 of the FREL submission, Kenya points out that “Perennial tree crops like coffee and tea are not considered as forests under this definition irrespective of whether they meet the definition of forests”. Could Kenya please explain how areas covered by these tree crops were distinguished and deducted from forested areas?	The mapping of land cover classes using the Random forest algorithm was done based on small zones classified by Agro-ecological zonation defined in the mapping manual as Spectral Stratification Zones. The small zones were then merged to form the national map. Within each zone perennial cropping areas are known and were therefore isolated from forests. The stratification method is explained in Annex 1 Methodology for Land Cover / Land Use Mapping page 77 of the FRL
10	<Temporarily unstocked areas>	Temporarily un-stocked areas would refer to areas within

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	Could Kenya please explain the approach followed to distinguish temporarily unstocked areas from deforested areas?	plantation areas (of which there are known boundaries of state forest plantations managed by Kenya Forest Service) that have been harvested and are as such un-stocked and awaiting to be replanted. Deforested areas are found in the three other forest strata (montane &Western rainforest,Mangrove&coastalforestsanddry land forests). Here deforestation refers to the conversion of a forest into a non-forest at any one mapping instance. Since our mapping is automated, all land cover changes from forestland to non-forestland (based on mapping classes), in the 4-year interval (between two mapping instances) could be treated as deforestation despite their management or tenure system.
10a	With regards to the yellow highlighting in Kenya's response to question 10, what measures has Kenya taken to avoid overestimating emissions due to temporarily unstocked forest areas that may be considered as deforested, based on the above response?	We do not have areas that are defined as temporary unstocked However, these areas may occur in public plantation forests and the answer to this question can be found in the response given in 4a and 4b above
11	<Application of SMF> In Table 3 on page 21, land conversion from plantation forest to non-forest is classified as SMF in blue colour. Could Kenya provide further detail of why this classification is not forest degradation, but SMF?	It is Sustainable Management of Forests because they have been cleared as part of plantation forest management and the areas are to be restocked to revert to plantations. In Kenya's, plantation management history, mature forests were harvestedbut some of the areas have remained for long without replanting resulting in temporary un-stocked non-forest areas or backlogs (forest plantation areas without trees yet to be replanted). This, however, falls under Sustainable Management of Forests. Asa REDD+ activity, SMF aims at making sure that in future all harvested areas will be replanted immediately.

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11a	Does Kenya´s response imply that cleared areas within the boundaries of state forest plantations are not considered as deforestation, and therefore their emissions are not included in the FREL? Or how are such emissions taken into account?	These emissions are taken into account under the SMF and in the excel file provided, their calculations are indicated by a blue coloured section
11b	According to the response, some plantation areas will not be replanted for long time after harvesting. Could Kenya provide the information on some examples of the length of the no-replanting-period? Like in minimum, maximum, and average? During the no-replanting-period, are these areas just left alone without any management?	Some plantation areas were not replanted for a long time because of a non existing management plan in these areas and some policy changes in the forest sector. We do not want to continue with this error/mistake of plantation management under the SMF REDD+ activity, we want to correct this error/mistake and ensure all areas that were not planted get planted. The current system of forest management in areas designated as public plantations is as follows 1. Trees are harvested when mature 2. The harvested areas are allocated to Forest adjacent communities to cultivate/till and plant crops 3. In the 2nd year of cultivating, the communities help the government to afforest these areas using exotic timber species 4. The planted trees grow together with crops in the 2nd and 3rd year of farming and as trees grow big, the communities stop cultivating by the 4th year Using annual or biannual mapping, the transition of forests into croplands after harvesting is noted and the regrowth of forests after afforestation is noted. All this is accounted under SMF
12	<Consistency with GHG inventory> It is not clear by the information contained in the submission if Kenya´s FREL is fully consistent with its latest National GHG	Kenya has not yet submitted the 3rd NC to the UNFCCC. We are in the process of developing the NIR which will form the GHG section of the 3rd NC. The land cover mapping method and

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	inventory. For instance, on page 22 of the submission, it is stated that “the National Inventory Report for Kenya’s 3rd NC has adopted the period 1995 – 2015 due to availability of data from other sectors while the FRL has adopted the period 2002 – 2018 to capture the period of implementation of recent forest sector policy decisions”. Could Kenya please clarify if full consistency exists between both documents?	Activity Data, Gases, Pools and the EF used in the FRL and the Draft NIR (LULUCF/LAND) is similar. However, the NIR calculates emissions at 5 year intervals between 1990-2015. While the FRL is based on a 2002-2018 period with emissions calculated at 4 year intervals. Therefore activity data for the two processes is borrowed from the same set of time series data. However, the fact that different years are used and different intervals per epoch means that the emissions are not exactly the same
12a	This follow-up question might relate to responses of 6, 13, and 14. While the NIR being prepared for 3rd NC is applying 5-year-interval between 1990-2015, the FRL is applying 4-year-interval between 2002-2018. Even though these are using the same set of time series data, it seems that these do not have consistency. Could Kenya further explain how these are consistent?	Please see response 6b above
13	It is not clear by the information contained in the FREL submission if the pools and GHG considered in it are consistent with those included in the national GHG emissions inventory. Could Kenya please confirm is this is the case?	This question is related to no 12 above Kenya has not yet submitted the 3rd NC to the UNFCCC. We are in the process of developing the NIR which will form the GHG section of the 3rd NC. The land cover mapping method and Activity Data, Gases, Pools and the EF used in the FRL and the Draft NIR (LULUCF/LAND) is similar. However, the NIR calculates emissions at 5 year intervals between 1990-2015. While the FRL is based on a 2002-2018 period with emissions calculated at 4 year intervals. Therefore activity data for the two processes is borrowed from the same set of time series data. However, the fact that different years are used and different intervals per epoch means that the emissions are not exactly the same
13a	This follow-up question might relate to responses of 6, 12 and 14.	Please see response 6b above

No.	Question	Response
	While the NIR being prepared for 3rd NC is applying 5-year-interval between 1990-2015, the FRL is applying 4-year-interval between 2002-2018. Even though these are using the same set of time series data, it seems that these do not have consistency. Could Kenya further explain how these are consistent?	
14	Could Kenya please clarify if the activity data, emission factors, methods and Tiers used for the construction of the FREL are the same as those applied for the development of the national GHG inventory?	This question is related to no 12 and 13 above Kenya has not yet submitted the 3rd NC to the UNFCCC. We are in the process of developing the NIR which will form the GHG section of the 3rd NC. The land cover mapping method and Activity Data, Gases, Pools and the EF used in the FRL and the Draft NIR (LULUCF/LAND) is similar. However, the NIR calculates emissions at 5 year intervals between 1990-2015. While the FRL is based on a 2002-2018 period with emissions calculated at 4 year intervals. Therefore activity data for the two processes is borrowed from the same set of time series data. However, the fact that different years are used and different intervals per epoch means that the emissions are not exactly the same
14a	This follow-up question might relate to responses of 6, 12, and 13. While the NIR being prepared for 3rd NC is applying 5-year-interval between 1990-2015, the FRL is applying 4-year-interval between 2002-2018. Even though these are using the same set of time series data, it seems that these do not have consistency. Could Kenya further explain how these are consistent?	Please see response 6b above
15	<Remaining forestland> On page 20 line 22, it is explained that any carbon stock changes do not occur in forestlands remaining forestland in specific strata/ ecozones in 4 years. Is this because of lack of data? If so, is it possible to include this point as future improvement?	Please note the statement in line 23 "***Which were mapped with a canopy remaining in the same canopy level in the two mapping years (e.g. 2002 and 2006)***."

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		Note that Kenya's GHG inventory relies on changes in land cover based on satellite imagery. This is because Kenya does not have enough Permanent sample plots to provide periodic data on forest changes. Therefore areas mapped under the same canopy class between two years are assumed to have maintained the same stock. We expect that once the PSP design is implemented, an improvement of this estimates will be made in future
16	<Carbon fraction> On page 32 of the FREL submission, Kenya states that “Forest biomass calculated as the sum of AGB and BGB was converted into Carbon using the IPCC carbon fraction of 0.47”. Could Kenya please explain why it didn´t use specific CF for each type of forest?	Kenya has not developed carbon fraction for any of the forest types and so it was decided to use the default IPCC value for all the forest types. One of the challenges for this is that there are different forest types with different tree species in Kenya and coming up with carbon fractions for each would be costly and time consuming. This can, however, be an area of future improvement.
17	<EF for canopy enhancement> While the “>=20yr” is applied for AGB value of canopy enhancement on the basis that “these are already grown forests” on page 33 line 17, page 33 line 15 explains the EFs for enhancement “where a canopy improvement was noted”. Could Kenya provide further explanation that a canopy improvement could occur even in grown forests, and how it was measured?	This question is related to question 5 aboveand also question 15 above In calculating enhancement of carbon stocks, we have two classes of enhancement 1. Enhancement of carbon stocks due to planting of trees/afforestation in areas where a non forest converts into a forest land. In this case we use the IPCC growth factor for trees less than 20 years 2. Enhancement of Carbon stocks due to improvement of canopy where an inferior canopy in year 1 converts to a superior canopy in year 2 (e.g. open forest in year 2002 converting to dense forest in year 2006). In this case we use the IPCC growth factor for tree >=20yr
17a	From the response, we understand that afforestation applies IPCC	Our system of mapping does not monitor a single land unit over

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	growth factor less than 20yr and canopy improvement applies growth factor >=20yr. Does this mean that an area where afforestation happens in epoch 1 and canopy improvement is observed in epoch 2 applies growth factor >=20yr in epoch2?	time. We map cumulative areas that changed at each epoch. S we cannot tell the specific land areas that were immediately converted into forests in the previous land cover change epoch We assume land areas that converted from non-forests into forests in a specific mapping epoch are young forests and apply the IPCC growth factor for less than 20yrs We assume that land areas that were already forests but improved from an inferior canopy class to a superior canopy class (e.g. open forest converted to a dense forest) are mature forests and use the IPCC growth factor for greater than 20 years Kenya's vision for developing many land cover maps under the SLEEK programme was to ensure a pixel based monitoring approach where a land unit is monitored over time and historical changes occurring in this unit used to calculate emissions. However, this vision is still in the pipeline and we hope to use it sometime in future
17b	Following up on the previous responses, could Kenya please explain how does it avoid overestimating the carbon stocks in forests when it applies the growth rates? In other words, how is it determined that a forest area has already reached its maximum carbon stock, so as to stop applying the growth rate to it?	In page 38 of the submission (3.2.3. Generating Emission factors from land use transitions), number 3 (a) explains how capping was done to reduce over estimation of Carbon stocks due to growth. The same is explained in page 39 number 4(b) When a growth rate was applied and the Carbon content of the growing forest exceeded the Carbon stock of such a forest (based on inventory data), then the maximum carbon stock of that specific forest was assumed to be the stock factor of the

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		forest (based on inventory data). An illustration of this is shown in cells AE16:AE19 of the excel spreadsheet 2014-2018
18	<Post-deforestation land use> On page 33 of the submission, Kenya explains that "In conversions of forests into non-forests, the Carbons stocks were assumed to go through immediate oxidation and IPCC 2006 guidelines used for Tier 1 default factors calculating stock changes". Does this mean that Kenya used default factors for post-deforestation land uses?	That is correct. This is because Kenya has no data on harvested wood products. We have assumed that all deforestation results to immediate emissions This is an area for future improvement and capacity building because it could result to an exaggeration of emissions especially when such wood is used for construction purposes. In the revised version of the FRL, we will correct the wording to make this clear
19	<Emissions from land use change> On page 41 para 2, a general explanation for emission factor in Table 19 is described briefly. Is it possible for Kenya to provide some explanation on Tables 20 to 23 on page 41 para 2 additionally?	Paragraph 2 on page 41 is misplaced and we will correct. It belongs to the previous section The description of emissions is detailed in section 4.2 for each REDD+ activity. We will add after paragraph 1 statements as follows "a detailed description of these tables is illustrated in section 4.2 for each REDD+ activity….." In the Revised FRL document, we will give an explanation of each table separately
20	<Data> Calculated emissions and sinks from REDD+ activities are shown in Tables 20 to 23. While numbers in cells are supposed to be products of AD and EF, they seem to be slightly different; for example, the product of canopy improvement in Dryland Forest from moderate to dense in the 2002-2006 epoch in Table 4, 107,414 (ha), and corresponded EF in Table 19, -15.88 (tonnes carbon/ha/4yr), should be -1,705,734 (tonnes carbon/4yr), but the reported result in Table	The spreadsheets will be provided to confirm the numbers. Note that the only Difference is due to EF decimal point reduction (round off) to 2dp during calculations. Therefore, the correct figure is-15.88224. The resultant table 20 and others were calculated directly using the initial value in the spreadsheets to be provided. The spreadsheets will, however, be provided to confirm the numbers.

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	20 is -1,705,968 (tonnes carbon/4yr). This kind of slight difference could be observed in many cells. For the purpose of reproduction by AT, could Kenya provide **all spreadsheets** for AD, EF, and calculated emissions and sinks?	Moreover, the FRL document would be revised and amended by explaining on the treatment of numbers, on round off of decimal points, on the tables so that the calculations can be well understood
20a	Could Kenya please provide the spreadsheet with the FREL calculations mentioned above in the response to question 20?	Spreadsheet has been provided. It is the one used in your question in 2b below
20b	We understand that the difference in the product might come from decimal point reduction. Still, the product from accurate EF, -15.88224, and forest area, 107,414 would be -1,705,974.93 slightly different from reported -1,705,968. Could Kenya provide all spreadsheets?	These must be very minor Random errors
21	<Exclusion of pools and gases> Could Kenya please explain what criteria was applied to determine that an excluded pool or GHG was not significant?	There is little or no research information on these pools and gases in Kenya. Expert judgement indicates that the non-prioritised pools are stable and have minimal changes This has been identified as an issue for future improvement and a need for capacity building.
22	<Clarification of expression> Could the description on page 46 line 13, “a dip in emissions in the year 2010” be corrected to “a dip in emissions in the period 2006 to 2010”?	That is correct. The sentence will be duly corrected
23	<Clarification for “minimal decline”> On page 51 line 7, Kenya describes attainment of a minimal decline in emissions from the forest sector. Could Kenya provide further explanation to use the expression of “minimal”? Is it possible for Kenya to provide quantitative analysis of contribution of associated activities?	The word minimal here is based on the trend from 2002-2018 and classified into mapping 5 epochs Note that this decline is identified based on a 4 point regression line (Figure 12). In section 6.1. page 61, Kenya explains that a 4 point regression line cannot be used to describe a trend. Therefore the word minimal is just qualitatively used and no

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		number should be associated to this decline because the justification to describe the decline (The strength of the regression line) is weak. In projecting the FRL, Kenya has decided to use a historical average
24	<Population increase rate> It seems that population growth closely relates to deforestation in Kenya. On page 60 line 2, population growth projection is explained as 2.5% in 2018. If this rate is projected to continue in the future, could Kenya provide any reference for the projection?	The population projection used here is based on UN projections We will revise this based on results of the recently release 2019 census report which gives an intercensul growth rate of 2.2% and a 2019 population of 47.6 Million in 2019 https://www.knbs.or.ke/?p=5621
24a	It is appreciated to show the reference for population growth rate and further provide the updated rate, 2.2%. Is this rate, 2.2%, similar to one from 2002 to 2018?	Note that this growth rate is used in projecting Kenya's population into the future. So we use the current growth rate (2.2%) provided by the Kenya bureau of Statistics
25	<Weak coefficient of determination> On page 61 line 11, it is explained that Kenya adopted an average of the historical emissions because the developed linear relationship had a weak coefficient of determination. Where options other than using the average considered for addressing the missing linear relationship?	With a weak regression line based on 4 points, our best option was a historical average Based on best practices elsewhere
26	<Ancillary data for sub categorization of species> On page 81 line 13, it is described that ancillary data will be used for sub categorization by species. Could Kenya provide further information on what this ancillary data is and how it is used?	The correct position is that no categorization of the public plantation has been done in the mapping described in this FRL. We will duly correct this information in the Revised FRL document. However for purposes of local planning and decision making, this is a proposed activity to supplement ground data records so that Kenya's mapping programme can be used to estimate and characterise species performance in the plantations
26a	From the main part of the submission, the forest strata, Plantation	Page 81 is an annex and we willcorrect the definition of forest

No.	Question	Response
	forest land seems to be limited to public forest, however, on page 81 line10, the plantation in private forest is implied. Does the forest strata, Plantation forest land, include both public and private forest?	plantations used here to harmonize with the one used in the main document of the FREL , e.g. page 7 (Identification of REDD+ Activities). Meanwhile, Plantation in REDD+ is currently only for public plantation and applies to SMF only About plantation forests growing in private farms, our response is that we have no capacity at present to differentiate plantation forests growing in private lands from other forests growing in the same private lands. We also do not have proper information on the tree planting objectives of farmers who plant trees in private farms (on farm tree planting). We have therefore used same EF for activity data occurring in areas outside public plantation areas for each of the three strata 1. Coastal &Mangrove forests 2. Dryland forests 3. Montane forests
27	In the spreadsheet provided, each period sheet contains total area in 4 forest strata in B103-E103. It is assumed that the sum of 4 forest strata in B103-E103 is supposed to be identical the sum of land use matrix (H3-X19), but the former is larger than the latter in each period. Could Kenya explain how this difference occurs?	Yes, the sum of land cover (not forest strata) indicated in B103-E103 is the total national area of Kenya which gives a sum of 59,202,479.07 ha. However, the sum of the land cover change matrix (K6:X19) is the sum of land cover changes that relate to the forest sector only. These are conversion that involves changes from a forest to a non-forest or a non-forest changing into a forest. Land cover changes from non-forest to non-forest are not included in land use matrix (H3-X19), for example, conversion of Annual croplands to non-forests (e.g. A66:A72) or change or water body to a non-forest (A88:A92) etc. are not included.This is why the sum of the land cover (forest sector related area - H3-X19) change matrix is different from the national area- B103-E103

No.	Question	Response
28	While the EF for deforestation to grassland applies the wooded grassland, 14.99, instead of open grassland, 6.95, the EF for deforestation to cropland applies the annual cropland, 0, instead of perennial cropland, 89.47. Could Kenya explain why the higher value applies for DF to GL and the lower value applies for DF to CL?	Grasslands comprise a large area of land cover classes. Many of these grasslands comprise a lot of woody material as illustrated in previous land cover mapping programmes e.g. the AFRICOVER map identifies several classes of woody grasslands including shrublands, thickets and savannah grasslands. Our decision is therefore influenced by knowledge that grasslands of Kenya comprise significant Carbon which cannot be equated to zero. However, lack of consistent data on the carbon content of the Croplands resulted to our use of an IPCC default value. This is a conservative value that may not be biased in cases where we do not have an accurate value locally. In case we access recent literature that can capture Carbon contents of croplands of Kenya's consistently, then we are ready to revise this EF and update it appropriately.
29	Tables 4-7 show that some area of cropland and grassland convert to dense and moderate forests, but is this kind of conversion possible in 4 years?	Yes it is possible. Primary colonising tree species like *Neoboutoniamacrocalyx* and fast growing exotic species like the Eucalypts will rapidly create a dense canopy and can convert a cropland into a dense forest in 4 years. Please note that this kind of conversion applied a growth factor to estimate carbon stock of the dense forest after 4 years (check spreadsheets e.g. AC16, AF16, AI16)
30	When cropland is converted to open montane forests, a removal factor of -43.23 applies. When open montane forests are converted to croplands, an emission factor of 43.23 applies. Does that mean that Kenya assumes the open montane forest newly growing on former cropland will reach full biomass after 4 years of growth?	The EF from cropland, alsowetland and settlement) to Mountain Open Forest is -43.23 YES THIS IS CORRECT as shown in cellAE16.This is the maximum value of stock gained by a forest that has grown from zero using the IPCC defaultgrowth factor (Please refer to our

No.	Question	Response
		response to question 31 below). Please refer 3.2.3. 3 a on page 38 in the FRL submission. When open montane forests are converted to croplands, an emission factor of 43.23 applies. THIS IS CORRECT as illustrated in cell AM8 because we assumed all the emissions due to this deforestation activity are released to the atmosphere Does that mean that Kenya assumes the open montane forest newly growing on former cropland will reach full biomass after 4 years of growth? PLEASE CHECK ANSWER FOR QUESTION 29
30a	Is Kenya applying capping to the EF of conversion from cropland to open forest in Montane & Western Rain Forest? Is this because carbon emission from conversion from open forest to cropland, 43.23, is lower than carbon stock from growth factor in Montane & Western Rain Forest, 94.44? Is this an only area where capping is applied?	The answer is Yes. The response to this question is also provided in 17b above Capping was mainly applied for conversions where growth rates exceed the carbon stocks of the resultant land cover category Cropland into open forest (Cell AE16) Grassland into open forests(Cell AE17) Wetlands into open forests(Cell AE18) Settlements/otherlands into open forests(Cell AE19)
31	There is a table that is the basis of the growth calculation in the Excel sheet, cells AH35-AJ38. Can Kenya please explain the values, and where these were taken from? Also, can Kenya please explain the multiplication factors used in cells AI25 to AJ28? (1.27 for Montane and Plantation, 1.28 for Dryland, and 1.2 for Coastal)	Cells AH35-AJ38 illustrate use of growth factors (AGB based on IPCC defaults) for calculating Carbon sequestration from afforestation (Table 17 page 36 of the FRL which I have also attached below). These growth factors were used for calculating carbon sequestration by young forests (Less than 20 years) based on IPCC guidance shown in Table 17

No.	Question	Response
		The source of each factor is explained in Table 17 in the FRL and also shown below In cells AI25 to AJ28? a multiplication of the IPCC AGB default values indicated in cells AI35-AJ38 with a below ground default factor for the various types of forests in Kenya is used (1.27 for Montane and Plantation, 1.28 for Dryland, and 1.2 for Coastal). The Source of each factor is explained in table 16 (page 36) of the FRL Noting that the BGB values do not differ significantly, and do not influence much variation in the overall FRL value, we request guidance on whether we should use a single factor to reduce complications of illustrating calculations. This is an item that we would like to prioritise for research to enhance the accuracy of estimating the forest sector emissions
32	Stock change vs gain loss method On page 81 of the submission it is stated that "The FRL has been developed using a gain loss method that uses land cover changes to inform changes in the forest stocks". However, on page 49 Kenya notes that "A stock change method was applied and the EF calculated as the difference between the CO2 value of the previous non-forest to the CO2 value of a plantation based on growth rate (Table 16)", and in general, the approach described in the submission seems to be a stock change method. Could Kenya please clarify which method did it use for estimating the FREL?	Our calculation is largely guided by land cover change processes making it a gain loss method. It is about processes of gain or loss which are determined by land cover change processes. The amount/volume of gain or loss is determined by the stocks of carbon in each kind of forest We request your guidance on this so that we can harmonise wordings in the resubmitted FRL. Please explain whether this is a gain loss approach or a stock change approach
33	Post-deforestation carbon stocks On page 33 of the submission, Kenya states that "In conversions of forests into non-forests, the Carbons stocks were assumed to go through immediate oxidation and IPCC 2006 guidelines used for Tier 1 default factors calculating stock changes". Does this imply that default factors were used for post-deforestation carbon stocks?	We have not calculated Post deforestation carbon stocks. We request whether there is a unified definition and methodology for calculating post deforestation carbon stocks. Wet have assumed that all emissions arising from

No.	Question	Response
		deforestation, forest degradation and tree harvesting in public plantation is immediately released into the atmosphere We wish to explore opportunities of calculating post deforestation carbon stocks using default factors in our revised FRL

Table 1: Emission factors for calculating forest growth due to afforestation

Forest strata	Biomass gain (Tonnes/ha)			Carbon from Biomass	CO_2 sequestered (Tonnes/ha)		Reference AGB value from IPCC V4.4
	AGB value	BGB[1]	Total		One year	4 years	
Montane and Western rain	10	3.70	13.70	6.44	23.61	94.44	Table 4.9 for Africa tropical rain forests for forests <20 yrs
Dryland	2.4	0.67	3.07	1.44	5.29	21.16	Table 4.9 for Africa tropical dry forests for forests< 20 yrs
Coastal and Mangrove	5	1.00	6.00	2.82	10.34	41.36	Table 4.9 for Africa tropical moist deciduous forests for forests < 20 yrs
Public Plantation	10	2.70	12.70	5.97	21.89	87.56	Table 4.10 for Africa Tropical mountain systems plantation forests

[1] EF used as in table 16 for shoot/root rations

Table 2: Specific Shoot/Root ratios for the different strata

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

Republic of Kenya

Ministry of Environment and Forestry

The National Forest Reference Level for REDD+ Implementation

August 2020

FOREWORD

Kenya is committed to participate in the Global climate change mitigation actions. We have submitted our Nationally Determined Contributions targets which aim to reduce National emissions by 30% and are in the process of updating our NDC based on current national circumstances. We have identified the forest sector as the main source of emission reductions with the hope of converting it from its current status of being a net emitter into a net sink. Guided by our Vision 2030 target of a minimum10% forest cover, Kenya has embarked on a number of forest restoration activities including committing to plant 5,000,000 trees under the Bonn Challenge and identification of an area of 5.1 million ha that has potential for tree based restoration.

Our commitment to participate in REDD+ is beyond doubt. After developing the REDD+ Proposal in the year 2012, we noted a need to enhance stakeholder involvement in the REDD+ process which slowed our submission of the relevant documents. Today we are in the process of developing the relevant tools required for REDD+ namely the National REDD+ Strategy (NRS), the Safeguard Information System (SIS), The National Forest Monitoring System (NFMS) and now submitted the Forest Reference Level (FRL).

The submission of this FRL is evidence enough that Kenya has capacity and is committed to monitor its forest resources which not only supports international reporting but is important for our national and local decision making processes. We note in this report some technological and data limitations but hope that a stepwise improvement programme will enhance the accuracy of our reporting and avail time series information that will inform policy implementation in the conservation of forests, natural resources and Climate change action plans.

The submission of this FRL sets the pace for Kenya to finalise on the other REDD+ related documents in readiness to participate in results based payment programmes as described by the Warsaw Framework on REDD+

DR. CHRIS K. KIPTOO, CBS
PRINCIPAL SECRETARY
MINISTRY OF ENVIRONMENT AND FORESTRY

ACKNOWLEDGEMENTS

I wish to appreciate the efforts that have been put towards the development of this document. Firstly I appreciate the support provided by the Japan International Cooperation Agency (JICA) under the Capacity Development Project for Sustainable Forest Management in the Republic of Kenya. This is the project that has sourced information and analysed data used to develop the FRL, and organized Technical Working Group meetings to review and improve the FRL document. Complementary to this, the System for Land based Emission Estimation for Kenya (SLEEK), housed at the Ministry of Environment and Forestry has mobilized resources to support development of a time series data set of land cover maps which provided land cover change information for this report. Specifically I appreciate the working relationship created by the Department of Resource Surveys and Remote Sensing (DRSRS) and the Kenya Forest Service (KFS) in ensuring the sustainability of the Mapping programme.

I appreciate the coordination and guidance provided by the Climate Change Response and REDD+ Coordination office of the Kenya Forest Service who engaged international experts (Food and Agriculture Organization of the United Nations, The Mullion Group, the Green House Gas Management Institute and The Coalition of Rainforest Nations) to provide comments and guidance. I also note the active participation of members from various institutions who have supported the completion of this assignment. Specifically I note the participation of Karatina University, Dedan Kimathi University, Jomo Kenyatta University of Agriculture and Technology, the Department of Resource Surveys and Remote Sensing, Kenya Forest Service, Conservation International, The Regional Centre for Mapping Resources for Development and the Ministry of Agriculture. I also appreciate the support of the stakeholder team that put the Technical team on its toes ensuring that the final product describes Kenya's historical emissions

With this kind of collaboration, I believe that we can enhance the conservation and monitoring of our forest resources in Kenya.

ALFRED N. GICHU,
HEAD: DIRECTORATE OF FOREST CONSERVATION;
NATIONAL REDD+ COORDINATOR & FOCAL POINT,
MINISTRY OF ENVIRONMENT & FORESTRY.

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AD	Activity Data
AGB	Above Ground Biomass
BGB	Below Ground Biomass
CBD	Convention on Biological Diversity
CF	Carbon Fraction
CO_2	Carbon Dioxide
EF	Emission Factor
EMCA	environmental Management and Conservation Act
FAO	Food and Agriculture Organization of the United Nations
FLEGT	Forest Law Enforcement, Governance and Trade
FPP	Forest Preservation Program
FRA	Forest Resources Assessment
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
GFOI MGD	Global Forest Observation Initiative Methods and Guidance Document
GHG	Green House Gases
IPCC	Intergovernmental Panel on Climate Change
ITTA	International Tropical Timber Agreement
JICA	Japan International Cooperation Agency
KEFRI	Kenya Forestry Research Institute
KFS	Kenya Forest Service
LAPSSET	Lamu Port South Sudan Ethiopia Transport Corridor
LCC	Land Cover Change Mapping
LCCS	Land Cover Classification System
MEF	Ministry of Environment and Forestry
MMU	Minimum Mapping Unit
NCCRS	National Climate Change Response Strategy
NDC	Nationally Determined Contribution
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NIR	National Inventory Report
NRS	National REDD+ Strategy
REDD+	Reducing Emissions from Deforestation and Forest Degradation, and the role of Conservation, Sustainable management of forests and Enhancement of forest

	carbon stock.
SDG	Sustainable Development Goals
SIS	Safeguard Information System
SLEEK	System for Land-based Emissions Estimation in Kenya
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change

EXECUTIVE SUMMARY

Kenya is a low forest cover country with a total forest area of 3,462,536 ha or about 5.9% of the total national area. The government of Kenya has a goal of enhancing forest cover to a minimum of 10 % of the National area by 2030. As a party to the UNFCCC, Kenya has committed to contribute to Global climate change mitigation and adaptation and has submitted its Nationally Determined Contribution (NDC) in line with the requirements of the Paris Climate change Agreement. The forest sector was identified as key to the realization of the national goals due to its comparatively high abatement potential. Based on data collected as part of this process, deforestation in the country is estimated at103,368 ha per year (0.17% of the national area) but conservation efforts achieve about 90,477ha of reforestation annually (0.15% of national area).

Kenya is establishing a Forest Reference Level(FRL) for REDD+to;1) exploit opportunities for reducing current emissions arising from deforestation and forest degradation, and 2) take advantage of opportunities for enhancement of carbon stock arising from afforestation, reforestation and restoration of degraded forest areas. The various building blocks for establishing the FRL were comprehensively discussed and agreed by a Technical Working Group that was established purposely to offer technical guidance for FRL development. An overview of the decisions is as follows:

- Forest definition: a minimum 15% canopy cover; minimum land area of 0.5 ha and minimum height of 2 meters.
- Scale: National
- Scope: REDD+ Activities include Reducing emissions from deforestation, Reducing emissions from forest degradation, Sustainable management of forest and Enhancement of forest carbon stocks.;
- Gases: covers only CO_2.
- Pools: Above Ground Biomass (AGB) and Below Ground Biomass (BGB).
- Reference period: 2002-2018
- Construction method: Historical Average of emissions and removals between 2002 and 2018, monitored at 4 year intervals

Using an approach 3 mapping and a combination of local and IPCC defaults, Kenya proposes a FRLof52,204,059 t CO_2/year. This FRL is derived from average annual historical emissions from deforestation, forest degradation, sustainable management of forests, and enhancement of forest carbon stocks in the period 2002-2018 monitored at 4 year intervals. The FRL for each of the REDD+ Activities has been calculated as 48,166,940 t CO_2/year for Deforestation, 10,885,950 t CO_2/year for forest degradation, 2,681,433 t CO_2/year for sustainable management of forests and -9,530,264 t CO_2/year for enhancement of carbon stocks.

Based on national circumstances, the projected future Emissions are based on an extrapolation of the average trend from the historical analysis for the net Emissions and for each of the REDD+ Activities. Since Kenya is in the process of developing a National REDD+ Strategy, the FRL provides an opportunity to monitor emission reductions based on the proposed Policies and Measures and their specific interventions.

The FRL process identifies a number of improvements for the future which include; enhancing the land cover mapping process to improve accuracy of Activity data, implementing an NFI to improve on Emission Factors and research to capture the variety of non CO_2 emissions from REDD+ activities and involve more pools.

1. INTRODUCTION

1.1. Relevance

In response to UNFCCC decision 1/CP.16 paragraph 71 (b) and decision 12/CP.17 paragraph 8 and 10, Kenya wishes to voluntarily submit to the United Nations Framework Convention on Climate Change (UNFCCC) the proposed National Forest Reference Level (FRL) for contribution to mitigation actions in the forest sector. In this context, this submission is premised on the consideration that the submission is subject to a technical assessment in accordance with decision 13/CP.19; decision 14/CP.19; and decision 12/CP.17. In preparing the FRL, Kenya has used a stepwise approach consistent with decision 12/CP.19; on the modalities for FRLs and FRELs; including the right to make adjustments to the proposed FRLs/FRELs based on national circumstances. This stepwise approach is strongly informed by availability of data, financial resources and capacities within the country for establishing the FRL.

1.2. The National Context

1.2.1. Country Profile

Kenya is one of the East African countries lying across the equator at latitude of 4° North to 4° South and Longitude 34° East to 41° East. The country is bordered by South Sudan and Ethiopia in the north, Somalia to the east, Indian Ocean to the south-east, Tanzania to the south and Uganda to the west (Fig. 1). The country has a total area of 592,038. km^2 including 13,400 km^2 of inland water and a 536km coastline.

Kenya’s geography is diverse and varied. The terrain gradually changes from the low-lying coastal plains to the Kenyan highlands reaching a peak of 5,199m above sea level at Mt Kenya. The Great Rift Valley located in the central and western part of the country basically dissects the Kenyan highlands into east and west. Further west, the altitude decreases towards Lake Victoria while northwards, there are vast drylands which are gradually being colonized to support livelihoods for the pastoralist communities and game ranchers. Kenya has six drainage patterns based on the direction of the waters and the majority of inland water bodies are found in the Rift Valley.

Kenya is divided into seven agro-climatic zones ranging from humid to very arid. Less than 20% of the land is suitable for cultivation, of which only 12% is classified as high potential (adequate rainfall) agricultural land and about 8% is medium potential land. The rest of the land is arid or semi-arid.

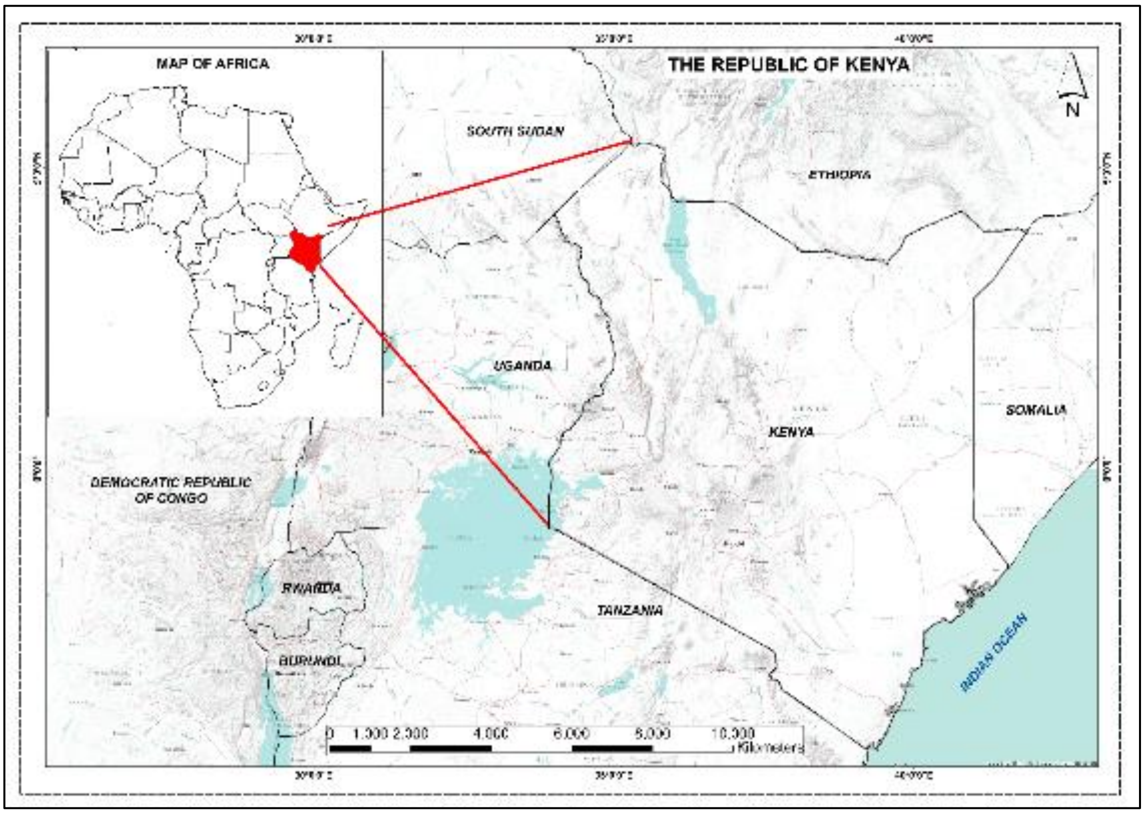

Figure 1: Location Map of Kenya

Kenya is a low forest cover country. The 2018 Land cover mappingshows a forest cover of 3,462,536 ha or about 5.9% of the country's total area, which has slightly declined from about 6.2% in the year 2002. Enhancing forest cover to a minimum of 10% is a key priority of the Government of Kenya. The Constitution (GoK, 2010) obliges the government to work and achieve a forest cover of at least 10% while the national development blueprint (Vision 2030) and the National Climate Change Response Strategy (NCCRS) aim to achieve this goal by 2030.As a party to the UNFCCC, Kenya has committed herself to contribute effectively to global climate change mitigation and adaptation efforts including a renewed resolve to conserve all available carbons stocks and enhancing its forest carbon. The country has signed the **Paris Agreement** and developed a **Nationally Determined Contribution (NDC)** to global climate change efforts. The success of the NDC will strongly be influenced by the forest sector due to its comparatively high abatement potential.

A Climate Change Strategy was developed in 2010 and this has led to the passing of the Climate Change Act in 2016. The Climate Change Act defines an institutional arrangement under the Ministry in charge of Environment to spearhead implementation of climate change activities and recognizes the need to mainstream climate change issues in all developmental programmes in the country. In addition, Climate Change Action Plans have been developed for the period 2013-2017 and also 2018-2022 to support implementation of pertinent and upcoming issues regarding climate change. The **Forest Act**of 2005 has also been reviewed into the Forest Conservation and Management Act of 2016 (GoK, 2016) to further strengthen the country's responses to protect forested landscapes and to provide opportunities for increasing the forest cover in line with national development aspirations. In mainstreaming Climate change in various sectors, additional policies in the land, agriculture and energy sectors have also been developed. In addition to this, Kenya has a National Development Plan which seeks to achieve the Vision 2030 targets through aggressive afforestation and reforestation and rehabilitation programs.

All these policy documents and Specifically the NDC regard the forestry sector as a priority area to move Kenya towards a low-carbon, climate-resilient development pathway. Specifically, in response to a global call for action contained in the **New York Declaration of forests, the Bonn Challenge and the Africa 100 million ha of forests (AFR100) commitment**, the Government of Kenya has committed to restore 5.1 million ha by 2030 equivalent to an average of 392,000 ha per year. The opportunities for restoration have been identified and current discussions revolve around the best strategies for restoration.

1.2.2. The Forest Sector

Kenya's economy is strongly dependent on natural resources including forestry. The Forest sector is the backbone of Kenya's Tourism since forests provide habitats for wild animals, offer dry season grazing grounds and protect catchments that provide water downstream. Forests maintain water catchments (defined as water towers) which support agriculture, industry, horticulture, and energy sectors contribute more than 3.6 per cent of GDP. In some rural areas, forests contribute over 75% of the cash income and provide virtually all of household's energy requirements. It is estimated that economic benefits of forest ecosystem services exceed the short-term gains of deforestation and forest degradation and therefore justify the need to conserve the forests.

Inspite of these important functions, deforestation and forest degradation have continued to pose challenges driven by among others pressure for conversion to agriculture, urbanization and other developments, unsustainable utilization of forest resources, inadequate forest governance and forest fires. The country is exploring a wide range of options, including policy reforms and investments, to protect the existing forests and to substantially restore forest ecosystems across the country.

Forests in Kenya are managed under three tenure systems: public, community and private.

Public forests are managed by both national government agencies (mainly Kenya Forest Service and Kenya Wildlife Service) and County Governments. Public forests are mainly managed for provision of environmental goods and services but they also contain a belt that is managed for timber, poles and fuelwood. Community forests are owned by communities or held in trust by county governments and where forest management rights and responsibilities are transferred from the Public Administration to local communities through long-term leases or management agreements. Private forests are owned or managed by individuals, institutions or corporate entities as freehold or leasehold. The Kenya Forest Service remains the foremost institution charged with the responsibility and mandate to ensure all forests in the country are sustainably managed.

1.3. REDD+ in Kenya

Past attempts to increase forest cover and address the problem of deforestation and forest degradation in the country have not been very successful. This can be attributed to among other factors; increasing demand for land for agriculture, urbanization and other developments, high energy demand and inadequate funding to support investments in the forestry sector. Unresponsive policy and poor governance in the forestry sector have often in the past compounded these problems.

In the year 2012, Kenya developed a consultative REDD+ readiness proposal which identified priorities in the National REDD+ implementation process. The National REDD+ strategy is currently being developed. It is noted that REDD+ presents a great opportunity to reverse the negative trends of forest loss by providing innovative approaches, including incentives from carbon finance that support implementation of a comprehensive strategy that effectively supports sustainable management and conservation of forests and at the same time reduce carbon emissions. In Kenya, REDD+ is evolving as an attractive means to reduce forest sector carbon emissions. Kenya's participation in REDD+ is premised on the conviction that the process holds great potential in supporting:

- Realization of constitutional requirement and vision 2030 objectives of increasing forest cover to a minimum of 10%;
- Government efforts in designing policies and measures to protect and improve its remaining forest resources in ways that improve local livelihoods and conserve biodiversity;
- Access to international climate finance to support investments in the forestry sector;
- Realization of the National Climate Change Response Strategy (NCCRS) goals.

- Contribution to global climate change mitigation and adaptation efforts as illustrated in Kenya's NDC.

Priority areas of focus in REDD+ include the following:

- Reducing pressure to clear forests for agriculture, settlements and other land uses;
- Promoting sustainable utilization of forests by promoting efficiency and energy conservation;
- Improving governance in the forest sector -by strengthening national capacity for Forest Law Enforcement, Governance (FLEG)- advocacy and awareness;
- Enhancement of carbon stocks through afforestation /Reforestation, and fire prevention and control.

2. THE FOREST REFERENCE LEVEL

2.1. Objectives of developing a National FRL

Kenya is establishing a Forest Reference Level as an objective benchmark for assessing performance of REDD+ activities. The FRL has been established in consistence with the country's greenhouse gas inventory process guided by the IPCC reporting principles of Transparency, Accuracy, Consistency and Comparability. In this report, Kenya focuses on four REDD+ activities; reducing emissions from deforestation, reducing emissions from forest degradation, sustainable management of forests and enhancement of forest carbon stocks.

2.2.The Building Blocks of the Forest Reference Level

2.2.1. Forest definition

A national forest definition for REDD+ has been agreed through a broad stakeholder consensus as a minimum 15% canopy cover; minimum land area of 0.5 ha and potential to reach a minimum height of 2 meters at maturity in situ.Perennial tree crops like coffee and tea are not considered as forests under this definition irrespective of whether they meet the definition of forests.

This definition was informed by some basic considerations;

- Kenya borrowed experience from the previous mapping under the AFRICOVER FAO programmed scribed in the Land Cover Classification System (LCCS) manual (Antonio, 2016). The LCCS manual identified the range for closed vegetation (more than 60-70 percent) – We adopted the middle value which is 65%, Open vegetation (70-60 percent to 40 percent), Very open vegetation (40 percent to 20-10 percent)– we identified the midpoint of the lower limit which is 15%. We identified closed vegetation as dense forest, open vegetation as moderate forest and very open vegetation as open forest.A preliminary study by Kinyanjui et al (2014) indicated that there were actual variations in forest biomass in the different canopy cover categories. Kenya's experience from AFRICOVER mapping indicated that there are dryland forests that reach only a maximum of 2m at maturity. Increasing the height threshold to 5m would have eliminated these areas from the national forests;
- The forest definition aimed at provision of opportunities to many stakeholders within the country to participate in incentivized forestry activities that reduces deforestation and forest degradation, support conservation and enhance carbon stocks. This also took into consideration 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

have been constrained by ecological conditions but are a priority for conservation by Kenya’s national development programmes;

- Technical considerations looked into the possibility of providing consistent data for establishing the reference level and for monitoring of performance based on available technology and the need to balance the costs of implementation and monitoring and the expected results based incentives
- Policy considerations identified consistency with the national forest agenda to optimize, manage and conserve the variety of forests of Kenya..

While the Second National Communication (SNC) to the UNFCCC used the FAO forest definition to provide information on forest cover in the country, it has since been agreed that the Third National Communication will be harmonized with the forest definition which is usedfor setting this FRL. This definition will also be used to inform monitoring of forest sector performance and reporting to other international treaties and protocols to which Kenya has subscribed.

2.2.2. Identification of REDD+ Activities

Kenya has classified forests in the country based on four strata (Figure 2). Three strata (Montane and Western rain. Coastal and Mangrove and Dryland) are based on Kenya’s broad ecological zones based on climate and altitude. They define the major biomes/ecological zones in which forests grow and align to the IPCC ecological zones[1]The 4th strata is a management zone and covers the public plantation forests which are managed by the Kenya Forest Service. These strata were used to define the scope of REDD+ Activities.

Kenya has decided on the following scope of REDD+ activities with their definitions:

➢ Reducing emissions from deforestation (Deforestation)

Deforestation is defined as the conversion of Forest to Non-Forest land use across all management systems in Montane and Western rain, Mangrove and coastal, and Dryland forest strata. Deforestation does not include planned and periodic felling of public plantation forests and associated carbon stock fluxes.

➢ Reducing emissions from forest degradation (Forest Degradation)

Forest degradation is defined as the degradation of forest canopy which changes from dense canopy coverage to moderate and open canopy coverage and from moderate to open canopy coverage in Montane and Western rain, Mangrove and Coastal, and Dryland forest strata.

➢ Sustainable management of forests

[1]Table 4.4. of the 2006 IPCC guidelines for GHGI.Volume 4: Agriculture, Forestry and Other Land Use

Sustainable management of forests which is limited to an area of 136, 902ha comprising of public Plantation Forests managed by Kenya Forest Service (KFS), is defined as theconversionof non-planted forest area to planted forest area. This is based on a backlog in replanting of areas designated for public commercial plantations. Kenya notes that any variations in canopy cover among plantation forests may not be associated to degradation and enhancement and adopted a single canopy cover for plantation forests. Sustainable management of forests aims at ensuring a balance between harvests and replanting activities of the public plantation forests in which case the net emissions will be equal to zero.

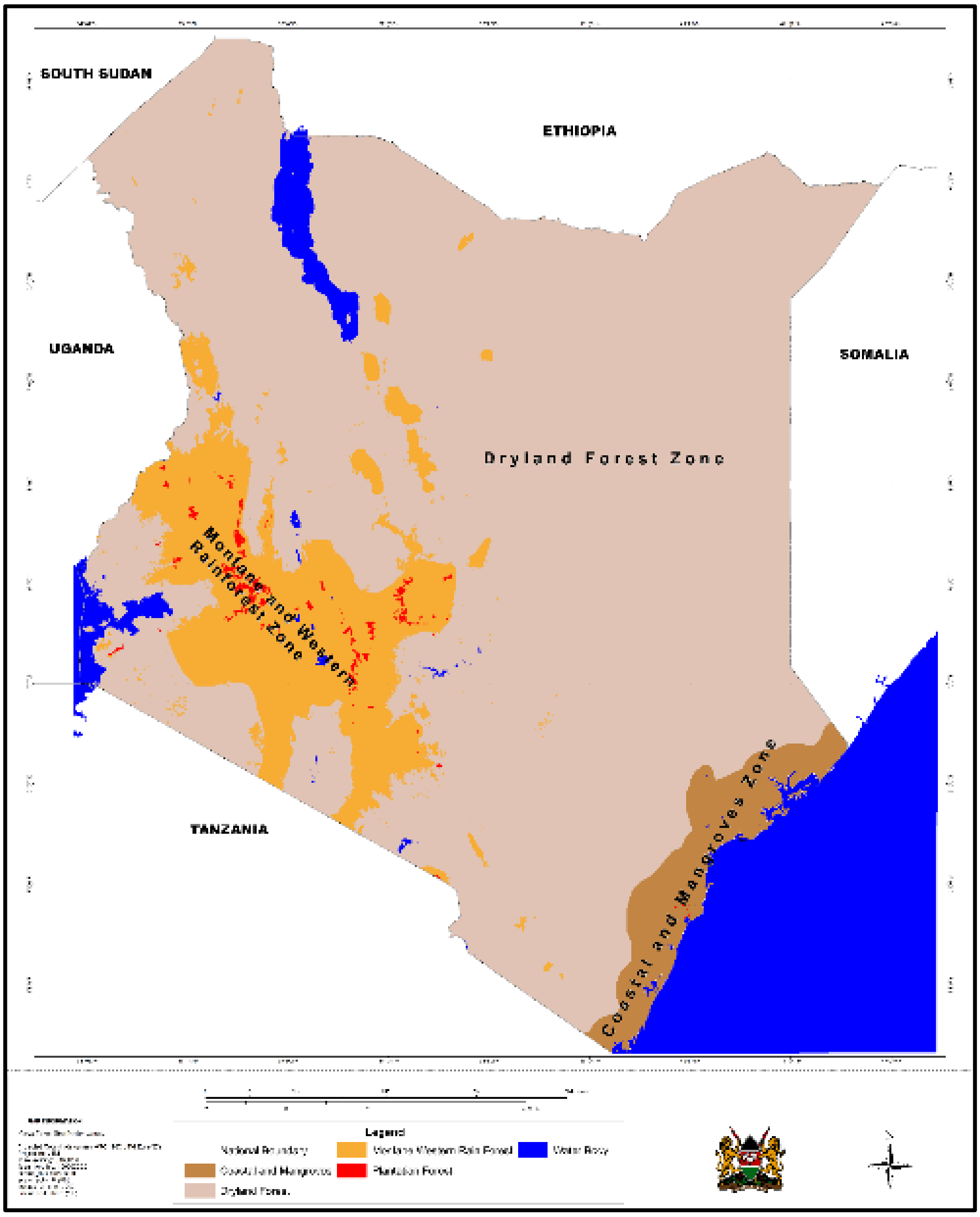

Figure 2: The Ecozones used to create forest strata

- Enhancement of forest carbon stocks

This refers to activities that increase carbon stocks in Montane and Western rain, Coastal and Mangrove, and Dryland forest strata through rehabilitation of degraded areas,reforestation and afforestation efforts.

Kenya has not included Conservation of Carbon Stocks as a REDD+ activity because there is not yet an agreed definition for this activity. It is noted that conservation activities that increase forest carbon stocks are already covered under enhancement of carbon stocks based on the definition provided above.

2.2.3. Carbon pools

Kenya selected the carbon pools as follows:

- Above-ground biomass
- Below-ground biomass

The carbon pools shown below were not considered when establishing the FRL:

- Soil organic carbon
- Litter
- Deadwood

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

a) Soil organic carbon

Kenya notes the requirements for Tier 1 reporting of the soil carbon stocks (2006 IPCC Guidelines) which require a land-use factor (FLU), a management factor (FMG) an input factor (FI), all that require a variety of information which is lacking in Kenya. In line with the stepwise approach and based on data availability, this pool can be included in Kenya's monitoring of GHGs from the forest sector in future.

b) Litter

There is limited information and research data in Kenya to support inclusion of this carbon pool. In the future, this pool will be researched further to support a more accurate estimation based on a stepwise approach.

c) Deadwood

There has not been enough research on the deadwood carbon pool. Data from a pilot forest inventory showed inconclusive results. Further research and collection of more data has been proposed to support its inclusion in future.

2.2.4. Scale

Kenya has chosen to establish a national FRL. This decision is informed by current forest management practices and evolving policies, legislation and institutional frameworks for forest sector reforms. There is broad consensus that REDD+ will be implemented through strong policies and other measures by the national government and county governments. Kenya's decision was also informed by the need to provide broad sectoral technical guidance and monitoring framework to support jurisdictional and project-level REDD+ activities.

2.2.5. Green House Gases (GHG)

Kenya's FRL only covers Carbon dioxide gas (CO_2). Non-CO_2 emission Gas such as Methane (CH_4), Carbon Monoxide (CO) and Nitrous Oxide (N_2O) have not been considered because Kenya does not have quantitative spatial data for Non-CO_2 emission Gases (such as emissions from forest fires and emissions from forests in wetlands). Nethertheless, forest fires and mangrove forests are major sources of non- CO_2 gases and may be considered in subsequent estimation.

2.3. Selection of Reference Period

The forest sector in Kenya has undergone a number of changes over the historical period. It started during the colonization of Kenya where white highlands were created and areas of forest plantation established from existing natural forests (Ochieng *et al.*, 1992). In 1957 under the then CAP 385 Laws of Kenya, a National Forest Policy was published to support the management of forests. The policy was further revised in 1968 with the objective of enhancing biodiversity conservation. However, the suspension of the "Shamba" system[2] in the 1980s and 1990s due to an increasing forest adjacent community, massive excisions of public forests and poor enforcement of conservation recorded large scale destruction of forests. In the year 2001, a partial implementation of the proposed excision of 167,000 ha of forests was done taking away 71,000 ha of forests mainly in the Mau Forest Complex, and converting it into agricultural land (Ministry of Lands, 2001).

The Kenya Indigenous Forest conservation Programme (KIFCON) of 1990-1994 (Wass, 1995) provided a first glimpse of the situation of forests in Kenya, illustrated poor stocking in natural forests due to massive human encroachment. Agitation for revision of the Forest Act started in 2002 culminating in enactment of the Forest Act 2005 which has further been revised to the Forest Conservation and Management Act of 2016. The First National Land cover maps were actualized under the Forest Preservation Program (FPP) (KFS, 2013) which produced Land

[2]Under the Shamba system, communities were allowed to reside inside forests and they actively participated in supporting forest plantation programmes

Cover / Land Use Map for 1990, 2000 and 2010 based on imageries of LANDSAT4, 5, 7 and ALOS. The maps illustrated a declining forest cover in the period 1990- 2000 and then a slight increase in the forest cover past year 2000 corresponding to improved forest policies. However, an improvement in forest policies of conservation may have favored only the forests of the white highlands (in this report described as Montane and Western Rain forests exposing the other forests to further degradation.

2.3.1. Aligning Reference period to changes in the Forest Sector

Policy has advised the selection of the reference period as **the period 2002 – 2018**. Such policies have been detailed in the introductory chapter of this document and are summarized below

1. The implementation of recent forest Acts i.e. Forest Act 2005 and Forest Conservation and Management Act of 2016 is expected to affect forest area changes positively.The agitation for a change in the forest act peaked in the year 2002 when a new government was elected and there was a general consensus that governance of forests should change. The forest act brought changes on management including community participation and made forest excisions more difficult than they were previously. The year 2002 is just after major excisions of montane forests that were done in 2001 (Ministry of Lands 2001) and no further excisions have been done. It implies a period of clearance of the excised forests but also a recovery of degraded forests next to excisions.

2. The coming of a new government in the year 2002 brought in planning of large scale development under the Vision 2030 targets. This came with urbanization and infrastructural growth, improved access into formerly pristine vegetation which exposes the dryland forests. By 2010, a new constitution was enacted and governance structures under devolved governments instituted. These changes have affected management and conservation of forests both positively and negatively. For example, proposals to increase agricultural land encroaches into former marginal lands where dryland forests existed. Similarly, developmental targets in the construction industry expose forests to further degradation because they are a major source of construction material

3. The period after the year 2002 has experienced enactment of many environmentally friendly policies that may favour forest conservation. The climate change related policies include The National Climate Change Strategy of 2010, Kenya Climate Change Act 2016, National Climate Change Framework Policy 2016 and Climate Change Action Plan 2018 among others. Land related polices include the Kenya Land Registration Act of 2012, The National Land Use policy of 2016 and the Kenya Land Act of 2016. Similarly, the Farm ForestryRules of 2009, the gazettement of the Kenya Water Towers Agency in 2012 and the Enactment of the Wildlife Conservation and Management Act 2016 are some of the recent policies that favour forest conservation.

2.3.2. Selecting a Reference period based on mapping tools

Activity data for Estimating Green House Gases from the Land sector which has been used in the National Inventory Report for 2019 and the FRL is based on Wall to Wall land cover mapping using LANDSAT imagery. The detailed procedures used to develop the maps are explained in chapter three of this report. To develop a time series set of maps, the 34 LANDSAT images that make a wall-to-wall map of Kenya were available for the period 1990 to 2018. The land cover products are available for the years 1990, 1995, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015 and 2018. However, analyzing land cover change associated with each available epoch e.g. on annual basis is a complex process. Under the System for Landbased Emission Estimation for Kenya (SLEEK) programme that supported the development of the land cover maps, an Integration Tool (FLINT) is proposed to provide an annual monitoring of emissions from the Land sector based on annual land cover maps. However, the integration tool is still under development.

It is noted that the National Inventory Report for Kenya's 3rd NC has adopted the period 1995 – 2015 due to availability of data from other sectors while the FRL has adopted the period 2002 – 2018 to capture the period of implementation of recent forest sector policy decisions. To harmonise emissions from the two processes and allow comparability, the two processes have used same EF and AD from the same pool of maps.

3. ACTIVITY DATA AND EMISSION FACTORS

3.1. Activity data

3.1.1. Kenya's Land Cover mapping programme

In 2013, Kenya launched the System for Land-Based Emission Estimation in Kenya (SLEEK) programme to support the National GHG inventory process. The SLEEK has done an extensive mapping using a semi-automated method and produced the Land Cover / Land Use Map for the year 1990, 1995, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015 and 2018 based on imagery of LANDSAT4, 5, 7 and 8.

The map production methodology applied by SLEEK is pixel based – supervised classification using Random forest algorithm. The SLEEK Land Cover Change Mapping (LCC) Process aims to create a consistent, sustainable and technically rigorous process for providing land cover and change information required for national land based greenhouse gas (GHG) estimation. The programme seeks to provide a nationwide, time series consistent land cover maps for Kenya. These maps allow analysis of land cover and cover change through time based on IPCC land cover categories and their subtypes based on local requirements. In addition to supporting SLEEK, the maps and statistics generated by the program are recognized as official Government documents for informing Government processes across the land sector – such as land use planning, tracking deforestation, and landscape restoration. These maps have also been used to support the REDD+ process in construction of the Forest Reference Level and the National Forest Monitoring System.

The methodology employed for the SLEEK mapping process and which is described in Annex 1 allows creation of Land Cover / Land Use Map in a short period at low cost without requiring manual interpretation and editing. The site training data for supervised classification was extracted through a ground truth survey supplemented by Google Earth in areas with poor accessibility. The minimum mapping unit (MMU) of Land Cover / Use class was 0.09ha due to pixel basis image classification methodology.However, filtering process was applied to ensure that forest mapping met the forest definition (0.5ha as minimum area) as agreed in the country. The detailed process of developing these maps is available in a Technical Manual (SLEEK, 2018). An illustration of the map products from this process is shown in Figure 3

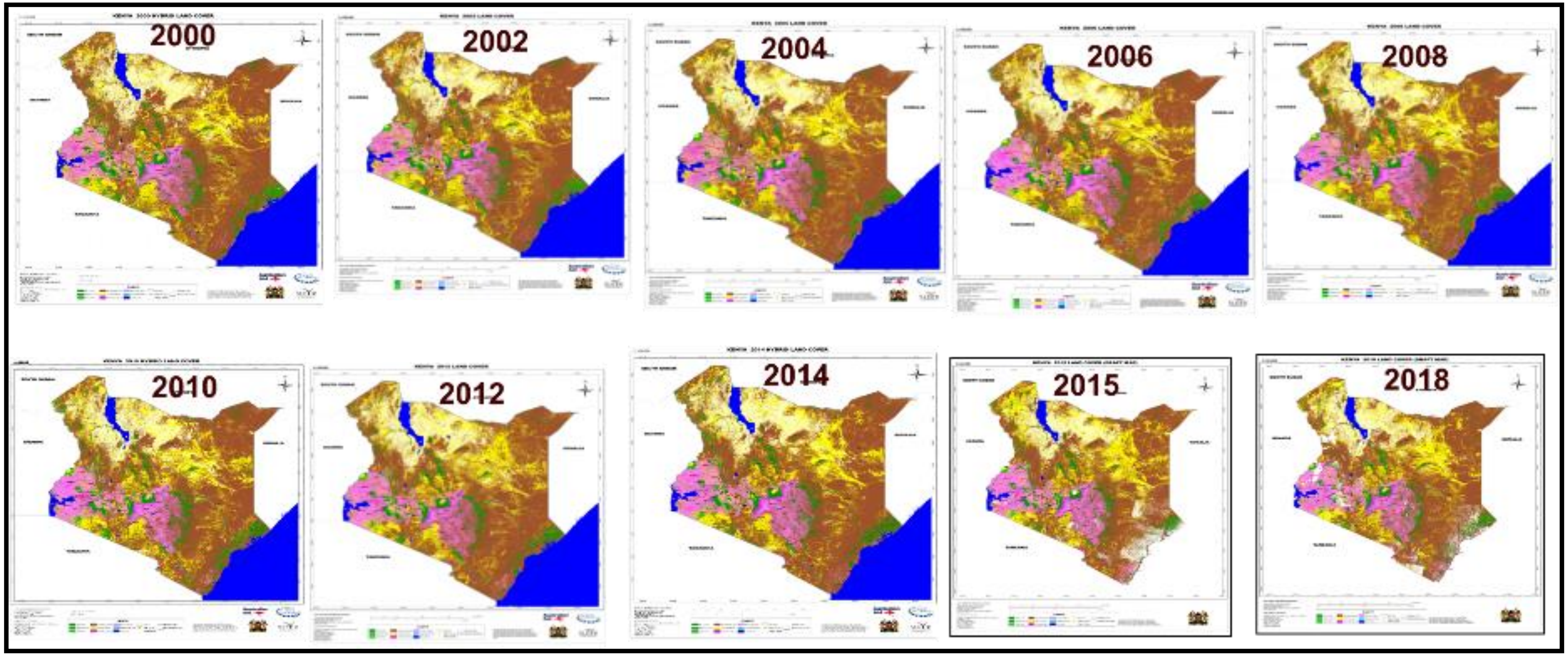

Figure 3: Some of the Wall-Wall time series Landcover maps from the SLEEK programme

Based on the complete time series mapping, the trend of forest cover for the period 2002-2018 is shown in percentages in Figure4. The figure shows a decline in forest cover from 6.2% (3,669,768 ha) in 2002 to 5.9% (3,462,536 ha) in 2018.

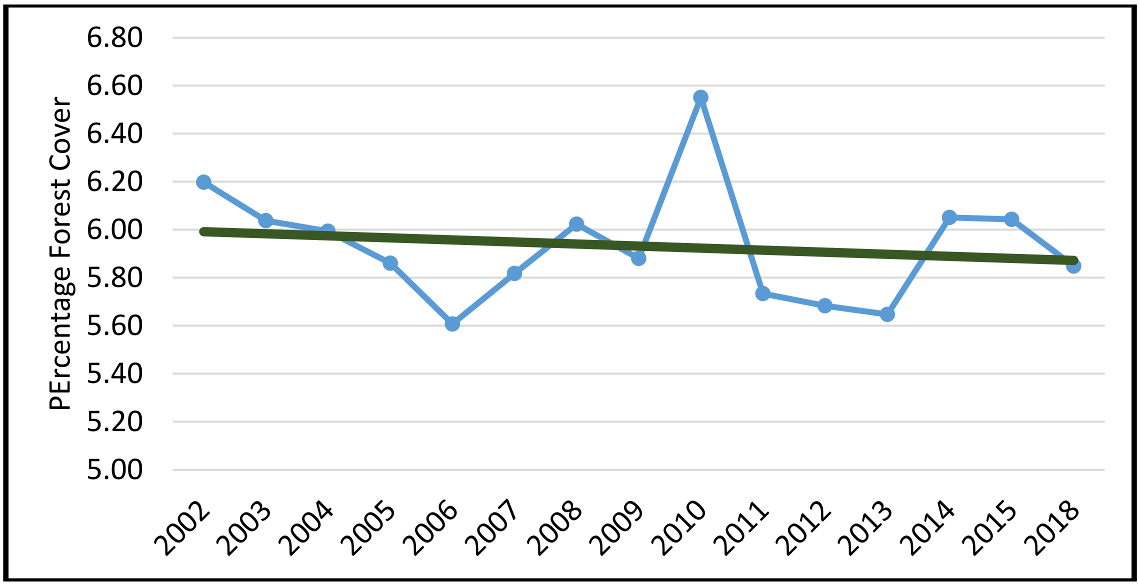

Figure 4: The Trend of forest cover change (%) (2002 – 2018)(SLEEK maps)

3.1.2. Stratification of forests

The land cover maps stratify forests into four strata (Figure 2) which have been adopted for assigning emission factors to different forest types. These strata are described in Chapter 2 of this report and follow the three forest ecozones of Kenya (Dryland forest areas, Montane & Western Rain forest areas and Coastal & Mangrove forest areas) defined by altitude and climate (Wass, 1995). The specific characteristics of the forests in each stratum are described in Annex 2. The fourth stratum is a 136,902 ha management stratum comprising of commercial Public Plantation forest areas managed by Kenya Forest Service (KFS), which spread across the ecozones. Non forest areas refer to Cropland, Grassland, Wetland, Settlement and Other land corresponding to the IPCC guidelines[3].

A second level stratification on the three strata based on ecozones (Dryland forest areas, Montane & Western Rain forest areas and Coastal & Mangrove forest areas) was done on the basis of canopy closure.The resultant canopy classes based on the forest definition described in Chapter 2, are: 15-40 % (Open), 40-65 % (Moderate), and above 65 % (Dense).However, for

[3]Note that the SLEEK mapping system has not allowed separation of settlement (built up areas) and Otherlands as described by the IPCC guidelines

the Public Plantation forest category managed by Kenya Forest Service (KFS), no subdivisions were done by canopy closure. This results to a total of 10 forest strata (Table 1). A conversion of a forest in a lower canopy class (e.g. open forest) to a higher canopy class (e.g. dense forest) results to Enhancement of Carbon stocks. Similarly a conversion of higher canopy forest to a lower canopy forest results to reduction in carbon stocks and is a forest degradation activity.

Table 1: Classification of Land Cover/Land uses for mapping under SLEEK

Land Category	First level stratification	Second level stratification
Forest	Montane& Western rainforest	Dense (canopy cover ≥65%)
		Moderate (Canopy cover 40-65%)
		Open (Canopy cover 15-40%)
	Coastal and Mangrove forests	Dense (canopy cover ≥65%)
		Moderate (Canopy cover 40-65%)
		Open (Canopy cover 15-40%)
	Dryland forest	Dense (canopy cover ≥65%)
		Moderate (Canopy cover 40-65%)
		Open (Canopy cover 15-40%)
	Public Plantation forest	Plantation forest
Non forest	Cropland	
	Grassland	
	Wetland	
	Settlement and Other lands[4]	

Table 2 below shows a product of the mapping process. It illustrates the specific areas of land uses mapped for the years 2002and 2018. The table gives an illustration of the coverage of the various land uses identified in Table 2. Forestlands comprise a small percentage of the total land area of Kenya at approximately 6% (ranging from 6.2% in 2002 to 5.9% in 2018) while grasslands dominate at about 70% of the total land cover in Kenya. Croplands show a slight increasing trend from 8.9% to 11.4% in the years 2002 and 2018 respectively. These numbers are important because they describe Kenya's national circumstances affecting the forest cover and how this is expected to change over time. A decline in forest cover in the period 2002 – 2018 provides an opportunity for REDD+ implementation not only to reverse this trend but also to increase the forest cover towards the constitutional target of 10%. Similarly, an expansion in the Cropland area may be attributed to decreasing grasslands and forestlands and is one of the challenges affecting conservation of forestlands.

[4] The SLEEK land cover automated mapping does not separate Settlements and otherlands. Settlements are manually digitized on each maps based on ancillary data

Table 2 also shows that most of the forests in Kenya are found in the dryland areas and the Montane forest areas. Each of these strata is faced by different drivers of deforestation but in spite of this, there is potential for enhancement of carbon stocks. The plantation forests managed by Kenya Forest Service (KFS) have the least area among the four strata and the areas have decreased over time. However, the area of Public plantation forests presented in Table 2 is only half of what is set aside for plantation forestry in Kenya and this provides an opportunity for increasing the forest cover within the plantation zones.

Table 2: 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**	**59,203,788**	**100**	**59,203,788**	**100**	**59,203,788**	**100**	**59,203,788**	**100**

3.1.2. Mapping land use transitions

The process of mapping land use transitions involved comparing change in maps from 2 time periods sequentially (e.g. 2002vs2006, 2006vs 2010, 2010vs 2014, and 2014 vs 2018). This resulted in a change map with areas remaining in the same land use type and areas changed to different land use types between 2-time periods (e.g. as shown in Figure 5) for the specific REDD+ activities. The process was repeated for each of the 4 time intervals (epochs) to generate activity data which was used to calculate emissions.

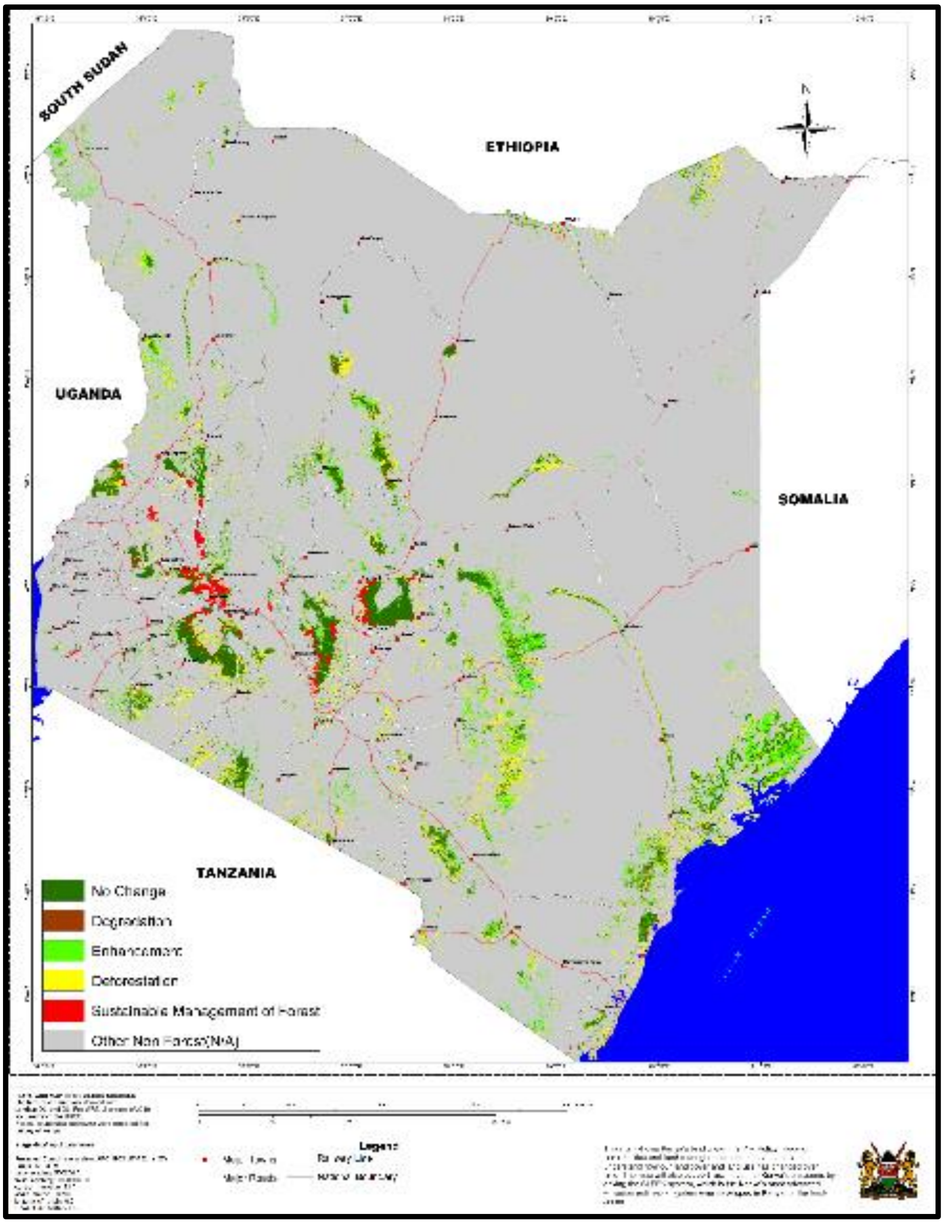

Figure 5: A Change maps (for year 2002-2006) used to generate activity data

3.1.3. Assigning Activity Data to REDD+ Activities

Based on the identified forest strata, Activity data on land use changes were assigned to each REDD+ activity to allow calculation of area change. A matrix was prepared to facilitate assigning the REDD+ activities to the different land use transitions, identify the specific areas of transition, with their specific Emission Factors and facilitate calculation of the overall emissions. The matrix below (Table3) provides an explanation how each REDD+ Activities will be accounted for while setting the FRL. This information is summarized below

1. Deforestation is conversion of Forests to Non forests in all canopy classes of Montane&Western Rain forest, Coastal and mangrove forests and Dryland forests and is indicated by Red colour
2. Degradation is conversion of a forest from a higher canopy class to a lower canopy class for all forests in the strata/ecozones of Montane&Western Rain forests, Coastal and mangrove forests and Dryland forests and is indicated by yellow colour
3. Enhancement of Carbon stocks is the conversion of Non forests into forests (afforestation and reforestation) and the improvement of forests from a lower canopy class to a higher canopy class in the strata/ecozones of Montane&Western Rain forests, Coastal and mangrove forests and Dryland forests and is indicated by green colour.
4. Sustainable management of forests is the conversion of non-forests into forests and sustainable harvesting (forests into non forests) in Public Plantation forest areas managed by Kenya Forest Service (KFS) and is indicated by blue colour. This aims at reducing backlogs by replanting and increasing productivity of the public plantation forests.Therefore harvesting of trees in this strata is also described as sustainable management of forests.
5. Forestlands remaining forestland in the strata/ecozones of Montane&Western Rain forests, Coastal and mangrove forests andDryland forests, which were mapped with a canopy remaining in the same canopy level in the two mapping years (e.g. 2002 and 2006) do not imply any carbon stock changes and have not been assigned any colour.
6. Conversions among non-forests e.g. cropland converted to wetland do not imply any emissions and have not been assigned any colour.

Table 3: Matrix for Allocating REDD+ activities to land use changes

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

3.1.4. Land cover change areas between years

The proposed land cover change matrix was populated with data based on the proposed epochs; 2002 -2006, 2006 -2010, 2010 -2014, and 2014-2018 as illustrated in Table 4. Calculations of area change are based on aforementioned strata (Montane&Western Rain forest areas, Coastal and mangrove forest areas, Dryland forest areas and Public Plantation forest zones) and their specific canopy classes (for Montane&Western Rain forests, Coastal and mangrove forests and Dryland forests). The area of each land use transition is illustrated and the colour on the table used to assign each change to a REDD+ activity as described in Table 3.

3.1.5. Transitions of forests based on land cover change matrices

A summary of land over transitions affecting the forest sector illustrates that

1. Most of the forests of Kenya are found in the Montane and Western Rain forest strata
2. The Montane dense forests are stable and have been increasing over the time series from 773,672ha in 2002 to 834,862 ha in 2018. This is unlike the dryland dense forests that have large fluctuations from 303,805ha in 2006, 425,505ha in 2010, 450,388ha in 2014 and 344,985ha in 2018
3. The largest conversions of forests occur in the dryland forest strata and the conversion is mainly from forests into grasslands and the reverse
4. The area of forestland remaining forestland in thePublic Plantation forest was 62,292 ha in 2002-2006 and had decreased to 56,315 ha in 2014-2018. Tree planting in these public plantations only accounted for about 11,000ha in the period 2002-2006 and 8,700ha in the period 2014-2018. This justifies the need to enhance forest cover in this strata towards full coverage of the designated 136,902 ha and be able to provide commercial wood products for Kenya’s growing economy.

Table 4: Land useChange (No of ha) for each forest strata in the 2002-2006 epoch

Forest strata			2006													
			Montane & Western Rain Forest			Coastal & Mangrove Forest			Dryland Forest			Public Plantation forest	Cropland	Grassland	Wetland	Settlement & Otherland
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open					
2002	Montane Forest & Western Rain Forest /	Dense	773,672	75,916	27,963								110,685	127,283	251	445
		Moderate	36,857	75,670	14,739								17,071	71,895	154	248
		Open	25,105	10,533	27,186								8,333	82,848	18	267
	Coastal& Mangrove Forests	Dense				114,602	11,053	3,190					2,458	36,401	490	623
		Moderate				100,716	77,558	22,429					9,195	130,990	431	1,039
		Open				12,055	4,378	1,861					1,509	18,267	22	128
	Dryland Forest	Dense							303,805	32,124	21,397		38,529	301,166	1,933	2,465
		Moderate							107,414	84,438	21,236		17,244	220,465	2,309	1,868
		Open							43,048	22,420	62,831		8,668	248,377	1,452	10,672
	Public Plantation forest											62,292	4,248	12,622	9	9
	Cropland		37,067	3,719	2,655	300	583	102	16,223	1,679	5,441	5,520				
	Grassland		103,916	73,048	33,153	52,514	41,374	40,874	343,099	132,028	228,734	5,515				
	Wetland		205	61	23	513	576	368	2,229	1,768	1,835	10				
	Settlement & Other land		462	64	48	266	156	115	1,707	1,360	4,005	4				

Table 5: Land use Change (No of ha) for each forest strata in the 2006-2010 epoch

Forest strata			2010													
			Montane & Western Rain Forest			Coastal& Mangrove Forest			Dryland Forest			Public Plantation forest	Cropland	Grassland	Wetland	Settlement & Otherland
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open					
2006	Montane Forest & Western Rain Forest /	Dense	749,295	38,797	18,012								57,504	111,178	256	2,243
		Moderate	74,676	79,707	9,679								4,647	70,133	44	125
		Open	29,698	13,517	20,443								4,500	37,492	16	101
	Coastal& Mangrove Forests	Dense				215,356	29,039	333					713	34,769	581	176
		Moderate				19,875	77,651	1,166					521	35,589	726	149
		Open				3,352	27,627	1,329					205	35,722	473	230
	Dryland Forest	Dense							425,505	39,428	26,851		28,583	291,829	2,881	2,449
		Moderate							62,214	76,621	17,783		3,653	112,795	1,870	881
		Open							28,938	28,669	68,159		9,935	200,598	2,053	7,129
	Public Plantation forest											61,183	4,178	7,968	11	0
	Cropland		67,138	8,536	8,401	2,485	2,573	298	27,969	4,497	12,733	3,819				
	Grassland		132,713	78,280	40,850	59,719	122,443	9,292	485,917	230,353	276,515	11,970				
	Wetland		222	39	28	402	552	18	2,850	1,283	1,359	17				
	Settlement & Other land		882	962	138	507	945	185	4,230	21,324	10,939	13				

Table 6: Land use Change (No of ha) for each forest strata in the 2010-2014 epoch

Forest strata			2014													
			Montane & Western Rain Forest			Coastal& Mangrove Forest			Dryland Forest			Public Plantation forest	Cropland	Grassland	Wetland	Settlement & Otherland
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open					
2010	Montane Forest & Western Rain Forest /	Dense	811,460	35,478	29,991								67,820	109,131	215	529
		Moderate	70,180	76,226	10,964								8,986	53,130	107	244
		Open	20,994	12,731	13,395								8,378	41,885	43	123
	Coastal& Mangrove Forests	Dense				221,815	20,895	768					1,186	55,669	460	902
		Moderate				59,002	59,199	1,835					4,427	135,127	912	327
		Open				623	926	646					978	9,361	15	72
	Dryland Forest	Dense							450,388	48,329	26,540		31,316	475,519	2,748	2,782
		Moderate							68,735	78,685	23,421		4,150	220,502	1,454	5,230
		Open							31,273	17,404	75,590		11,696	268,363	1,887	8,126
	Public Plantation forest											64,384	5,889	6,707	12	9
	Cropland		62,635	6,649	3,452	2,606	460	15	28,717	4,707	3,493	5,109				
	Grassland		118,181	70,500	46,412	137,075	37,087	2,216	385,810	134,613	168,121	11,987				
	Wetland		330	11	10	1,126	344	2	4,112	1,266	412	15				
	Settlement & Other land		1,938	128	239	368	194	3	2,708	1,202	6,554	11				

Table 7: Land use Change (No of ha) for each forest strata in the 2014-2018 epoch

Forest strata			2018													
			Montane & Western Rain Forest			Coastal& Mangrove Forest			Dryland Forest			Public Plantation Forest	Cropland	Grassland	Wetland	Settlement & Otherland
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open					
2014	Montane Forest & Western Rain Forest /	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& 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 Forest	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
	Public Plantation forest											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				

3.1.6. Annual and percentage areas of change

The tables 8-12 illustrate annual areas of change for each stratum based on the land use change matrices presented in tables 4-7. Figure 4 compares the contribution of the forest strata to deforestation

1. Table 8 shows that the area of deforestation in Kenya (average 338,863ha) has slightly exceeded the area of reforestation (average 326,794ha) and therefore there has been a net loss of forests. The greatest transition of forests to non forests and the reverse occurs in the dryland forest strata. A REDD+ programme to reduce deforestation is expected to reverse this trend
2. Table 9 shows that the process of degradation of forests is slightly less than that of canopy improvement at 59,736ha versus 69,813ha. This implies that afforestation programmes have been on an improvement trend. A continuous improvement of the planted forests enhances their stocks and justifies this as a REDD+ activity
3. Table 10 shows that in public Public Plantation forest areas, the process of harvesting forests has slightly exceeded the process of planting implying that the plantation forests have more planting backlogs and their forest area has been reducing. A sustainable management programme is expected to reverse this trend.
4. Table 11 gives the average deforestation rate in Kenya as 0.58% of the total land area which implies an area of 9.27% of the total land area was deforested in the 2002-2018 reference period. This is against an afforestation area of 8.83% of the total land area. In effect a net area of 0.44% of Kenya's total land area was deforested in the reference period. Figure 6 shows the specific deforestation areas among strata in the different mapping epochs
5. Table 12 illustrates the rates of forest degradation and enhancement of forest canopy in conserved areas. The table shows that the areas under canopy improvement are slightly more (at 0.12% of the national land area) than the areas undergoing forest degradation (at 0.1% of the national land area).

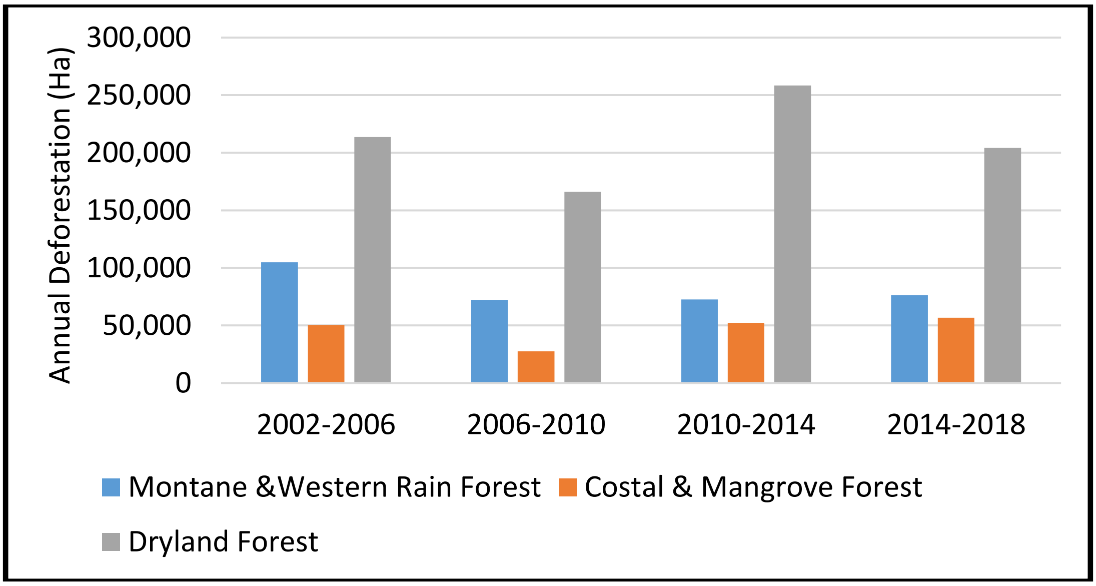

Figure 6: The contribution of strata to the annual deforestation in the reference period

Table 8: Annual transitions (No of ha); Deforestation and Afforestationamong forest strata

Forest strata	Area (ha/yr) of Deforestation					Area (ha/yr) of Afforestation				
	2002-2006	2006-2010	2010-2014	2014-2018	Average	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	104,874	72,059	72,648	76,322	81,476	63,605	84,547	77,621	67,426	73,300
Coastal& Mangrove Forest	50,388	27,463	52,359	56,664	46,719	34,435	49,855	45,374	44,777	43,610
Dryland Forest	213,787	166,164	258,443	204,279	210,668	185,027	269,992	185,429	199,089	209,884
Total	369,049	265,687	383,450	337,265	338,863	283,068	404,394	308,424	311,292	326,794

Table 9: Annual transitions (No of ha); Forest degradation and Canopy improvement

Forest strata	Area (ha/yr) of Forest Degradation					Area (ha/yr) of Forest enhancement by Canopy improvement				
	2002-2006	2006-2010	2010-2014	2014-2018	Average	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	29,655	16,622	19,108	20,461	21,461	18,124	29,473	25,976	15,104	22,169
Coastal& Mangrove Forest	9,168	7,634	5,874	22,830	11,377	29,287	12,714	15,138	6,032	15,793
Dryland Forest	18,689	21,016	24,572	43,316	26,898	43,220	29,955	29,353	24,878	31,852
Total	57,512	45,272	49,555	86,607	59,736	90,631	72,142	70,467	46,013	69,813

Table 10: Annual transitions forsustainable management in public Plantation forests

Forest strata	Area (ha/yr) of Sustainable Management of forests				
	2002-2006	2006-2010	2010-2014	2014-2018	Average
Harvested area	4,222	3,039	3,155	6,298	4,178
Afforested area	2,762	3,955	4,280	2,185	3,296
Net (Deficit/backlog)	-1,460	916	1,125	-4,113	-882

Table 11: Annual transitions (% of national area); Deforestation and Afforestation

Forest strata	Percentage of national area Deforested					Percentage of national area Afforested				
	2002-2006	2006-2010	2010-2014	2014-2018	Average	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	0.18	0.12	0.12	0.13	0.14	0.11	0.14	0.13	0.11	0.12
Coastal& Mangrove Forest	0.09	0.05	0.09	0.10	0.08	0.06	0.08	0.08	0.08	0.07
Dryland Forest	0.36	0.28	0.44	0.35	0.36	0.31	0.46	0.31	0.34	0.35
Total	0.63	0.45	0.65	0.58	0.58	0.48	0.68	0.52	0.53	0.55

Table 12: Annual transitions (% of national area); Forest degradation and Canopy improvement

Forest strata	Percentage of national area withForest Degradation					Percentage of national area with Canopy improvement				
	2002-2006	2006-2010	2010-2014	2014-2018	Average	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	0.05	0.03	0.03	0.03	0.04	0.03	0.05	0.04	0.03	0.04
Coastal& Mangrove Forest	0.02	0.01	0.01	0.04	0.02	0.05	0.02	0.03	0.01	0.03
Dryland Forest	0.03	0.04	0.04	0.07	0.05	0.07	0.05	0.05	0.04	0.05
Total	0.10	0.08	0.08	0.15	0.10	0.15	0.12	0.12	0.08	0.12

Table 13: Area of forestland remaining forestland in the reference period

Forest strata	Area (ha) of Forestland that remained forestland					Percentage of forestland (based on national land area) that remained forestland				
	2002-2006	2006-2010	2010-2014	2014-2018	Average	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	1,067,639	1,033,823	1,081,420	1,086,615	1,067,374	1.80	1.75	1.83	1.84	1.80
Coastal& Mangrove Forest	347,841	375,728	365,710	320,549	352,457	0.59	0.63	0.62	0.54	0.60
Dryland Forest	698,714	774,168	820,364	744,965	759,553	1.18	1.31	1.39	1.26	1.28
Public Plantation Forest	62,292	61,183	64,384	56,315	61,044	0.11	0.10	0.11	0.10	0.10
Total	**2,176,487**	**2,244,903**	**2,331,878**	**2,208,444**	**2,240,428**	**3.68**	**3.79**	**3.94**	**3.73**	**3.78**

3.1.7. Area of stable forests

The area of forests that remained forests between two mapping years is shown in table 13. An area of slightly over 2 million hectares has remained forest in the reference period and averages at 2,240,428ha. The Montane and Western Rain forest stratum has the biggest contribution to the stable forest maintaining an area slightly over 1 million hectares (average 1,067,374ha) in the reference period. The Dryland forests and the Coastal and Mangrove strata have also significantly stable forests. The table shows that an area of 3.78% of Kenya's land area has remained forestland in the reference period. This area of stable forestsand the area that underwent afforestation and the reduction of areas that have been undergoing deforestation contribute towards meeting the country's target of 10% forest cover.

3.2. Emission Factors (EF)

Two sets of data were used to generate Emission Factors; stock change and growth rates.

3.2.1. Emission factors from stock change

Emission Factors for changes in forest carbon stocks were based on 1st level and 2nd level stratification of forests described in Table 1 above. Stratified sampling was used and forest stock data collected in a Pilot Forest Inventory by ICFRA (KFS, 2016) and CADEP-SFM (JICA, 2017)was used to assign biomass stockto each strata and sub strata.It is noted that Kenya has not conducted a comprehensive National Forest Inventory (NFI) that would have effectively supported the establishment of emission factors. According to the step-wise approach, it is expected that the NFI will be implemented in future[5].Therefore, data from the pilot inventory that covered all the forest strata was used. The data was collected from a total of 121 plotsand is illustrated in Annex 3. A simple average of the field data for each stratum was used as the Biomass stock for each sub strata.

The EFswere estimated for Deforestation (conversion of forests into non forests) by the following process.Firstly, the values of AGB in each plot were computed (Table14), using the forest inventory datadescribed above and locally acceptableallometric equations (Table15).The values of BGB were calculated by applying the R/S ratio per forest strata based on IPCC 2006 guidelines for each stratum(Table 16). Forest biomass calculated as the sum of AGB and BGB was converted into Carbon using the IPCC carbon fraction of 0.47. Further, the conversion to CO_2 is based on the ratio of molecular weights (44/12) (IPCC 2006). Finally, Emission Factors were estimated as the differences in carbon stocksin an area at two points in time (e.g. 2002 and 2006).

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[5] The ICFRA project developed technical manuals for Biophysical assessment of Forest resources and also developed a design for an NFI. However, the NFI has not been implemented

In conversions of forests into non-forests, the Carbons stocks were assumed to go through immediate oxidation[6].

3.2.2. Emission Factors due to forest growth

Emission Factors due to forest growth were classified into two as shown below

3.2.2.1. Conversion of non-forests into forests

The EFs due to afforestation (conversion of a non-forest into a forest) shown in Table 17were calculated using a growth rate for each of the forest strata for trees < 20yr, because in the 4 year change period such the forests have not attained 20 years. Choice of EF was based on the fact that a forest undergoes a process of growth after planting and does not immediately achieve the carbon stock of the forest it is mapped into but attains a carbon stock value described by its growth rate and the number of years of growth. The growth rates were calculated based on IPCC 2006 guidelines as shown in Table 17.

3.2.2.2. Improvement of forest stock due to canopy enhancement

The EFs for Enhancement (improvement of Carbon stocks where a canopy improvement was noted between two years of mapping are shown in Table 18. They were calculated using a growth rate associated to each of the forest strata for trees >=20yr. The >=20yr is selected on the basis that these are already grown forests which had previously been degraded and are undergoing stock enhancement. Choice of EF was based on the fact that a forest undergoes a process of growth after conservation measures are initiated and a canopy improvement (as in the case of an open forest converting to a dense forest) does not result to the carbon stock of the forest it is mapped into, but attains a carbon stock value described by its growth rate and the number of years of growth typical to such a foreststratum.

[6]Kenya has no system in place for monitoring carbon fluxes of harvested wood products

Table 14: Emission Factors from NFI for forest type class

Forest strata	Canopy Cover	ABG	BGB	TOTAL		
		Biomass Tonnes/ha)[7]	Biomass Tonnes/ha)[8]	Biomass (Tonnes/ha)[9]	Carbon (Tonnes/ha)[10]	CO_2 (Tonnes/ha)[11]
Montane & Western Rain	Dense	244.80	90.57	335.37	157.62	577.95
	Moderate	58.43	21.62	80.05	37.62	137.96
	Open	18.31	6.77	25.08	11.79	43.23
Coastal & Mangrove	Dense	94.63	18.93	113.55	53.37	195.69
	Moderate	52.75	10.55	63.30	29.75	109.08
	Open	24.01	4.80	28.81	13.54	49.64
Dryland	Dense	42.43	11.88	54.31	25.53	93.60
	Moderate	34.52	9.67	44.19	20.77	76.15
	Open	14.26	3.99	18.26	8.58	31.47
Plantation		324.79	87.69	412.48	193.87	710.84
Cropland Wetland &Settlements/ Otheralands		0	0	0	0[12]	0
Grassland				8.7[13]	4.09	14.99

7 Stock obtained from Pilot NFI and allometric equations as simple average of plot data for each stratum
8 Calculated using the IPCC root/shoot Ratio shown in table 9
9 Sum of ABG and BGB
10 Calculated using Carbon fraction of 0.47
11 Calculated using CO_2 molecular formula of 44/12
12 The Cropland Carbon Factor obtained from IPCC default values for tier 1 reporting: 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4: Chapter 5(Cropland) Table 5.8: Default Biomass Stocks Present On Cropland , After Conversion From Forestland
13 The Grassland Carbon Factor obtained from IPCC default values for Tropical Dry Grasslands: 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4: Chapter 6 (Grassland) Table 6.4: Default Biomass Stocks Present On Grassland , After Conversion From Other Land Use

Table 15: List of allometric equations used for AGB Estimation

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	$1.04+0.06*d*GW_{bamboo}$ $GW_{bamboo}=1.11+0.36*d^2$ (bamboo diameter > 3 cm) $GW_{bamboo}=1.11+0.36*3.1^2$ (bamboo diameter ≤ 3 cm)	Muchiri and Muga. 2013
Climbers in natural forests	-	-	$e^{(-1.484+2.657*\ln(DBH))}$	Schnitzer et al. 2006

Table 16: Specific Shoot/Root ratios for the different strata

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

Table 17: Emission factors for calculating forest growth due to afforestation

Forest strata	Biomass gain (Tonnes/ha)			Carbon from Biomass	CO_2 sequestered (Tonnes/ha)		Reference AGB value from IPCC V4.4
	AGB value	BGB[14]	Total		One year	4 years	
Montane and Western rain	10	3.70	13.70	6.44	23.61	94.44	Table 4.9 for Africa tropical rain forests for forests <20 yrs
Dryland	2.4	0.67	3.07	1.44	5.29	21.16	Table 4.9 for Africa tropical dry forests for forests< 20 yrs
Coastal and Mangrove	5	1.00	6.00	2.82	10.34	41.36	Table 4.9 for Africa tropical moist deciduous forests for forests < 20 yrs
Public Plantation	10	2.70	12.70	5.97	21.89	87.56	Table 4.10 for Africa Tropical mountain systems plantation forests

Table 18: Emission factors used for calculating forest growth due to enhancement

[14] EF used as in table 16 for shoot/root rations

Forest strata	Biomass gain (Tonnes/ha)			Carbon from Biomass	CO_2 sequestered (Tonnes/ha)		Reference AGB value from IPCC V4.4
	AGB value	BGB[15]	Total		One year	4 years	
Montane and Western rain	3.1	1.15	4.25	2.00	7.32	29.28	Table 4.9 for Africa tropical rain forests for forests >20 yrs
Dryland	1.8	0.50	2.30	1.08	3.97	15.88	Table 4.9 for Africa tropical dry forests for forests > 20 yrs
Coastal and Mangrove	1.3	0.26	1.56	0.73	2.69	10.76	Table 4.9 for Africa tropical moist deciduous forests for forests > 20 yrs
Public Plantation	10	2.70	12.70	5.97	21.89	87.56	Table 4.10 for Africa Tropical mountain systems plantation forests

[15]EF used as in table 16 for shoot/root rations

3.2.3. Generating Emission factors from land use transitions

Using Carbon stock data (Tables 14 to 18), the EFassociated with each land use transition, were calculated and assigned to each REDD+ activity as illustrated in Table 19. These calculations were done as follows

1. Deforestation which is conversion of a forest to a non-forest in Montane &Western Rain forests, Coastal & mangrove forests and Dryland forests;
    a. Instantaneous Oxidation[16] was assumed for all deforestation. Therefore,the EF is the difference between the CO_2 value of the initial forest strata/canopy class and the CO_2 value of the non-forest
    b. All forest conversions into Croplands, Wetlands and Settlements&Otherlands attain a CO_2 value of Zero after conversion. The EF is the difference between the CO_2 of the former forest and zero
    c. All forest conversions into Grasslands attain a CO_2 value of 14.99Tonnes/ha after conversion. The EF is the difference between the CO_2 of the former forest and 14.99 Tonnes/ha
2. Forest Degradation which is the conversion of a forest from a higher canopy class to a lower canopy class in Montane &Western Rain forests, Coastal & mangrove forests and Dryland forests
    a. Instantaneous Oxidation was assumed for all degradation[17]. Therefore, the EF is the difference between the CO_2 value of the initial forest canopy class and the CO_2 value of the new forest canopy class within a stratum
3. Enhancement of Carbon stocks due to conversion of non-forests into forests in Montane &Western Rain forests, Coastal &mangrove forests and Dryland forests was calculated as follows
    a. A growth factor was adopted for each stratum (Table 17) to give the amount of CO_2 gained in a planted/young forest (in this case a forest that is less than 20 years) in the 4 year period. In case the calculation of growth results to a stock which is more than the stock factor of the specific canopy class, a capping was done to retain the stock of the specific canopy class.
    b. The EF for conversion of Croplands, Wetlands and Settlements &Otherlands into forestlands was the difference between zero and the CO_2 value after growth

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16.There is no data on harvested wood products. Most of the activities that convert forests to non-forests in the specified strata may result to instantaneous oxidation

17.Data on drivers of degradation is not reliable enough to estimate emissions as shown in a preliminary study to this work - Options for Estimating GHG Emissions/Sinks from Forest Degradation, Forest Fires and Forest Revegetation. A Report To Support Establishment of Kenya's Forest Reference Level of 4years

c. The EF for conversion of grasslands into Forestlands was the difference between a CO_2 value of 14.99 Tonnes/ha and the CO_2 value of the forest after 4 years of growth

4. Enhancement of Carbon stocks due to improvement of Canopy in forests from a lower canopy class to a higher canopy class in Montane and Western Rain forests, Coastal and mangrove forests and Dryland forests was calculated as follows
   a. A growth factor was adopted for each stratum (Table 18) to give the amount of CO_2 gained in an existing forest (in this case a forest that is more than 20 years[18]) in the 4 year period
   b. The EF was calculated as the difference between the previous CO_2 value (for the starting year) and the new CO_2 value after forest enhancement (end year). In case the calculation of growth results to a stock which is more than the stock factor of the specific canopy class, a capping was done to retain the stock of the specific canopy class.
5. In Sustainable management of forest which is the conversion of non-forests into forestlands in areas designated as public Plantation zones[19], EF were calculated as follows
   a. A stock change method was applied and the EF calculated as the difference between the CO_2 value of the previous non-forest to the CO_2 value of a plantation based on growth rate (Table 16).
   b. A Conversion of a Cropland, Wetland and Settlements &Otherlandsinto a forestland changes carbon stocks from a zero CO_2 value to a CO_2 value to 87.56 Tonnes/ha
   c. A conversion of a grassland to a forestland changes carbon stocks from a CO_2 value of 14.99 Tonnes/ha to a CO_2 value of 87.56 Tonnes/ha

Based on these EF, the largest emissions occurred when dense montane forests were converted into either Croplands, Wetlands or Settlement and Otherlands resulting to a net emission of 577.95 Tonnes of CO_2 per ha (Table 19). The reverse however, does not sequester the equivalent of emitted GHG because the forest is still in a recovery mode at age 4 and a growth factor is used to calculate the CO2 sequestered. Table 19 does not illustrate emission factors from non-forests converting to non-forests.

[18] IPCC Table 4.9 classifies forests into less than 20 years or more than 20 years to determine Growth rate Factors

[19] NB: future Definitions of sustainable management of forests may include plantation forests remaining plantations where stock improvement is considered. This requires periodic inventories

Table 19: Matrix of EF setting for various land use changes and REDD+ activities

Forest strata			End Year													
			Montane &Western Rain Forest			Coastal & Mangroves Forest			Dryland Forest			Plantation	Cropland	Grassland	Wetland	Settlement & Other land
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open					
Start year	Montane &Western Rain Forest	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 & Mangroves 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 Forest	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											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. EMISSIONS FROM LAND USE CHANGE

4.1. Emission Estimates

Activity data for land use change conversions (Table 4) and the Emission Factors calculated for the specific land use conversions (Table 19) were used to calculate CO_2 emissions associated with each land use change for each epoch. This is shown in Tables 20-23[20]. A brief description of each of the tables is given below with illustrations from the Dense forest category of the montane and western rain forest which is a major source of emissions.

Table 20 for the period 2002-2006 shows emissions for each of the REDD+ activities highlighted in different colours. For example emissions from deforestation of Montane Dense forests into croplands and grasslands emitted 63,970,436 tonnes of CO_2 and 71,655,345 tonnes of CO_2 respectively. At the same time, afforestation activities that converted croplands into dense montane forests sequestered 3,500,587 tonnes of CO_2.Table 21 is for the period 2006-2010. Like Table 20 above, it illustrates emissions for different REDD+ activities. Emissions from deforestation of Montane Dense forests into croplands declined to 33,234,376 tonnes of CO_2 as compared to the 2002-2006 period while those from conversion of Montane dense forests into grasslands also decreased to 62,588,594 tonnes of CO_2 compared with the period 2002-2006. Sequestration from conversion of croplands into montane dense forests increased to 6,340,425 tonnes of CO_2 and those from conversion of grasslands into montane dense forests reached 10,543,466 tonnes of CO_2.

Table 22 is illustrates emissions for the period 2020-2014. In this period, emissions from conversions of dense montane forests into croplands reduced to 39,197,047 tonnes of CO_2 while those from conversion of the same forest into grasslands also decreased to61,436,643 tonnes of CO_2. The three tables therefore illustrate a declining trend of deforestation in the period 2002 - 2014. Table 23 however shows an increase in emissions from the dense montane forests converting into croplands resulting into 51,342,310 tonnes of CO_2 though emissions converting the same forests into grasslands reduced compared to the previous trends (51,702,465 tonnes of CO_2). Sequestration from afforestation of croplands and grasslands into dense montane forests were also moderate at 7,426,718 tonnes of CO_2 and 6,782,015 tonnes of CO_2 respectively.

These results show that on overall, emissions from deforestation in the dense montane and western rain forest strata have exceeded sequestration efforts from afforestation activities. The same trend is illustrated in the other forest categories. .

[20] Numbers have been rounded off to eliminate decimals

Table 20: Emissions (CO_2Tonnes) calculated for land use changes(2002 to 2006)

Forest strata			2006													
			Montane &Western Rain Forest			Coastal & Mangroves Forest			Dryland Forest			Plantation	Cropland	Grassland	Wetland	Settlement & Other land
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense				
2002	Montane &Western Rain Forest	Dense	0	33,402,790	14,952,439	0	0	0	0	0	0	0	63,970,436	71,655,345	144,916	256,958
		Moderate	-1,079,014	0	1,396,195	0	0	0	0	0	0	0	2,355,007	8,840,448	21,194	34,144
		Open	-734,972	-308,355	0	0	0	0	0	0	0	0	360,219	2,339,276	759	11,540
	Coastal & Mangroves Forest	Dense	0	0	0	0	957,251	465,807	0	0	0	0	480,910	6,577,554	95,791	121,980
		Moderate	0	0	0	-1,083,064	0	1,333,070	0	0	0	0	1,002,960	12,324,488	47,025	113,301
		Open	0	0	0	-129,630	-47,079	0	0	0	0	0	74,933	632,966	1,072	6,353
	Dryland Forest	Dense	0	0	0	0	0	0	0	560,352	1,329,447	0	3,606,220	23,672,823	180,967	230,717
		Moderate	0	0	0	0	0	0	-1,705,968	0	948,998	0	1,313,196	13,483,713	175,828	142,251
		Open	0	0	0	0	0	0	-683,703	-356,075	0	0	272,758	4,091,434	45,693	335,808
	Plantation			0	0	0	0	0	0	0	0	0	3,019,518	8,782,822	6,589	6,398
	Cropland		-3,500,587	-351,190	-114,753	-12,418	-24,117	-4,203	-343,535	-35,565	-115,221	-483,208		0	0	0
	Grassland		-8,255,667	-5,803,365	-936,099	-1,384,632	-1,090,906	-1,077,714	-2,121,493	-816,374	-1,414,338	-400,154		0	0	0
	Wetland		-19,387	-5,729	-1,004	-21,221	-23,838	-15,210	-47,195	-37,433	-38,861	-890		0	0	0
	Settlement & Other land		-43,653	-6,077	-2,081	-10,996	-6,455	-4,761	-36,156	-28,809	-84,815	-347		0	0	0

Table 21: Emissions (CO_2Tonnes) calculated for land use changes (2006 to 2010)

			2010													
			Montane &Western Rain Forest			Coastal & Mangroves Forest			Dryland Forest			Plantation	Cropland	Grassland	Wetland	Settlement & Other land
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense				
2006	Montane &Western Rain Forest	Dense	0	17,070,483	9,631,385	0	0	0	0	0	0	0	33,234,376	62,588,594	147,829	1,296,129
		Moderate	-2,186,221	0	916,880	0	0	0	0	0	0	0	641,058	8,623,860	6,009	17,258
		Open	-869,436	-395,724	0	0	0	0	0	0	0	0	194,514	1,058,624	704	4,357
	Coastal & Mangroves Forest	Dense	0	0	0	0	2,514,938	48,646	0	0	0	0	139,539	6,282,487	113,702	34,396
		Moderate	0	0	0	-213,728	0	69,327	0	0	0	0	56,881	3,348,489	79,186	16,287
		Open	0	0	0	-36,046	-297,093	0	0	0	0	0	10,178	1,237,805	23,475	11,411
	Dryland Forest	Dense	0	0	0	0	0	0	0	687,757	1,668,294	0	2,675,256	22,938,859	269,626	229,252
		Moderate	0	0	0	0	0	0	-988,102	0	794,694	0	278,196	6,898,571	142,429	67,092
		Open	0	0	0	0	0	0	-459,594	-455,333	0	0	312,609	3,304,391	64,602	224,316
	Plantation			0	0	0	0	0	0	0	0	0	2,969,681	5,544,797	7,997	192
	Cropland		-6,340,425	-806,099	-363,176	-102,764	-106,401	-12,314	-592,272	-95,234	-269,644	-334,294		0	0	0
	Grassland		-10,543,466	-6,219,016	-1,153,433	-1,574,598	-3,228,446	-245,011	-3,004,578	-1,424,344	-1,709,779	-868,478		0	0	0
	Wetland		-21,011	-3,680	-1,194	-16,609	-22,848	-759	-60,353	-27,178	-28,782	-1,521		0	0	0
	Settlement & Other land		-83,329	-90,817	-5,957	-20,950	-39,100	-7,668	-89,580	-451,569	-231,643	-1,127		0	0	0

Table 22: Emissions (CO_2 Tonnes) calculated for land use changes (2010 to 2014)

			2014													
			Montane &Western Rain Forest			Coastal & Mangroves Forest			Dryland Forest			Plantation	Cropland	Grassland	Wetland	Settlement & Other land
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense				
2010	Montane &Western Rain Forest	Dense	0	15,610,247	16,036,988	0	0	0	0	0	0	0	39,197,047	61,436,643	124,214	305,593
		Moderate	-2,054,576	0	1,038,642	0	0	0	0	0	0	0	1,239,653	6,533,103	14,763	33,623
		Open	-614,621	-372,719	0	0	0	0	0	0	0	0	362,152	1,182,669	1,879	5,334
	Coastal & Mangroves Forest	Dense	0	0	0	0	1,809,649	112,104	0	0	0	0	232,125	10,059,001	89,979	176,559
		Moderate	0	0	0	-634,485	0	109,077	0	0	0	0	482,940	12,713,774	99,468	35,646
		Open	0	0	0	-6,702	-9,963	0	0	0	0	0	48,549	324,386	742	3,570
	Dryland Forest	Dense	0	0	0	0	0	0	0	843,032	1,648,963	0	2,931,093	37,377,617	257,218	260,428
		Moderate	0	0	0	0	0	0	-1,091,665	0	1,046,613	0	316,036	13,485,959	110,723	398,281
		Open	0	0	0	0	0	0	-496,680	-276,412	0	0	368,015	4,420,666	59,385	255,702
	Plantation			0	0	0	0	0	0	0	0	0	4,186,177	4,667,342	8,765	6,653
	Cropland		-5,915,120	-627,891	-149,208	-107,782	-19,014	-614	-608,119	-99,679	-73,974	-447,272		0	0	0
	Grassland		-9,388,981	-5,600,946	-1,310,483	-3,614,253	-977,878	-58,429	-2,385,584	-832,356	-1,039,548	-869,672		0	0	0
	Wetland		-31,185	-1,054	-432	-46,590	-14,223	-63	-87,077	-26,814	-8,727	-1,276		0	0	0
	Settlement & Other land		-183,019	-12,069	-10,341	-15,202	-8,029	-127	-57,351	-25,447	-138,787	-977		0	0	0

Table 23: Emissions (CO_2 Tonnes) calculated for land use changes (2014 to 2018)

			2018													
			Montane &Western Rain Forest			Coastal & Mangroves Forest			Dryland Forest			Plantation	Cropland	Grassland	Wetland	Settlement & Other land
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open	Dense				
2014	Montane &Western Rain Forest	Dense	0	21,651,842	10,552,404	0	0	0	0	0	0	0	51,342,310	51,702,465	240,417	474,592
		Moderate	-1,178,313	0	1,221,932	0	0	0	0	0	0	0	1,573,535	6,618,484	10,728	4,507
		Open	-288,162	-302,242	0	0	0	0	0	0	0	0	278,178	1,456,014	436	1,093
	Coastal & Mangroves Forest	Dense	0	0	0	0	7,614,288	199,091	0	0	0	0	1,256,626	28,942,580	319,374	161,431
		Moderate	0	0	0	-236,831	0	121,268	0	0	0	0	388,871	4,743,776	50,009	25,466
		Open	0	0	0	-11,996	-10,637	0	0	0	0	0	5,469	96,905	469	572
	Dryland Forest	Dense	0	0	0	0	0	0	0	1,708,213	2,620,098	0	2,298,665	35,836,894	362,633	215,951
		Moderate	0	0	0	0	0	0	-919,222	0	1,482,003	0	362,697	7,824,389	93,596	77,496
		Open	0	0	0	0	0	0	-337,031	-324,191	0	0	126,249	3,060,342	45,466	134,488
	Plantation			0	0	0	0	0	0	0	0	0	12,709,896	5,053,745	18,233	16,058
	Cropland		-7,426,718	-770,231	-283,940	-69,858	-106,163	-18,121	-449,021	-194,042	-215,215	-340,227		0	0	0
	Grassland		-6,782,015	-3,883,689	-1,099,942	-2,026,449	-2,176,942	-353,769	-2,336,368	-1,283,405	-979,692	-350,685		0	0	0
	Wetland		-25,201	-16,642	-537	-14,167	-13,066	-1,582	-34,902	-22,924	-39,737	-1,245		0	0	0
	Settlement & Other land		-81,816	-10,063	-73,567	-16,442	-19,446	-614	-35,299	-51,327	-69,442	-567		0	0	0

4.2. Emissions Estimates per REDD+ Activities

The Emissions were calculated for each of the selected REDD+ activities and also the net emissions for the Country. Calculation of emissions per REDD+ activity allows the identification of REDD+ policies and measures that can address the drivers of emissions in the selected activities

4.2.1. Emissions from Deforestation

Table 24 illustrates that deforestation has an average annual emission of 48,166,940 Tonnes of CO_2in the reference period implying that a total of 770,671,037 Tonnes of CO_2 were emitted in the period 2002-2018. The greatest emissions came from the Montane and western Rain forests with an annual average of 30,121,437 Tonnes of CO_2. Though larger in area, the dryland strata did not present as high emissions due to the smaller forest area here and also their associated lower Emission Factors. Historically, the period 2002-2006 had the greatest emissions at 54,755,246 Tonnes of CO_2. However, Figure 7 shows that after a dip in emissions in the year 2006-2010, there has been a gradual increase in emissions post year 2010. Though very minimal, there is an overall decrease in the emissions due to deforestation in the Reference period.

Table 24: Historical Annual CO_2 Emissions from Deforestation

Forest strata	Emissions (Tonnes of CO_2)				
	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	37,497,560	26,953,329	27,609,168	28,425,689	30,121,437
Coastal& Mangrove Forest	5,369,833	2,838,459	6,066,685	8,997,887	5,818,216
Dryland Forest	11,887,852	9,351,299	15,060,281	12,609,716	12,227,287
Total	54,755,246	39,143,087	48,736,134	50,033,292	48,166,940

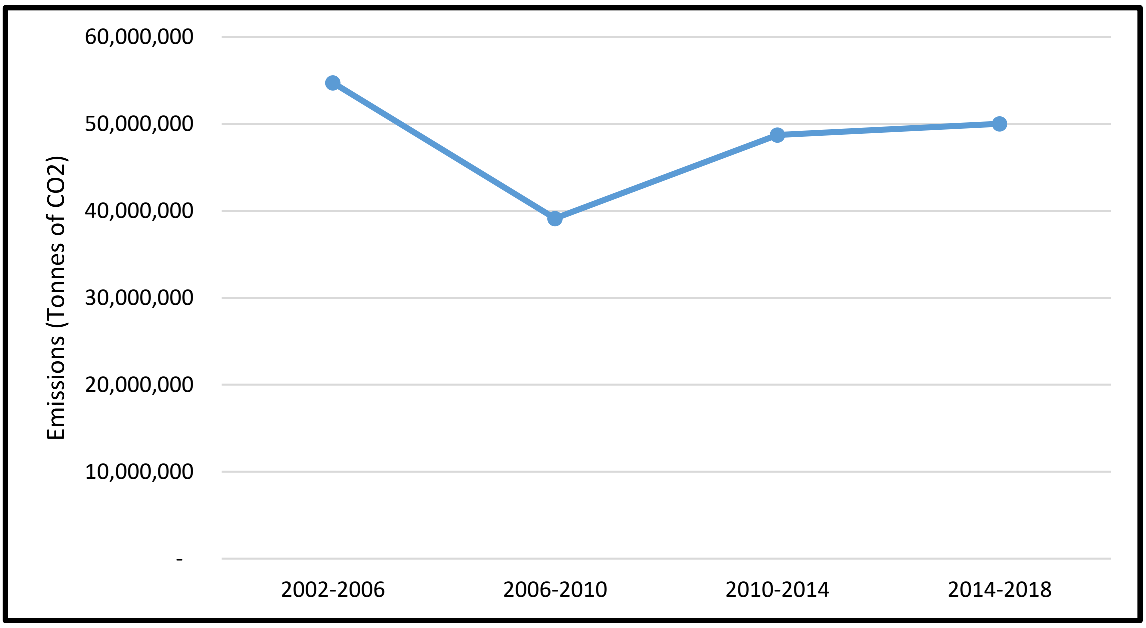

Figure 7: The Trend of Emissions due to Deforestation in the period 2002-2018

4.2.2. Emissions from Forest Degradation

Table 25 illustrates that forest degradation has an average annual emission of 10,885,950 Tonnes of CO_2 in the reference period implying a total of 174,175,207 Tonnes of CO_2 were emitted in the period 2002-2018. About 82% of emissions due to forest degradation came from the Montane and Western Rain forests with an annual average of 8,967,639 Tonnes of CO_2. Historically, the period 2002-2006 had the greatest emissions at 13,836,587Tonnes of $CO_2$and the trend of emissions from this REDD+ activity decreases with time (Figure 8).

Table 25: Historical Annual CO_2 Emissions from Forest Degradation

Forest strata	Emissions (Tonnes of CO_2)				
	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	12,437,856	6,904,687	8,171,469	8,356,545	8,967,639
Coastal& Mangrove Forest	689,032	658,228	507,708	1,983,662	959,657
Dryland Forest	709,699	787,686	884,652	1,452,579	958,654
Total	13,836,587	8,350,601	9,563,829	11,792,785	10,885,950

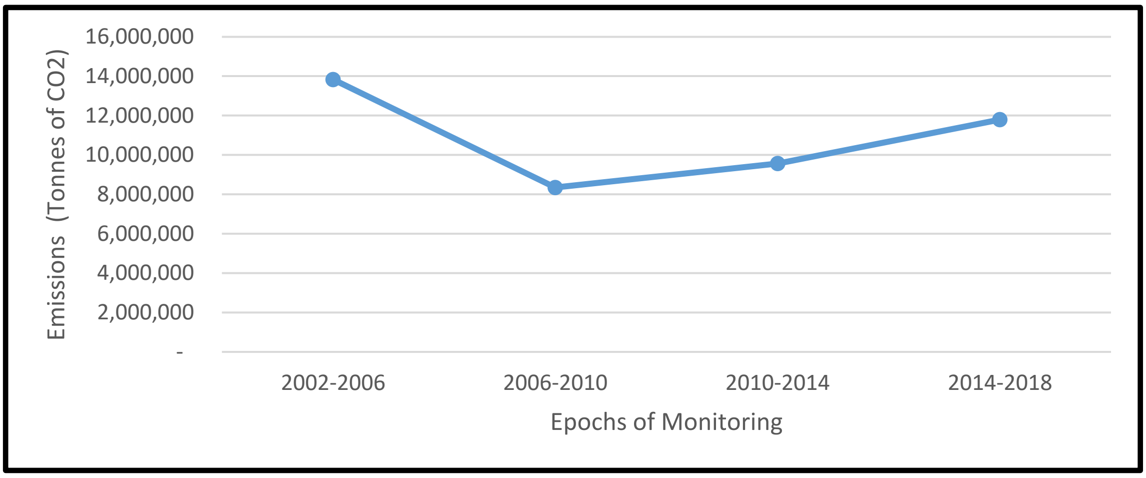

Figure 8: The Trend of Emissions due to Forest Degradation in the period 2002-2018

4.2.3. CO_2Sinks due to Afforestation (Enhancement of Carbon)

Table 26shows the CO_2 sinks due to afforestation activities. There was an annual removal of 8,205,540Tonnes of $CO_2$from the atmosphere in the reference period implying a total of 131,288,638 Tonnes of CO_2 were sequestered from the atmosphere due to afforestation activities in the period 2002-2018. About 67% of the sequestered CO2 was achieved in the Montane and Western Rain forests with an annual average of 5,522,268Tonnes of CO_2. Historically, Sequestration of CO_2 due to afforestation programmes has been increasing in the reference periodbecause a negative gradient illustrates the trend of increasing sequestration volumes (Figure 9).

Table 26: Historical Annual CO_2sinks from Afforestation

Forest strata	Emissions (Tonnes of CO_2)				
	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	-4,759,898	-6,407,901	-5,807,682	-5,113,591	-5,522,268
Coastal& Mangrove Forest	-919,118	-1,344,367	-1,215,551	-1,204,155	-1,170,798
Dryland Forest	-1,279,949	-1,996,239	-1,345,866	-1,427,843	-1,512,474
Total	**-6,958,965**	**-9,748,507**	**-8,369,099**	**-7,745,589**	**-8,205,540**

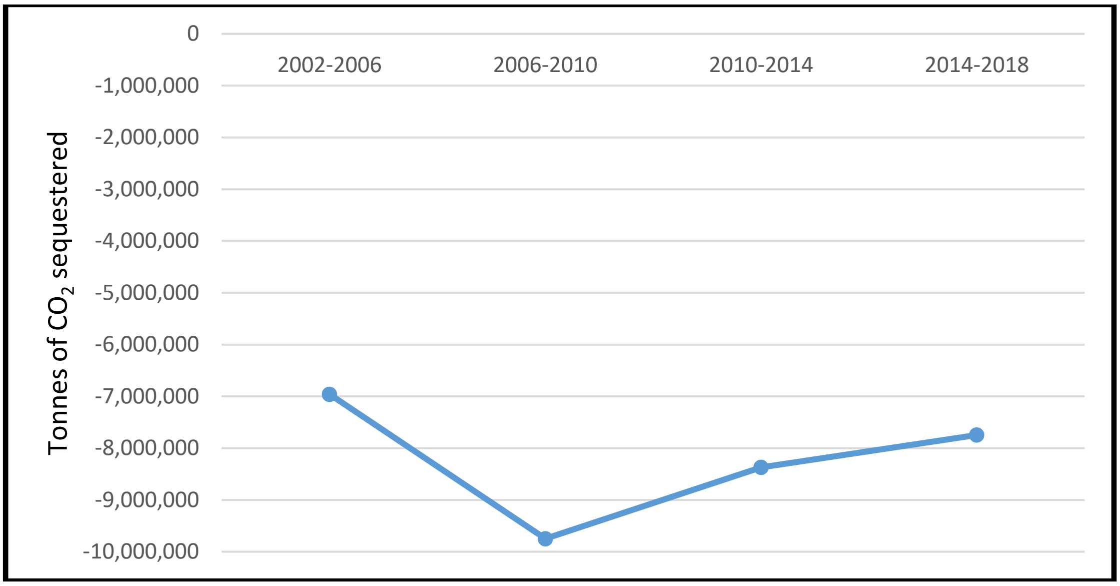

Figure 9: The Trend of CO_2 sequestration due to afforestation

4.2.4. CO_2 Sinks due to Canopy improvement (Enhancement of Carbon)

Table 27 shows the CO_2 sinks due to canopy improvement. There was an annual removal of 1,324,724 Tonnes of CO_2 from the atmosphere in the reference period implying a total of -21,195,588 Tonnes of CO_2 were sequestered from the atmosphere due to forest conservation and canopy improvement activities in the period 2002-2018. All the strata have a significant contribution to the sequestered CO_2implying that this is an activity that should be prioritized in all the strata. Historically, Sequestration of CO_2 due to forest conservation and canopy improvement have been on a decrease in the reference period with 1,531,965 Tonnes of CO_2 sequestered in the period 2002-2006 as compared to 902,157 Tonnes of CO_2 sequestered in the period 2014-2018 (Figure 10).

Table 27: Historical Annual CO_2 sinks from Canopy improvement

Forest strata	Emissions (Tonnes of CO_2)				
	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	-530,585	-862,845	-760,479	-442,179	-649,022
Coastal& Mangrove Forest	-314,943	-136,717	-162,788	-64,866	-169,828
Dryland Forest	-686,437	-475,757	-466,189	-395,111	-505,874
Total	**-1,531,965**	**-1,475,319**	**-1,389,456**	**-902,157**	**-1,324,724**

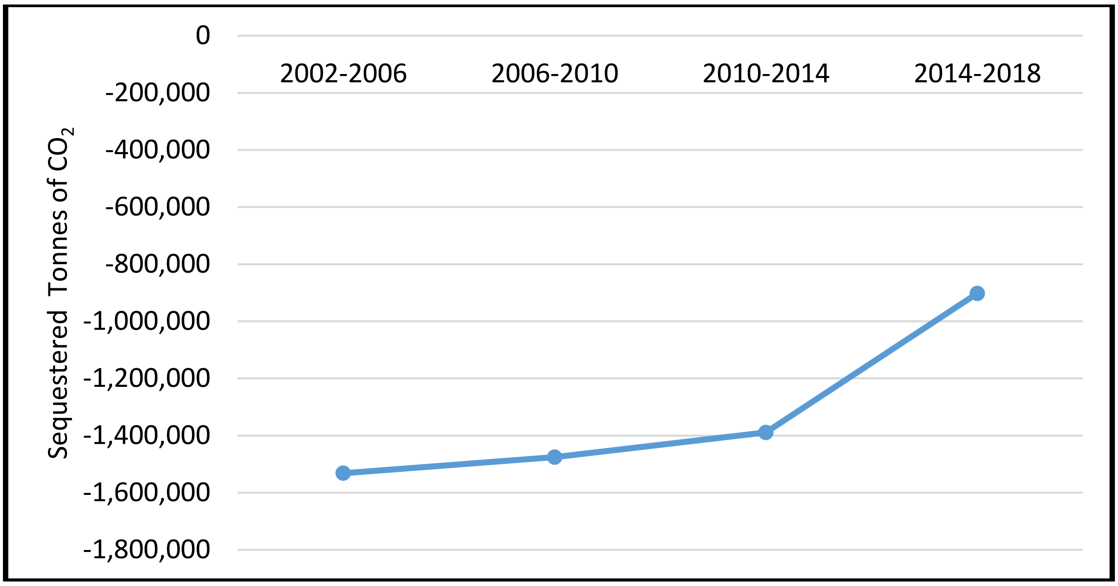

Figure 10: The Trend of CO_2 sequestration due to Canopy improvement

4.2.5. Emissions of CO_2due to sustainable management of forests

Table 28 shows the CO_2 sinks due to sustainable management of forests. A backlog in the replanting programme of the public plantation forests of Kenya, has resulted in a net emission of CO_2 from the public plantation forests with an average emission of 2,681,433 Tonnes of CO_2 implying a total of 42,902,925 Tonnes of CO_2 were emitted in the period 2002-2018. Historically, Emissions from this stratum have an increasing trend (Figure 11).

Table 28: Historical Annual CO_2Emissions from public forest plantations

Forest strata	Emissions (Tonnes of CO_2)				
	2002-2006	2006-2010	2010-2014	2014-2018	Average
Harvesting	2,953,832	2,130,667	2,217,234	4,449,483	2,937,804
Replanting	-221,150	-301,355	-329,799	-173,181	-256,371
Net	**2,732,682**	**1,829,312**	**1,887,435**	**4,276,302**	**2,681,433**

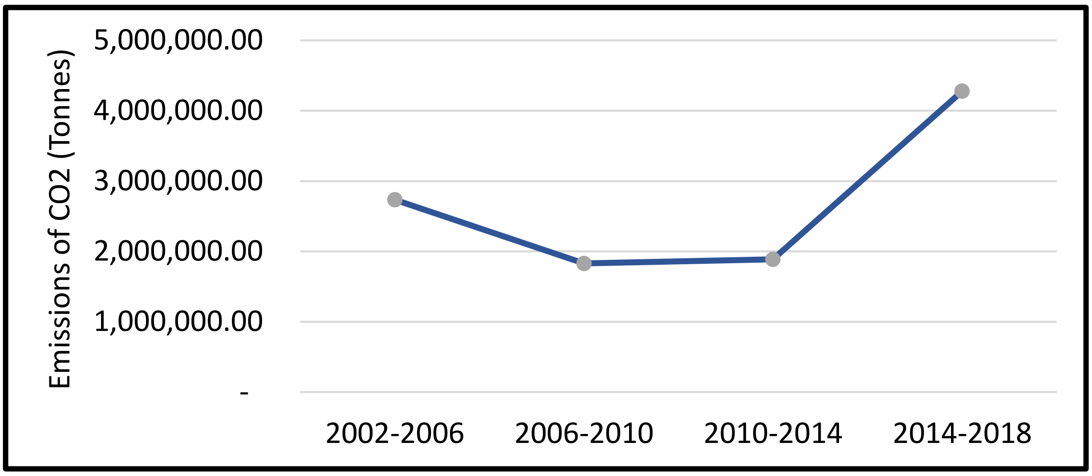

Figure 11: The Trend of CO_2Emissions in the public plantation forests

4.2.6. Net National Emissions

The Reference period provides a net Emissions of CO_2 at the national Level. Table 29 illustrates that Kenya has an average annual emission of 52,204,059 Tonnes of CO_2 in the reference period implying a total Net emission of 835,264,942.23 Tonnes of CO_2 in the period 2002-2018. The dip in emissions in the period 2006-2010 (Figure 12) does not comprise an outlier based on 2 standard deviations from the mean (at 95% CI, the emissions range from 30,829,478 to 84,208,165 Tonnes of CO_2). Figure 12 shows that in the reference period, Kenya has attained a minimal decline in Emissions from the forest sector. This minimal decline of Emissions is associated with activities like a decline in deforestation, a decline in forest degradation, an improvement in the conservation activities which enhance forest canopy and an enhanced afforestation programme.

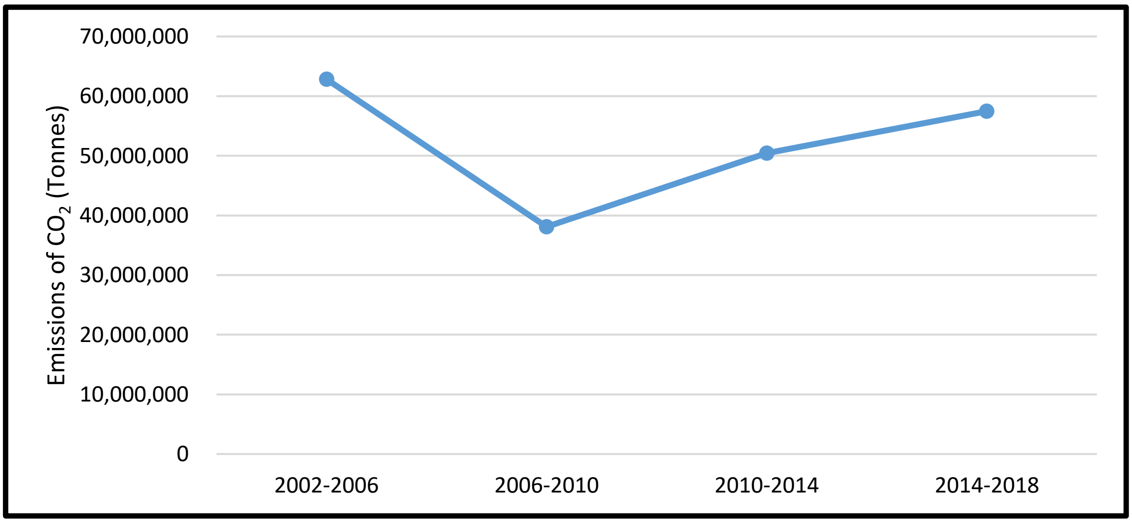

Figure 12: The Trend of Net Emissions in the period 2002-2018

Table 29: Historical Annual CO_2 Net Emissions classified by forest strata

Forest Strata	Emissions (Tonnes of CO_2)				
	2002-2006	2006-2010	2010-2014	2014-2018	Average
Montane &Western Rain Forest	44,644,932	26,587,270	29,212,476	31,226,464	32,917,786
Coastal& Mangrove Forest	4,824,805	2,015,603	5,196,054	9,712,528	5,437,247
Dryland Forest	10,631,166	7,666,989	14,132,878	12,239,340	11,167,593
Public Plantations	2,732,682	1,829,312	1,887,435	4,276,302	2,681,433
Total	**62,833,585**	**38,099,174**	**50,428,843**	**57,454,634**	**52,204,059**

The greatest emissions came from the Montane and Western Rain forests with an annual average of 32,917,786 Tonnes of CO_2 (Table 29 and Figure 13). The annual emissions for the Dryland forest strata, the Coastal and Mangrove strata and the Public Public Plantation forest strata were 11,167,593 Tonnes of CO_2, 5,437,247 Tonnes of CO_2 and 2,681,433 Tonnes of CO_2 respectively. Historically, the period 2002-2006 had the greatest emissions at 62,833,585 Tonnes of $CO_{2.}$

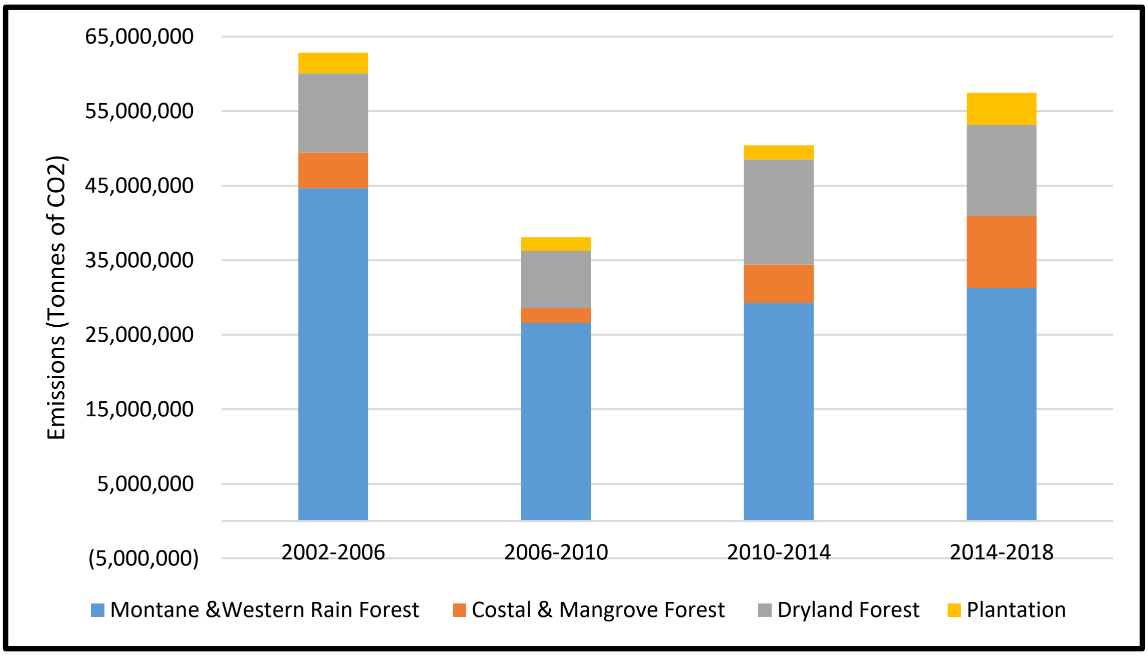

Figure 13: A cumulative bar graph to compare emissions among the forest strata of Kenya

The summary of the statistics associated with emissions from the specific REDD+ activities is shown in table 30 and Figure 14. Deforestation has the biggest contribution to national emissions with an average of 48,166,940 Tonnes of CO2. A key Category Analysis shows that

Deforestation contributes over 68% of the national CO_2 sources and sinks and is therefore a main activity to be addressed in Reducing Emissions for REDD+. Similarly, Emissions from Forest degradation and Enhancement of carbon stocks are significant activities for Kenya's REDD+ programme. Though akey Category Analysis identifies that public plantation forests of Kenya are not a Key source of Emissions for the REDD+ programme(3.76%), these forests supply material for wood based industries and therefore support livelihoods and economic development and qualify as an important REDD+ activity.

Table 30: Historical Annual CO_2 Net Emissions classified by REDD+ Activity

REDD+ Activity	Emissions (Tonnes of CO_2)					KCA
	2002-2006	2006-2010	2010-2014	2014-2018	Average	
Deforestation	54,755,246	39,143,087	48,736,134	50,033,292	48,166,940	67.59
Degradation	13,836,587	8,350,601	9,563,829	11,792,785	10,885,950	15.28
Sustainable management of forest	2,732,682	1,829,312	1,887,435	4,276,302	2,681,433	3.76
Enhancement	-8,490,930	-11,223,826	-9,758,555	-8,647,746	-9,530,264	13.37
Total (Emission estimates (Net)	**62,833,585**	**38,099,174**	**50,428,843**	**57,454,634**	**52,204,059**	

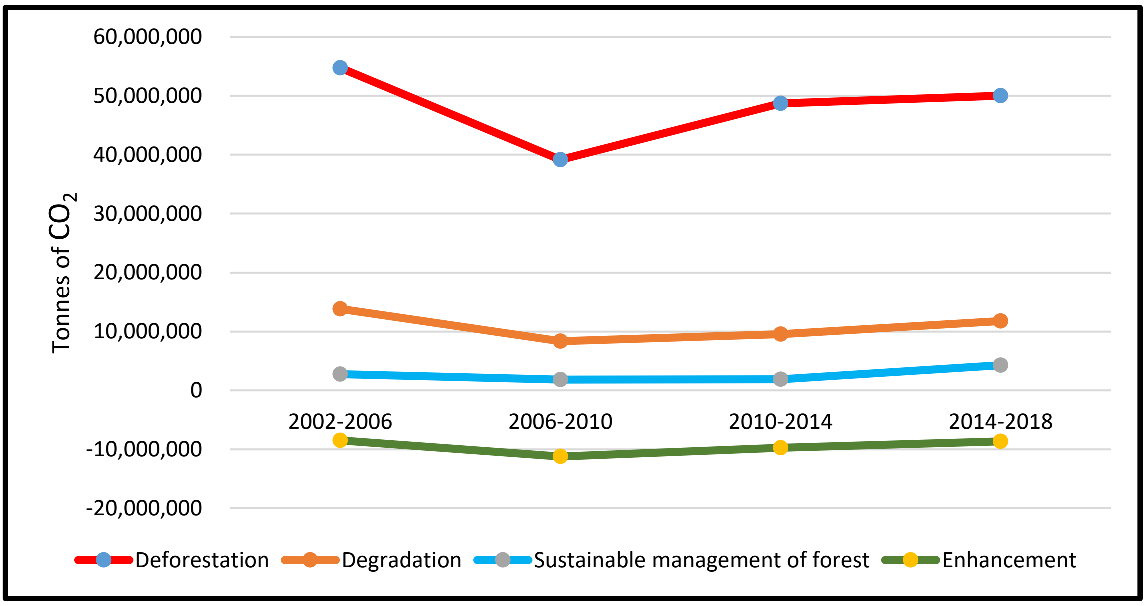

Figure 14: Comparison of Annual Emissions from REDD+ Activities in the reference period

5. NATIONAL CIRCUMSTANCES

5.1. Qualitative analysis

This section describes how the national circumstances are likely to influence future forest sector emissions and removals. The national circumstances considered include current and evolving institutional arrangements for forest management and administration, implementation of policies and legislation, national and international forest commitments, and national development strategies likely to impact on future forest resources management and conservation.

The forest sector is today a critical asset for economic growth, environmental sustainability, and provision of social and cultural values. For instance, about 50,000 people are directly employed in the forest sector while about 300,000–600,000 are indirectly employed depending on the sector, (FAO, 2015). Further, over 2 million households within 5 kilometers from forest edges have significant dependency on the forest services and products which include, cultivation, grazing, fishing, fuel, food, honey, herbal medicines, water and other benefits.

The results of emissions classified by stratashow that Montane forests have historically (In the reference period) accounted for the largest source of emissions and this may be attributed to encroachment of forests and their conversion to agriculture specifically before enactment of the Forest Act 2005 and its subsequent revisions. Another major source of emissions is identified as the dryland forests where agriculture is actively converting former dryland forests into arable land (Drigo et al., 2015).Poor management of plantation forests has resulted to backlogs as illustrated by reduced forest cover in the plantation zones and this stratum has become a source of emissions.

5.2. Socio-Economic profile

Kenya has experienced significant growth in population in the recent past. As Kenya seeks to transit from a Least Developed country to a middle-income economy[21] a number of developmental activities have been proposed for implementation. Such activities target industrial development and development of service industries but also note the need to enhance conservation of environment and natural resources including forests.

The current population of about 50 million (Figure 15) has a very high positive relationship with forest cover and the rates of deforestation and forest degradation The government has proposed drastic measures to boost food production, including increased acreages under irrigation and provision of subsidies for agricultural inputs. There is rapid urbanization in the country as a result of growth in population and an enabling economic environment in the country. The expansion of cities and towns will continue to cause deforestation and forest degradation by encroaching into the forest areas and causing increased demand of forest products for construction and energy. Both rural and urban population is highly dependent on biomass energy especially the use of charcoal accounting for 60% energy demand (Drigo et al., 2015).

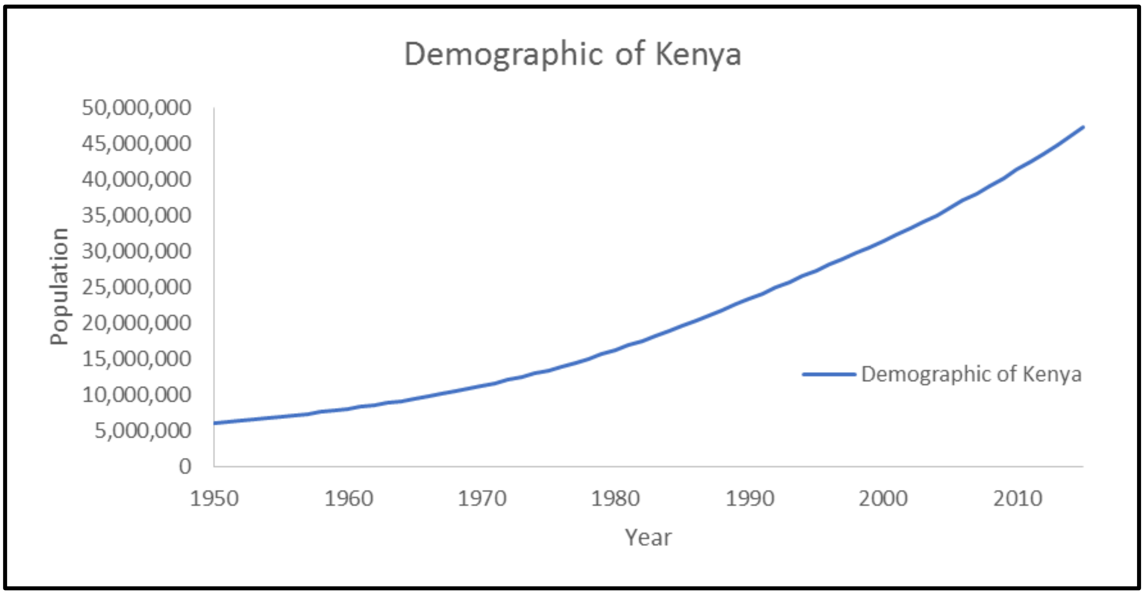

Figure 15: Kenya's Demographic trend (UN 2019)

5.3. Infrastructural, and industrial developments

Kenya has an aggressive infrastructural, commercial and industrial development programme based on the vision 2030. This development is likely to result in clearing of large areas of previously forested landscapes. The surrounding forest areas are also more likely to be

[21] Vision 2030 targets

converted to settlements leading to deforestation and forest degradation. It has been pointed out that the current and planned developments are concentrated in the fragile ecosystems including the dryland forest and woodland areas which will adversely affect the forest cover in the country. The current and planned developments that are expected to lead to planned deforestation and forest degradation include Konza technology city, Isiolo Port, Lamu port, LAPSSET Project, comprising of a road, rail and pipeline connecting Kenya to South Sudan and Ethiopia, The Northern Corridor Transport Project, Construction of a standard gauge railway line from Mombasa to Kisumu, Creation of a one-million-ha irrigation scheme in the Tana Delta.

5.4. Development Priorities and commitments

There are different development priorities recognized in the country due to the set national development agenda, agreements within regional economic blocks, international treaties and multilateral agreements. Most of these agreements have identified forests and woodlands as important resources for economic growth and poverty reduction, especially with regard to energy, food, and timber. There are also other non-timber forest products and environmental services that underpin ecosystem functions in support of agricultural productivity and sustainability". Important development priorities affecting the forest sector include; SDG Targets, UNFCCC, Convention on Biological Diversity (CBD), Forest Law Enforcement and Governance (FLEG), International Tropical Timber Agreement 2006 (ITTA), Reducing Emissions from Deforestation and Forest Degradation (REDD+ mechanisms) and the United Nations Convention to Combat Desertification (UNCCD)

The Sustainable Development Goals (SDG) which recognize multiple functions of forests including ensuring conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems, the need to mobilize resources for forest management, protecting forest catchments area in line with obligations under international agreements (SDG15.1, SDG15.2, SDG15b, SDG6.6) by year 2020. Under the United Nations Framework Convention on Climate Change (UNFCCC), through the Nationally Determined Contribution (NDC) the government has committed to contribute to the mitigation and adaptation to climate change by using the forest sector as the main sink for GHG Emissions.

While significant changes in policy and Legislation have been undertaken over the last decade that seeks to strengthen sustainable forest management and conservation, the country's forest resources continue to experience severe pressure from the expanding agricultural frontier, settlements and other developments. There are genuine concerns that commitments to national and international forest goals may not be realized if the current challenges are not addressed. There is expectation, however, that improved governance of the sector arising from the devolution and public participation in management may reverse the current negative practices. This is, however, expected to take some time as capacities within county governments are strengthened to assume expanded responsibilities. Figure 16 illustrates the historical trend of areas under agriculture and cropland in the reference period based on the mapping programme that was used to develop this FRL. It can be noted that the area of grasslands has been decreasing while that of cropland has been increasing.

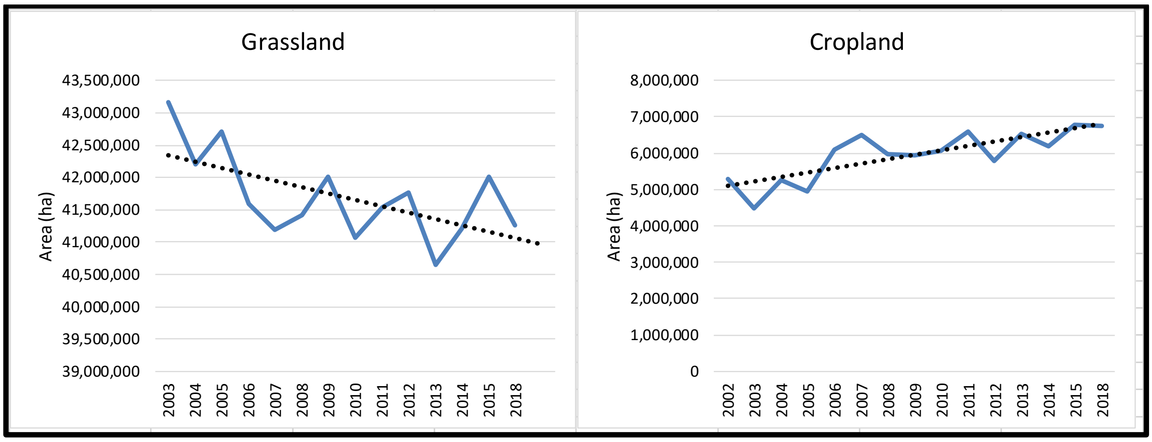

Figure 16: Historical Trends of Grassland and Cropland (SLEEK maps)

5.5. ForestSector Governance

As described in the introductory part, Kenya has policies and legislation for sustaining its resources and ecosystems. According to the Constitution and Vision 2030[22], Kenyadesires toachieve and maintain at least 10% forest cover of the total national land area by the year 2030. Further, the Forest Conservation and Management Act, 2016 identifies all the forest tenure systems of Kenya (Public, community and private forests) as potential for reforestation towards meeting the constitutional requirements of the 10% forest cover. The Forest Landscape Restoration Project for Kenya[23]identified a potential of afforesting up to 5.1 million ha in the different strata of Kenya which would double the current forest area and therefore exceed the 10% forest cover target.

The other key policies and legislation that have a bearing on the forest management include; National Wildlife Conservation and Management Act, 2013, supporting management of forest areas in significant wildlife habitats; The Land Act, 2012 and the County Government Act, 2013which requires engagements of the local communities in the planning and management of

[22] The Constitution states that "land in Kenya shall be held, used and managed in a manner that is equitable, efficient, productive and sustainable," and entrenches "sound conservation and protection of ecologically sensitive areas."
[23]http://www.kenyaforestservice.org/index.php/2016-04-25-20-08-29/news/437-forests-and-landscape-restoration-a-key-component-of-climate-change-mitigation-and-adaptation

forest resources to ensure sustainable and strategic environmental, ecological, social, cultural and economic benefit sharing. Other important policy and legislation include Environmental Management and Coordination (Amendment) Act, 2015; The EnergyPolicy 2014; Agriculture, Fisheries and Food Authority Act, 2013; The Water Act, 2012; National Museums and Heritage Act, 2006; and the Climate change Act, 2016.

The country recognizes the forest sector as a key sector in her national development strategies and plans which include the national Climate Change Response Strategy (2010), and the Kenya Green Economy Strategy and Implementation Plan (2017) which recognizes the critical role of the forest sector in meeting the climate change mitigation and adaptation obligations.

Kenya has already developed a National Determined Contribution (NDC) in line with her commitment to the global climate change goals under the Paris climate agreement in which it identifies forests as a significant sector in reducing emissions and meeting the NDC targets.

Figure 17 is a projection of the forest cover increase that would allow Kenya to meet the Vision 2030 requirement of 10% forest cover. This graph is developed based on the forest cover recorded in year 2018.

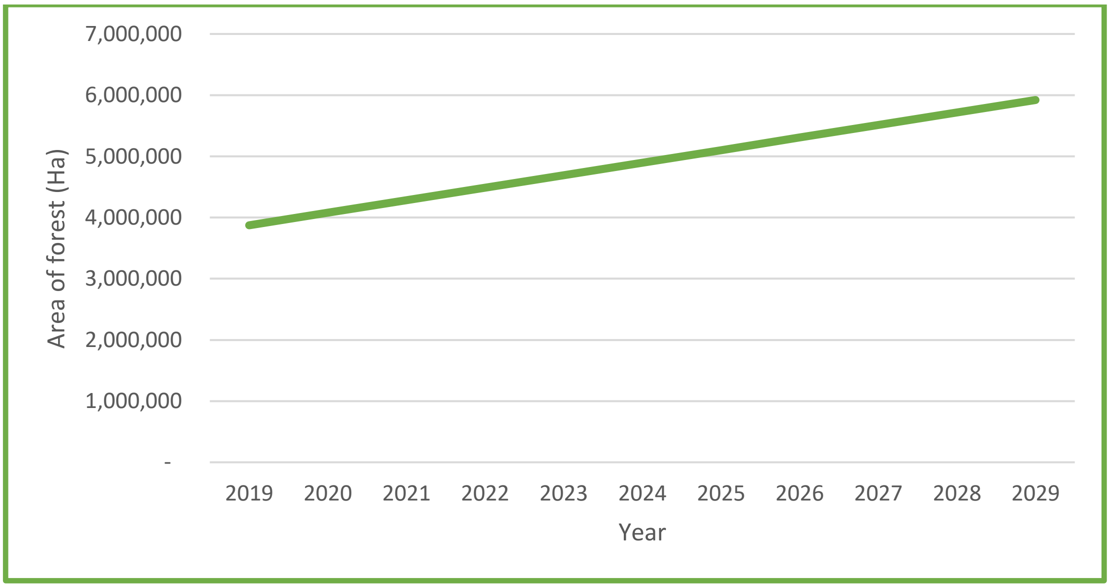

Figure 17: Projected forest cover towards 10% by year 2030[24]

5.6. Governance challenges

A few challenges manifest and have continued to cause significant deforestation and forest

[24] Estimated at afforesting/increasing forest cover by 204,727ha per year

degradation in Kenya. The main challenge in the management of the forest resources is the increasing population and associated increased demand for forest products and services. Though the government has clear policies to support conservation of forests, a spiralling population poses pressure on the forest resource and calls for enhanced awareness in supporting conservation measures. It is noted that the ongoing development of the Forest strategy has noted these challenges and seeks to create an all-inclusive strategy that will support forest conservation.

Historically poor enforcement of forest regulations has been a challenge to forest conservation. This is exacerbated by the dwindling funding for conservation activities in Kenya and the small human resource capacity within the Kenya Forest Service (MENR 2016). A continuous improvement in the functions of the Kenya Forest Service and the involvement of communities through Community forest Associations is expected to enhance enforcement though successful community management of forests in Kenya has only been actualised in communities with harmonised cultural characteristics (KWTA, 2014). It is hoped that an all-encompassing REDD+ strategy will enhance awareness of conservation, involvement of more stakeholders and a campaign towards environmental protection.

Overlapping policies and institutional mandates, Policy conflicts, inadequate land tenure policies, and inadequate collaboration among forest conservation agenciesare identified asother governance challenge affecting forest conservation (FAO, 2017). It is noted that the Environmental Management and Coordination Act (EMCA) (NEMA, 2018)is the supreme environmental law and seeks to enhance forest conservation and biodiversity conservation. However implementation of the EMCA is still a challenge. Other challenges including Inadequate regulation of grazing in the semi- arid and arid lands woodland and Dryland forests that has resulted to overstocking and overgrazing leading to wide spread deforestation and degradation of forestswhich needs to be addressed through programmes that support development of marginal areas.

5.7. Factors influencing future Emissions

No modelling studies have so far been carried out to understand how various land use and land resources policies implementation will manifest in future against the challenges of competing land claims by key economic sectors, increasing population and increased demand for forest resources and food insecurity. As discussed in chapter 2, it is proposed that the FRL will be projected based on the historical average of emissions using the 2002-2018 data. The foregoing discussion has illustrated two major factors that will influence emissions in Kenya. Population growth and increased demands for developmental needs, has historically put pressure on the forests. With the projected population growth of 2.2% in 2019[25] an equivalent increase in emissions would increase CO_2 Emissions in the four REDD+ activities from the current annual average of 52,204,059 Tonnes of CO_2. Noting that population increase is not the only factor influencing forests of Kenya, a Business as Usual scenario under the current forest product consumption rates would increase CO_2 emissions from the forest sector unless efforts are put in place to integrate emission reductions in developmental activities.

On the conservation front, Kenya's vision 2030 targets an increase in forests from the current 5.85% in 2018 to 10% in 2030. This translates to an increase of the current forest cover by 0.3458% per year which is equivalent to 207,213 ha per year for the period 2019 to 2030. Such a planting and conservation rate if implemented would reverse Kenya's emission status from the current state of net emission to a net sink.

The ongoing discussion therefore proposes that a projection of the future emissions for Kenya would preferably use a historical average to represent a business as usual scenario. A decrease in emissions in the future would therefore illustrate an extra effort by the country to deviate from the Business As Usual scenario towards reducing emissions

[25] 2019 census report gives an inter census growth rate of 2.2% and a 2019 population of 47.6 Million in 2019. https://www.knbs.or.ke/?p=5621

6. PROJECTIONS OF THE FRL

6.1. Historical averageprojected into the future

The values of Emission estimates of each REDD+ activityare shown in the Tables 29 and 30.The value of Net emission is calculated as the sum of emissions arising from the four REDD+ activities (Deforestation, Forest degradation, Sustainable Management of Forests and Enhancement) and also classified by forest strata (Montane and western Rain forests, Coastal and Mangrove forests, Dryland forests and Public plantation forests). It is also hoped that emissions in the future will be monitored at 4 year intervals because Kenya is continuously improving its land cover mapping programme. There are also plans to implement a National Forest Inventory based on the designs that have already been developed.

The process of projection adopted an average of the historical emissions. It was noted that the linear relationship developed from the 4 point data (2002-2006, 2006-2010, 2010-2014 and 2014-2018) had a weak Coefficient of Determination (R^2) which explains that the trend of emissions is not accurately defined by the time series monitoring. A historical average therefore explains that a Business as Usual scenario is assumed in projecting emissions into the future and the assumptions for this are clearly explained in the Chapter on National Circumstances. The Chapter on National Circumstances did not identify any need to create an adjustment of the average emissions because there are no specific development and human livelihood activities prioritized by the government that may result to a reversal of the ongoing conservation activities.

6.2. Projected Net National Emissions

A projection of Emissions using the Business as Usual Scenario is an extension of the average emissions into the future (Figure 18 and table 31).The table presents the averages calculated for the historical period and their projection into the future which implies that the same historical numbers have been projected into the future.

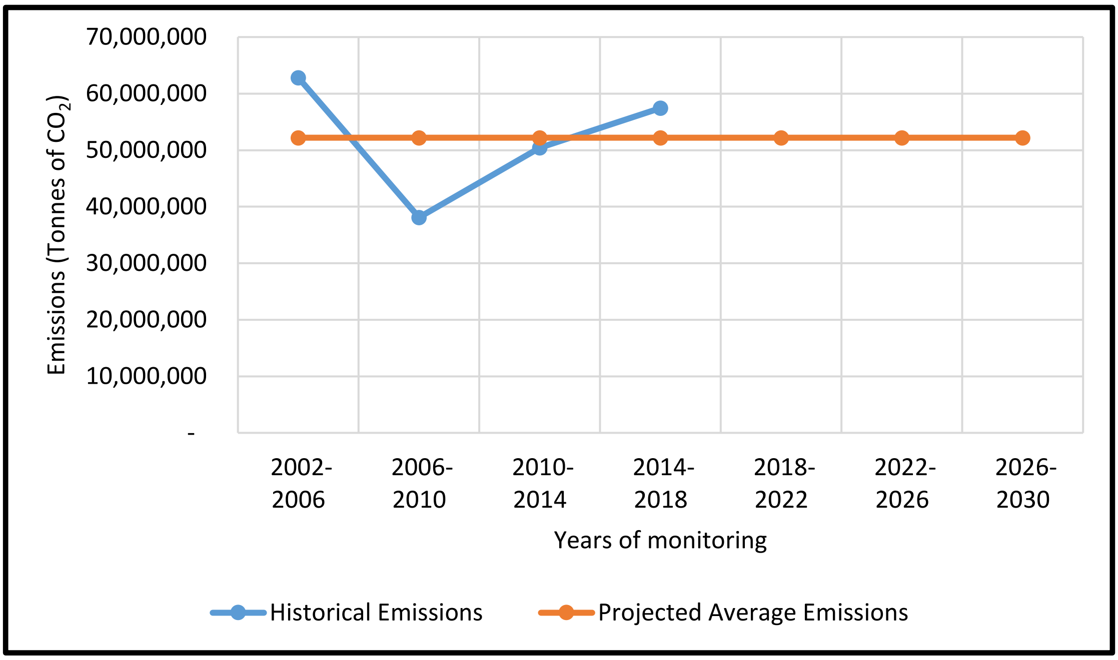

Figure 18: Projections of Net Emissions

6.3. Projected emissions from REDD+ activities

Projected emissions for the various REDD+ activities and based on the historical average emissions for each REDD+ activity are shown in Figure 19 and table 31.The table presents the averages calculated for the historical period and their projection into the future which implies that the same historical numbers have been projected into the future.

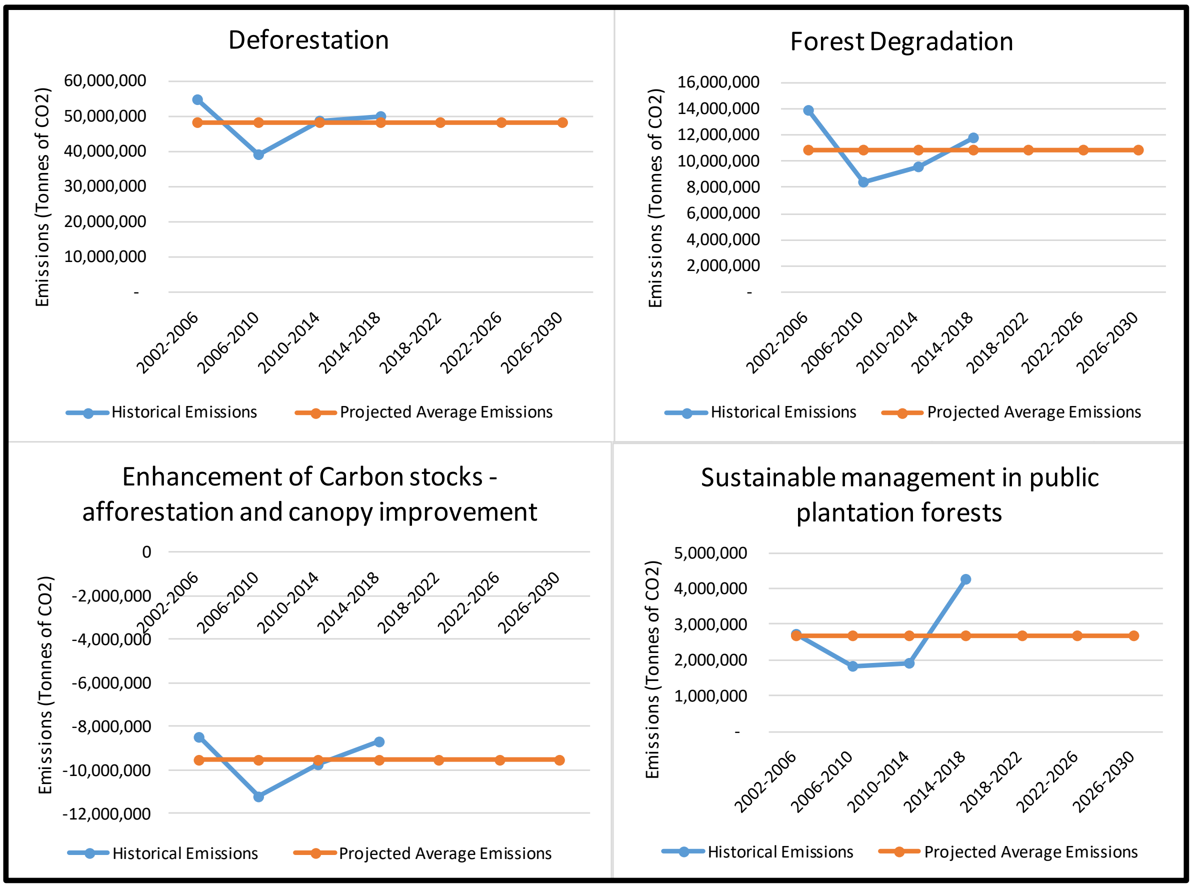

Figure 19: Projections of Annual Emissions from the selected REDD+ Activities

Table 31: Projected Annual CO_2 Emissions based on historical averages

REDD+ Activity	2002-2006	2006-2010	2010-2014	2014-2018	2018-2022	2022-2026	2026-2030
Deforestation	48,166,940	48,166,940	48,166,940	48,166,940	48,166,940	48,166,940	48,166,940
Degradation	10,885,950	10,885,950	10,885,950	10,885,950	10,885,950	10,885,950	10,885,950
Sustainable management of forest	2,681,433	2,681,433	2,681,433	2,681,433	2,681,433	2,681,433	2,681,433
Enhancement	-9,530,264	-9,530,264	-9,530,264	-9,530,264	-9,530,264	-9,530,264	-9,530,264
Total (Emission estimates)	**52,204,059**	**52,204,059**	**52,204,059**	**52,204,059**	**52,204,059**	**52,204,059**	**52,204,059**

7. UNCERTAINTY OF THE FRL

7.1 Uncertainty of AD

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. Statistically robust and transparent approaches are critical to ensure the integrity of land use change information. The steps followed were as recommended by Global Forest Observation Initiative Methods and Guidance Document[26]. The most common approach for accuracy assessment is to conduct ground referencing where each pixel in the land cover map is verified. However, field work is normally expensive and time consuming and therefore sampling methods were used to generate representative classes for field verification.

7.1.1. Uncertainty of individual land cover maps

The 2018 map was developed during the same year and allowed ground truthing. A total of 1894 field sample points were visited for ground truthing donebased on accessibility, and security situation in Kenya. Another 1905 sample were independently interpreted using Google Earth as high resolution imagery. Since no ground truthing would be done for historical maps, ground truthing was done using Google Earth imagery.

The classification accuracy was calculated by comparing the classification result with presumably correct information (ground truth) as indicated by either field verification and/or Google Earth imagery. The accuracy assessment results illustrated in Table 32 show values for all the years and highlight the years that were used for the FRL. Table 33 shows the correctness of each of the landcover classes. In all the years used for developing the FRL, the accuracy of the maps is within acceptable limits and have over 70% agreement.

[26]Methods and Guidance from the Global Forest Observations Initiative Version 2: Integration of remote-sensing and ground-based observations for estimation of emissions and removals of greenhouse gases in forests

Table 32: Kappa Coefficients of the time series Land cover maps

S/No	Year	Overall Accuracy %	Kappa Coefficient	S/No	Year	Overall Accuracy %	Kappa Coefficient
1	2000	83.018	0.743	9	2009	89.485	0.851
2	2002	87.030	0.815	10	2010	82.392	0.748
3	2003	83.931	0.738	11	2011	81.818	0.727
4	2004	81.611	0.705	12	2012	77.526	0.705
5	2005	82.258	0.749	13	2013	83.139	0.764
6	2006	88.713	0.828	14	2014	75.635	0.7025
7	2007	78.227	0.697	15	2015	78.870	0.727
8	2008	78.001	0.688	16	2018	76.021	0.705

Table 33: Correctness of the 2018 land cover map by land cover classes

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%			

7.1.2. Uncertainty of change Maps (Activity Data)

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. The results of uncertainty are presented in Table 34.

$$S\left(\hat{p}_{\cdot j}\right) = \sqrt{\sum_{i=1}^{q} W_i^2 \frac{\frac{n_{ij}}{n_{i\cdot}}\left(1 - \frac{n_{ij}}{n_{i\cdot}}\right)}{n_{i\cdot} - 1}}.$$

Table 34: Uncertainty of Activity Data

Uncertainty (%) of Change map 2002-2006	
Overall Accuracy	41.05
Overall Uncertainty	4.94
Limits	41.05%±4.94%
Uncertainty (%) of Change map 2006-2010	
Overall Accuracy	51.9
Overall Uncertainty	4.03
Limits	51.9%±4.03%
Uncertainty (%) of Change map 2010-2014	
Overall Accuracy	35.75
Overall Uncertainty	2.17
Limits	35.75%±2.17%
Uncertainty (%) of Change map 2014-2018	
Overall Accuracy	30.01
Overall Uncertainty	2.15
Limits	30.01%±2.15%

Noting that 4 intervals were used for the AD, an average of the uncertainties for the 4 epochs was used to calculate the overall uncertainty of AD as illustrated below,

$$\frac{4.94}{4} + \frac{4.03}{4} + \frac{2.17}{4} + \frac{2.15}{4} = 3.32$$

Therefore the average uncertainty of the maps is 3.32%.

The mean accuracy of the Activity data was calculated using the same method from data for the four epochs and gives a mean of 39.68%

$$\frac{41.05}{4} + \frac{51.9}{4} + \frac{35.75}{4} + \frac{30.01}{4} = 39.68$$

7.2. Uncertaintyof EF

In Kenya, a full national forest inventory has never been implemented. The number of plots in the pilot forest Inventory which was done for EF setting was limited to only 121 plots distributed among the 10 strata described in Table 2. An analysis of the data shows high uncertainty of the mean (Table 35) which is attributed to the small sample size. The standard deviations are extremely high illustrating a need for creating substrata within all the selected strata. A comparison of the data with other independently carried out research in the specific forests of Kenya (e.g. Kinyanjui *et al* 2014, Glenday, 2006 and Kairo, 2009) also showed a great variation in carbon and biomass values within strata of Kenya and thus, an NFI using the nationally approved methodology will be expected to be implemented in the future to provide more accurate values of EF for the variety of forests. This may necessitate creating further substrata within the current ones.

Table 35: Uncertainty of the Field data

Strata	Canopy Class	Mean (Tonnes of AGB)	Std Dev	No Samples	Uncertainty	Uncertainty of mean
Montane & Western Rain Forest	Dense	244.80	157.94	8	126.46	44.71
	Moderate	58.43	34.64	7	116.20	43.92
	Open	23.26	13.64	6	114.94	46.92
Coastal & Mangrove forest	Dense	94.63	45.03	18	93.27	21.98
	Moderate	60.45	31.90	12	103.43	29.86
	Open	35.47	34.03	16	188.04	47.01
Dryland Forest	Dense	42.43	32.11	8	148.33	52.44
	Moderate	34.52	15.01	8	85.22	30.13
	Open	14.26	6.89	7	94.70	35.79
Plantation	Plantation	324.79	249.38	36	150.49	25.08

Due to the limitations in the EF data, a Bootstrap simulation according to the 2006 IPCC Guidelines[27] (Volume 1 Chapter 3) was used to calculate the Uncertainty of the EF. The Bootstrap simulation helps to obtain the confidence interval of the mean in cases where of the uncertainty of the mean is not a symmetric distribution. The results of the bootstrap analysis describes the ranges of 95 % Probability of the confidence interval. Then, the 2.5 Percentile and

[27]Volume 1 chapter 3of the 2006 IPCC guidelines. Uncertainty

the 97.5 Percentile are 142.34 and 228.95, respectively. The mean EF is 183.51 and the uncertainty of the EF was calculated as 24.8%

7.2. Uncertainty of FRL

Olofsson, et al, (2013) have explained that the error of the estimated Green House Gas emission is a product of the AD and EF and provide the following formula for estimating the error propagation

$$SDCO_2 = \sqrt{\overline{Total_{carbon}}^2_{1\to2} \left[\left(\frac{SD^2_{Emissions_{factor}}}{\overline{Emissions_{factor}}^2_{1\to2}} \right) + \left(\frac{SD^2_{Activity_{data}}}{\overline{Activity_{data}}^2_{1\to2}} \right) \right]}$$

The uncertainty of AD and uncertainty of EF were 2.9 % and 24.8 % respectively. The total CO_2 calculated for the FRL was 52,204,059. Therefore the uncertainty of the FRL was calculated as

$$\textit{Uncertainty of the FRL} = \sqrt{52{,}204{,}059^2 * [(24.8^2/183.51^2) + (3.32^2/39.68^2)]}$$

The Uncertainty of this Submission is ± 8,299,540. This implies that the FRL is 52,204,059 ± 8,299,540 t CO2/year which is equivalent to 16%:

8. FUTURE IMPROVEMENTS

Kenya will develop its FRL according to astepwise approach informed by available data, expertise and technologies. There are proposed improvements in the future FRL setting. Listed as follows

8.1. National Forest Inventory

The Emission factors presented in this FRL are based on a very small sample size representing the different forest strata of Kenya. As noted in the accuracy assessment section, better accuracy of this EF would be achieved when a wider data set is considered. Similarly, the wide variations in the collected data within strata calls for creation of sub strata to enhance accuracy. It is noted that within the current strata there exists some sub strata which may require sub sampling. For example, within the Montane and Western rain forest strata, Montane forests can be separated from Bamboo forests and Western rain forests to create three strata. Similarly, separation of Mangrove forests from Coastal forests would enhance accuracy noting the great variation in the tree characteristics and biomass components (Kairo et al., 2009).

An NFI should develop permanent sample plots which will provide better information on stock changes and growth rates. This FRL has adopted IPCC default values for growth rates and these might not be very accurate at the strata specific level. For example growth rates for the Montane and western rain forests have been adopted from the Tropical rain forests of the world. However Kenya's Montane forest have slightly less stocking (Kinyanjui etal., 2014) and growth rates compared to the tropical rain forests, but they can also not be classified as mountain ecosystemsunder the IPCC classification system because the mountain ecosystems of Kenya have dwarf vegetation that is slow growing. Data from such PSPs will also illustrate if there are changes in forest carbon stocks when a forest remains in the same canopy class in two mapping years.

8.2. Land cover mapping

The SLEEK land cover mapping programme has generated 18 maps using Approach 3 of the IPCC guidelines[28]. From this time series set of land cover maps, five maps were selected to develop this FRL. An improvement in the accuracy of the maps would have made it possible to select more maps and shorter time intervals would have been adopted to create a more realistic scenario for the FRL. Though the use of 4 year intervals to describe land cover changes and

[28]2006 IPCC Guidelines for National Greenhouse Gas Inventories. Chapter 3: Consistent Representation of Lands

historical emissions was used, the future reporting of Biennial Update Reports may require doing monitoring at 2 or 1 year intervals. This implies a need for capacity building to enhance the accuracy of the maps so that they may provide accurate estimates of Emission trends

The land cover maps used in the FRL have 7 land cover classes. It is noted that settlements and other lands have been mapped as a single category and this can be a source of errors. An improvement in the mapping programme would enhance accuracy moving from a Tier 1 reporting towards a Tier 3 reporting.

8.3. Carbon pools

Currently, only AGB and BGB have been considered. In future, dead wood, litter, soil organic matter and harvested wood productsshould be measured and included in subsequent FRL estimation. It is noted that immediate oxidation for all deforestation as presented in this FRL may not be the case on the ground.

8.4. Non CO_2 emissions

In this FRL, CO_2 is the only gas considered. Noting that emissions from the forest sector include other non CO_2 emissions, it is proposed that further research should be done to allow inclusion of CH_4 and N_2Ogases.

8.5. Calculation of Root Shoot Ratios and Carbon fractions

The FRL has used IPCC default factors for calculation of BGB from the AGB values. The ratios were aligned to nearly similar IPCC defaults based on characteristics of local vegetation types. Noting the variety of conditions in which trees of Kenya grow, there is need to ascertain these numbers on the ground. For example trees growing in drylands have been found to have deep roots that support water uptake as compared to those growing in montane and rain forest conditions (Owate et al, 2018). Estimates of shoot root ratios for the mangrove trees have yielded varying results based on the specific mangrove species.

In addition to this, the current FRL uses the IPCC 2006 defaults for biomass carbon fraction. Recent literature (e.g. Komiyama et al 2008) illustrate that this fraction varies with tree species and wood component. As such, there is need to ascertain this for each of the vegetation type and make the estimates of the FRL more accurate.

8.6. Post deforestation emissions

All deforestation has assumed instantaneous oxidation but this is not the case for harvested wood products. Similarly the method provided here assumes that forest degradation is fully captured when a forest canopy degrades from a superior to an inferior canopy. A more realistic method would have analyzed data for harvested wood products. However, such data which changes over time is not available in Kenya and there is not accurate method of estimating it. A mechanism for collecting such data should be put in place to allow better estimation of Emissions from the forest sector.

Regarding the use of IPCC Tier 1 Default EF for croplands, literature was available from Kuya et al (2012) and Owate et al (2018) and gives an illustration of the Carbon contents in perennial croplands of Kenya which mainly comprise agroforestry systems. However, no literature was available for annual croplands which comprise a bigger portion of the croplands of Kenya. Lack of data on EF for grasslands, wetlands and other lands also guided the use of Tier 1 methodology. This is an area for future improvement where provision of local EF for each of the land use types and strata used in the FRL would allow Kenya to accurately capture emission fluxes due to land use changes and report at a higher tier.

8.7. Calculation of emissions into the future

The future monitoring of emissions based on the FRL projections will be done in short time epochs. Therefore, lands converted to forestlands will be assigned the growth factors based on their forest strata and sub strata. However, such lands should be isolated so that they do not exaggerate emissions from deforestation in the subsequent change map. This activity is not included in the current land cover change analysis. A model that has been tested in Kenya under the SLEEK programme requires further testing because its efficient use would greatly enhance emission estimation into the future.This model has been used to do an external validation of this FRL.

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ANNEXES

Annex 1 Methodology for Land Cover / Land Use Mapping

1. Classes for Land Cover / Land Use Map

The categorized classes for Land Cover / Land Use Map was 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 were adopted from IPCC where these classes were further subcategorized. The IPCC classes are:

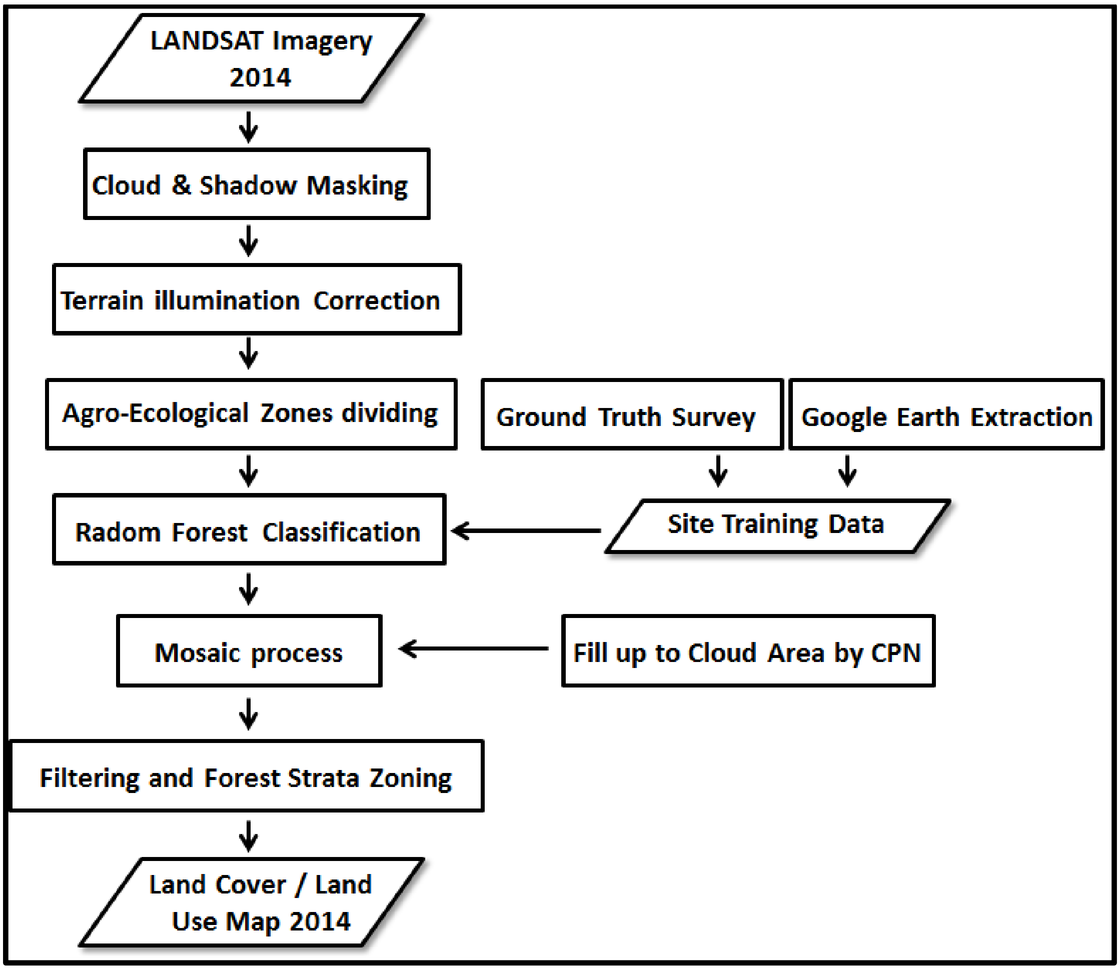
- Forestland,
- Cropland,
- Grassland,
- Settlement,
- Wetlands and
- Other lands.

The subcategorized classes were based on local definitions of land cover and land use. Forest and forest conversion were of high importance in terms of carbon stocks and emissions. The forestland was subcategorized based on national forest definition which is canopy density not less than 15%, and was divided into three categories: Open, moderate and dense. The cropland was divided into two categories: annual crops, and perennial crops. The grassland had also been classified into wooded grass (shrubs and grasses) and open glass. The wetland had been mapped as two categories: water body and vegetated wetland. And the other land was included barren land, rocks, soils and beaches. However, the settlement was not classified due to required alternative methodology other than Satellite Imagery Remote Sensing.

For the subcategorized forestland by forest definition, it was mixed type of forest e.g. plantation and dryland forest. The subcategorized forestland i.e. open, moderate and dense had been zoned by ancillary data which was classified by forest strata definitions in Kenya. The forest strata definitions are described in Annex 2. The table 2 in the report show sub categorization of forestland.

2. Methodology for preparation of Land Cover / Land Use Map

The Land Cover / Land Use Maps were created based on the following process steps using Landsat Imagery as show in the Figure below. The best available Landsat images for each year were selected from the USGS archive which provided a complete cloud-free (threshold 20% cloud cover) coverage of Kenya. Cloud cover was a major consideration. Dry season images are preferred for classification purposes as these allow for better discrimination between trees and grasses or crops.



Flow chart for preparation of Land Cover / Land Use Map 2014

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 have 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 was divided into 'spectral stratification zones' (SSZ). 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 were initially based on Kenya's Agro-Ecological Zones.

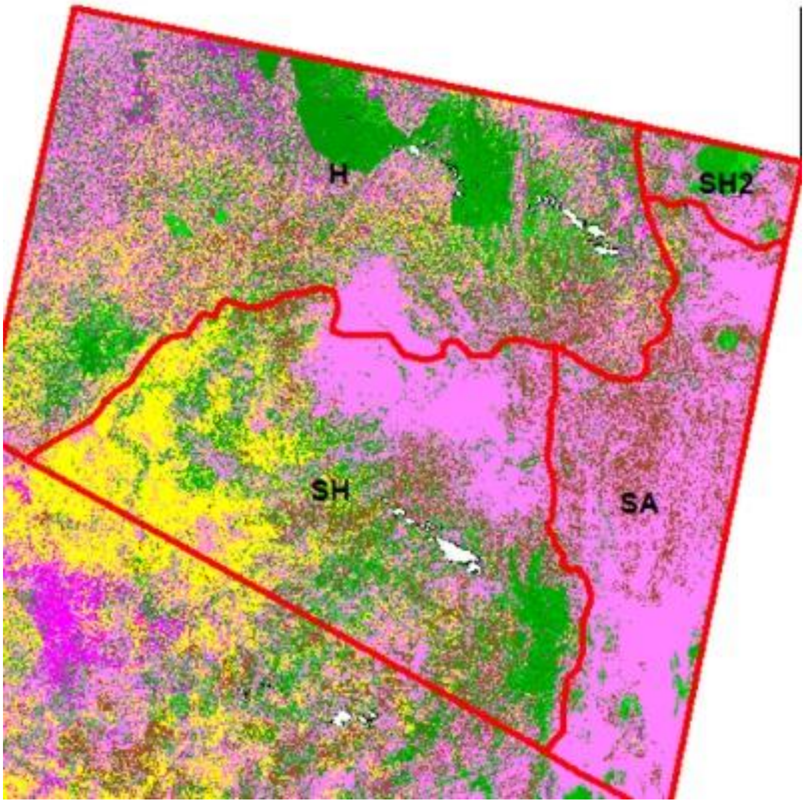
4) Random Forest classification with training data (ground truth survey and Google Earth)

For image classification method, supervised (Maximum Likelihood Classifier) and Random Forest classification had been tested. As a result of the test, The Random Forest classification has better accuracies than supervised classification. The Random Forest classification had been selected as method for preparation of Land Cover / Land Use Map.

Training sites were 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 represented the full range spectral variation of that class in the zone for that scene, and 'balanced' with respect to the different spectral colors for that class. The set of training data contained enough pixels. The prepared site training data was applied to individual terrain-corrected and masked images which had been processed as Random Forest classification process. And this process was applied separately to each stratification zone within the image.

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

The mosaic process was required due to the application of Random Forest classificationto individual images. Individual images were mosaicked as one classified image map. The Figure below shows mosaicked individual classification result for a single scene from 2014.



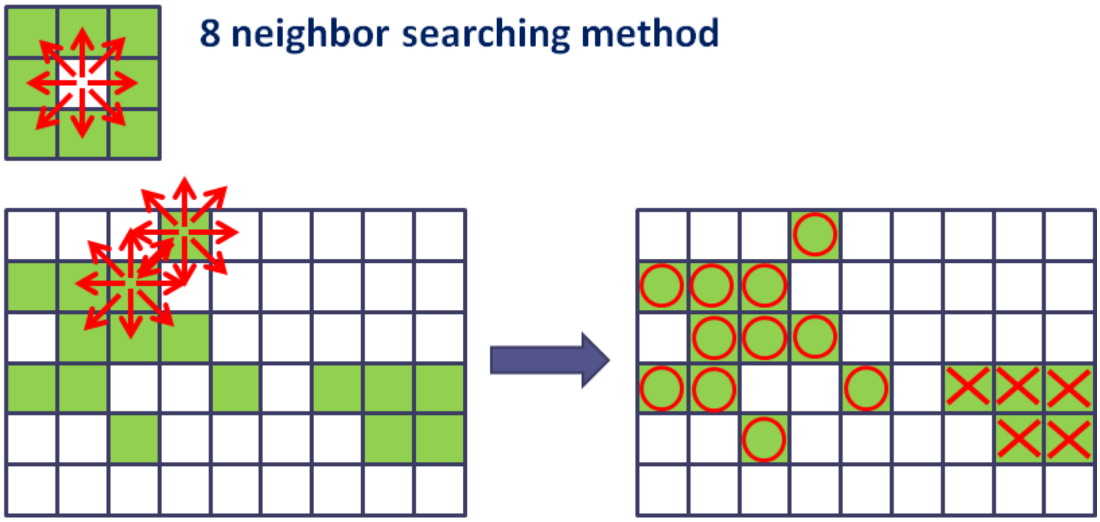
Mosaicked individual classification result for a single scene from 2014

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

The multi-temporal processing was 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 was utilized to fill up the gap area.

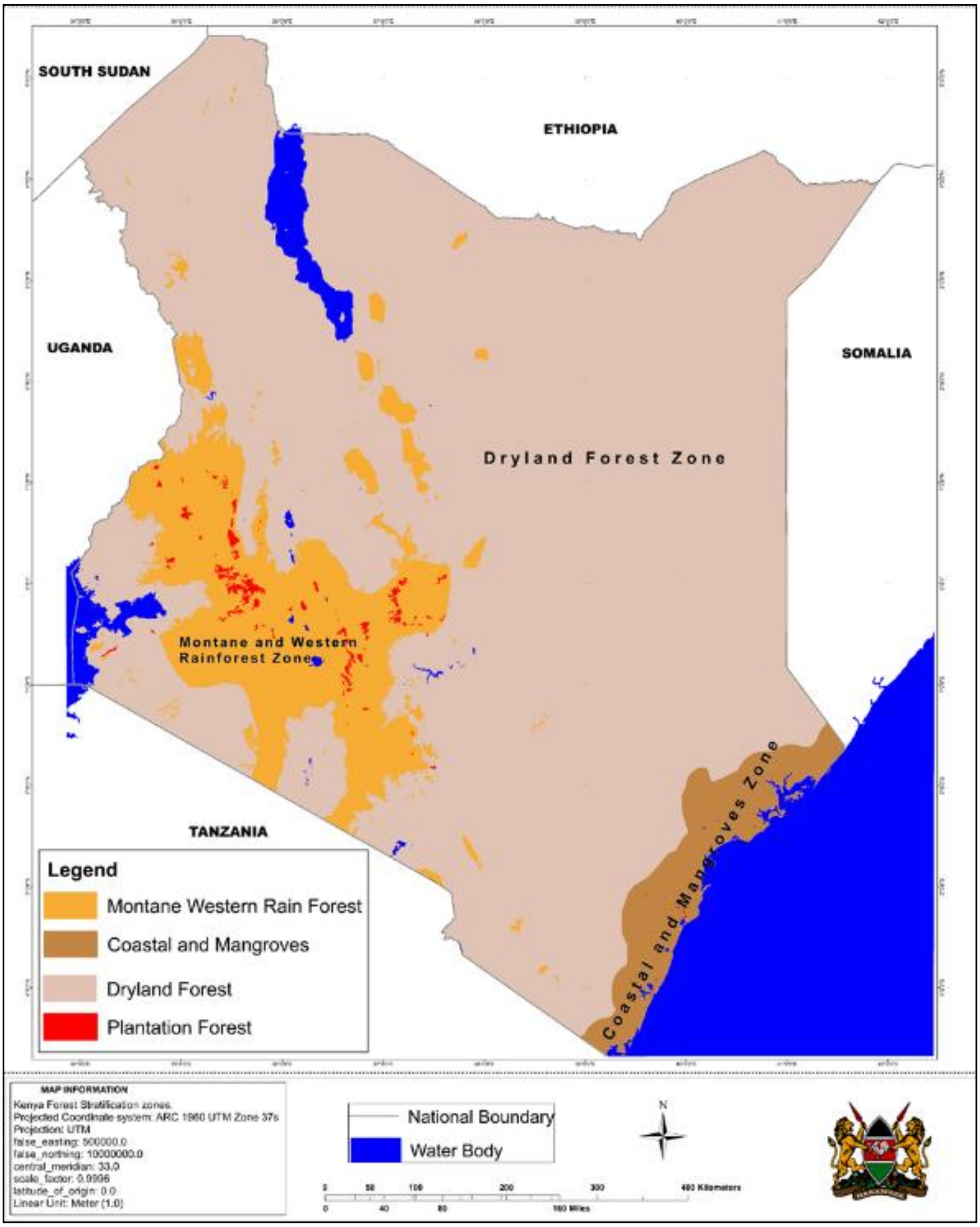
6) Filtering and Forest Strata Zoning

The mosaicked and filled up image map was 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) neighbors filtering method was preferred and used for mapping. The eight (8) neighbors filtering method used eight (8) direction searching and clumping as one connected forest as shown in the Figure below. 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.



Eight (8) neighbors filtering

The filtered classification result map was zoned by forest strata zoning. This forest strata zoning information was generated by the forest strata definition as shown in the Figure below.



Forest Strata Zone Image

As explained above,the process steps for the Land Cover / Land Use Map were applied to allyears:1990, 1995, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015 and 2018.

Annex 2: Forest Strata Definitions and Supporting Descriptions

1. **Public Plantation forest land:** Refers to an area of 136,902 ha which has been set aside by the government to support commercial plantation forestry and are managed by KFS. These are areas with even aged monocultures and 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. In public forests, exotic plantation species include *Cupressus lusitanica, Eucalyptus sp.* and several pine species (*P. patula* in montane areas and, *P. carribeae* in coastal forests).

2. **Mangroves and coastal forests**
   a. 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 mucranata*, then *Bruguieragymnorrhiza, Ceriops tagal*, *Avicennia marina, Lumnitzeraracemosa* and *Heritieralitoralis* respectively (Kokwaro, 1985; Kairo et al., 2001). Other mangrove species include *Xylocarpusgranatum* and *Xylocarpusmollucensis*. Shapefiles of the mangrove zones which will be used for sub categorization are available at KFS.
   b. **The coastal forests:** These are the forests found in the coastal region of Kenya within a 30km strip from shoreline. 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. This class was defined as unique by the KIFCON in Wass (1994) and the shapefiles of the forests are available at KFS.
3. **The montane and western rain forests and bamboo:**
   a. **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 differ in species composition due to climate and altitude. 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 highland bamboo (*Yushaniaalpina*) predominates.

b. **The 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. The trees are significantly taller and larger as compared to the other forests of Kenya. The shapefile describing these forests developed by KIFCON is available at KFS.

4. **The 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*, *Platycepheliumvoense, Manilkara, Lannea, Balanites aegyptiaca, Melia volkensii, Euphorbia candelabrum* and *Adansoniadigitata*. The category also includes riverine forests in dry areas. Their carbon stocks may differ from that of other forests due to leaf shedding, elongated rooting systems and high specific wood density.

Categorization of these forests will be done using the shapefiles developed by KIFCON (1994) which are based on climate and altitude. These shapefiles are available at Kenya Forest Service

.

Annex 3The Plot data form the Pilot NFI

Montane and Western rain forest Dense Canopy

Project	Cluster	Plot	Forest type	Canopy cover (%)	D/M/O	AGB Volume (m3/ha)				AGB Biomass (ton/ha)				AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total			
ICFRA	5999	2	Montane Forest	100.0	Dense	263.89	1.61		265.49	208.38	0.98	7.88	217.24	97.94	0.46	3.70	102.10	Nyeri	Nyeri	Tetu
ICFRA	6001	1	Montane Forest	79.2	Dense	105.90	0.00	0.00	105.90	87.87	0.00	0.00	87.87	41.30	0.00	0.00	41.30	Nyeri	Nyeri	Tetu
ICFRA	6002	4	Montane Forest	95.0	Dense	195.91	0.00		195.91	160.50	0.00	3.16	163.67	75.44	0.00	1.49	76.92	Nyeri	Nyeri	Aberdare Forest
JICA	915	2	Montane Forest	95.0	Dense	246.38	0.00	0.00	246.38	200.15	0.00	0.00	200.15	94.07	0.00	0.00	94.07	Nyeri	Nyeri	Gathiuru
JICA	9141	1	Montane Forest	98.3	Dense	361.74	0.00	0.00	361.74	288.13	0.00	0.00	288.13	135.42	0.00	0.00	135.42	Nyeri	Nyeri	Narumoru
JICA	9150	1	Montane Forest	99.2	Dense	646.28	0.00	0.00	646.28	511.25	0.00	0.00	511.25	240.29	0.00	0.00	240.29	Nyeri	Nyeri	Narumoru
JICA	9150	2	Montane Forest	99.2	Dense	532.79	0.00		532.79	427.02	0.00	2.11	429.13	200.70	0.00	0.99	201.69	Nyeri	Nyeri	Gathiuru
JICA	912	1	Montane Forest	65.0	Dense	72.25	0.00	0.00	72.25	60.93	0.00	0.00	60.93	28.63	0.00	0.00	28.63	Nyeri	Nyeri	Kabaru
	Average								303.34				244.80				115.05			
	SD												157.94				74.23			
	CV (%)												64.52				64.52			

Montane and Western rain forest Moderate canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover	D/M/O	AGB Volume (m3/ha)				AGB Biomass (ton/ha)				AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total			
ICFRA	6002	1	Montane Forest	61.7	Moderate	39.26	0.00		39.26	33.33	0.00	1.58	34.91	15.66	0.00	0.74	16.41	Moderate	Nyeri	Aberdare Forest
ICFRA	6002	2	Montane Forest	47.5	Moderate	40.15	0.00	0.00	40.15	34.24	0.00	0.00	34.24	16.09	0.00	0.00	16.09	Moderate	Nyeri	Aberdare Forest
ICFRA	6002	3	Montane Forest	63.3	Moderate	52.47	0.00	0.00	52.47	44.93	0.00	0.00	44.93	21.12	0.00	0.00	21.12	Moderate	Nyeri	Aberdare Forest
ICFRA	6162	2	Montane Forest	40.0	Moderate	135.33	0.00		135.33	108.50	0.00	3.48	111.97	50.99	0.00	1.63	52.63	Moderate	Nyeri	Tetu
JICA	911	1	Montane Forest	44.2	Moderate	22.90	0.00	0.00	22.90	19.71	0.00	0.00	19.71	9.26	0.00	0.00	9.26	Moderate	Nyeri	Kabaru
JICA	912	2	Montane Forest	51.7	Moderate	79.36	0.00	0.00	79.36	66.89	0.00	0.00	66.89	31.44	0.00	0.00	31.44	Moderate	Nyeri	Kabaru
JICA	928	2	Montane Forest	49.2	Moderate	117.65	0.00		117.65	95.87	0.00	0.52	96.39	45.06	0.00	0.24	45.30	Moderate	Nyeri	Narumoru
	Average								69.59				58.43				27.46			
	SD												34.64				16.28			
	CV (%)												59.28				59.28			

Montane and Western rain forest Open canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover	Canopy coverage	AGB Volume (m3/ha)				AGB Biomass (ton/ha)				AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total			
JICA	911	2	Montane Forest	21.7	Open	23.49	0.00	0.00	23.49	20.48	0.00	0.00	20.48	9.63	0.00	0.00	9.63	Nyeri	Nyeri	Kabaru
JICA	913	1	Montane Forest	25.0	Open	12.23	0.00	0.00	12.23	10.57	0.00	0.00	10.57	4.97	0.00	0.00	4.97	Nyeri	Nyeri	Kabaru
JICA	913	3	Montane Forest	30.8	Open	13.88	0.00	0.00	13.88	12.25	0.00	0.00	12.25	5.76	0.00	0.00	5.76	Nyeri	Nyeri	Kabaru
JICA	913	4	Montane Forest	16.7	Open	32.10	0.00	0.00	32.10	27.69	0.00	0.00	27.69	13.01	0.00	0.00	13.01	Nyeri	Nyeri	Kabaru
JICA	9120	3	Montane Forest	30.0	Open	21.45	0.00		21.45	19.05	0.00	1.51	20.56	8.95	0.00	0.71	9.66	Nyeri	Nyeri	Kabaru
	Average								20.63				18.31				8.61			
	SD												6.97				3.28			
	CV (%)												38.07				38.07			

Coastal forest and Mangrove Dense canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover (%)	Canopy coverage	AGB Volume (m3/ha)				AGB Biomass (ton/ha)				AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total			
JICA	922	2	Coastal Forest	94.2	Dense	168.62	0.00		168.62	140.95	0.00	0.39	141.34	66.25	0.00	0.18	66.43	Kilifi	Malindi	Gede
JICA	922	3	Coastal Forest	92.5	Dense	170.55	0.00	0.00	170.55	138.68	0.00	0.00	138.68	65.18	0.00	0.00	65.18	Kilifi	Malindi	Gede
JICA	930	1	Coastal Forest	99.2	Dense	73.05	0.00		73.05	63.40	0.00	1.70	65.10	29.80	0.00	0.80	30.60	Kilifi	Malindi	Jilore
JICA	930	2	Coastal Forest	77.5	Dense	92.18	0.00		92.18	78.77	0.00	0.47	79.24	37.02	0.00	0.22	37.24	Kilifi	Malindi	Jilore
JICA	9210	2	Coastal Forest	99.2	Dense	102.77	0.00		102.77	86.45	0.00	22.52	108.98	40.63	0.00	10.59	51.22	Kilifi	Malindi	Gede
JICA	9210	4	Coastal Forest	100.0	Dense	204.43	0.00		204.43	168.15	0.00	5.79	173.94	79.03	0.00	2.72	81.75	Kilifi	Malindi	Gede
JICA	9230	2	Coastal Forest	94.2	Dense	102.87	0.00		102.87	86.60	0.00	2.80	89.40	40.70	0.00	1.32	42.02	Kilifi	Malindi	Jilore
JICA	9230	3	Coastal Forest	100.0	Dense	88.11	0.00	0.00	88.11	76.95	0.00	0.00	76.95	36.17	0.00	0.00	36.17	Kilifi	Malindi	Jilore
ICFRA	3019	1	Mangrove Forest	96.7	Dense	180.97	0.00	0.00	180.97	160.92	0.00	0.00	160.92	75.63	0.00	0.00	75.63	Kwale	Other	Other
ICFRA	3046	4	Mangrove Forest	80.8	Dense	39.40	0.00	0.00	39.40	39.64	0.00	0.00	39.64	18.63	0.00	0.00	18.63	Kwale	Other	Other
ICFRA	3047	3	Mangrove Forest	72.5	Dense	65.95	0.00	0.00	65.95	59.79	0.00	0.00	59.79	28.10	0.00	0.00	28.10	Kwale	Other	Other
ICFRA	3062	2	Mangrove Forest	95.8	Dense	67.24	0.00	0.00	67.24	87.45	0.00	0.00	87.45	41.10	0.00	0.00	41.10	Kwale	Other	Other
ICFRA	3063	1	Mangrove Forest	78.3	Dense	54.38	0.00	0.00	54.38	52.51	0.00	0.00	52.51	24.68	0.00	0.00	24.68	Kwale	Other	Other
ICFRA	3070	1	Mangrove Forest	91.7	Dense	50.63	0.00	0.00	50.63	45.91	0.00	0.00	45.91	21.58	0.00	0.00	21.58	Kwale	Other	Other
ICFRA	3070	2	Mangrove Forest	100.0	Dense	80.42	0.00	0.00	80.42	98.48	0.00	0.00	98.48	46.28	0.00	0.00	46.28	Kwale	Other	Other
ICFRA	3070	3	Mangrove Forest	89.2	Dense	51.41	0.00	0.00	51.41	78.42	0.00	0.00	78.42	36.86	0.00	0.00	36.86	Kwale	Other	Other
ICFRA	3070	4	Mangrove Forest	78.3	Dense	38.43	0.00	0.00	38.43	35.64	0.00	0.00	35.64	16.75	0.00	0.00	16.75	Kwale	Other	Other
ICFRA	3085	4	Mangrove Forest	93.3	Dense	120.94	0.00	0.00	120.94	170.89	0.00	0.00	170.89	80.32	0.00	0.00	80.32	Kwale	Other	Other
	Average								97.35				94.63				44.47			
	SD												45.03				21.16			
	CV (%)												47.59				47.59			

Coastal forest and Mangrove Moderate canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover	Canopy coverage	AGB Volume (m3/ha)				AGB Biomass (ton/ha)				AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total			
JICA	921	1	Coastal Forest	60.0	Moderate	85.44	0.00	0.00	85.44	70.85	0.00	0.00	70.85	33.30	0.00	0.00	33.30	Kilifi	Malindi	Gede
JICA	923	3	Coastal Forest	49.2	Moderate	79.82	0.00	0.00	79.82	66.27	0.00	0.00	66.27	31.15	0.00	0.00	31.15	Kilifi	Malindi	Jilore
JICA	925	1	Coastal Forest	44.2	Moderate	70.79	0.00	0.00	70.79	58.25	0.00	0.00	58.25	27.38	0.00	0.00	27.38	Kwale	Kwale	Msambweni
JICA	950	1	Coastal Forest	50.8	Moderate	28.75	0.00	0.00	28.75	25.39	0.00	0.00	25.39	11.93	0.00	0.00	11.93	Kwale	Kwale	Kwale
JICA	9210	1	Coastal Forest	60.8	Moderate	63.74	0.00	0.00	63.74	53.94	0.00	0.00	53.94	25.35	0.00	0.00	25.35	Kilifi	Malindi	Gede
JICA	9230	1	Coastal Forest	63.3	Moderate	63.47	0.00	0.00	63.47	53.71	0.00	0.00	53.71	25.24	0.00	0.00	25.24	Kilifi	Malindi	Jilore
JICA	9241	3	Coastal Forest	60.0	Moderate	83.10	0.00	0.00	83.10	67.80	0.00	0.00	67.80	31.87	0.00	0.00	31.87	Kwale	Kwale	Kwale
ICFRA	3011	2	Mangrove Forest	41.7	Moderate	13.31	0.00	0.00	13.31	11.39	0.00	0.00	11.39	5.35	0.00	0.00	5.35	Kwale	Other	Other
ICFRA	3063	2	Mangrove Forest	47.5	Moderate	41.38	0.00	0.00	41.38	63.92	0.00	0.00	63.92	30.04	0.00	0.00	30.04	Kwale	Other	Other
JICA	960	1	Mangrove Forest	60.8	Moderate	62.07	0.00	0.00	62.07	53.58	0.00	0.00	53.58	25.18	0.00	0.00	25.18	Kwale	Kwale	Msambweni
JICA	961	3	Mangrove Forest	50.0	Moderate	63.67	0.00	0.00	63.67	55.12	0.00	0.00	55.12	25.91	0.00	0.00	25.91	Kwale	Kwale	Msambweni
	Average								59.59				52.75				24.79			
	SD												18.33				8.62			
	CV (%)												34.75				34.75			

Coastal forest and Mangrove Open canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover	Canopy coverage	AGB Volume (m3/ha)				AGB Biomass (ton/ha)				AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total			
JICA	950	2	Coastal Forest	30.8	Open	25.95	0.00	0.00	25.95	22.97	0.00	0.00	22.97	10.80	0.00	0.00	10.80	Kwale	Kwale	Kwale
JICA	9241	1	Coastal Forest	36.7	Open	28.30	0.00	0.00	28.30	24.57	0.00	0.00	24.57	11.55	0.00	0.00	11.55	Kwale	Kwale	Kwale
JICA	9241	2	Coastal Forest	35.0	Open	48.47	0.00	0.00	48.47	40.43	0.00	0.00	40.43	19.00	0.00	0.00	19.00	Kwale	Kwale	Kwale
JICA	9290	3	Coastal Forest	36.7	Open	38.61	0.00	0.00	38.61	33.62	0.00	0.00	33.62	15.80	0.00	0.00	15.80	Kwale	Kwale	Kwale
JICA	9291	1	Coastal Forest	36.7	Open	25.05	0.00	0.00	25.05	21.68	0.00	0.00	21.68	10.19	0.00	0.00	10.19	Kwale	Kwale	Kwale
JICA	9291	2	Coastal Forest	29.2	Open	68.63	0.00	0.00	68.63	57.54	0.00	0.00	57.54	27.04	0.00	0.00	27.04	Kwale	Kwale	Kwale
JICA	9291	3	Coastal Forest	35.8	Open	31.82	0.00	0.00	31.82	27.15	0.00	0.00	27.15	12.76	0.00	0.00	12.76	Kwale	Kwale	Kwale
ICFRA	3026	3	Mangrove Forest	16.7	Open	30.30	0.00	0.00	30.30	30.08	0.00	0.00	30.08	14.14	0.00	0.00	14.14	Kwale	Other	Other
ICFRA	3046	1	Mangrove Forest	15.8	Open	2.67	0.00	0.00	2.67	2.45	0.00	0.00	2.45	1.15	0.00	0.00	1.15	Kwale	Other	Other
ICFRA	3047	1	Mangrove Forest	20.0	Open	8.45	0.00	0.00	8.45	8.01	0.00	0.00	8.01	3.76	0.00	0.00	3.76	Kwale	Other	Other
JICA	960	3	Mangrove Forest	20.0	Open	23.20	0.00	0.00	23.20	20.35	0.00	0.00	20.35	9.57	0.00	0.00	9.57	Kwale	Kwale	Kwale
JICA	960	4	Mangrove Forest	31.7	Open	7.00	0.00	0.00	7.00	6.34	0.00	0.00	6.34	2.98	0.00	0.00	2.98	Kwale	Kwale	Msambweni
JICA	961	1	Mangrove Forest	30.0	Open	23.90	0.00	0.00	23.90	20.80	0.00	0.00	20.80	9.78	0.00	0.00	9.78	Kwale	Kwale	Msambweni
JICA	961	2	Mangrove Forest	25.0	Open	22.58	0.00	0.00	22.58	20.08	0.00	0.00	20.08	9.44	0.00	0.00	9.44	Kwale	Kwale	Msambweni
	Average								27.50				24.01				11.28			
	SD												14.18				6.66			
	CV (%)												59.05				59.05			

Dryland forest Dense canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover	D/M/O	AGB Volume (m3/ha)				AGB Biomass (ton/ha)				AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total			
ICFRA	1887	2	Dryland Forest	66.7	Dense	16.02	0.00	0.00	16.02	13.97	0.00	0.00	13.97	6.56	0.00	0.00	6.56	Baringo	Baringo	Marigat
ICFRA	2048	3	Dryland Forest	75.0	Dense	13.93	0.00	0.00	13.93	11.94	0.00	0.00	11.94	5.61	0.00	0.00	5.61	Baringo	Baringo	Marigat
JICA	918	1	Dryland Forest	77.5	Dense	68.66	0.00	0.00	68.66	58.04	0.00	0.00	58.04	27.28	0.00	0.00	27.28	Makueni	Makueni	Kibwezi
JICA	918	2	Dryland Forest	88.3	Dense	119.50	0.00		119.50	97.01	0.00	8.67	105.68	45.59	0.00	4.08	49.67	Makueni	Makueni	Kibwezi
JICA	920	1	Dryland Forest	67.5	Dense	33.46	0.00	0.00	33.46	29.65	0.00	0.00	29.65	13.94	0.00	0.00	13.94	Makueni	Makueni	Kibwezi
JICA	9170	2	Dryland Forest	95.0	Dense	42.00	0.00	0.00	42.00	36.18	0.00	0.00	36.18	17.00	0.00	0.00	17.00	Makueni	Makueni	Kibwezi
JICA	9170	3	Dryland Forest	93.3	Dense	49.01	0.00	0.00	49.01	41.56	0.00	0.00	41.56	19.53	0.00	0.00	19.53	Makueni	Makueni	Kibwezi
	Average								48.94				42.43				19.94			
	SD												32.11				15.09			
	CV (%)												75.68				75.68			

Dryland forest Moderate canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover	D/M/O	AGB Volume (m3/ha)				AGB Biomass (ton/ha)				AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total			
ICFRA	1887	4	Dryland Forest	60.8	Moderate	30.92	0.00	0.00	30.92	27.57	0.00	0.00	27.57	12.96	0.00	0.00	12.96	Baringo	Baringo	Marigat
ICFRA	1888	2	Dryland Forest	56.7	Moderate	25.98	0.00	0.00	25.98	22.47	0.00	0.00	22.47	10.56	0.00	0.00	10.56	Baringo	Baringo	Marigat
JICA	918	3	Dryland Forest	42.5	Moderate	58.26	0.00	0.00	58.26	49.71	0.00	0.00	49.71	23.36	0.00	0.00	23.36	Makueni	Makueni	Kibwezi
JICA	918	4	Dryland Forest	42.5	Moderate	13.65	0.00	0.00	13.65	11.68	0.00	0.00	11.68	5.49	0.00	0.00	5.49	Makueni	Makueni	Kibwezi
JICA	9170	1	Dryland Forest	47.5	Moderate	32.74	0.00		32.74	29.17	0.00	5.06	34.23	13.71	0.00	2.38	16.09	Makueni	Makueni	Kibwezi
JICA	9190	1	Dryland Forest	58.3	Moderate	54.65	0.00	0.00	54.65	46.82	0.00	0.00	46.82	22.01	0.00	0.00	22.01	Makueni	Makueni	Kibwezi
JICA	9190	2	Dryland Forest	60.8	Moderate	62.05	0.00	0.00	62.05	55.48	0.00	0.00	55.48	26.08	0.00	0.00	26.08	Makueni	Makueni	Kibwezi
JICA	9190	3	Dryland Forest	60.8	Moderate	31.66	0.00		31.66	27.57	0.00	0.64	28.21	12.96	0.00	0.30	13.26	Makueni	Makueni	Kibwezi
	Average								38.74				34.52				16.23			
	SD												15.01				7.05			
	CV (%)												43.47				43.47			

Dryland forest Open canopy coverage

Project	Cluster	Plot	Forest type	Canopy cover	D/M/O	AGB Volume (m3/ha)				AGB Biomass (ton/ha)				AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total			
ICFRA	1888	1	Dryland Forest	20.0	Open	22.40	0.00	0.00	22.40	19.80	0.00	0.00	19.80	9.31	0.00	0.00	9.31	Baringo	Baringo	Marigat
ICFRA	1888	3	Dryland Forest	32.5	Open	8.74	0.00	0.00	8.74	7.72	0.00	0.00	7.72	3.63	0.00	0.00	3.63	Baringo	Baringo	Marigat
ICFRA	1888	4	Dryland Forest	26.7	Open	6.63	0.00	0.00	6.63	5.78	0.00	0.00	5.78	2.72	0.00	0.00	2.72	Baringo	Baringo	Marigat
ICFRA	2211	4	Dryland Forest	36.7	Open	11.30	0.00	0.00	11.30	10.30	0.00	0.00	10.30	4.84	0.00	0.00	4.84	Baringo	Baringo	Marigat
ICFRA	2212	1	Dryland Forest	35.0	Open	26.09	0.00	0.00	26.09	23.95	0.00	0.00	23.95	11.25	0.00	0.00	11.25	Baringo	Baringo	Marigat
ICFRA	2212	2	Dryland Forest	29.2	Open	21.59	0.00	0.00	21.59	19.51	0.00	0.00	19.51	9.17	0.00	0.00	9.17	Baringo	Baringo	Marigat
ICFRA	2370	4	Dryland Forest	37.5	Open	15.2680927	0.00	0.00	15.27	12.79	0.00	0.00	12.79	6.01	0.00	0.00	6.01	Baringo	Baringo	Marigat
	Average								16.00				14.26				6.70			
	SD												6.89				3.24			
	CV (%)												48.28				48.28			

Public Plantation forest

Project	Cluster	Plot	Forest type	Canopy cover	D/M/O	AGB Volume (m3/ha)				AGB Biomass (ton/ha)				AGB Carbon stock (ton/ha)				County	District	Division
						Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total	Tree	Bamboo	Climber	Total			
ICFRA	287	1	Plantation	100.0	Dense	578.35	0.00	0.00	578.35	473.36	0.00	0.00	473.36	222.48	0.00	0.00	222.48	Kericho	Kericho	Londian
ICFRA	287	2	Plantation	100.0	Dense	646.20	0.00	0.00	646.20	527.43	0.00	0.00	527.43	247.89	0.00	0.00	247.89	Kericho	Kericho	Londian
ICFRA	288	1	Plantation	90.0	Dense	270.18	0.00	0.00	270.18	221.46	0.00	0.00	221.46	104.09	0.00	0.00	104.09	Kericho	Kericho	Londian
ICFRA	288	2	Plantation	88.3	Dense	111.99	0.00		111.99	92.84	0.00	1.65	94.49	43.63	0.00	0.78	44.41	Kericho	Kericho	Londian
ICFRA	447	1	Plantation	100.0	Dense	690.31	0.00	0.00	690.31	558.65	0.00	0.00	558.65	262.56	0.00	0.00	262.56	Kericho	Kericho	Londian
ICFRA	447	3	Plantation	89.2	Dense	311.50	0.00	0.00	311.50	252.08	0.00	0.00	252.08	118.48	0.00	0.00	118.48	Kericho	Kericho	Londian
ICFRA	447	4	Plantation	98.3	Dense	409.91	0.00	0.00	409.91	335.08	0.00	0.00	335.08	157.49	0.00	0.00	157.49	Kericho	Kericho	Londian
ICFRA	607	2	Plantation	91.7	Dense	1,078.64	0.00	0.00	1,078.64	864.66	0.00	0.00	864.66	406.39	0.00	0.00	406.39	Baringo	Koibatek	Mumberes
ICFRA	607	3	Plantation	82.5	Dense	987.63	0.00	0.00	987.63	784.27	0.00	0.00	784.27	368.61	0.00	0.00	368.61	Baringo	Koibatek	Mumberes
ICFRA	1082	1	Plantation	96.7	Dense	1,205.69	0.00	0.00	1,205.69	968.77	0.00	0.00	968.77	455.32	0.00	0.00	455.32	Baringo	Baringo	Other
ICFRA	1083	1	Plantation	79.2	Dense	836.62	0.00	0.00	836.62	675.93	0.00	0.00	675.93	317.69	0.00	0.00	317.69	Baringo	Koibatek	Eldama ravine
ICFRA	1083	2	Plantation	86.7	Dense	662.83	0.00	0.00	662.83	519.80	0.00	0.00	519.80	244.31	0.00	0.00	244.31	Baringo	Koibatek	Eldama ravine
ICFRA	1241	1	Plantation	90.0	Dense	647.91	0.00	0.00	647.91	524.72	0.00	0.00	524.72	246.62	0.00	0.00	246.62	Baringo	Koibatek	Esageri
ICFRA	1241	2	Plantation	96.7	Dense	715.18	0.00	0.00	715.18	582.32	0.00	0.00	582.32	273.69	0.00	0.00	273.69	Baringo	Koibatek	Esageri
ICFRA	1241	3	Plantation	92.5	Dense	652.09	0.00	0.00	652.09	534.50	0.00	0.00	534.50	251.22	0.00	0.00	251.22	Baringo	Koibatek	Esageri
ICFRA	1241	4	Plantation	80.0	Dense	500.59	0.00	0.00	500.59	410.79	0.00	0.00	410.79	193.07	0.00	0.00	193.07	Baringo	Koibatek	Esageri
ICFRA	1242	1	Plantation	80.0	Dense	205.15	0.00		205.15	168.42	0.00	3.21	171.63	79.16	0.00	1.51	80.67	Baringo	Koibatek	Eldama ravine
ICFRA	1242	2	Plantation	89.2	Dense	143.35	0.00		143.35	117.53	0.00	5.32	122.85	55.24	0.00	2.50	57.74	Baringo	Koibatek	Eldama ravine
ICFRA	1242	3	Plantation	100.0	Dense	473.19	0.00		473.19	386.66	0.00	1.27	387.93	181.73	0.00	0.60	182.33	Baringo	Koibatek	Eldama ravine
ICFRA	6000	4	Plantation	86.7	Dense	548.94	0.00	0.00	548.94	444.25	0.00	0.00	444.25	208.80	0.00	0.00	208.80	Nyeri	Nyeri	Tetu
ICFRA	6001	3	Plantation	75.0	Dense	299.83	0.00	0.00	299.83	242.10	0.00	0.00	242.10	113.79	0.00	0.00	113.79	Nyeri	Nyeri	Aberdare Forest
ICFRA	6161	3	Plantation	80.8	Dense	298.85	0.00		298.85	240.62	0.00	0.77	241.39	113.09	0.00	0.36	113.45	Nyeri	Nyeri	Aberdare Forest
ICFRA	6161	4	Plantation	83.3	Dense	127.41	0.00		127.41	103.69	0.00	1.37	105.06	48.74	0.00	0.64	49.38	Nyeri	Nyeri	Aberdare Forest
ICFRA	286	1	Plantation	50.0	Moderate	28.98	0.00	0.00	28.98	24.47	0.00	0.00	24.47	11.50	0.00	0.00	11.50	Kericho	Kericho	Other
ICFRA	287	4	Plantation	55.0	Moderate	60.81	0.00	0.00	60.81	52.85	0.00	0.00	52.85	24.84	0.00	0.00	24.84	Kericho	Kericho	Londian
ICFRA	6000	2	Plantation	54.2	Moderate	152.90	0.00		152.90	122.41	0.00	1.88	124.29	57.53	0.00	0.88	58.42	Nyeri	Nyeri	Tetu
ICFRA	6000	3	Plantation	51.7	Moderate	327.41	0.00	0.00	327.41	265.47	0.00	0.00	265.47	124.77	0.00	0.00	124.77	Nyeri	Nyeri	Tetu
ICFRA	6001	2	Plantation	53.3	Moderate	106.77	0.00	0.00	106.77	90.52	0.00	0.00	90.52	42.54	0.00	0.00	42.54	Nyeri	Nyeri	Aberdare Forest
ICFRA	6001	4	Plantation	59.2	Moderate	149.86	0.00	0.00	149.86	123.64	0.00	0.00	123.64	58.11	0.00	0.00	58.11	Nyeri	Nyeri	Aberdare Forest
JICA	914	3	Plantation	24.2	Open	429.01	0.00	0.00	429.01	332.00	0.00	0.00	332.00	156.04	0.00	0.00	156.04	Nyeri	Nyeri	Kabaru
JICA	928	1	Plantation	29.2	Open	91.69	0.00	0.00	91.69	74.61	0.00	0.00	74.61	35.07	0.00	0.00	35.07	Nyeri	Nyeri	Narumoru
JICA	929	1	Plantation	27.5	Open	121.34	0.00	0.00	121.34	99.14	0.00	0.00	99.14	46.60	0.00	0.00	46.60	Nyeri	Nyeri	Gathiuru
JICA	9140	4	Plantation	29.2	Open	51.24	0.00	0.00	51.24	41.46	0.00	0.00	41.46	19.49	0.00	0.00	19.49	Nyeri	Nyeri	Kabaru
JICA	9141	2	Plantation	36.7	Open	138.06	0.00	0.00	138.06	110.33	0.00	0.00	110.33	51.86	0.00	0.00	51.86	Nyeri	Nyeri	Kabaru
JICA	9141	3	Plantation	38.3	Open	276.81	0.00	0.00	276.81	218.79	0.00	0.00	218.79	102.83	0.00	0.00	102.83	Nyeri	Nyeri	Gathiuru
JICA	9141	4	Plantation	25.0	Open	113.62	0.00	0.00	113.62	91.21	0.00	0.00	91.21	42.87	0.00	0.00	42.87	Nyeri	Nyeri	Kabaru
	Average								401.41				324.79				152.65			
	SD												249.38				117.21			
	CV (%)												76.78				76.78			

REDD+ TRAINING ON MEASUREMENT, REPORTING AND VERIFICATION (MRV)

PROGRAMME

5h and 6th July 2017
in Naivasha - MASADA HOTEL

DAY 1

Time	Activity
8.30am - 9.00am	Registration
9.00am - 9.20am	Introductions and Training Objectives. Quick overview of CADEP-SFM project *Mr. Peter Nduati, Project Manager*
9.20am - 10.50am	Outline of REDD+ Background and Mechanism of REDD+ • Mr. Kazuhisha KATO
11.00am - 11.30am	**HEALTH BREAK/TEA BREAK**
11.30am - 1.00pm	Outline of REDD+ Background and Mechanism of REDD+ • Mr. Kazuhisha KATO
1.00pm - 2.00pm	**LUNCH BREAK**
2.00pm - 3.30pm	Progress of Kenya's REDD+ • Peter Nduati
3.30pm - 4.00pm	**HEALTH BREAK / TEA BREAK**
4.00pm - 5.30pm	Outline of NFMS as part of MRV's M • Kazuhisha KATO

DAY 2

Time	Activity
8.30am - 10.00am	Measurement for Activity Data AD Introduction to remote sensing and utilization of remote sensing in forest monitoring • Mr. Kei SATO
10.00am - 10.30 am	**HEALTH BREAK/TEA BREAK**
10.30am - 12.00pm	Measurement for Activity Data AD SLEEK map development Land cover/land use conversion matrix • Ms. Faith MUTWIRI
12.00pm - 1.30pm	Measurement for Emission Factor EF National Forest Inventory NFI • Mr. Kazuhiro YAMASHITA
1.30 pm - 2.30 pm	**LUNCH BREAK**
2.30 pm - 4.00pm	Measurement for Emission Factor EF Conversion from Biomass to Carbon Stock • Ms. Sahori FUJIMURA
4.00pm - 4.10pm	END OF TRAINING
4.10pm - 4.30pm	**HEALTH BREAK/TEA BREAK**

PARTICIPANTS TO THE REDD+ MRV(MEASUREMENT,REPORTING AND VERIFICATION) TRAINING ON 5TH AND 6TH JULY,2017 IN NAIVASHA

No	NAME	COUNTY	CONSERVANCY
1	ERICK ABUNGU	NANDI	North Rift
2	TOBIAS ACHUNGU	UASINGISHU	North Rift
3	PATRICIA KITHEKA	NAIROBI	Nairobi
4	PHILIP KOSGEY	NAIROBI	Nairobi
5	ROBERT KIPLAGAT TARUS	NYERI	Central Highlands
6	CAROLINE JULIA NJUA	KIAMBU	Central Highlands
7	BENJAMIN PARENO	KAJIADO	Nairobi
8	BENJAMIN MUINDI	KAJIADO	Nairobi
9	CHARLES MURIUKI	KAJIADO	Nairobi
10	DANIEL MBURU	KAJIADO	Nairobi
11	ELIZABETH MUTHONI KARIUKI	EMBU	Eastern
12	MARGARET WANJIRU (NYANDARUA)	NYANDARUA	Central Highlands
13	EUNICE NJOROGE	NYANDARUA	Central Highlands
14	DOMINIC MUSANGO	KFS HEADQUARTERS	
15	ALEX KATHUKU	KFS HEADQUARTERS	
16	CAROLINE BUSURU	KFS HEADQUARTERS	
17	EDWARD K. MUNENE	BARINGO	Mau
18	BONIFACE MULWA	KERICHO	Mau
19	AMBROSE GENGA	NAKURU	Mau
20	PETER KARIUKI KOORO	KIRINYAGA	Central Highlands
21	PETER NGANGA	KIRINYAGA	Central Highlands
22	SIMON GUCHU	THIKA	Central Highlands
23	FREDRICK OJUANG	KFS HEADQUARTERS	
24	MARGARET WANJIRU(NAIROBI)	NAIROBI	Nairobi

Questionnaire for participants

MRV Training in Naivasha 2017

at ______________, ________________2017

first name	family name

Question	Answer	
1. According to the Fourth Assessment Report of the IPCC, which was published in 2007, about 30% of GHG emissions comes from deforestation and forest degradation. Also, FAO shows that deforestation is in progress in particular Brazil, Indonesia, and tropical Africa.	True	False
2. In the Cancun agreement, the Parties are required to set (a) action plan and/or national strategy of REDD+, (b) Forest reference levels and / or forest reference emission levels, (c) National forest monitoring system, and (d) Safeguard information system.	True	False
3. In a phased approach, it is divided into three phases, which are first phase; readiness, the second phase; implementation, and the third phase; full implementation.	True	False
4. The five activities of REDD + are, (i) Reducing emissions from the deforestation, (ii)reducing emissions from the forest degradation, (iii) conservation of forest carbon stocks, (iv) Enhancement of forest carbon stocks, and (v)monitoring of the forest carbon stocks.	True	False
5. It is necessary to clarify the driving forces of the deforestation and forest degradation, which are the basis for implementation of the REDD + activities.	True	False
6. For the calculation of the emission/removal, "Emission factor" that can be grasped by remote sensing image analysis and "Activity data" that can be grasped by National forest inventory and Biomass survey are required.	True	False
7. There are 5 items in the Safeguard for REDD+, (e.g. forest governance, respect for the knowledge and right of indigenes people, conservation of natural forest and biodiversity).	True	False
8. GCF is the biggest market among carbon markets.	True	False
9. The resolution of LANDSAT satellite image which is used in SLEEK is 10m.	True	False
10. High reflection from vegetation occurs in the near infrared.	True	False
11. The classification method used in SLEEK is a supervised classification	True	False
12. The classification accuracy of the land cover / land use map created by SLEEK is less than 70%	True	False

Question	Answer	
13. Sampling for NFI implementation requires statistical processing.	True	False
14. The internationally approved shape of sampling plot is only square.	True	False
15. The plot shape of Kenya is that circle is proposed.	True	False
16. In the plot of the ICFRA proposal, regeneration have to be measured.	True	False
17. The amount of biomass is half (1/2) of the dry weight	True	False
18. Kenya has developed original allometric equation to calculate EF.	True	False
19. When designing a biomass survey, tree of the maximum diameter class must be included in the sample	True	False
20. By using BCEF, the amount of biomass can be calculated from volume.	True	False

Thank you.

Plan of Operation (Five Years Work Plan) & Annual Work Plan for July 2016- June 2017

24th November 2016

Plan of Operation (Five Years Work Plan) for Component 3

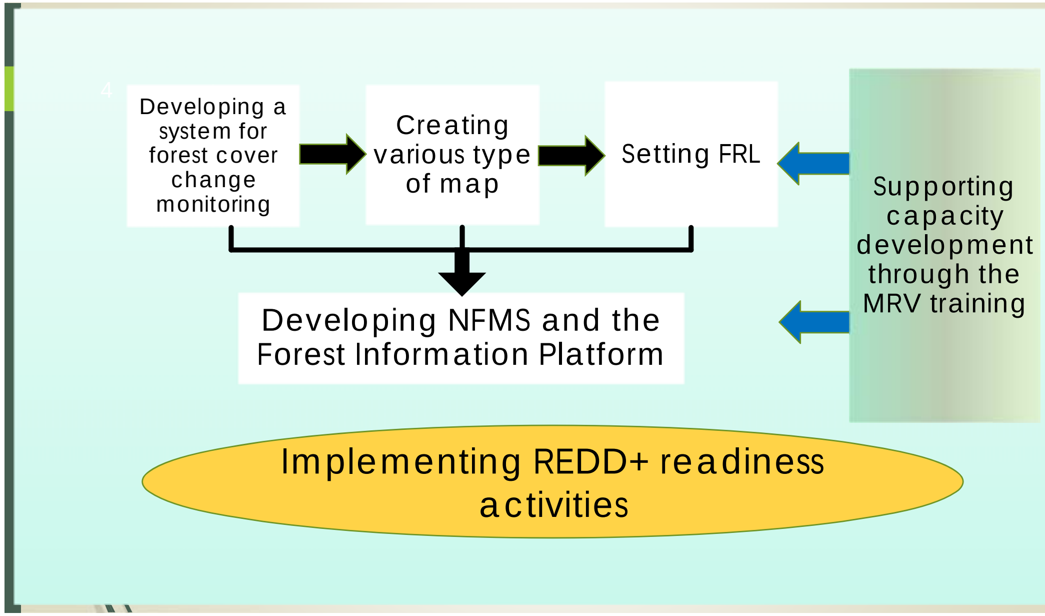
Main Objectives & Indicators

Objectives of Component 3:

- To develop NFMS (National Forest Monitoring System) and Forest Information Platform using the outputs produced in the past
- To support capacity development of C/P organizations through the implementation of REDD+ Readiness
- To develop a system for periodical forest monitoring

Indicators

- NFMS is established.
- FRL is established in consultation with other stakeholders.
- Land Cover/ Land Use Map of 2020 is created.
- Annual forest cover monitoring is conducted until end of project.



			Year	2016	2017	2018	2019	2020	2021
Output 3: REDD+ Readiness			Month	7–12	1–12	1–12	1–12	1–12	1–6
3.1		Design, develop and test the NFMS for Kenya.	Plan / Actual						
	1	Development of the NFMS	Plan / Actual						
	2	Design and Development of the Forest Information platform	Plan / Actual						
	3	Installation of the Forest Information platform	Plan / Actual						
	4	Making a test Installation of the Forest Information platform through OJT	Plan / Actual						
3.2		Operationalize the NFMS.	Plan / Actual						
	1	Review and improvement of NFMS	Plan / Actual						
	2	Review and improvement of the achievement of the prototype operation on the Forest Information platform	Plan / Actual						
	3	Operation of the new Forest Information platform with the review and improvement	Plan / Actual						
3.3		Conduct accuracy assessment of 2014 Land Cover/Land Use Map which is developed by SLEEK (System for Land-Based Emission Estimation in Kenya).	Plan / Actual						
	1	Process assessment for correctness of Land Cover/Land Use Map 2014	Plan / Actual						
	2	Result assessment for correctness of Land Cover/Land Use Map 2014	Plan / Actual						
	3	Report of assessment result	Plan / Actual						
3.4		Create Land Cover/Land Use Change Map using 4 historical data of Land Cover/Land Use Maps.	Plan / Actual						
	1	Reediting the classified category of Land Cover/Land Use Map 2014 as the need arises	Plan / Actual						
	2	Creation of Land Cover/Land Use Change Map	Plan / Actual						
3.5		Collect information on emission factors, set emission factors and develop 2014 Carbon Map.	Plan / Actual						
	1	Collection of information for emission factor	Plan / Actual						
	2	Conduct additional pilot forest inventory survey for setting emission factor	Plan / Actual						
	3	Preparation of carbon map in 2014	Plan / Actual						
3.6		Analyze the land cover/land use changes based on the 4 time historical data of Land Cover/Land Use Maps.	Plan / Actual						
3.7		Develop and evaluate FRL(Forest Reference level)with stakeholders.	Plan / Actual						
	1	Setting FRL	Plan / Actual						
	2	Evaluation of FRL	Plan / Actual						
	3	Improvement of FRL based on the evaluation	Plan / Actual						
3.8		Operate yearly forest cover change monitoring.	Plan / Actual						
	1	Consideration to sustainable method for forest cover change monitoring	Plan / Actual						
	2	Development for function of forest cover change monitoring	Plan / Actual						
	3	Operation by OJT	Plan / Actual						
	4	Review and improvement to pilot operation result	Plan / Actual						
	5	Operation by OJT	Plan / Actual						
	6	Review and improvement to operation result in previous year	Plan / Actual						
3.9		Create 2020 Land Cover/Land Use Map.	Plan / Actual						
	1	Preparation for land cover/land use map creation guidance	Plan / Actual						
	2	Improvement of guidance material of land cover/land use map creation	Plan / Actual						
	3	Guidance for creation of land cover/land use map at pilot area	Plan / Actual						
	4	Guidance for creation of Land Cover/Land Use Map 2020	Plan / Actual						
	5	Create 2020 Land Cover/Land Use Map by Kenyan side	Plan / Actual						
3.10		Train C/P for new technology or methodology of MRV and test them for future development of MRV system in Kenya	Plan / Actual						
	1	Preparing the plan of MRV training	Plan / Actual						
	2	Implementation of MRV training	Plan / Actual						
	3	Review and improvement of the MRV training	Plan / Actual						
	4	Reflecting the MRV training to NFMS as the need arises	Plan / Actual						

6

Annual Work Plan (July 2016 to June 2017)

Component 3

7

Major Activities until June 2017

- Development of the NFMS
- Design and Development of the Forest Information platform
- Process and result assessment for correctness of Land Cover/Land Use Map 2014
- Creation of Land Cover/Land Use Change Map
- Conduct forest inventory survey for setting emission factor
- Preparation of carbon map in 2014
- Development for function of forest cover change monitoring
- Operation of yearly forest cover change monitoring by OJT

Activities		Sub-Activities	FY	1st Year											
			Q	I			II			III			IV		
			Year	2016						2017					
			Month	7	8	9	10	11	12	1	2	3	4	5	6
Output 3: REDD+ Readiness															
3.1		Design, develop and test the NFMS for Kenya.													
	1	Development of the NFMS	Plan	■			■			■					■
	2	Design and Development of the Forest Information platform	Plan	■	■			■	■	■	■	■	■	■	■
3.3		Conduct accuracy assessment of 2014 Land Cover/Land Use Map which is developed by SLEEK (System for Land-Based Emission Estimation in Kenya).													
	1	Process assessment for correctness of Land Cover/Land Use Map 2014	Plan	■	■										
	2	Result assessment for correctness of Land Cover/Land Use Map 2014	Plan			■	■								
	3	Report of assessment result	Plan					■	■	■					
3.4		Create Land Cover/Land Use Change Map using 4 historical data of Land Cover/Land Use Maps.													
	1	Reediting the classified category of Land Cover/Land Use Map 2014 as the need arises	Plan							■					
	2	Creation of Land Cover/Land Use Change Map	Plan							■	■	■	■	■	■
3.5		Collect information on emission factors and develop 2014 Carbon Map.													
	1	Collection of information for emission factor	Plan	■			■			■					
	2	Conduct additional pilot forest inventory survey for setting emission factors	Plan							■	■	■	■	■	■
	3	Preparation of carbon map in 2014	Plan												■
3.6		Analyze the land cover/land use changes based on the 4 time historical data of Land Cover/ Land Use Maps.	Plan												■
3.8		Operate yearly forest cover change monitoring.													
	1	Consideration to sustainable method for forest cover change monitoring	Plan				■								
	2	Development for function of forest cover change monitoring	Plan				■								
	3	Operation by OJT	Plan							■					
	4	Review and improvement to pilot operation result	Plan												■
3.9		Create 2020 Land Cover/Land Use Map.													
	1	Preparation for Land Cover Map creation guidance	Plan							■					
3.10		Train C/P for new technology or methodology of MRV and test them for future development of MRV system in Kenya													
	1	Preparing the plan of MRV training	Plan				■			■					

Thank you for your attention!

State Department of Natural Resources

KENYA Forest Service

Outline of Capacity Development Project for Sustainable Forest Management in Kenya (CADEP-SFM)

24th Nov. 2016

Background of the Project

- The government of Kenya (GOK) set a goal to increase the forest cover rate from 7% (as measured in 2010) to 10% by 2030 in its national constitution established in 2010.
- Climate Change is a crucial issue in Kenya. It is projected that in the next 100 years, the average temperature in the East Africa region could increase by 3 ℃ as a result of climate change.
- The promotion of REDD+ will contribute to increasing the forest cover and climate change mitigation policy in Kenya.
- For more than 20 years, JICA has provided technical cooperation for KEFRI and KFS on promoting social forestry, research and development of breeding for draught tolerant varieties, etc.
- GOK requested Japan for a technical cooperation on the capacity development for sustainable forest management, including the support to Kenya's REDD+ readiness activities, in 2015.

Capacity Development Project for Sustainable Forest Management in Kenya

Project period : June, 2016 – June, 2021 (5 years)
Implementation Agency : Ministry of Environment and Natural Resources(MENR), Kenya Forest Service(KFS), Kenya Forestry Research Institute(KEFRI), County Governments(CG)

Overall Goal

Sustainable forest management is promoted in Kenya towards the national forest cover target of 10% (2030)

Project Purpose

National capacity at the national and county level for sustainable forest management is strengthened

African Initiative for Combating Desertification to Strengthen Resilience to Climate Change

Outputs

Policy Support
MENR

*Enhanced implementing and monitoring capacities of forest –related policies.
*Prepare policy briefs based on the results of monitoring.

Pilot implementation through County Government , Private sector
CG, KFS

*Select 2 Counties as pilot.
*Assist pilot Counties to promote sustainable forest management.
*Design and implement a scheme to work with private sector to promote the use of improved seedlings.

REDD+ Readiness
KFS

*Develop NFMS (National Forest Monitoring System).
*Develop and evaluate FRL (Forest Reference Level).
*Create 2020 Land Cover/Land Use map.

Tree Breeding
KEFRI

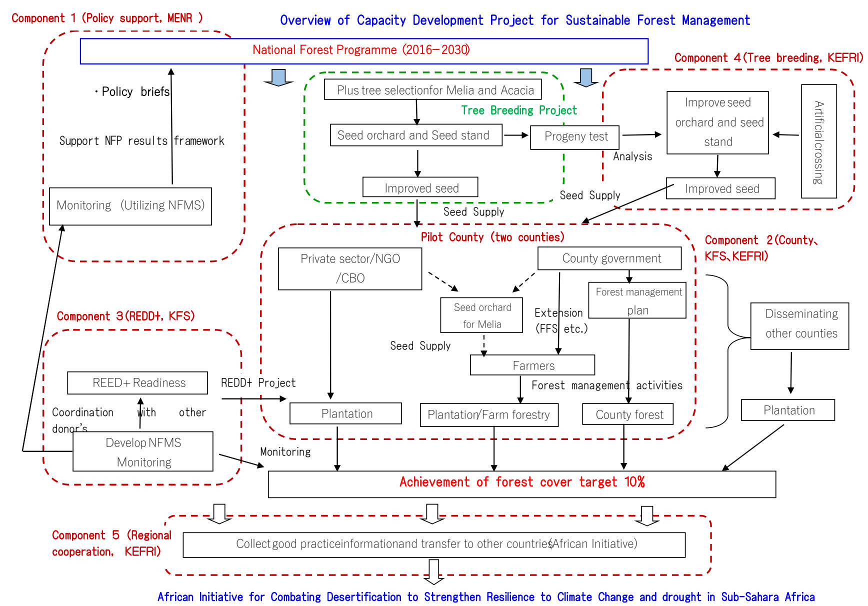
*Improve seed orchards and seed stands.
*Support to establish seed orchards in the pilot Counties.

Reginal Cooperation
KEFRI

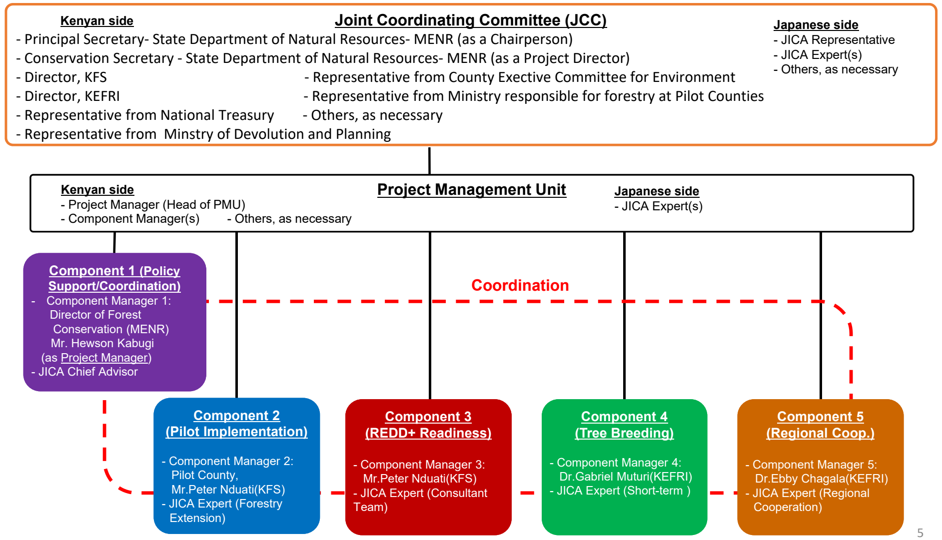
*Collect and share good practice information for strengthening the resilience to climate change.
*Hold regional cooperation meetings and forum.

Project on Development of Drought Tolerant Trees for Adaptation to Climate Change (2012 – 2017)

*Established Seed orchards for Melia volkenssi and Seed stands for Acacia tortillis in Kitui and Kibwezi



Project Implementation Structure



Monitoring of the Project

MENR (State Department of Natural Resources), KFS, KEFRI, pilot County Government and JICA will jointly and regularly monitor the progress of the Project through the Monitoring Sheets based on the Project Design Matrix (PDM) and Plan of Operation (PO).

The Monitoring Sheets will be reviewed every six (6) months.

Outline of REDD+

The REDD+ Readiness Component
in
the Capacity Development Project for the Sustainable Forest Management
in the Republic of Kenya

By Kazuhisa KATO - Compornent3 Team Leader
2017.7.5

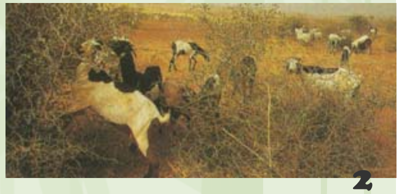
Background
(Global Environmental Crises and the Consideration of Solution)

1. Promotion of Sustainable Forest Management

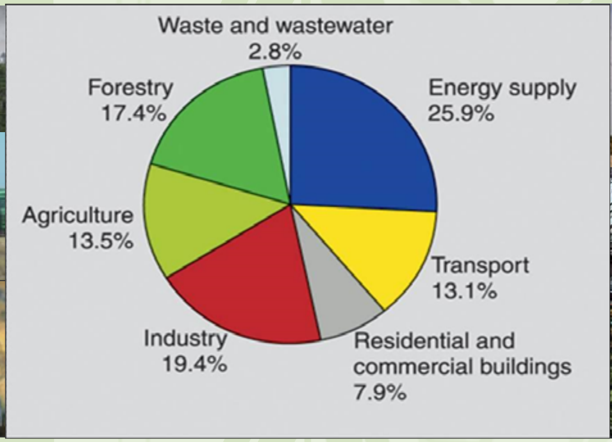
- **The Earth Summit ; UN Conference on Environment and Development (1992 Agenda 21)**
- **Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management**
- **Conservation and Sustainable Development of All Types of Forests**

2. Measures against Global Warming

- **The Intergovernmental Panel on Climate Change (IPCC) points out global warming**
- **THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)**

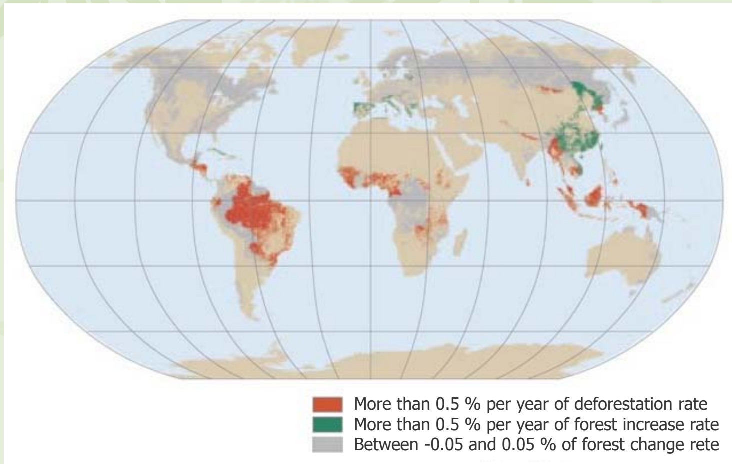


How much of the greenhouse gases (GHG) are emitted by the forestry sector



Source: IPCC Fourth Assessment Report, 2007

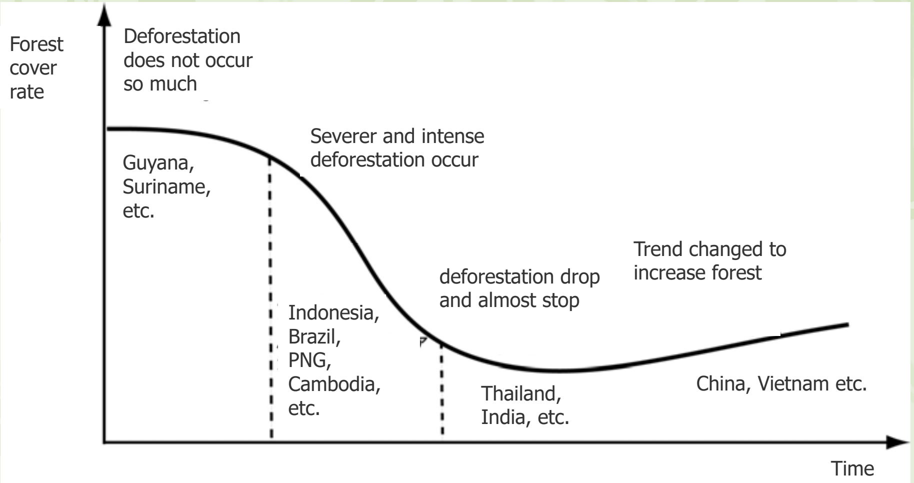
Change of forest area in the world



Rate of forest area change from 2000 to 20005
Information source: FRA 2005 by FAO

- Net deforestation area in the world was 7.3 million ha (2000–2005)
- Deforestation concentrating in the developing countries
- However, forest conditions in the developing countries were not same
- Biggest deforestation：3.1 million ha in Brazil and 1.87 million ha in Indonesia which account for 60 % of the world deforestation area

Pattern of forest change



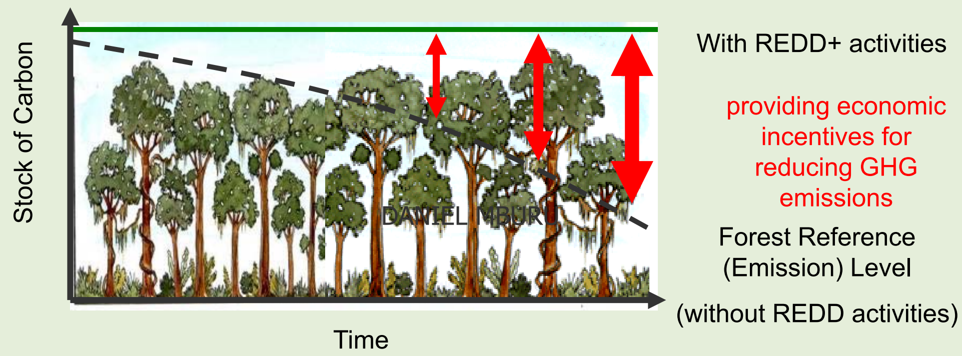
What is REDD Plus?

- REDD+ (REDD-plus) Mechanism

  The basic concept of REDD+ is to provide economic incentives such as funding to developing countries for activities reducing GHG emissions from deforestation and forest degradation, and maintaining or enhancing carbon stocks through forest conservation.

- ✓ REDD is "Reducing Emissions from Deforestation and Forest Degradation"
- ✓ "+" is forest conservation, sustainable forest management and enhancement of forest carbon sinks

Concept of REDD+



Framework under the United Nation

Over a decade ago, most countries joined an international treaty -- the United Nations Framework Convention on Climate Change (UNFCCC) -- to begin to consider what can be done to mitigate global warming and to cope with whatever temperature increases are inevitable.

In addition to the treaty: the Kyoto Protocol, which has more powerful (and legally binding) measures, was adopted in 1997 and came into force in 2005. the Paris agreement, which has no legal binding, was adopted in 2015 and came into force in 2016 following Kyoto Protocol.

The UNFCCC secretariat supports all institutions involved in the climate change process, particularly the COP, the subsidiary bodies and their Bureau (SBSTA).

Proposing REDD+ mechanism

COP11 (Montreal, 2005)

"Acquisition of carbon credit through REDD: Reducing Emissions from Deforestation in the Developing Country" was proposed jointly by Papua New Guinea and Costa Rica on behalf of the Coalition for Rainforest Nations

"Pioneering this proposal, it was began to rapidly take up REDD in international negotiations on the climate change"

Launching REDD Mechanism

COP13 (Bali, Indonesia 2007)

"Policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation (REDD) in developing countries;
and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries".

"Bali Action Plan"

Progress of discussion on REDD Mechanism

COP15 (Copenhagen, 2009)

"Recognizing the crucial role of reducing emissions from deforestation and forest degradation and the need to enhance the sequestration of GHG, and immediately establishing a system of REDD+, providing positive incentives, and advancing the mechanism to enable the funding from the developed country "

"The Copenhagen Accord"

Progress of discussion on REDD Mechanism

COP16 (Cancun, 2010)

"the following REDD+ overall framework was determined"

・Decision made on the following five (5) REDD+ activities
(i) Reducing emissions from deforestation, (ii) reducing emissions from forest degradation, (iii) Conservation of forest carbon stocks, (iv) Sustainable management of forests, and (v) Enhancement of forest carbon stocks,

・Decision made on the following four (4) requirements to implement REDD+ in the developing countries
(1) REDD+ National Strategy, (2) Forest Reference (Emission) Level (FREL/FRL), (3) National Forest Monitoring System (NFMS), (4) Safeguards

"The Cancun Agreement"

Progress of discussion on REDD Mechanism

COP19 (Warsaw, 2013)

"Necessary technical items after The Cancun Agreement were agreed, showing more detail view of REDD+. Discussion of technical issues on REDD+ was completed. The following seven (7) decisions documents were agreed"

(1) modalities for national forest monitoring systems, (2) the timing and the frequency of presentations of the summary of information on the safeguards, (3) addressing the drivers of deforestation and forest degradation, (4) guidelines and procedures for the technical assessment of submissions on proposed REL/RL, (5) modalities for measuring, reporting and verifying (MRV), (6) coordination of support for the implementation of activities, including institutional arrangements (7) work programme on results-based finance

"Warsaw Framework for REDD+"

【Five activities decided as REDD+ activities】

① Reducing emissions from deforestation

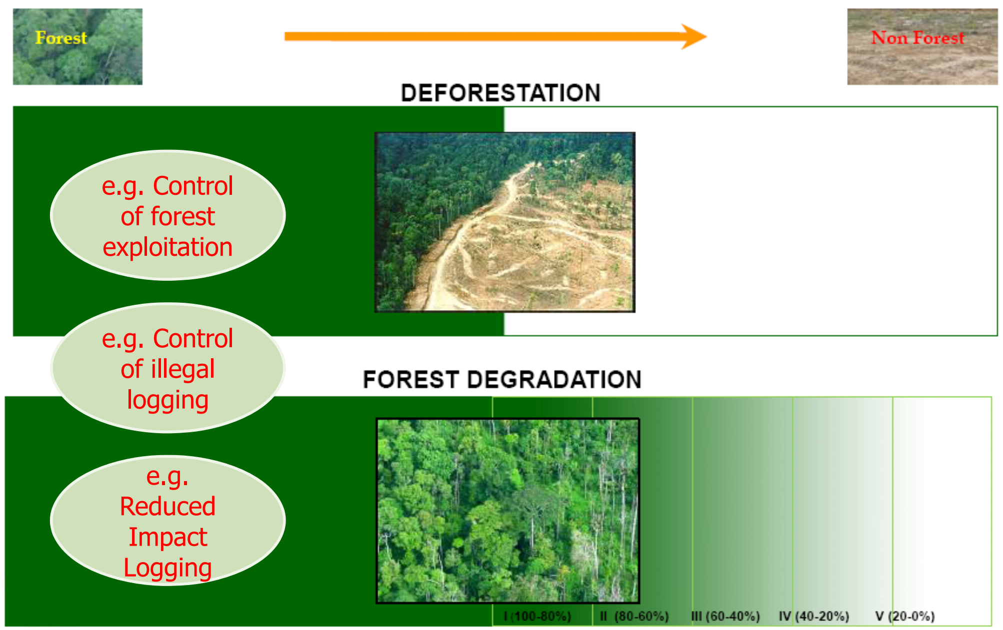
② Reducing emissions from forest degradation

③ Conservation of forest carbon stocks

④ Sustainable management of forests

⑤ Enhancement of forest carbon stocks

【Deforestation and Forest Degradation】



Source: Reference Emission Levels Indonesia - Ruandha Sugardiman、MRV Meeting Mexico.

【Conservation of forest carbon stocks】
【Sustainable management of forest】
【Enhancement of forest carbon stocks】

Forest Management

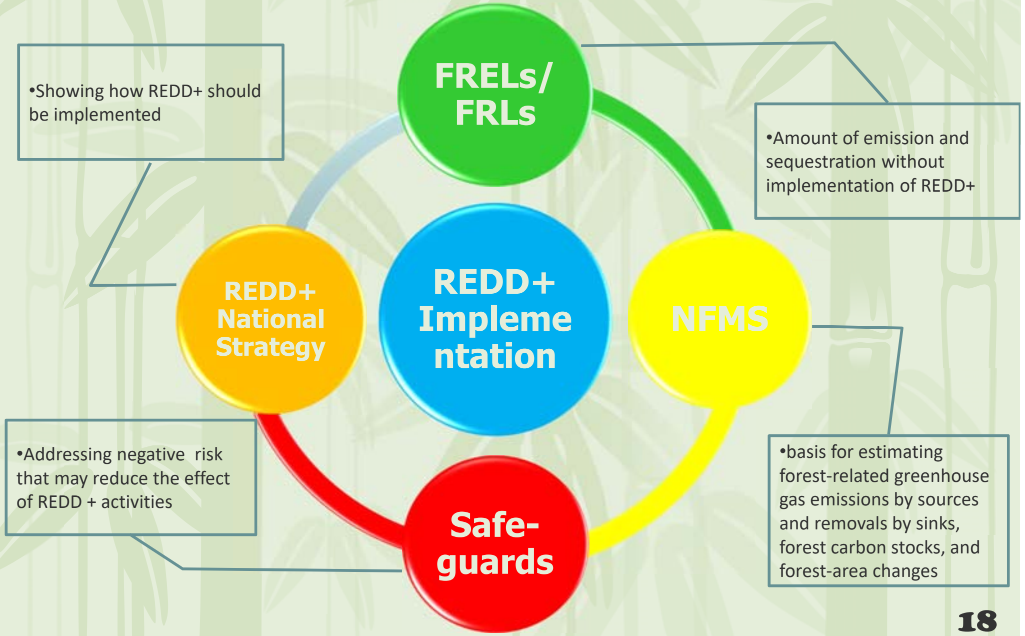
Plantation

【Scope of REDD+】

REDD+ is covered by three categories of land use change according to the IPCC Good Practice Guidance for LULUCF:

1. Forests converted to other lands
   - Deforestation
2. Forests remaining as forests
   - Forest degradation
   - Conservation of forest carbon stocks
   - Sustainable management of forests
   - Enhancement of forest carbon stocks in existing forests
3. Other lands converted to forests
   - Enhancement of forest carbon stocks in bare lands

【Requirement for implementation of REDD+ (The Cancun Agreement) 】



【The Requirement (1) REDD+ National Strategy】

Points to be Considered on REDD+ National Strategy

- Measures against drivers of deforestation and forest degradation
  - ✓ Since deforestation and forest degradation drivers are different by each country, measures that match the drivers of each country should be applied
  - ✓ In the implementation of REDD + at the national and sub-national levels, "policies and measures (PaMs)" are effective and necessary
- Cross-sectoral initiatives
  - ✓ Cross-sectoral approach with development policies and land-use policies closely related to REDD+ is necessary

Therefore, it is necessary to formulate the REDD + national strategy through the participation of various stakeholders

【The Requirement (2) Safeguards】

The following seven Safeguards should be supported and protected

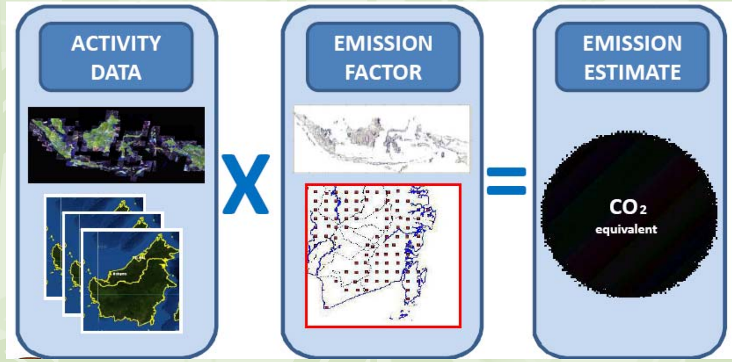
1. **Actions complement or are consistent with the objectives of national forest programmes and relevant international conventions and agreements;**
2. **Transparent and effective national forest governance structures, taking into account national legislation and sovereignty;**
3. **Respect for the knowledge and rights of indigenous peoples and members of local communities;**
4. **The full and effective participation of relevant stakeholders, in particular, indigenous peoples and local communities;**
5. **Actions are consistent with the conservation of natural forests and biological diversity;**
6. **Actions to address the risks of reversals (related to non-permanence);**
7. **Actions to reduce displacement of emissions (related to leakage) .**

【Issues to be considered for Safeguards】

- How criteria and indicators for each item are set
- How to address safeguard issues
- Safeguard Information System(SIS) (Inter-communicational, Transparent, Accessibility, Easily evaluated by a third party（Check list and the evaluation of results））
- Monitoring system

【The Requirement (3) National Forest Monitoring System (NFMS) 】

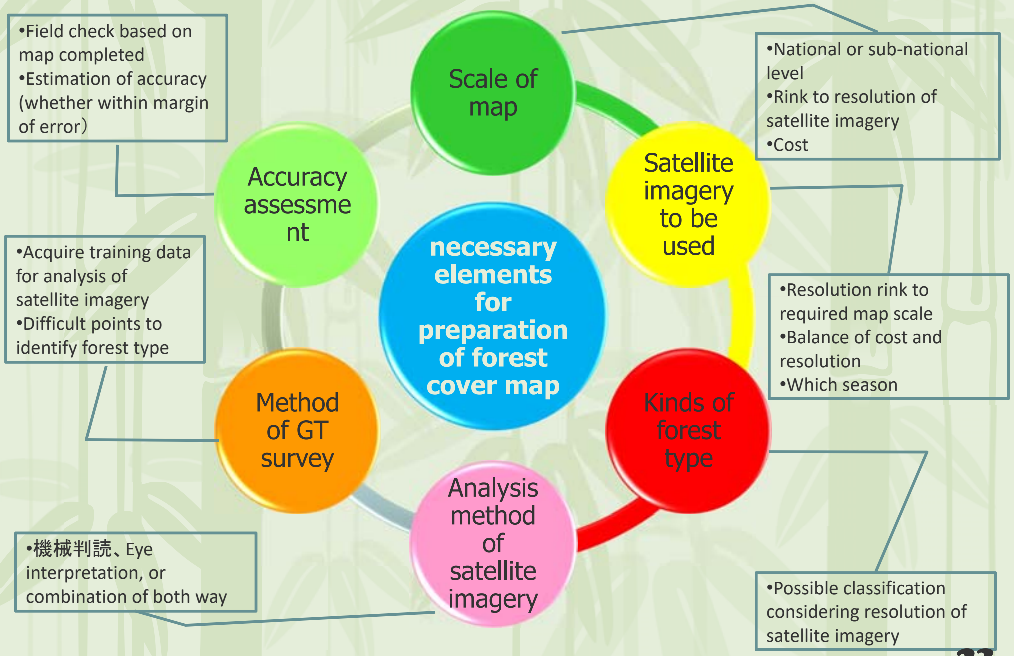
【Necessary monitoring based on the estimation method of emission amount】



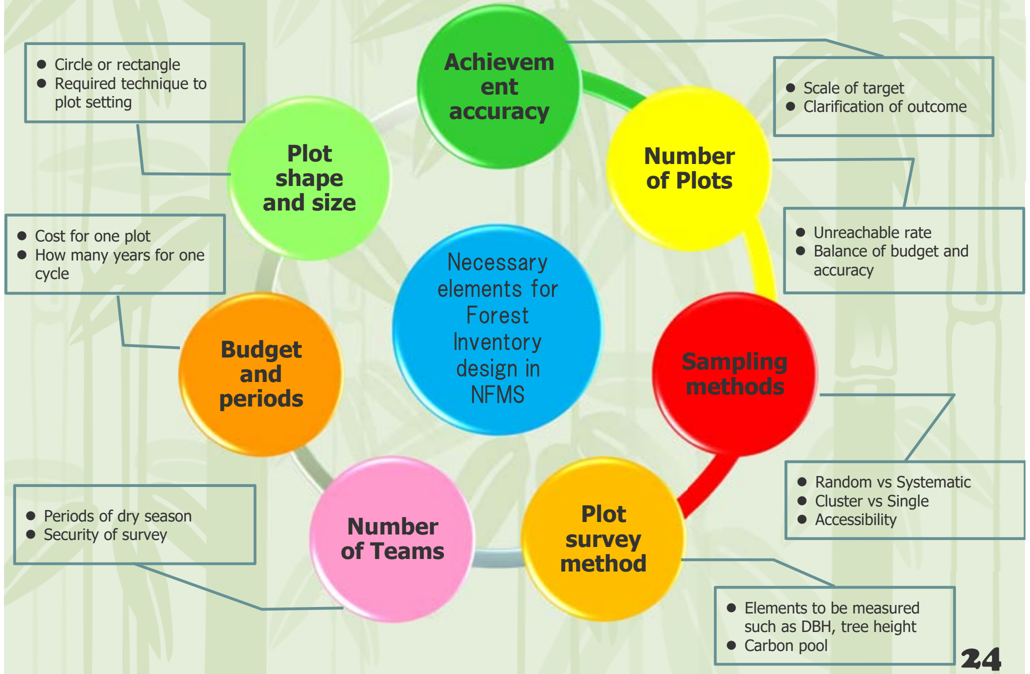
Forest area change（unit:ha）→ Preparation of forest cover map

Carbon stock change（unit:CO2 t/ha）→ Implementation of forest inventory

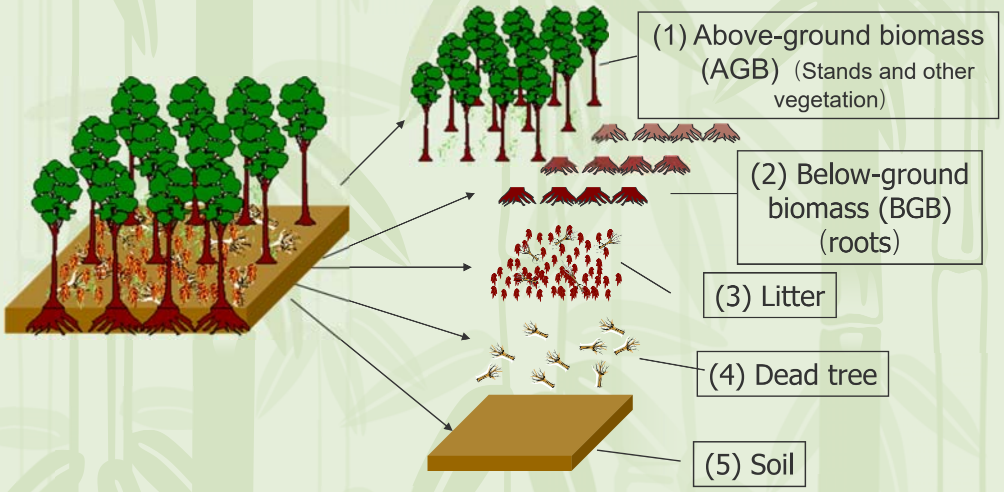
【Points to be considered for preparation of forest cover map】



【Points to be considered for design of forest inventory】



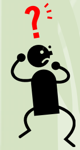
【Carbon Pools in a Forest】



【Points to be considered on designing REDD+ monitoring system 】

What is the driving force of deforestation

Is there any biomass data



How about deforestation scale, 100 ha ?

Is there any degradation in our country

Do we have any forest type maps or satellite imageries

National Forest Inventory Program

Designated national authorities, staff, their knowledge…

【MRV】

M: Measurable

R: Reportable

V: Verifiable

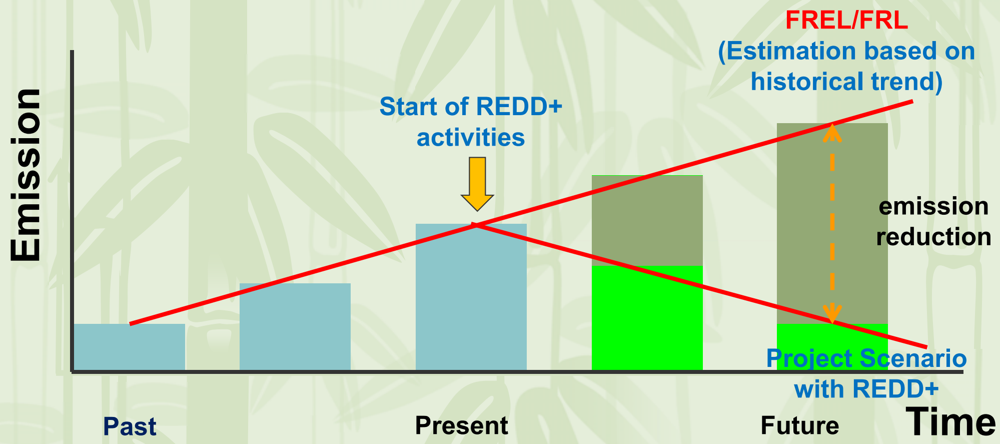
with respect to **M** among them, on which discussion and consideration has been progressing most

1) Implementing forest inventory to record the state of forests
2) Recording changes of the forest based on remote sensing and ground-truth survey
3) Converting the change in forest to changes in the amount of carbon

【Points on establishing MRV system】

- Each country needs to build a forest monitoring system at the national level with high transparency based on each situation and capabilities
- In accordance with IPCC guidance, the estimation of emissions and removals which eliminated the uncertainty as much as possible is necessary
- For monitoring and reporting, substantial participation of indigenous and local communities is recommended
- Although the need is recognized for the "report" and "verification" of the MRV system, the details still not yet completely agreed (it is recognized that "Report" is made by Biennial Update Report (BUR))
- The need to build the MRV system in anticipation of a benefit-sharing system

The Requirement (4) FREL/FRL



- FRELs/FRLs establish business-as-usual (BAU) baselines against which actual emissions are compared.
  ⇒Emission reductions are estimated as the difference between actual emissions and FRELs/FRLs within an established period.
- FRELs/FRLs are benchmarks for assessing each UNFCCC Party's performance and determine its eligibility for international, results-based payment for REDD+

Common Understanding of What FRELs and FRLs Refer to

- FRELs only count emissions of the greenhouse gases (GHGs) from deforestation and forest degradation.
- FRLs count both emissions of GHGs from deforestation and forest degradation and removals of GHGs from the "sink" activities such as enhancement of forest carbon stock.

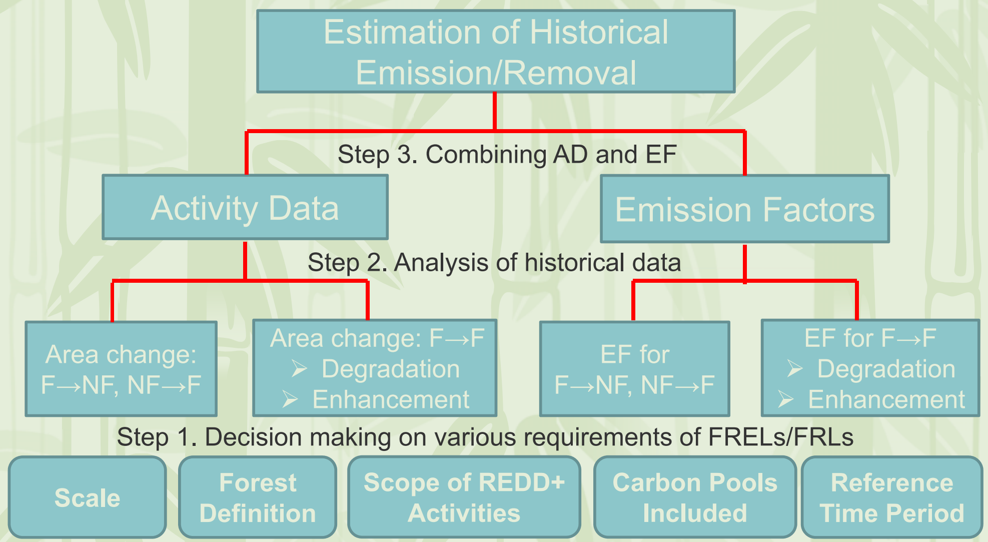
Outline of Development of FRELs/FRLs

Development of FRELs/FRLs can be simplified to the 2 components under the UNFCCC guidance:

1. Analysis of Historical Change of Forests
2. Estimation of Future Change of Forests with Adjustment by National Circumstances

Developing country Parties in establishing FRELs/ FRLs should do so transparently taking into account **historic data**, and adjust for **national circumstances** (decision 4/CP.15, paragraph 7)

Process of Estimating Historical Change



F: forest
NF: non forest
EF: emission factor

Source: Meridian Institute, 2011 (modified)

FRELs/FRLs Requirements – Scale

Comparison between different approaches:

UNFCCC	FCPF-CF	JCM (draft)
➢ National ➢ Subnational (as an interim measure)	➢ National ➢ One or more jurisdiction ➢ Designated area (e.g. eco-regions)	Project level

Countries that submitted FRELs/FRLs to the UNFCCC:

Brazil	Subnational: Amazonia biome (out of 6 biomes in the country)
Colombia	Subnational: Amazon biome (out of 5 biomes in the country)
Ecuador	National
Guyana	National
Malaysia	National (only the permanent reserved forests)
Mexico	National

FRELs/FRLs Requirements – Forest Definition

There is no guidance on how to define the forest for REDD+ under any REDD+ standards, but most countries actually use the same criteria used for CDM: minimum area between 0.05 and 1 ha; minimum average height between 2 and 5 m; minimum cover between 10 and 30 %.

Countries that submitted FRELs/FRLs to the UNFCCC:

	Minimum Area	Minimum Height	Minimum Cover
Brazil	0.5 ha	5 m	10%
Colombia	1 ha	5 m	30%
Ecuador	1 ha	5 m	30%
Guyana	1 ha	5 m	30%
Malaysia	Based on the national legislation		
Mexico	50 ha	4 m	10%

FRELs/FRLs Requirements– Scope of REDD+ Activities

Comparison between different approaches:

UNFCCC	FCPF-CF	JCM (draft)
➢ One or more of the 5 defined REDD+ activities ➢ Significant activities should not be excluded ➢ Justification of why omitted activities are not significant	➢ Deforestation: required ➢ Degradation: required if emissions from degradation are greater than 10% of total emissions. ➢ Enhancement: optional	In accordance with the UNFCCC (no detailed information available)

Countries that submitted FRELs/FRLs to the UNFCCC:

Brazil	Deforestation
Colombia	Deforestation
Ecuador	Deforestation
Guyana	Deforestation, Degradation
Malaysia	Sustainable Forest Management
Mexico	Deforestation

FRELs/FRLs Requirements – Carbon Pools

Comparison between different approaches:

UNFCCC	FCPF-CF	JCM (draft)
➢ Significant pools should not be excluded. ➢ Justification of why omitted pools are not significant.	➢ Carbon pools less than 10% of total emissions in the covered area may be excluded. ➢ Exclusion of the pool is also allowed if it is demonstrated to be conservative.	Carbon pools less than 5% of total emissions from the project may be excluded.

Countries that submitted FRELs/FRLs to the UNFCCC:

Brazil	AGB, BGB, Litter
Colombia	AGB, BGB
Ecuador	AGB, BGB, Deadwood, Litter
Guyana	AGB, BGB, Deadwood, Litter, Soil
Malaysia	AGB, BGB, Litter
Mexico	AGB, BGB, Deadwood, Litter

FRELs/FRLs Requirements – Reference Period

Comparison between different approaches:

	UNFCCC	FCPF-CF	JCM (draft)
Reference Period	Not specified	➢ Up to 10 yrs. (up to 15 yrs. with justification) ➢ End year: two years before assessment of the draft ER Program	At least 10 yrs. back from the project start
Number of Data Points Required	Not specified	Not specified	At least 5 data points

Countries that submitted FRELs/FRLs to the UNFCCC:

	Reference Period	Number of Data Points
Brazil	1996 – 2005	11: Every year
Colombia	2000 – 2012	7: Every two years
Ecuador	2000 – 2008	2: 2000, 2008
Guyana	2001 – 2012	6: 2001, 2005, 2009, 2010, 2011, 2012
Malaysia	1990 – 2011	22: Every year
Mexico	2000 – 2010	11: Every year

Extrapolation of the Historical Trend

Comparison between different approaches:

UNFCCC	FCPF-CF	JCM (draft)
"Adjustment for national circumstances" is allowed.	➢ FRELs/FRLs should not exceed average annual emissions over the reference period. ➢ Upward adjustment is only allowed for countries with high forest cover and historically low deforestation.	➢ Average emissions of the reference period ➢ Regression formula based on historical trends ➢ Projection models

Countries that submitted FRELs/FRLs to the UNFCCC:

Brazil	Historical average
Colombia	Historical average with qualitative adjustment
Ecuador	Historical average
Guyana	Historical average with quantitative adjustment
Malaysia	Historical average
Mexico	Historical average

Findings from the six countries FREL/FRL

- ➢ Most countries follow a stepwise approach, initially including a limited number of REDD+ activities, carbon pools
  - ❖ These countries intend to expand its scope as more complete and better quality data become available.
- ➢ Some of FRELs/FRLs submitted cover subnational
  - ❖ These countries intend to develop National FRELs/FRLs, combining the subnational FRELs/FRLs.

Additional FRELs/FRLs Submitted

Country	Scale	Forest Definition	REDD+ Activities	Carbon Pools	Reference Period	Method of extrapolation
Chile	Subnational	Cover: 10% Area: 0.5ha	Deforestation Degradation Enhancement Conservation	AGB BGB Dead wood Soil	1997 – 2012	Historical average
Costa Rica	Subnational	Cover: 30% Height: 5m Area: 1ha	Deforestation Enhancement	AGB BGB Dead wood Litter	1st period (1997 – 2009): 1986 – 1996 2nd period (2010 – 2025): 1997 – 2009	Historical average
Ethiopia	National	Cover: 20% Height: 2m Area: 0.5ha	Deforestation Enhancement	AGB BGB Dead wood	2000 – 2013	Historical average
Indonesia	Subnational	Cover: 30% Height: 5m Area: 0.25ha	Deforestation	AGB Soil	1990 – 2012	Historical average
Peru	Subnational	Cover: 10% Height: 5m Area: 0.09ha	Deforestation	AGB BGB	2001 – 2014	Historical forest change trend
Vietnam	National	Cover: 10% Height: 5m Area: 0.5ha	Deforestation Degradation Enhancement	AGB BGB	1995 – 2010	Historical average
Zambia		Cover: 10% Height: 5m Area: 0.5ha	Deforestation	AGB BGB Dead wood	2000 – 2014	Historical average

【Warsaw Framework for REDD+】

(1) modalities for national forest monitoring systems,
(2) the timing and the frequency of presentations of the summary of information on the safeguards,
(3) addressing the drivers of deforestation and forest degradation,
(4) guidelines and procedures for the technical assessment of submissions on proposed REL/RL,
(5) modalities for measuring, reporting and verifying (MRV),
(6) coordination of support for the implementation of activities, including institutional arrangements
(7) work programme on results-based finance

http://unfccc.int/resource/docs/2013/cop19/eng/10a01.pdf#page=34

①Modalities for national forest monitoring systems (NFMS)

Outline : The development of NFMS should take into account the most recent guidance provided in IPCC, and the NFMS should provide data and information that are transparent, consistent over time, and are suitable for measuring, reporting and verifying.

Function : NFMS should build upon existing systems as appropriate, and enable the assessment of different types of forest in the country, including natural forest, as defined by the Party.

②the timing and the frequency of presentations of the summary of information on the safeguards

Outline : Developing country Parties should start providing the summary of information on safeguards in their national communication or communication channel, including via the web platform of the UNFCCC, after the start of the implementation of activities of REDD+. The frequency of subsequent presentations of the summary of information should be consistent with the provisions for submissions of national communications

③addressing the drivers of deforestation and forest degradation

Outline : Encouraging all Parties, relevant organizations, and the private sector and other stakeholders, to continue their work to address drivers of deforestation and forest degradation and to share the results of their work on this matter; and developing country Parties to take note of the information from ongoing and existing work on addressing the drivers of deforestation and forest degradation.

④ Guidelines and procedures for the technical assessment of submissions on proposed REL/RL

Objectives of technical assessment : To assess the consistency with the guidelines for submissions of information on FREL/FRL, and to offer a facilitative and non-intrusive technical exchange of information keeping the construction and future improvements of FREL/FRL in mind.

Composition of assessment team : Each submission shall be assessed by two LULUCF experts selected from the UNFCCC roster of experts, one from a developed country and one from a developing country. The Consultative Group of Experts on National Communications from Parties not included in Annex I to the Convention may nominate one of its experts to participate in the technical assessment as an observer.

Timing and method of publication : Assessment sessions will be organized once a year. Assessment will be done for about a year. the Party may modify its submitted FREL/FRL in response to the technical inputs of the assessment team. Publication of final report on assessment results is made via the web platform on the UNFCCC website.

⑤ Modalities for measuring, reporting and verifying (MRV)

Outline : To be consistent with the methodological guidance provided in decision of COP15, and any guidance on the MRV of nationally appropriate mitigation actions (NAMA) . Data and information used in the estimation of forest-related emissions by sources and removals by sinks etc. should be transparent, and consistent over time and with the FREL/FRL

Report : The Data and information will be submitted through the biennial update reports (BUR) and technical annex by Parties. The technical team of experts shall make an analysis and prepare a technical report to be published via the web platform.

⑥ Coordination of support for the implementation of activities, including institutional arrangements

Requirement : To designate a national entities or focal points of developing country

Function of the entity : Identify needs and functions related to the coordination of support, strengthen the sharing of relevant information, knowledge, experiences and good practices, identify possible needs and gaps in coordination of support, provide opportunities to exchange information between the relevant bodies, provide information and any recommendations to improve the effectiveness of finance.

⑦ Work programme on results-based finance

Requirement to obtain finance : developing countries seeking to obtain and receive results-based finance of REDD+ activities should meet requirement of The Cancun Agreement, and those actions should be fully measured, reported and verified, the countries should provide the most recent summary of information on the safeguards before they can receive results-based payments;

Publication of information : To establish an information hub on the web platform on the UNFCCC website as a means to publish information on the results of the activities, and corresponding results-based payments;

Green Climate Fund : The Green Climate Fund (GCF) plays a role of result-based financing the REDD+ activities.

Financing methods discussed in REDD+ mechanism

- **Fund method:** Developing countries implement REDD+ activities on the basis of funds. As such funds, e.g. an international fund, fund between the two countries developed and developing countries, the multilateral fund can be considered. ➡ GCF can become the biggest funding source.
- **Market method:** making a deal for emission reduction amount of carbon as credits in carbon markets
- **Hybrid method:** Combination of fund method and market method

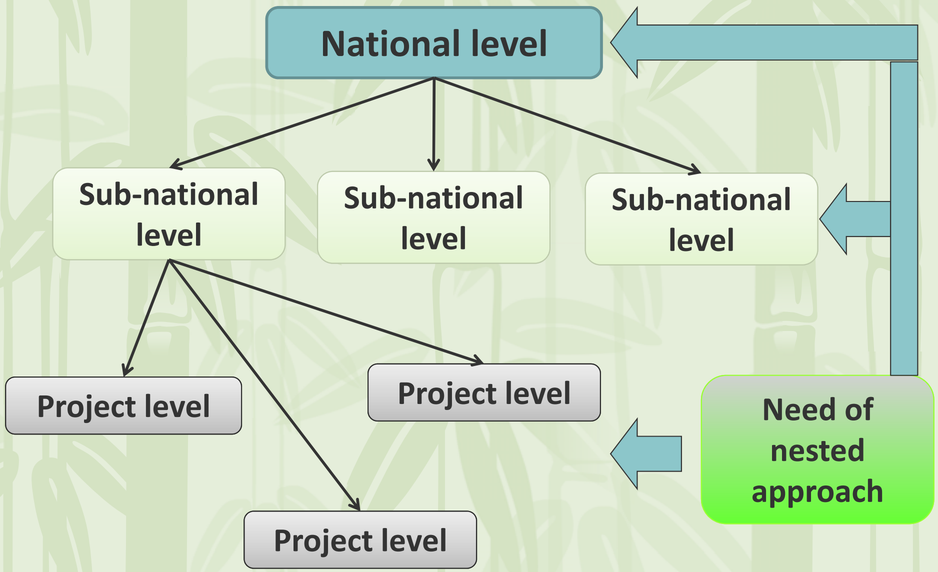
Advantages & issues of three Financing methods

- **Fund method**: The readiness fund can be provided, it is not necessarily to strictly take result-oriented basis
  - Possible to provide advance funding to business
  - Depending on the outcome of the emission reduction, it is possible to obtain additional funds too.
  - No deal in the market･If it is not result-based payment, long-term funding may be difficult
- **Market method**: method based on the payment by result-based
  - If carbon credits as amount for emissions reductions of developed countries can be offset, it is possible to collect large amount of money
  - Since reliability of the market is required, REDD + activities that the MRV system are established are required, also increase in the effectiveness of the business can be recognized
  - If getting involved in the market priority, interest in the forest focus on only carbon, diversity of forest function is neglected
- **Hybrid method**:
  - it is possible to obtain funds by the fund method in the preparation stage and early stage of implementation, it is possible to obtain the large amount of money in the market method after entering the full-scale implementation stage

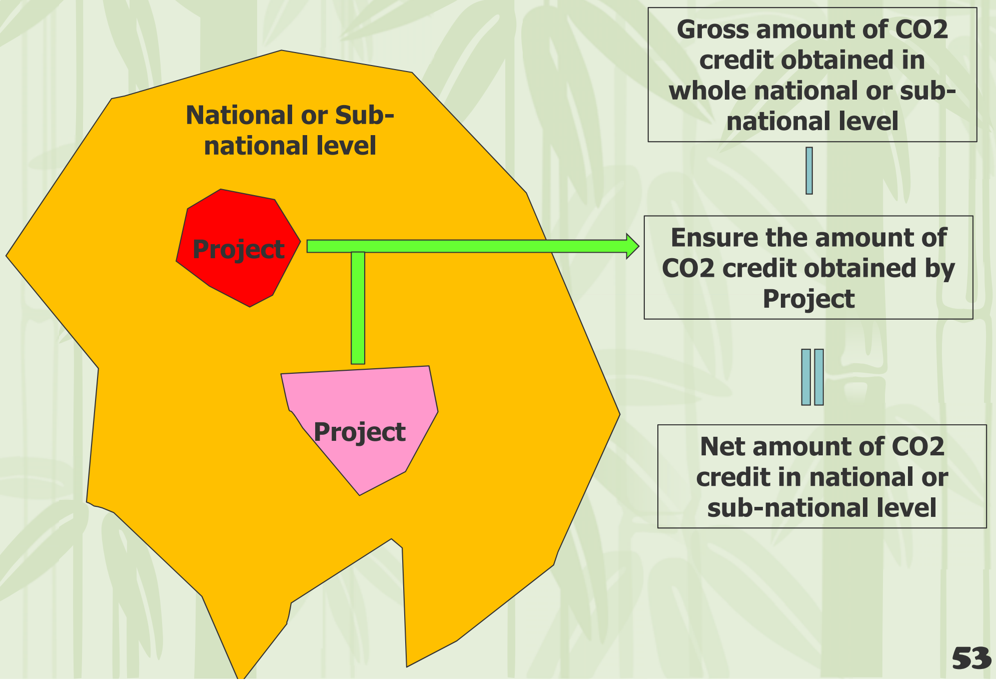
Phased approach of REDD+ implementation

Phase 1	Phase 2	Phase 3
Preparing National REDD+ strategy, improvement of the capabilities required to REDD + implementation	Trial of REDD + activities in accordance with the countries' ability (continuation of capacity building)	Aiming at making markets, the implementation of REDD + activities in the results-based by robust monitoring system

Level of REDD+ (Three Classes)



Example of Nested Approach



Process of practice of REDD+ activities

Step 1
- Identifying drivers to promote deforestation and forest degradation

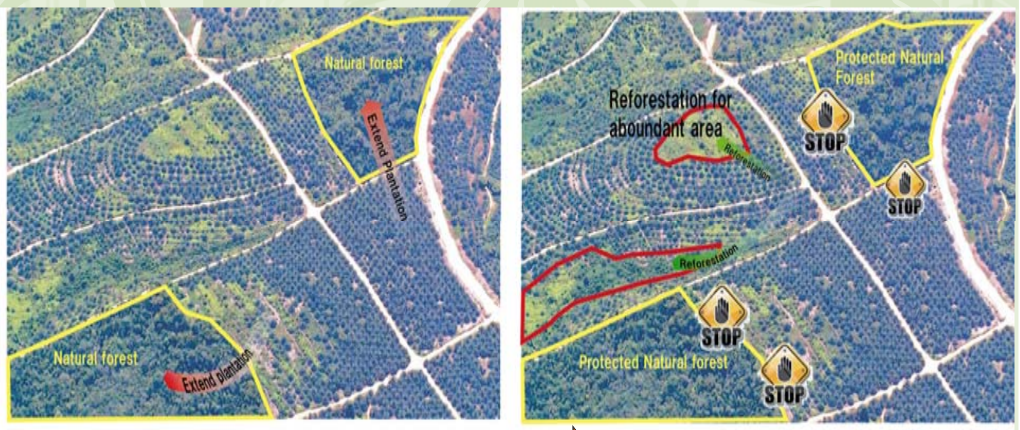
→ Issue is to quantitatively grasp the drivers

Step 2
- Formulating strategy of REDD+ including action plan

Step 3
- Practicing REDD+ activities by PaMs based on the strategy

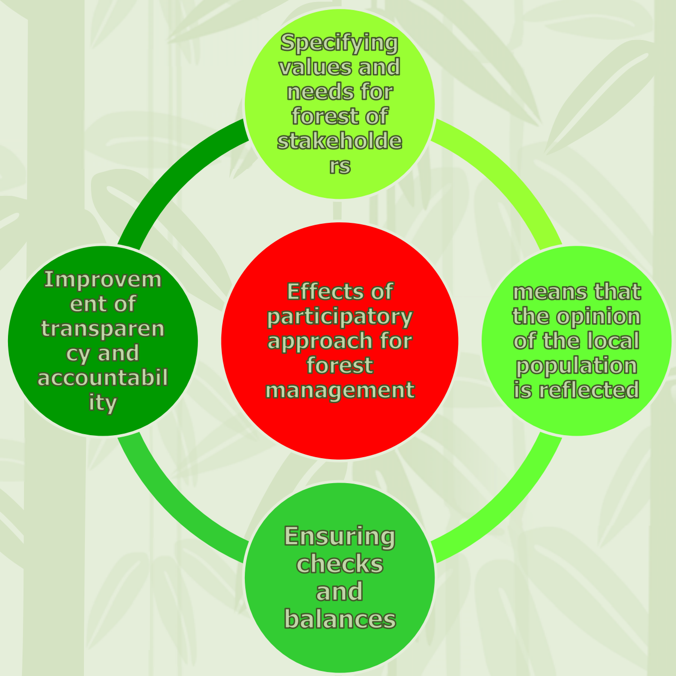
→ Issues are capacity, technology and governance

REDD Mechanism and Concept



Business as usual (Now) → Protection activity → Protect forest and sequence carbon (Future)

Participatory forest management for success of REDD+



Consistency with other fields for success of REDD+

- The development with a deforestation such as agriculture, timber exports, and mining are often given to priority on the policy, and it is not uncommon that site to be protected as forest and area of development planned competes.

- Therefore, If the developing countries commit to and implement REDD+, the consistency with the development policies and climate change measures in the field of non-forest is important.

Outline of National Forest Monitoring System (NFMS) as a Part of MRV's M

The REDD+ Readiness Component
in
the Capacity Development Project for the Sustainable Forest Management
in the Republic of Kenya

By Kazuhisa KATO - Compornent3 Team Leader
2017.7.5

UNFCCC Requirements

Mechanism of REDD+

Readiness (To receive results-based finance, developing country party should have the following in place)	Implementation (Developing country party undertake the following activities to receive results based finance)
☐ A national strategy or action Plan	☐ Reducing emissions from deforestation
☐ An assessed forest reference emission level and/or Forest reference level	☐ Reducing emissions from forest degradation
☑ A national forest monitoring system (NFMS)	☐ Conservation of forest carbon stocks
☐ A system for providing information on how the safeguards are being addressed and respected	☐ Sustainable management of forests
	☐ Enhancement of forest carbon stocks

1/CP.16 The Cancun Agreements Paragraph 70,71

Modalities for national forest monitoring systems

Decision 11/CP.19

2. Decides that the development of Parties' national forest monitoring systems for the monitoring and reporting of the activities,1 as referred to in decision 1/CP.16, paragraph 70, with, if appropriate, subnational monitoring and reporting as an interim measure, should take into account the guidance provided in decision 4/CP.15 and be guided by the most recent Intergovernmental Panel on Climate Change guidance and guidelines, as adopted or encouraged by the Conference of the Parties, as appropriate, as a basis for estimating anthropogenic forest-related greenhouse gas emissions by sources, and removals by sinks, forest carbon stocks, and forest carbon stock and forest-area changes;

3. A lso decides that robust national forest monitoring systems should provide data and information that are transparent, consistent over time, and are suitable for measuring, reporting and verifying anthropogenic forest-related emissions by sources and removals by sinks, forest carbon stocks, and forest carbon stock and forest-area changes resulting from the implementation of the activities referred to in decision 1/CP.16, paragraph 70, taking into account paragraph 71(b) and (c) consistent with guidance on measuring,reporting and verifying nationally appropriate mitigation actions by developing country Parties agreed by the Conference of the Parties, taking into account methodological guidance in accordance with decision4/CP.15;

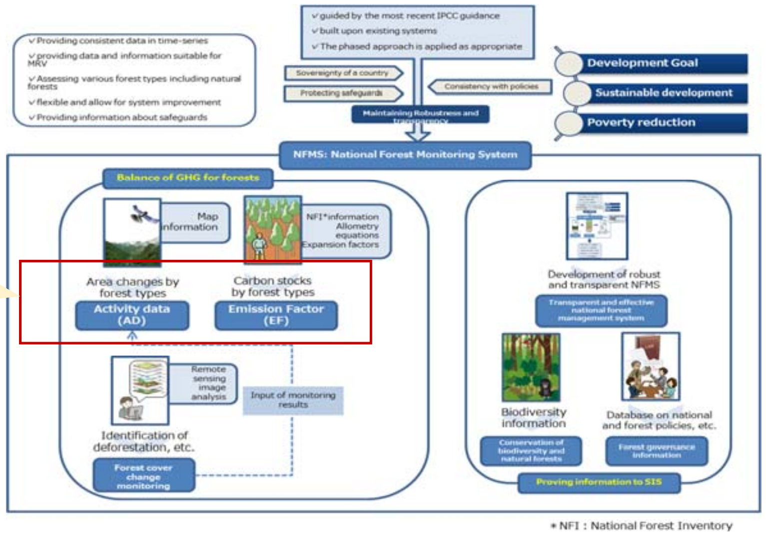
Definition of the NFMS in Kenya

Defining the NFMS as methodology and the NFMS as a database (forest information platform)

- **NFMS**
  Methodology of how forests are monitored
- **Forest Information Platform**
  A database to provide information that does not only include the information identified according to the NFMS but the information necessary for implementing REDD+ and sustainable forest management

Modalities for national forest monitoring systems

Need to Identify each methodologies as Kenya REDD+



Development of the NFMS

Contents(What)	Purpose(Why: Why the information is needed)	Needed Information (Which: by which information the contents are developed)	Specific information (How: How the information is obtained)	Methodologies (How: How to grasp the information)	Place to get information (Where: where the information is prepared)	Frequency and time(When: When and how often the data is updated)	Persons in charge(Who: Who are the persons in charge)
Activity data							
Emission Factor							
Forest cover change monitoring							
Contribution to Safeguard							
Others if any							

Have to be decided

Development of the NFMS

Contents(What)	Purpose(Why: Why the information is needed)	Needed Information (Which: by which information the contents are developed)	Specific information (How: How the information is obtained)	Methodologies (How: How to grasp the information)	Place to get information (Where: where the information is prepared)	Frequency and time(When: When and how often the data is updated)	Persons in charge(Who: Who are the persons in charge)
Activity data	Grasping the Balance of GHG from forests	Area changes by forest types	Land Use Land Cover MAP	Method that is used by SLEEK	SLEEK	Every years?	SLEEK
Emission Factor	Grasping the Balance of GHG from forests	Carbon stocks per hectare (ha) by forest types	EF is Calculated by multiplying the Result of National Forest Inventory and allometric equation that will be selected for Kenya REDD+.	Carbon esitimation【Forest】 NFI Methodology : ICFRA Allometric equation : Proposed by ICFRA and modified by JICA 【Non Forest】 Apply Tier 1 data of IPCC guideline	KFS, ○○Department	NFI : At any times or every○years	KFS○○Department Mr.○○
Forest cover change monitoring	Grasping information about deforestation and forest degradation	Forest cover change monitoring developed by the Work	・Analysis of remote sensing data (it will be developed in the Work) ・Use of JJ-FAST		KFS (C/P of the Work)?	Once/year (frequency in the Work)?	KFS○○Department Mr.○○
Contribution to Safeguard	Providing safeguard information system (SIS) with information on forest governance	Diagram of forest governance system in Kenya, Forest-related laws and programmes	Summarize the organization chart of KFS, forest-related policies, programmes, laws and treaties.	Link to Safeguard information system	KFS, ○○Department KFS, △△Department	At any times or ○ times/year	KFS○○Department Mr.○○
	Providing SIS with information for consideration of biodiversity	Wild animals and plants protection area map National Park map Other biodiversity information	Collaboration with the Kenya Wildlife Service (KWS), Incorporate biodiversity information item into forest inventory item	Link to Safeguard information system	KWS, In charge of NFI department	At any times or every○years Modification after the implementation of forest inventory	KFS○○Department Mr.○○

Methodology to develop AD

- **Forest Definition:**

Minimum surface area	0.5ha
Minimum Height	2m
Minimum Cover	15%

- **MAP :**

Map	SLEEK MAP
Image	Land Sat image or any available and more aculeate image
Methodology	Wall to Wall Supervised Classification Developing 2014 map as base map
Time	Every two years??

Methodology to develop AD

- Stratification: SLEEK stratification will be used

forest classe
Montane Forest, Western Rain Forest and Bamboo Forest
Mangrove Forest and Coastal Forest
Dryland Forest
Plantation

X

Canopy coverage classe
Dense
Moderate
Open

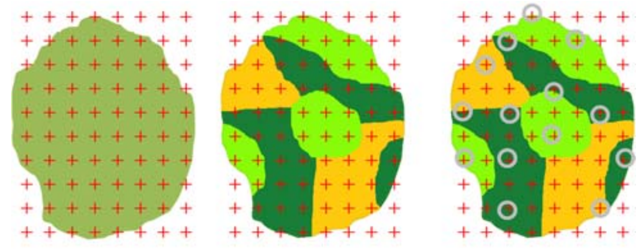
= 12 forest types

Methodology to develop EF

- NFI is utilized for developing EF

Sampling Design of NFI

1 Systematic sampling method: Distance of 2km-by-2km: (4km^2 grids) over the whole country
2 Stratified sampling method: SLEEK stratification (12 forest types)
3 Random sampling method: The number of clusters to be calculated based on the SLEEK stratification.



Systematic sampling method Stratified sampling method Random sampling method

Methodology to develop EF

- Sampling Design of NFI

ICFRA proposal: Cluster sampling method

- Cluster design is as follows. However, since SLEEK stratification is used that means, it is needed to decide how the cluster design will be adjusted, e.g. left side figure is for forest except for mangrove, right side figure is for mangrove. In addition, cluster method itself should be re-considered whether it is applied or not because of possibility that more than two forest types are mixing in a cluster.

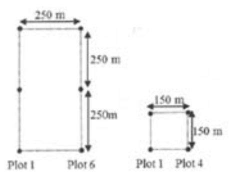


Figure . Cluster designs in Strata 1-3 (left) by ICFRA and in Stratum 4 (right).

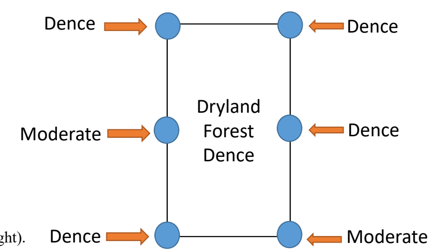


Figure . Example of cluster with more than two forest type mixed

In this case, how can the data be compiled?
Moderate data is compiled as Dense forest or moderate forest?
Otherwise no cluster method applied?

Methodology to develop EF

- Plots shape

ICFRA proposal: Cercle shape is used as mentioned in the following figure. However, since SLEEK stratification is used, it is needed to decide how each shape will be applied to the SLEEK stratification, e.g. left side is for non-forest, right side is for forest.

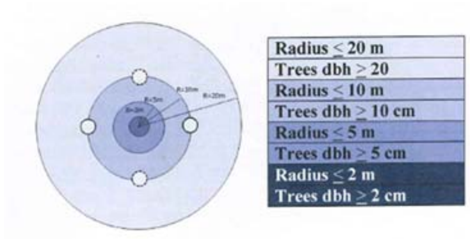


Figure . Sample plot design for Stratum 1 and 3

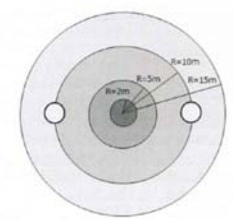


Figure . Sample plot design for Stratum 2 and 4

*ICFRA 2016. Proposal for National Forest Resources Assessment (NFRA) in Kenya.

Methodology to develop EF

- Measurement method in the plots:

- ICFRA proposal: As mentioned in the table

Table .Measurement on the circular sample plots.

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

*ICFRA 2016. Proposal for National Forest Resources Assessment (NFRA) in Kenya.

Methodology for contribution to SIS

- How NFMS can contribute to SIS

1. **Actions complement or are consistent with the objectives of national forest programmes and relevant international conventions and agreements**
2. **Transparent and effective national forest governance structures, taking into account national legislation and sovereignty**
3. **Respect for the knowledge and rights of indigenous peoples and members of local communities**
4. **The full and effective participation of relevant stakeholders, in particular, indigenous peoples and local communities**
5. **Actions are consistent with the conservation of natural forests and biological diversity**
6. **Actions to address the risks of reversals (related to non-permanence)**
7. **Actions to reduce displacement of emissions (related to leakage)**

Policies and laws related REDD+
Conventions related climate change already ratified
National REDD+ strategy

Institutional Arrangement for REDD+ with role of each institution
Information on forest governance

Rule & regulation and other detailed information (area, data on endangered and of precious species etc.) of protected area including national parks

Proposed contents for NFMS document

Chapter 1	Background and Purpose	
Chapter 2	UNFCCC Requirements	
Chapter 3	Basic conditions for NFMS	3.1 Scale
		3.2 REDD+ Activity
		3.3 Forest Definition
		3.4 Carbon Pool
		3.5 Scope of GHG
Chapter 4	Conceptual design of the NFMS in Kenya	4.1 Composition of NFMS
		4.1.1 Monitoring Function
		4.1.2 Data Management Function
		4.2 Phased Approach
		4.3 Relation with Other Activities
Chapter 5	NFMS Components	5.1 Activity Data
		5.2 Emission Factor
		5.3 Forest Cover Change Monitoring
		5.4 Providing information to SIS
		5.5 Data Management System in the Forest Information System
Chapter 6	Institutional Arrangement for NFMS	6.1 Institutional Arrangement for Monitoring Function
		6.2 Institutional Arrangement for Data Management Function
Chapter 7	Calendar of NFMS	
Chapter 8	Cost Considerations	

Chapter 1 : Background and Purpose

Write the Background and Purpose for developing NFMS in Kenya

- Example -

The Followings should be described in the chapter

✓ Forest conditions in Kenya
✓ Importance of REDD+
✓ Summary of progress of REDD+ in Kenya
✓ Necessity and requirement of NFMS based on COP decision
✓ Relation between NFMS and MRV
✓ Contents of NFMS document

Chapter 2 : UNFCCC Requirements

Write the principal COP decisions that have defined the requirements of an NFMS developed to implement REDD+

- Example -

The principal COP decisions that have defined the requirements of an NFMS developed to implement REDD+ activities include:

Decision 4 of COP 15 in 2009 in Copenhagen, Denmark
The Conference of the Parties requests developing country Parties to establish, according to national circumstances and capabilities, robust and transparent national forest monitoring systems that:

(1) 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;

(2) Provide estimates that are transparent, consistent, as far as possible accurate, and that reduce uncertainties, taking into account national capabilities and capacities;

(3) 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, Decision 11 of COP 19 in 2013 in Warsaw, Poland … etc.

Chapter 3 : Basic conditions for NFMS

Write current Forest Monitoring situation in Kenya (If there are no activity about them, write it as there are no activity.)

- Example -

- Scale
  National or sub-national scale which Kenya selected
- REDD+ Activity
  REDD+ activities to be selected from among five REDD+ activities shown in COP decision and definition of each REDD+ activity
- Forest Definition
  Threshold between forest and non-forest from the viewpoints of minimum tree crown cover value, minimum land area, and minimum tree height
- Carbon Pool
  Selected carbon pool from among five forest carbon pools
- Scope of GHG
  Selected GHG

Chapter 4 : Conceptual design of the NFMS in Kenya

Write conceptual design of the NFMS in Kenya

- Example -

Composition of the NFMS

Defining the NFMS as methodology and the NFMS as a database (forest information platform)

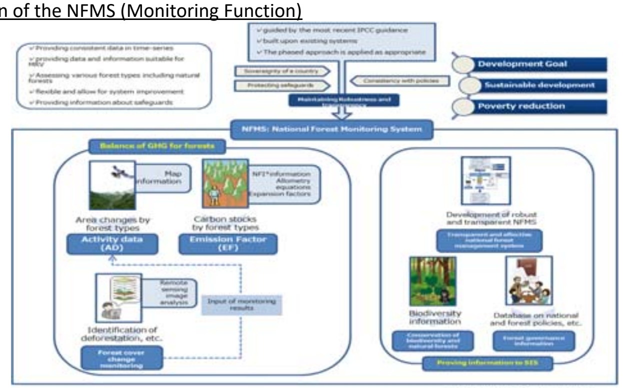
- **NFMS**
  Methodology of how forests are monitored
- **Forest Information Platform (FIP)**
  A database to provide information that does not only include the information identified according to the NFMS but the information necessary for implementing REDD+ and sustainable forest management

Chapter 4 : Conceptual design of the NFMS in Kenya

Write conceptual design of the NFMS in Kenya

- Example -

Composition of the NFMS (Monitoring Function)



* NFI : National Forest Inventory

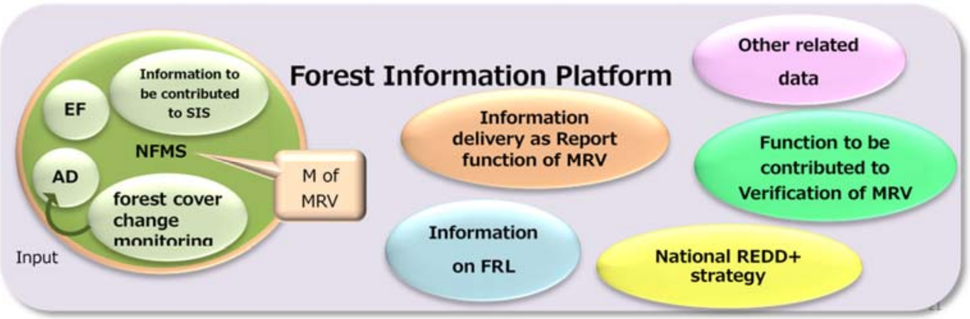
Chapter 4 : Conceptual design of the NFMS in Kenya

Write conceptual design of the NFMS in Kenya

- Example -

<u>Composition of the NFMS (Data management Function)</u>

Forest Information Platform to be developed by JICA project will be utilized as data management for REDD+



Chapter 4 : Conceptual design of the NFMS in Kenya

Write conceptual design of the NFMS in Kenya

- Example -

<u>Phased Approach</u>

The NFMS will be developed in a phased approach that is synchronized with the implementation of the three phases of the REDD+ program, which is depicted in Figure. The criteria that will be used to guide the development through each of these phases include UNFCCC requirements, national policies, the availability of data, operational costs, and the capacities of users of the NFMS to operate the system and use the information provided in a meaningful manner.

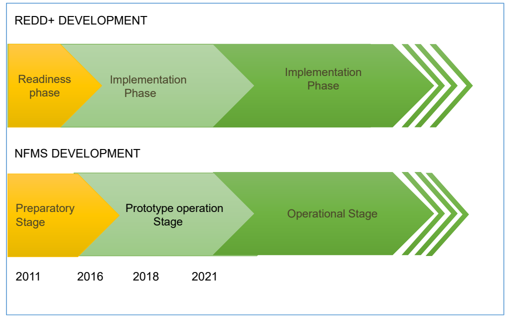


Figure Phased approaches of the development of the REDD+ program and the NFMS in Kenya

Chapter 4 : Conceptual design of the NFMS in Kenya

Write conceptual design of the NFMS in Kenya

- Example -

<u>Relation with other activities</u>

Although the NFMS of Kenya will be developed as an independent system, it will be related to other activities, as well, and linked to those activities such as the SIS. The information that will be required by the SIS and provided through the NFMS – particularly through its Monitoring Function - will be determined in concert with the development of the SIS to avoid duplication in the functions and nature of the information that will be managed… etc.

Chapter 5 : NFMS Components

Write how to develop NFMS components

- Example -

<u>Activity Data</u>

Kenya has monitored the distribution of forest areas using satellite-based Land use / Land cover maps since 1990. Therefore, activity data should be developed based on the LULC map.
Purpose, Scope (land classification, measurement interval), Methodology, and Accuracy assessment should be described.

Map	Land use/ Land cover Map
Responsible agency	SLEEK
Image	Land Sat image or any available and more aculeate image
Methodology	Wall to Wall Supervised Classification Developing 2014 map as base map
Interval year	Every two year?

Chapter 5 : NFMS Components

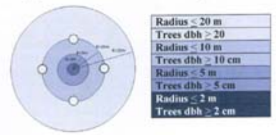
Write how to develop NFMS components

- Example -

Emission Factor

Kenya will estimate emission factor using data of National Forest Inventory (NFI). The methodology of the NFI will be implemented using the methodology to be approved as Kenya's NFI methodology.
Purpose, Scope (Target carbon pool, Tire level, implementation cycle), and Methodology should be described

- Sampling method
  - ✓ Systematic sampling method: distance of 2km-by-2km (4km^2 grids) over the whole country
  - ✓ Stratified sampling method: 4 forest classes (Montane Forest, Western Rain Forest and Bamboo Forest, Mangrove Forest and Coastal Forest, Dryland Forest, and Plantation) and 3 class of canopy coverage, total 12 forest types
  - ✓ Random sampling method: Necessary number of clusters of each forest type are selected from grids
  - ✓ Cluster sampling method:
- Shape of plots: Cercle plots
- Measurement items and method in the plot: DBH, tree height, etc.
- Conversion method to carbon stock data: allometric equation



Chapter 5 : NFMS Components

Write how to manage data in the forest information platform

- Example -

Function of the Forest Information Platform (FIP) and system for update and operation of FIP should be mentioned in this section.

Chapter 6 : Institutional Arrangement for NFMS

Write Institutional Arrangement for the NFMS in Kenya

- Example -

Institutional arrangement for monitoring function and data management function

Institutions to be involved in the decision making and implementation of the following monitoring should be illustrated by each function (monitoring function and data management function).

In addition, if there are institutions to be involved in coordination and/or consultation of the monitoring should be also illustrated.

- ✓ Activity Data
- ✓ Emission Factors
- ✓ Some other necessary information and data such information and data related with Safeguard

Chapter 7 : Calender of NFMS

Write Calendar of NFMS

Example

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Map Creation (AD)	X	X	X		X		X		X		X		X		X		X
National Forest Inventory (EF)							X					X					X
Forest Reference level				X				X					X				
Result-Based payment Submission									TA-BUR 2020		TA-BUR 2022		TA-BUR 2024		TA-BUR 2026		TA-BUR 2028

Chapter 8 : Cost Considering

Write costs to develop and implement NFMS

- Example -

The costs of the major elements associated with developing and implementing the NFMS are estimated in Table.

	Activity and Cost Items	Unit cost	Quantity	Cost
1	Satellite Land use/cover mapping			
1.1	Pre-processing			
1.1.1	Personnel cost			
2	Accuracy verification survey			
2.1	Personnel cost			
2.2	High resolution satellite image			
2.3	Travel cost			
2.3	Field survey cost			
3	National Forest Inventory			
3.1	Field work			
3.1.1	Personnel cost			
3.1.2	Travel cost			
3.1.3	Field survey cost			
3.1.4	Equipment cost			
3.2	Indoor work			
3.2.1	Personnel cost			
3.2.2	Laboratory test – litter			
3.2.3	Laboratory test - soil			

REPUBLIC OF KENYA
Ministry of Environment and Natural Resources
Kenya Forest Service
REDD+ Readiness Component

Lecture for Basic Remote Sensing

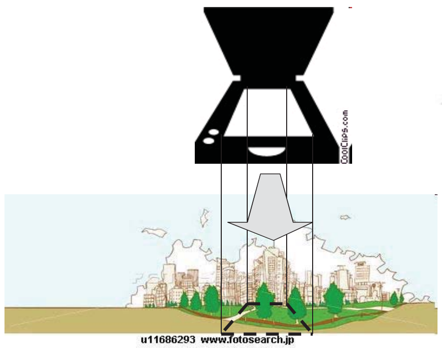
Date: 6th July 2017

By Faith MUTWIRI and Kei SATO

What is Remote Sensing?

Concept of Typical Remote Sensing

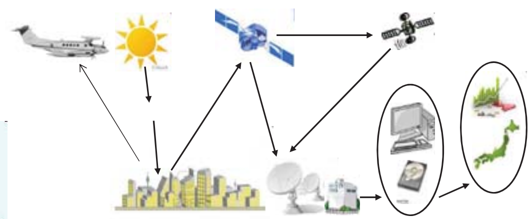
Scanning to the Earth
Earth Observation from Space



like Flatbed Scanner

Earth Surface Information Gathering

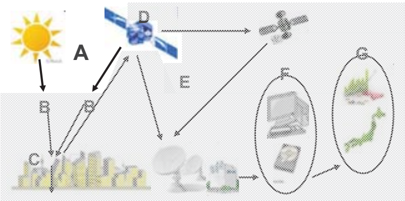
Processes of Remote Sensing
for Gathering Earth Surface Information

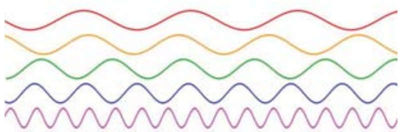


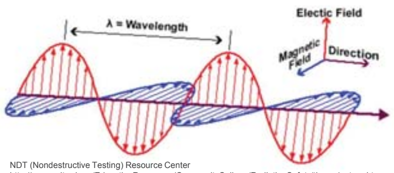
Indirect Measurement
using Electromagnetic Wave

Basic Knowledge of Remote Sensing

Electromagnetic Radiation



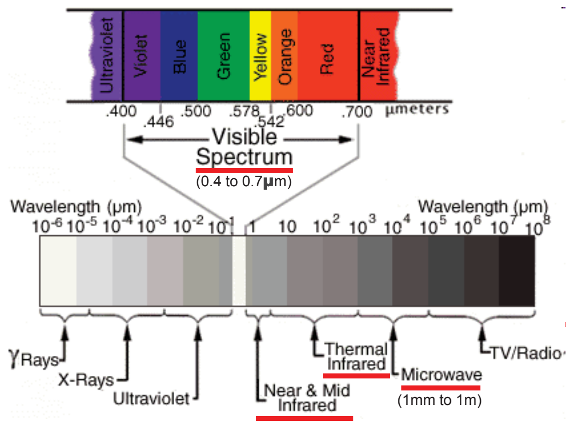




NDT (Nondestructive Testing) Resource Center
http://www.ndt-ed.org/EducationResources/CommunityCollege/RadiationSafety/theory/nature.htm

C = λν
λ: wavelength (m)
ν: frequency (cycle per second, Hz)
c: speed of light (3×10^8 m/s)

Electromagnetic Spectrum



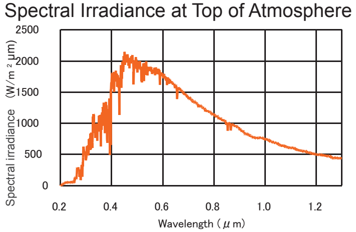
Band	Wavelength (mm)
Ka	7.5-11
K	11-16.7
Ku	16.7-24
X	24-37.5
C	37.5-75
S	75-150
L	150-300
P	300-1000

Remote Sensing Used Wavelength

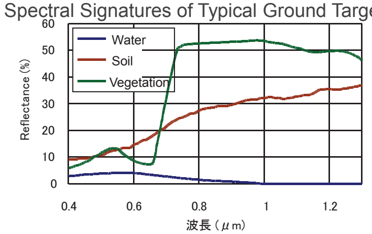
1 cm = 10^{-2} m
1μm = 10^{-6} m
1 nm = 10^{-9} m

Wavelength of Visible-Infrared Remote Sensing

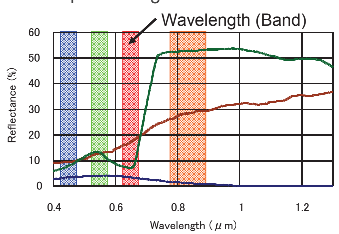
Spectral Irradiance at Top of Atmosphere

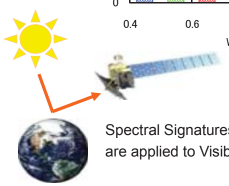


Spectral Signatures of Typical Ground Targets



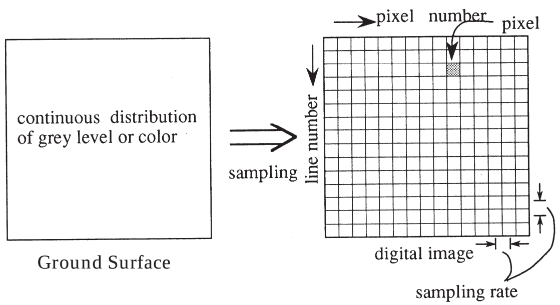
Remote Sensing Sensors' Wavelengths' and Spectral Signature

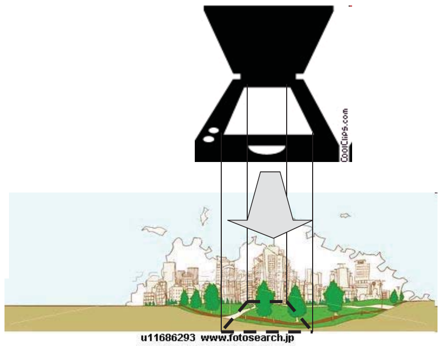




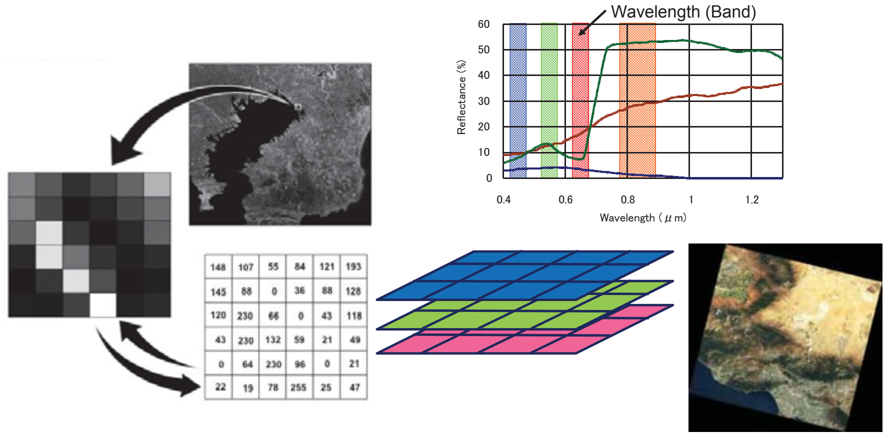
Spectral Signatures that reflected on Earth Surface are applied to Visible-Infrared Remote Sensing

What is scanning to the Earth?





What is scanning to the Earth?



Source:https://landsat.gsfc.nasa.gov/landsat-8/landsat-8-bands/

Limitation of Remote Sensing

Sampling Size and Quantization Bit Rate on Imagery

The digital imagery is defined by sampling size and quantization bit rate.

The quantization bit rate is determined by how many levels it is necessary to express the information.

The sampling size is determined by the utilization purpose.
For examples, what you want to know what's that or what gender, age….

Limitation of Remote Sensing

Different Quantization Bit Rate and its Effect on Imagery

Effects depend on the different quantization bit rate

Sampling Size
256X256

8 bit	4 bit
2 bit	1 bit

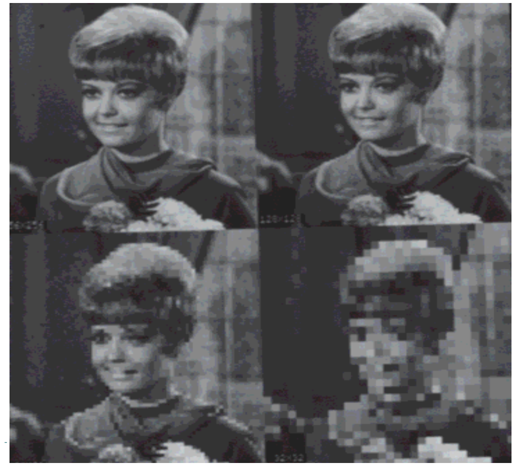
Limitation of Remote Sensing

Different Sampling Size and its Effect on Imagery

Effects depend on the different sampling size

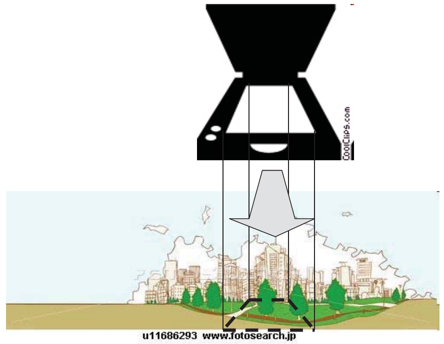
8bit Quantization

256X256	128X128
64X64	32X32

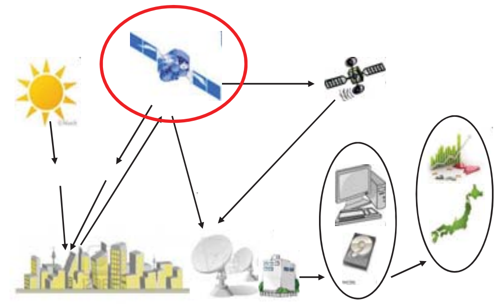


What is Satellite Imagery Remote Sensing?

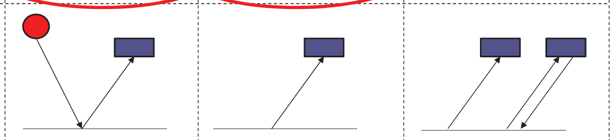
What is Satellite Imagery Remote Sensing?



e.g. LANDSAT Satellite series

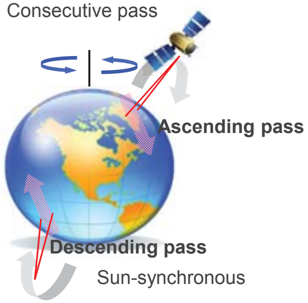


Type of LANDSAT Satellite as typical EO satellite

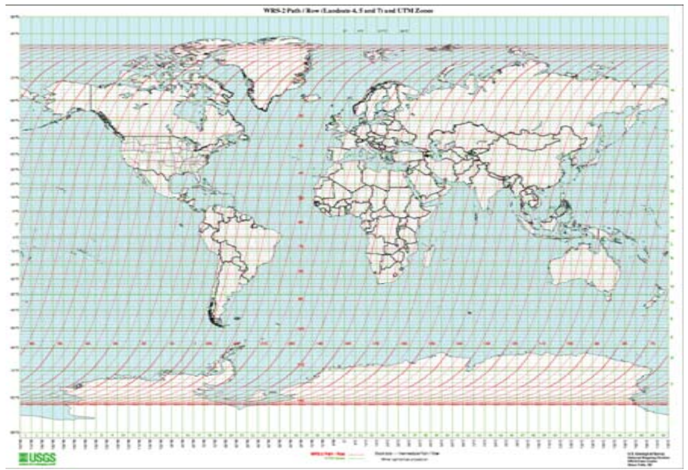
	Visible･Infrared Remote Sensing	Thermal Remote Sensing	Microwave Remote Sensing
			
Radiation Source	Sun	Target	Target Radar
Measurement Target	Reflectance	Thermal Radiation (Temperature/emissivity)	Microwave Radiation backscattering coefficient
Spectral Radiance	Solar Radiation 0.5μm 3−4μm	Earth Radiation 10μm	

LANDSAT Orbit and Swaths

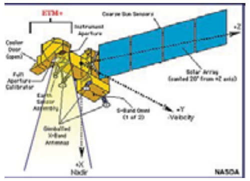
New Area with each Consecutive pass



Local Sun Time



Specification of LANDSAT 7



Sun-synchronous Sub-Recurrent Orbit
Recurrent Period 16 days
Circles the Earth every 98.9 minutes
altitude of 705 km (438 mi)
Launched: April1999

Sensor	Wavelength Range/ Frequency	Spatial Resolution	Observation Width
Enhanced Thematic Mapper Plus (ETM+)	Band 1 Visible (0.45 – 0.52 µm) Band 2 Visible (0.52 – 0.60 µm) Band 3 Visible (0.63 – 0.69 µm) Band 4 Near-Infrared (0.77 – 0.90 µm) Band 5 Near-Infrared (1.55 – 1.75 µm) Band 6 Thermal (10.40 – 12.50 µm) Band 7 Mid-Infrared (2.08 – 2.35 µm) Band 8 Panchromatic (PAN) (0.52 - 0.90 µm)	Band 1 30 m Band 2 30 m Band 3 30 m Band 4 30 m Band 5 30 m Band 6 60 m Low Gain / High Gain Band 7 30 m Band 8 15 m	Swath width, 185 km (115 mi)

Source:http://landsat.usgs.gov/about_landsat7.php
http://www.satimagingcorp.com/satellite-sensors/alos.html

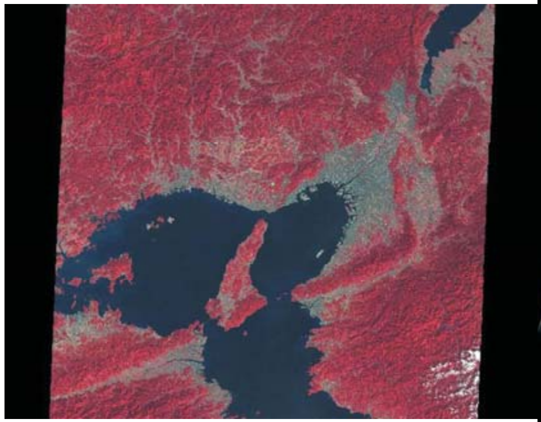
Specification of LANDSAT 8

Sun-synchronous Sub-Recurrent Orbit
Recurrent Period 16 days
Circles the Earth every 98.9 minutes
altitude of 705 km (438 mi)
Launched: February 2013

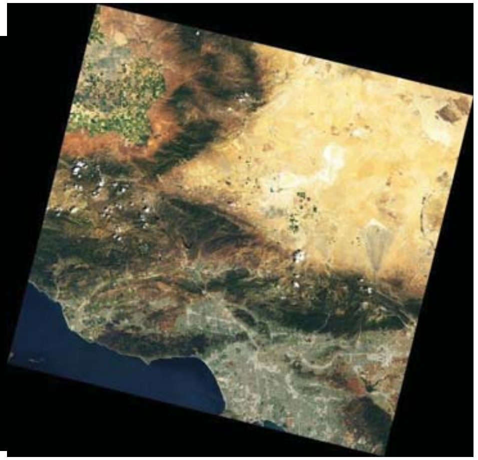
Sensor	Wavelength Range/ Frequency	Spatial Resolution	Observation Width
Operational Land Imager (OLI)	Band 1 New Deep Blue (0.43 – 0.45µm) Band 2 Visible (0.45 – 0.52 µm) Band 3 Visible (0.53 – 0.60 µm) Band 4Visible (0.63 – 0.68 µm) Band 5 Near-Infrared (0.85 – 0.89 µm) Band 6 SWIR 2 (1.56 – 1.66 µm) Band 7 SWIR 3 (2.10 – 2.30 µm) Band 8 PAN (0.50 – 0.68 µm) Band 9 SWIR (1.36 - 1.39 µm)	Band 1 30 m Band 2 30 m Band 3 30 m Band 4 30 m Band 5 30 m Band 6 30 m Band 7 30 m Band 8 15 m Band 9 30m	Swath width, 185 km (115 mi)
Thermal Infrared Sensor (TIRS)	Band 10 TIRS 1 (10.60 - 11.19 µm) Band 10 TIRS 2 (11.50 - 12.51 µm)	Band10 100m Band11 100m	

Source:https://landsat.gsfc.nasa.gov/landsat-8/landsat-8-bands/

LANDSAT Imagery



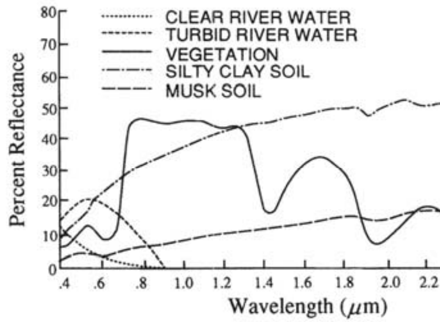
False Color (LANDSAT 7)



True Color (LANDSAT 8)

Source:https://landsat.gsfc.nasa.gov/landsat-8/landsat-8-bands/

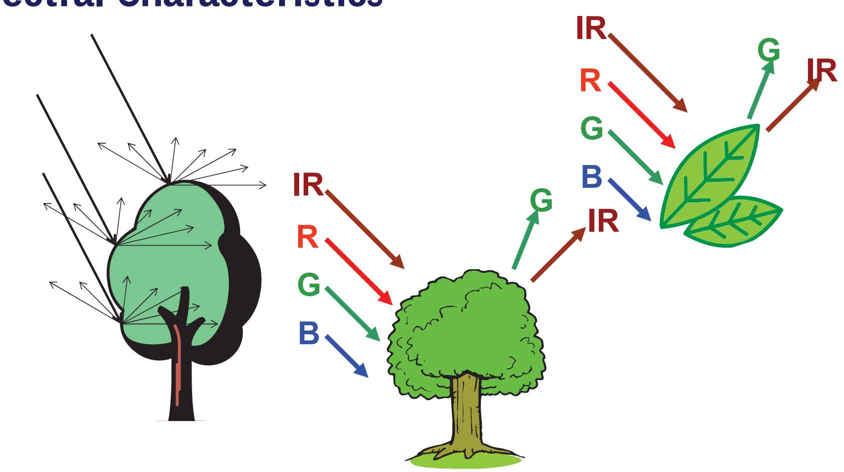
Characteristic of Electromagnetic Wavelength



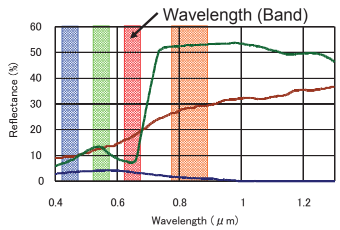
Spectral Band	Wavelength	Resolution	Solar Irradiance
Band 1 - Coastal / Aerosol	0.433 – 0.453 µm	30 m	2031 W/(m²µm)
Band 2 - Blue	0.450 – 0.515 µm	30 m	1925 W/(m²µm)
Band 3 - Green	0.525 – 0.600 µm	30 m	1826 W/(m²µm)
Band 4 - Red	0.630 – 0.680 µm	30 m	1574 W/(m²µm)
Band 5 - Near Infrared	0.845 – 0.885 µm	30 m	955 W/(m²µm)
Band 6 - Short Wavelength Infrared	1.560 – 1.660 µm	30 m	242 W/(m²µm)
Band 7 - Short Wavelength Infrared	2.100 – 2.300 µm	30 m	82.5 W/(m²µm)
Band 8 - Panchromatic	0.500 – 0.680 µm	15 m	1739 W/(m²µm)
Band 9 - Cirrus	1.360 – 1.390 µm	30 m	361 W/(m²µm)

Figure shows **three curves of spectral reflectance** for typical land covers; vegetation, soil and water.

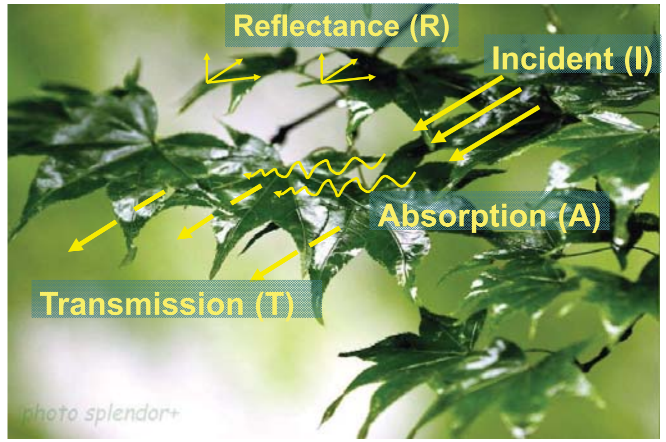
Spectral Characteristics



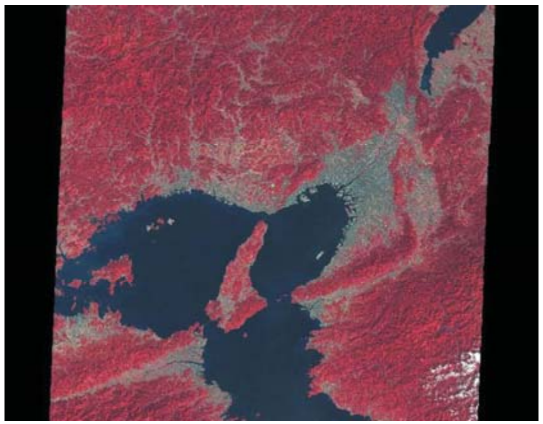
Visible-Infrared Remote Sensing



Model of Radiation and Target Interaction



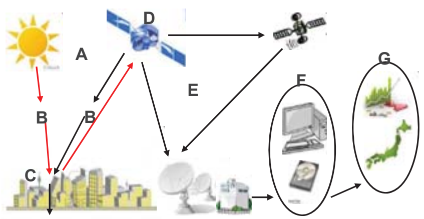
Gathering the reflection from the Earth Surface



False Color

Earth Surface Information Gathering

Processes of Remote Sensing
for Gathering Earth Surface Information



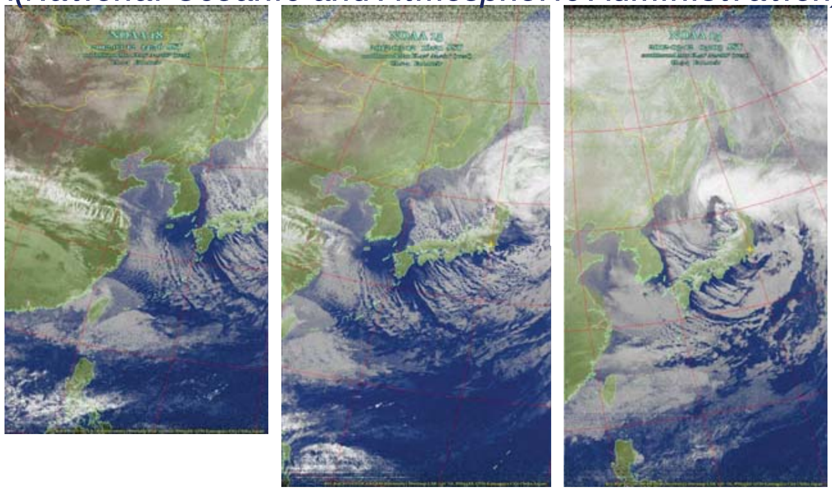
NOAA(National Oceanic and Atmospheric Administration)

Now Operating:
NOAA 15 : AM Secondary **NOAA 18 : PM Secondary**
NOAA 16 : PM Secondary **NOAA 19 : PM Primary**
NOAA 17 : AM backup
Geostationary Orbit
Altitude: Approximately 870 km
Launched: 02/06/2009 **NOAA 19**

Sensor	Wavelength Range/ Frequency	Spatial Resolution	Observation Width
AVHRR/3	Channel 1: 0.58 - 0.68(μm)(Visible) Channel 2: 0.725 - 1.00(μm) (NIR) Channel3A: 1.58 - 1.64(μm) (NIR) Channel3B: 3.55 - 3.93(μm) (MIR) Channel 4: 10.30 - 11.30(μm) (TIR) Channel 5: 11.50 - 12.50(μm) (TIR)	0.5 km 1.0 km 1.0 km 1.0 km 1.0 km 1.0 km	Swath Width : 2800km

Source:http://ja.allmetsat.com/satellite-noaa.php

NOAA(National Oceanic and Atmospheric Administration)



ALOS

Sun Synchronous Sub-Recurrent Orbit
Recurrent Period: 46 days
Sub cycle: 2 days
Altitude: Approximately 692km (above the equator)
Launched: January 2006

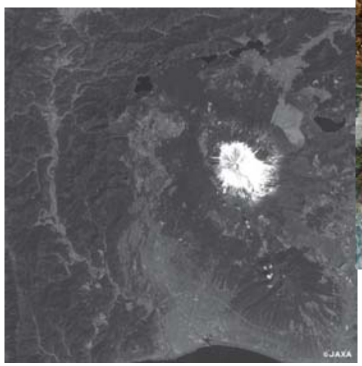
Sensor	Wavelength Range/ Frequency	Spatial Resolution	Observation Width
PRISM	0.52-0.77(μm)	2.5m	Swath Width : 35km(Triplet mode) 70km(Nadir Only)
AVNIR-2	Band1:0.42-0.50 (μm)(blue) Band2:0.52-0.60 (μm)(green) Band3:0.61-0.69 (μm)(red) Band4:0.76-0.89 (μm)(near-IR)	10m	Swath Width : 70km
PALSAR	Frequency L-Band 1.3 (GHz)	10m(fine resolution mode) 100m(Scan Sar mode)	Observation Swath : 70km(fine mode) 250-350km(Scan SAR)

Source:http://www.alos-restec.jp/en/staticpages/index.php/aboutalos
http://www.satimagingcorp.com/satellite-sensors/alos.html

ALOS

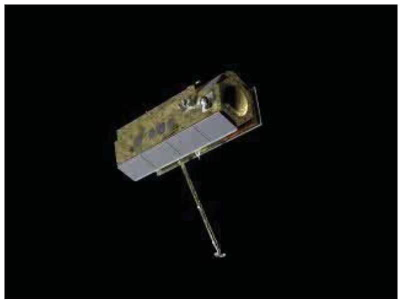
PALSAR

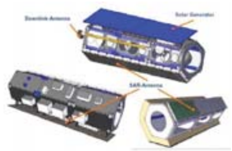
AVNIR-2



PRISM

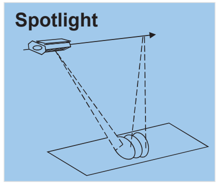
TerraSAR-X (Commercial Satellite)





Sensor	Active Phased Array X Band SAR
Satellite Mass	1,230kg
Antenna Size	4.8m × 0.7m × 0.15m
Orbit	Sun Synchronous Sub-Recurrent
Recurrent Period	11 days
Orbit Altitude	514km
Angle of inclination with respect to the equator	97.44°
Equatorial Crossing Time （Local Time）	06:00±0.25h（Descending） 18:00±0.25h（Ascending）

Three Acquisition mode of TerraSAR-X



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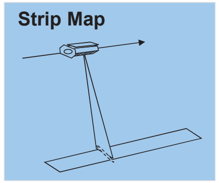
High Resolution



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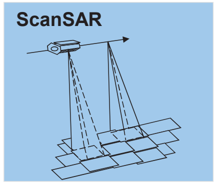
High Resolution



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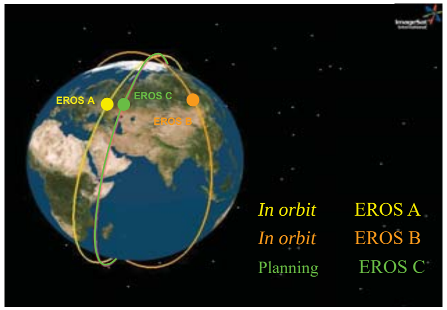
Large Area

TerraSAR-X (Commercial Satellite)

Sub-Meter Commercial Satellite EROS-A&B

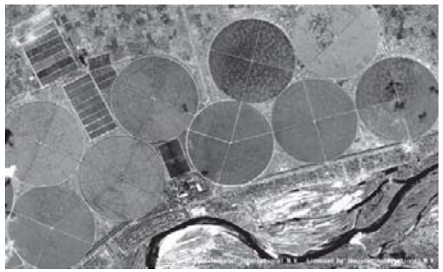
EROS-A

2000～
ImageSat International
Designed Life Time 10years
Overflight AM9:45 (EROS-A)
AM13:45 (EROS-B)
over Japan
Altitude:500km
Recurrent Period : less than 7days



	EROS-A	EROS-B	EROS-C
Launch	Dec.,2000	Apr.,2006	(Designed)
Wavelength	0.50 -0.90 mm	0.50-0.90 mm	0.50-0.90 mm
Ground Resolution	1.9 m	0.7 m	0.7 m 2.8 m (Multi-mode)
Swath	14 km	7 km	―

Sub-Meter Commercial Satellite EROS-A&B



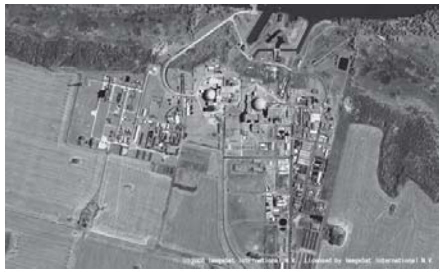
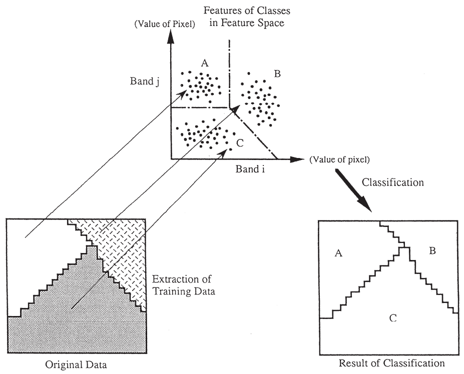


Image processing for classification

What is image classification?



In many cases, classification will be undertaken using a computer, with the use of mathematical classification techniques.

This Figure shows the concept of classification of remotely sensed data.

Methodology of classification processing

Pixel based classification **Object based classification**

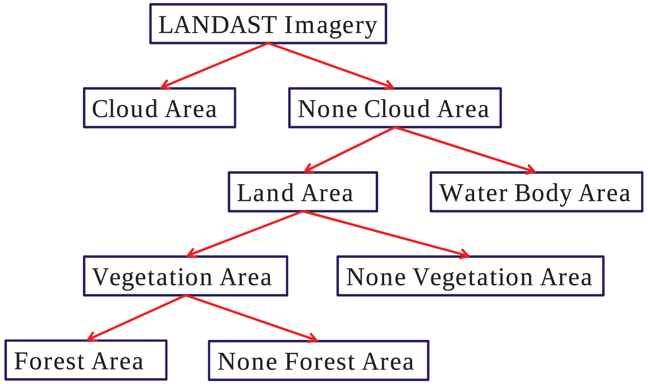
Typical methodology of classification processing

- Multi level slice classifier
- Decision tree classifier
- Minimum distance classifier
- Maximum likelihood classifier
  - Supervised, unsupervised, clustering

Other methodology of classification processing

- Fuzzy theory
- Expert system
- Neural Network i.e. AI

Decision Tree classifier



Supervised classification

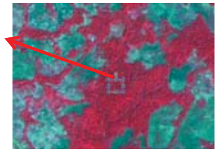
Extraction of site training data

- Ground Truth Survey
- Refer to the Google Earth

LANDAST Imagery

Input

Site Training Data



Supervised classification process

To classify into similar characteristic cluster of pixel value based on site training data

Land Cover / Land Use Map

Example as application of Satellite Remote Sensing

Extraction of logging area by image processing

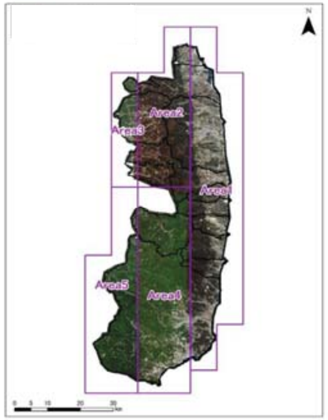
Satellite Imagery

NDVI calculation

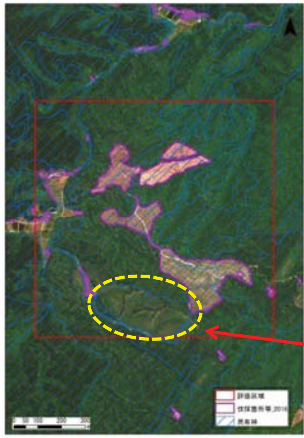
Setting threshold of NDVI

Extraction of logging area

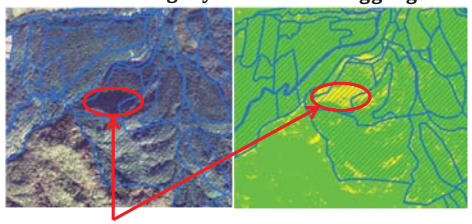
$$\mathrm{NDVI} = \frac{NIR - R}{NIR + R}$$



Extraction of logging area by image processing



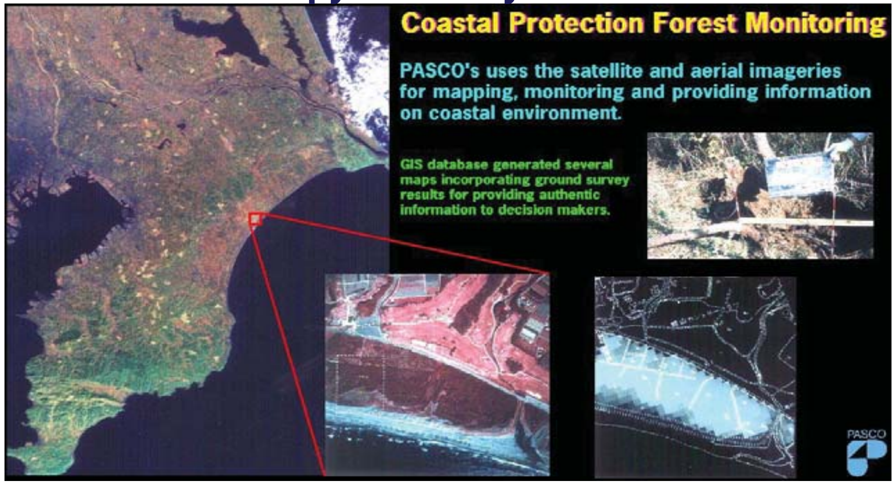
Satellite Imagery Extracted logging Area



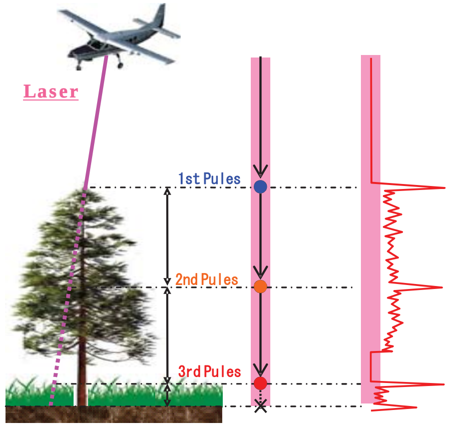
Affected by shadow

Affected by grass after logging

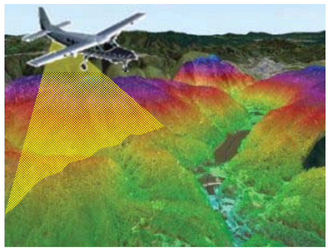
Extraction of Canopy Dense by NDVI and BI

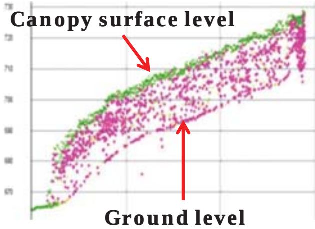


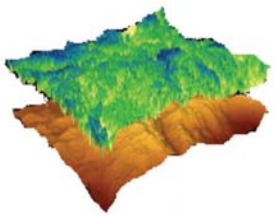
Analysis of Airborne Lidar survey for canopy density



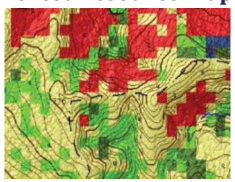
Analysis of Airborne Lidar survey for canopy density







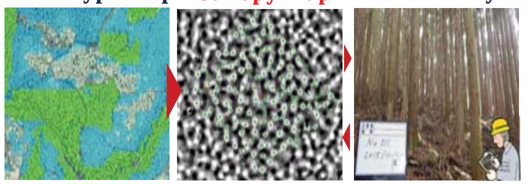
Forest Resource Map



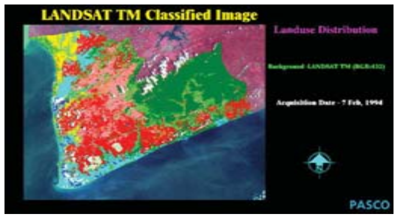
Forest Type Map

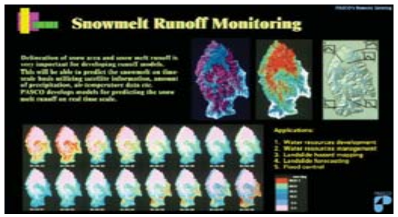
Individual Canopy Map

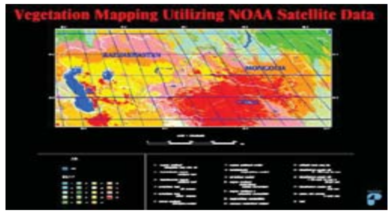
Site Survey



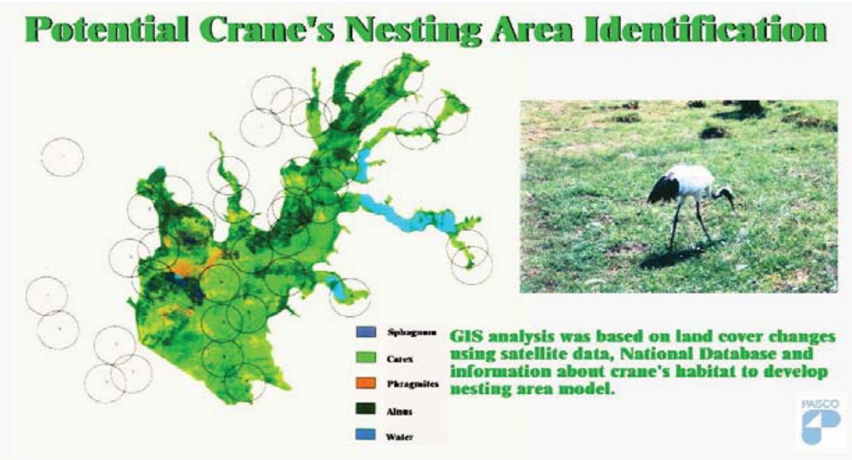
Example of other application



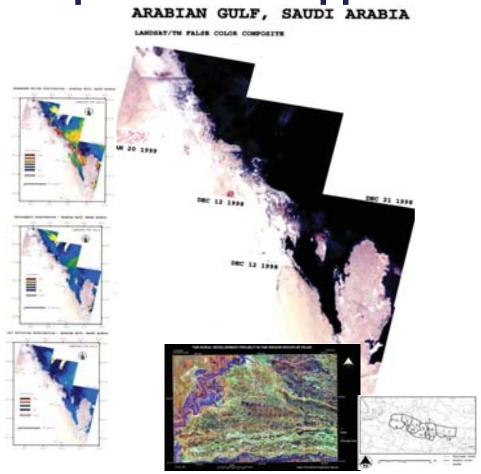


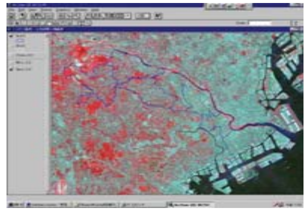


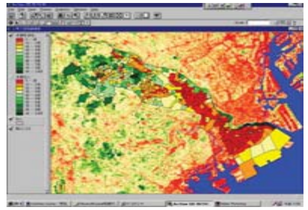
Example of other application



Example of other application







Thank you very much!

Contact address: f.mukabi@gmail.com
koetia2696@pasco.co.jp

REPUBLIC OF KENYA
Ministry of Environment and Natural Resources
Kenya Forest Service

MRV TRAINING - ACTIVITY DATA

Date: 5th to 6th June 2017

By Faith MUTWIRI and Kei SATO

SLEEK Time Series Land Cover / Land Use Map preparation

Activity Data

Introduction

- Mapping done in support of the SLEEK to establish robust MRV (Measurement, Reporting and Verification) system to track land-based emissions.
- SLEEK designed to track all emissions and removals in the land-sector;
- The mapping team provides land cover and change information required for national land based greenhouse gas estimation
- A multi-institutional Technical Working Group established to do the mapping,
- Work strongly guided by a Technical and process manual.

Capacity building

- Several trainings have been undertaken by FAO and CSIRO

1.CSIRO (Commonwealth Scientific and Industrial Research)
- ➢Random Forest classification and scripts used in the classification
- ➢Terrain illumination correction
- ➢Change detection and time series

2.FAO (Food Agricultural Organization
- ➢Accuracy Assessment
- ➢Change detection using Google Earth Engine
- ➢Land Cover Classification System (LCCS)
- ➢Data collection using collect earth

Methodology

1. Testing of methods

A. Methods as used by various institutions were tested.

- **Maximum likelihood,**
- **Progressive extraction and disaggregation of land covers,**
- **Random forest classification and**
- **Decision tree classifier.**

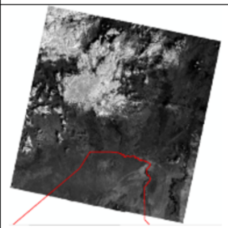
B. Classification using Random Forest – pixel based method was selected

✓**Open source**
✓**Store probability's**
✓**Accurate**
✓**Ease of implementation**

2. Data acquisition - *Data selection*

- **Cloud cover** – desired 0% cloud cover, low cloud cover (20%) is acceptable
- **Season** – dry season - January to February and July to August.
- **Sensor** - Landsat 5, Landsat 7 SLC-on, Landsat 8 are preferred over Landsat 7 SLC-Off
- **Date** - If more than one cloud-free choice is available, then dates of neighbouring scenes are considered (same-date with neighbours in the path or close date to neighbouring row will be preferred)

Sample of Data acquisition - *Data selection report*

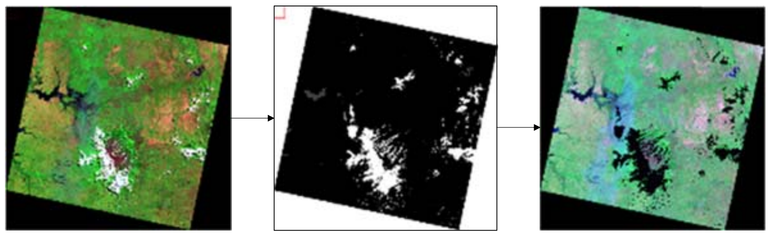
Image ID/Path-Row	Sensor	Season	Description	Screen Shot	Availability on Archive
P170_R056_2014_016	L8	Dry	Out 22 images this was the best. Good Image. No cloud within the Kenya boundary region		Y

Note: These archives were accessed at (http://glovis.usgs.gov/ or http://earthexplorer.usgs.gov/).

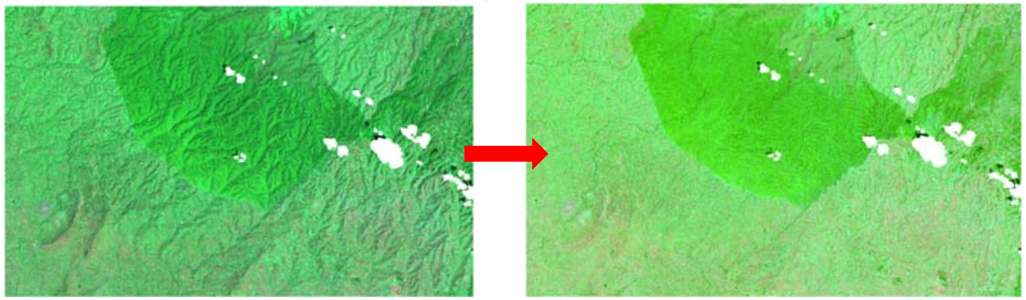
3. Data preparation

1.Cloud and shadow masking

- **masking all cloud and shadow**
- **Used "cfmask" band from USGS**



2. **Terrain illumination Correction**
   - variations in slope and aspect
   - to correct terrain illumination effects so that the same land cover will have a consistent digital signal



3. **Projection to the Kenyan Coordinate System**
   - Projection from **UTM WGS 84** to **UTM Arc1960 37 South**

4. Land Use Land Cover Classification

1. Land cover classes for LCC Mapping

I. Forest
1. Dense Forest > 65% canopy cover
2. Moderate Forest 40 - 65% canopy cover
3. Open Forest 15 - 40% canopy cover

II. Cropland
1. Annual Cropland
2. Perennial cropland

III. Grassland
1. Open Grassland
2. Wooded grassland

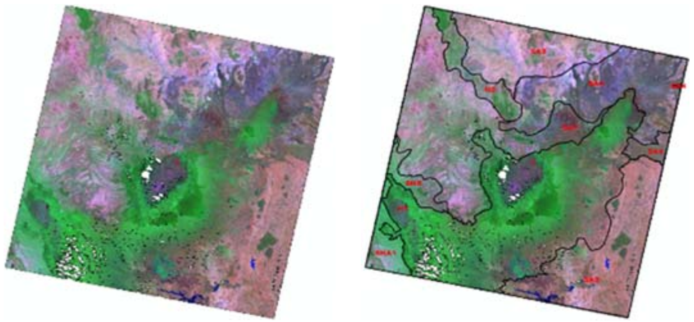
IV. Wetland
1. Open Water
2. Vegetated wetland

V. Settlement

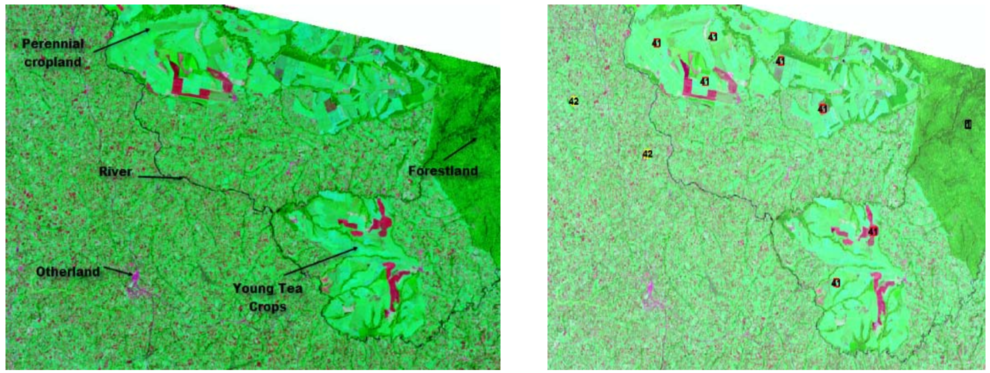
VI. Otherland

2. Stratification - spectral stratification zones

- Land use land cover variations in Kenya
- spectral stratification zones were initially based on Kenya's Agro-Ecological Zones later modified

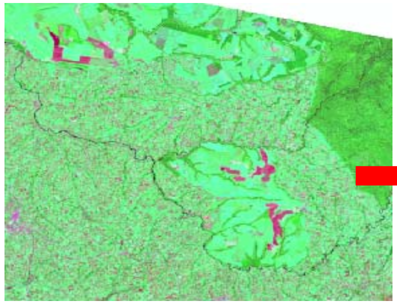


3. Selection of Training Sites

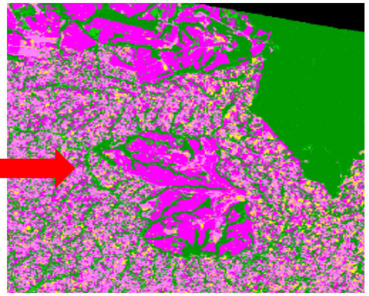


4. Classification using Random Forests

- Running R-Scripts



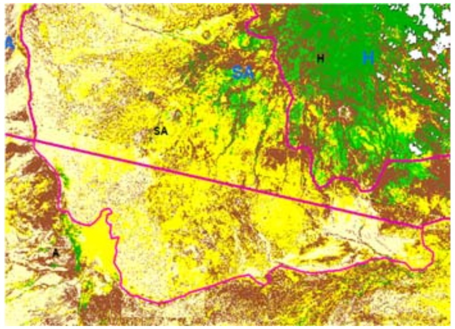
Landsat Image



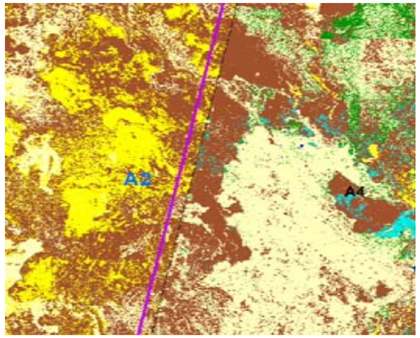
Output: Classified Image

5. QA/QC of the classification

- Checking for consistent classification results across scene and zone boundaries (pink lines)



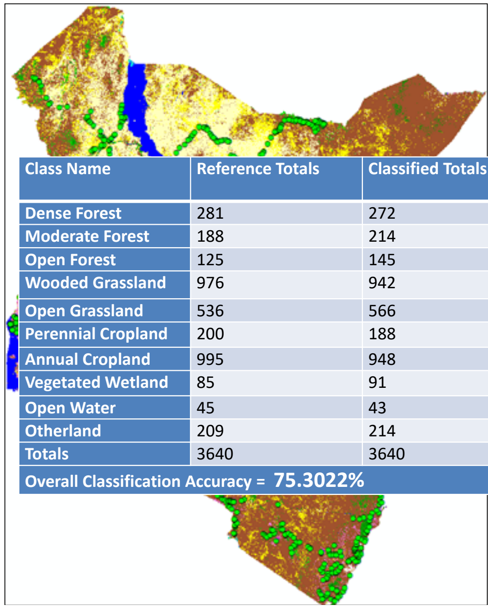
- Classification inconsistencies between neighbouring scenes



5. Accuracy Assessment

- Checking the correctness of the map
- Sampling Procedure - *Proportionate stratified random*
  - ➢ To consider accessibility
  - ➢ To consider number of points per day
  - ➢ To consider balance of class type
  - ➢ To consider interested class type
  - ➢ To consider accommodation possibility

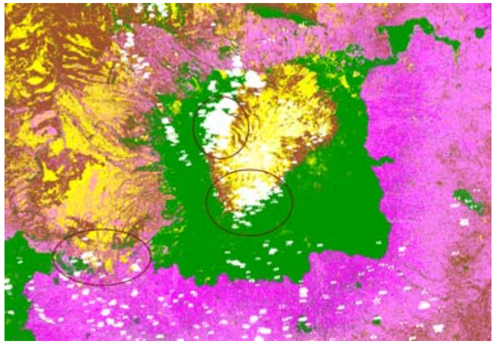
Results - SLEEK Team

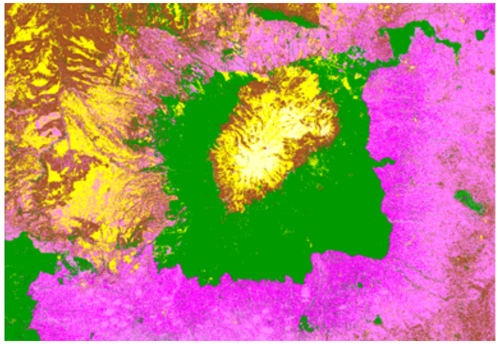


Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Dense Forest	281	272	216	76.87%	79.41%
Moderate Forest	188	214	148	78.72%	69.16%
Open Forest	125	145	94	75.2%	64.83%
Wooded Grassland	976	942	737	75.51%	78.24%
Open Grassland	536	566	395	73.69%	69.79%
Perennial Cropland	200	188	150	75%	79.79%
Annual Cropland	995	948	726	72.96%	76.58%
Vegetated Wetland	85	91	66	77.65%	72.53%
Open Water	45	43	36	80%	83.72%
Otherland	209	214	173	82.78%	80.84%
Totals	3640	3640	3640		
Overall Classification Accuracy = **75.3022%**					

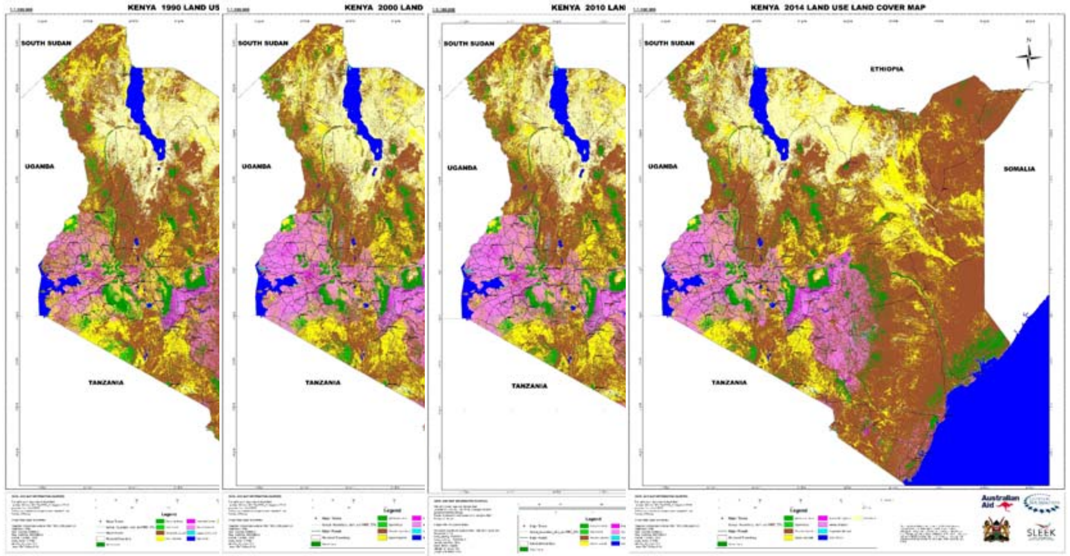
5. CPN (Conditional Probability Network)

- Due to data gaps a mathematical model known as a conditional probability network (CPN) is used to fill.
- It uses the time series maps and the probability bands developed during classification



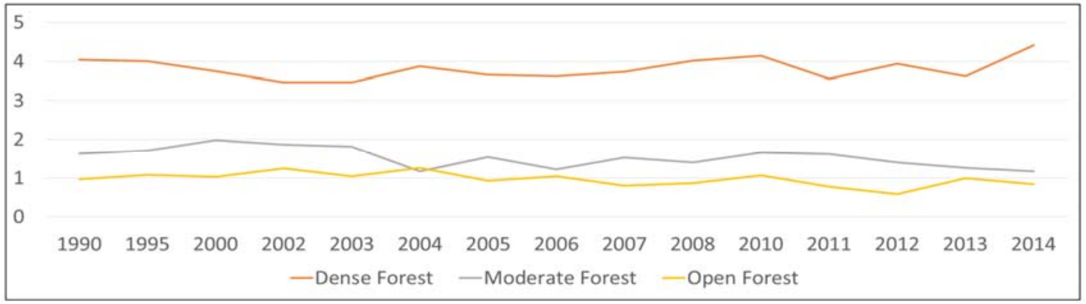


Time Series Maps

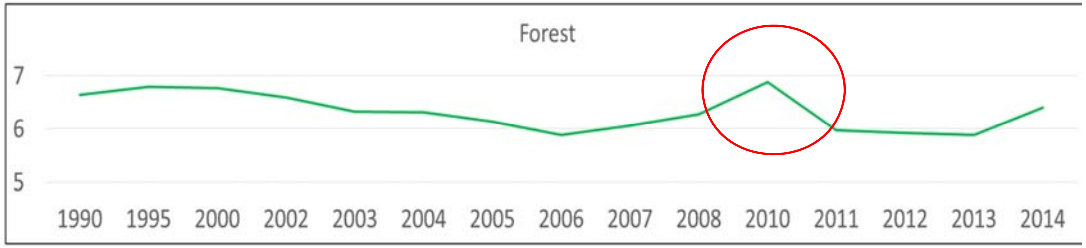


Statistics

	1990	1995	2000	2002	2004	2006	2008	2010	2012	2014
Dense Forest	4.06	4.21	3.77	3.60	4.14	3.89	4.30	4.29	4.09	4.53
Moderate Forest	1.32	1.56	2.02	1.74	0.94	0.94	1.07	1.49	1.18	1.00
Open Forest	1.28	1.10	1.02	1.24	1.21	1.00	0.81	1.06	0.53	0.82
Wooded Grassland	57.65	57.65	55.19	55.60	54.64	54.02	52.66	53.07	54.41	54.13
Open Grassland	16.76	16.84	17.42	16.09	16.49	16.39	17.79	16.60	16.62	15.72
Perennial Cropland	0.55	0.48	0.42	0.54	0.62	0.61	0.48	0.53	0.52	0.59
Annual Cropland	5.37	5.79	6.83	8.03	8.06	9.32	9.02	9.22	8.72	9.38
Vegetated Wetland	0.05	0.06	0.04	0.07	0.04	0.08	0.07	0.10	0.08	0.07
Open Water	2.04	2.04	2.05	2.05	2.02	1.99	2.01	2.06	2.11	2.07
Otherland	10.91	10.27	11.23	11.05	11.83	11.76	11.80	11.58	11.73	11.69

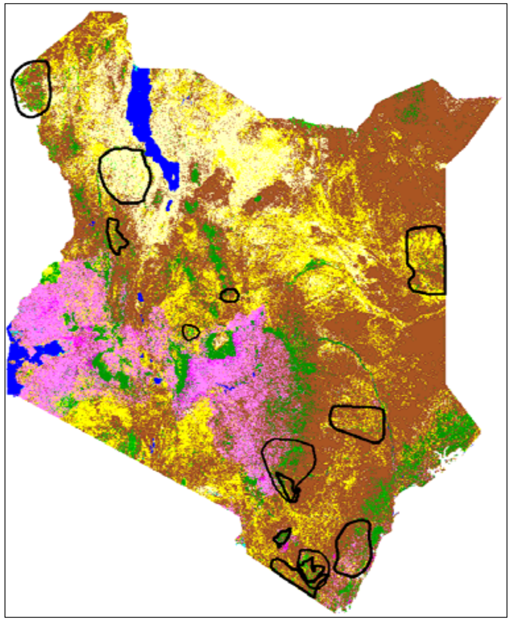


Statistics Cont...

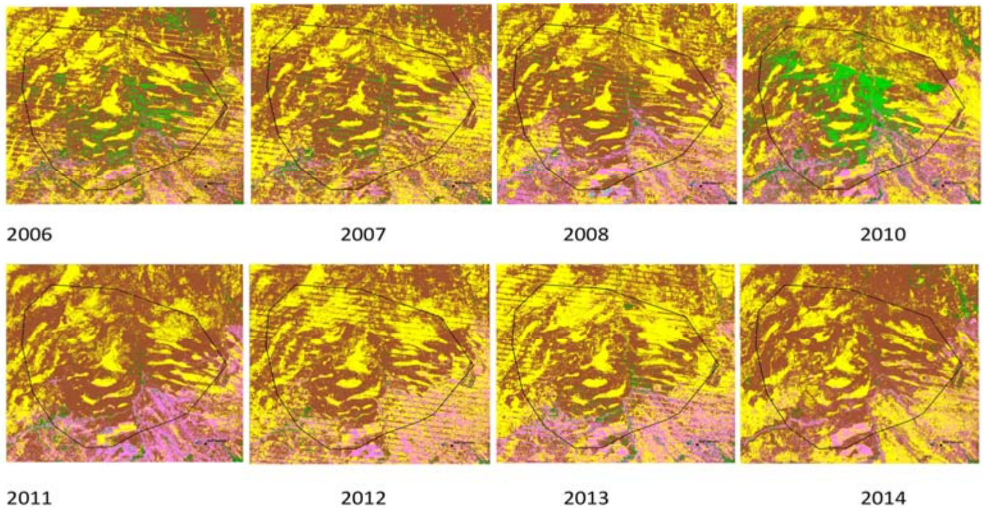


Post Classification

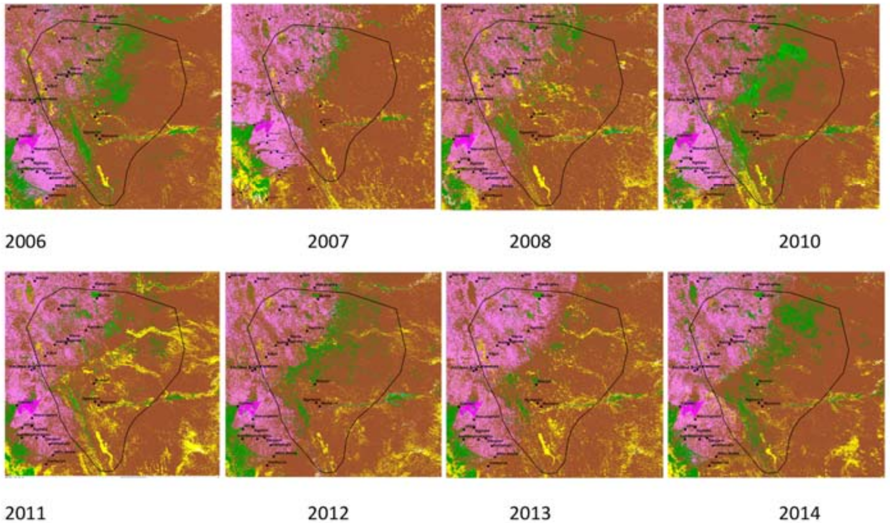
- In 2010 inconsistency in forest cover
- Post analysis of the land use land cover map
- Identifying areas with issues in Forest coverage year 2010



Post Classification - *Laikipia*

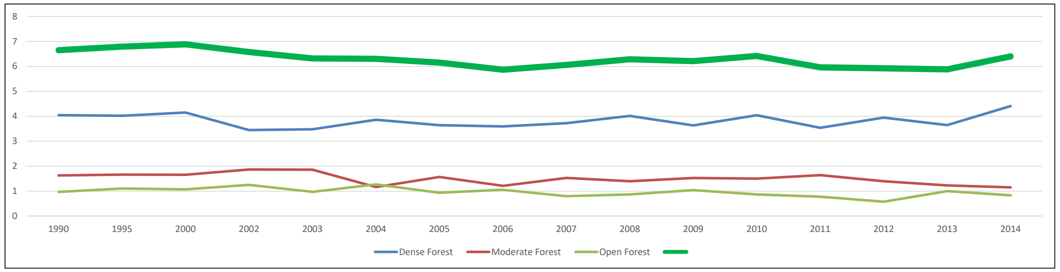


Post Classification - *Kitui*



Statistics after post classification

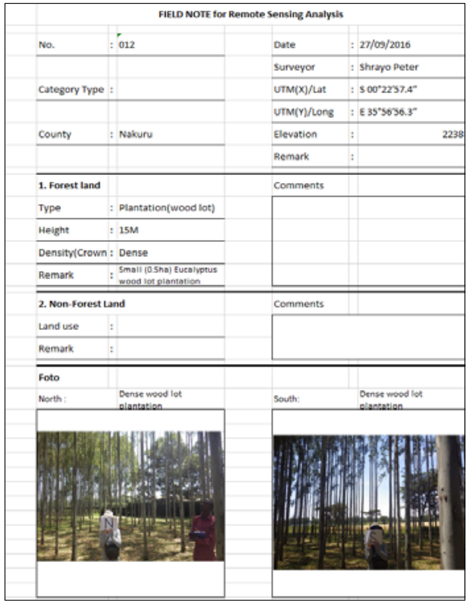
	1990	1995	2000	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Dense Forest	4.05	4.02	4.15	3.45	3.48	3.86	3.64	3.60	3.72	4.02	3.64	4.04	3.54	3.95	3.65	4.41
Moderate Forest	1.63	1.66	1.66	1.87	1.86	1.17	1.57	1.22	1.53	1.40	1.53	1.50	1.64	1.40	1.23	1.15
Open Forest	0.97	1.11	1.07	1.25	0.98	1.27	0.94	1.06	0.80	0.87	1.04	0.87	0.78	0.58	1.00	0.84
Wooded Grassland	57.90	58.03	52.97	55.66	56.95	54.70	56.37	53.96	51.35	52.30	55.14	53.21	49.91	54.00	51.21	54.01
Open Grassland	16.65	16.64	16.59	16.07	16.04	16.50	15.78	16.34	18.33	17.83	15.91	16.83	20.50	16.67	17.62	15.73
Perennial Cropland	0.54	0.48	0.53	0.54	0.44	0.61	0.53	0.60	0.48	0.47	0.58	0.53	0.56	0.53	0.52	0.60
Annual Cropland	5.30	5.72	9.28	8.00	6.90	8.04	7.59	9.38	10.14	9.17	9.05	9.25	10.15	8.88	10.15	9.42
Vegetated Wetland	0.05	0.06	0.10	0.07	0.05	0.04	0.07	0.08	0.10	0.08	0.08	0.10	0.07	0.09	0.09	0.07
Open Water	2.04	2.04	2.05	2.05	2.03	2.02	2.03	1.99	2.06	2.00	2.04	2.05	2.02	2.11	2.06	2.07
Otherland	10.87	10.23	11.60	11.05	11.28	11.79	11.47	11.78	11.47	11.85	11.00	11.61	10.83	11.79	12.48	11.70



REDD + Decision on Activity Data

1. Accuracy Assessment

- **Checking the correctness of the map**
- **Sampling Procedure - *Proportionate stratified random***



FIELD NOTE for Remote Sensing Analysis

No.	: 012	Date	: 27/09/2016
		Surveyor	: Shrayo Peter
Category Type	:	UTM(X)/Lat	: S 00°22'57.4"
		UTM(Y)/Long	: E 35°56'56.3"
County	: Nakuru	Elevation	: 2238
		Remark	:

1. Forest land — Comments

Type	: Plantation(wood lot)
Height	: 15M
Density(Crown	: Dense
Remark	: Small (0.5ha) Eucalyptus wood lot plantation

2. Non-Forest Land — Comments

Land use	:
Remark	:

Foto

North : Dense wood lot plantation

South: Dense wood lot plantation

Result

Correctness Table by Verification Survey (SLEEK and JICA Consultant team)

Class Name	Land Cover / Land Use	Number of correct	Accuracy Ratio
Dense Forest	312	239	76.6%
Moderate Forest	221	152	68.8%
Open Forest	150	97	64.7%
Wooded Grassland	984	761	77.3%
Open Grassland	581	406	69.9%
Perennial Cropland	205	165	80.5%
Annual Cropland	989	748	75.6%
Vegetated Wetland	95	70	73.7%
Open Water	47	40	85.1%
Other Land	215	174	80.9%
TOTAL	**3799**	**2852**	**75.1%**

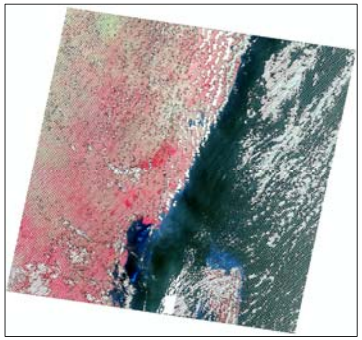
Class Name	Land Cover / Land Use	Number of correct	Accuracy Ratio
Forest	683	488	71.4%
Wooded Grassland	984	761	77.3%
Open Grassland	581	406	69.9%
Perennial Cropland	205	165	80.5%
Annual Cropland	989	748	75.6%
Vegetated Wetland	95	70	73.7%
Open Water	47	40	85.1%
Other Land	215	174	80.9%
TOTAL	**3799**	**2852**	**75.1%**

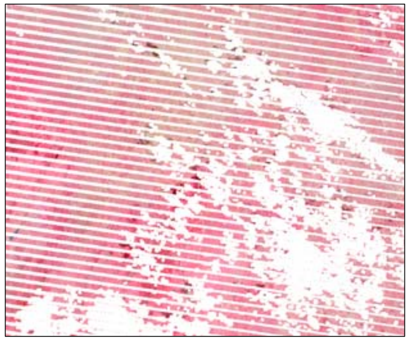
REDD + Decision on Activity Data

2. Reference year and interval

Data screening

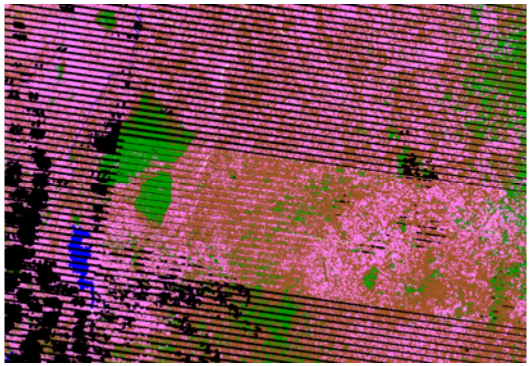
- The quality of Land Cover/ Land Use Map by image classification is affected by the quality of source data which is satellite imagery.
- So the good quality satellite imagery shall be utilized
- Stripping is from end of May 2003



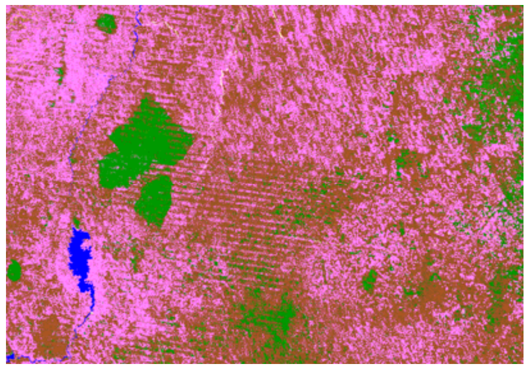


Stripping effect on classification

2006 Land cover Land use map



Before CPN



After CPN

Result of data screening and Recommendable Year

	1990	1995	2000	2002	2003	2004	2005	2006
No DATA (%)	10.59%	14.35%	6.50%	6.53%	8.56%	23.77%	20.86%	23.13%
LANDSAT4 (scene)	26	0	0	0	0	0	0	0
LANDSAT5 (scene)	8	34	0	0	0	0	0	0
LANDSAT7 (scene)	0	0	34	34	34	34	34	34
Missing scenes	0	0	0	0	0	0	0	0
LANDSAT8 (scene)	0	0	0	0	0	0	0	0
Stripping Effect (scene)	0	0	0	0	0	34	34	34
Ratio of Stripping Effect (%)	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**100.00%**	**100.00%**	**100.00%**

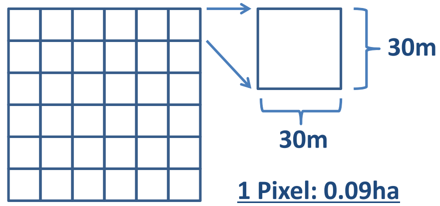
	2007	2008	2009	2010	2011	2012	2013	2014
No DATA (%)	26.14%	28.00%	15.85%	6.81%	12.51%	20.85%	16.98%	3.75%
LANDSAT4 (scene)	0	0	0	0	0	0	0	0
LANDSAT5 (scene)	0	0	11	24	15	0	0	0
LANDSAT7 (scene)	34	34	23	9	19	34	13	0
Missing scenes	0	0	0	1	0	0	0	0
LANDSAT8 (scene)	0	0	0	0	0	0	21	34
Stripping Effect (scene)	34	34	23	9	19	34	13	0
Ratio of Stripping Effect (%)	**100.00%**	**100.00%**	**64.60%**	**26.50%**	**55.90%**	**100.00%**	**38.20%**	**0.00%**

10 Year's epoch shall be utilized and 2014 as recent Activity Data

2. Image Filtering to meet Forest Definition

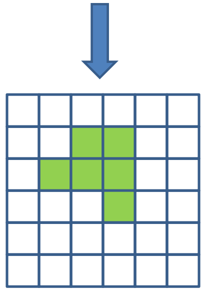
Image vs. Forest Definition

0.5ha as minimum mapping unit was considered as concept of SLEEK Map



LANDSAT Imagery

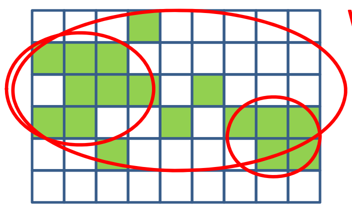
Forest Definition
- Canopy Cover Ratio: $\geq$ 15%
- Area size: 0.5ha



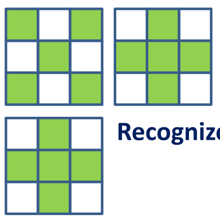
Forest area size: 0.54ha

Definition of Pixel Cluster

How to gather the forest class of pixels as one cluster for the filtering of unsatisfied forest definition?
What is forest cluster?



Which area do you think as one forest class of pixel cluster?

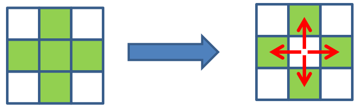


Recognized it as connected

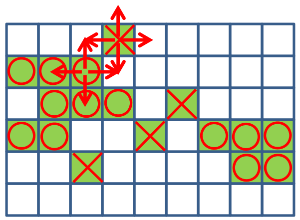
Recognized it as connected

Cluster Searching Method 1

How to searching the forest cluster as same group?

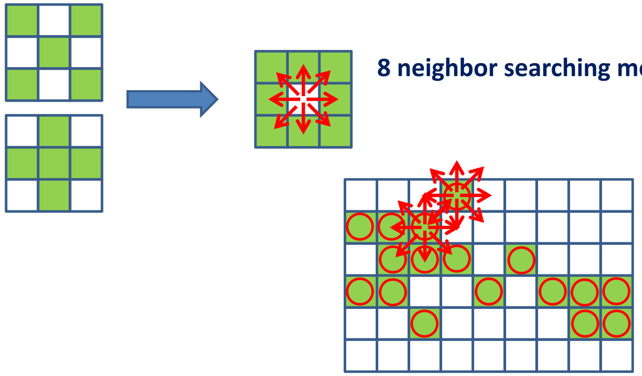


4 neighbor searching method



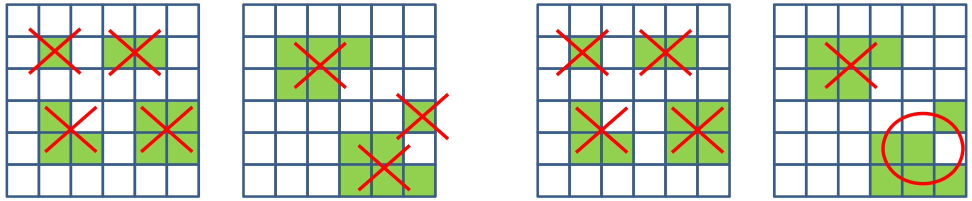
Cluster Searching Method 2

How to searching the forest cluster as same group?



Elimination of Cluster

Eliminate the pixels which are less than 6 pixels

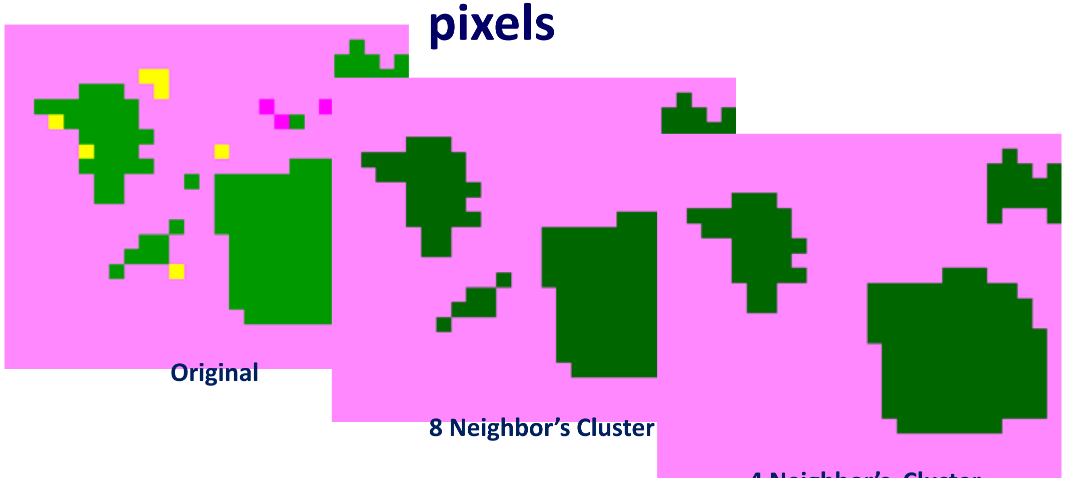


4 neighbor searching method

8 neighbor searching method

<u>Eliminated less than 6 pixels will be replace neighbor bigger cluster of class Type</u>

Example of Elimination which is less than 6 pixels



Thank you very much!

Contact address: f.mukabi@gmail.com
koetia2696@pasco.co.jp

What is national forest inventory?

- To evaluate forest resource of the entire country (e.g. areas volume and increment of growing stock, etc.)
- To evaluate forest resources survey, periodically
- To have carried out by the unified technique in most European and North American countries
- Today, sample-based national forest inventory data can be used for accurate carbon absorption by the forest.

(FFPRI 2012)

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➢ Introduction

- **Definition of forest inventory**
- **Types of forest inventory**
- **History of NFI**

Definition of forest inventory

- **Inventory :** a detailed list of items (tabulated information) classified according to their properties, as well as the action or process of creating the said list
- **Forest inventory:** a quantitative and qualitative inventory of the forest and the process for measuring and analysing information

  Content, concepts, definitions of used inventories are permanently adapted to users' needs.

Types of forest inventory

Forest inventory: There are two main types of forest inventory:

- **Forest inventory:** by counting and comprehensive survey, is generally used in the management unit.
- **National Forest Inventory** by statistical sampling method at the country level.

Types of forest inventory

- **Forest inventory** by counting and comprehensive survey

Example –Forest management inventory
- Forest exploitation inventory

Method - Development of forest types maps using aerial photos
- Calculation of forest volumes by sampling temporary or permanent plots
- Identification of the volumes of each tree group using GIS and register

Objective – Planification by forest management units
- Analysis of wood supply and yield

* It is difficult to provide statistical accuracy .

Types of forest inventory

- **National Forest Inventory (NFI)**

Method - Statistical sampling design
- Actual measure of fixed plots: offers the advantage of a chronological track
- Inventory interval : about 5 to 10 years

Objective - Collect forest data over the country using uniform definitions
- Accountability for global environmental issues
- International report for the Convention on climate change and Kyoto Protocole, Process for forest sustainable management and REDD, etc.

* It is difficult to have detailed information per unit.

History of NFI

- The collection of some forest data goes back to the 19th century in Europe and North America.
- Mathematical basis of sampling methods used in NFI were developed in the early 19th century.
- NFI based on statistical sampling methods, were initiated by:
  - Nordic countries in the late 1910 and early 1920 ;
  - France, in 1958 ;
  - Democratic Republic of Germany, in the 60's (Federal Republic of Germany, in 1987) ;
  - Austria and Spain, in the 60's;
  - Switzerland in the 80's.

History of NFI

- Nowadays, NFI based on statistical methods, targetting a representative sampling, are carried out in most of European and North- american countries.
- Globally, there are still many countries that never carry out a NFI although new NFI are initiated every day:
  - Japan started in 1999 ;
  - Cameroon, in 2003.

  * NFI was made in 8 countries, including Cameroon and Zambia until 2009, and continued in 14 countries, including Kenya, DRC, Gambia, Angola and Tanzania, with the support of FAO (NFMA).
- Due to some international agreements, such as the Kyoto Protocol, the need for forest information significantly increased.

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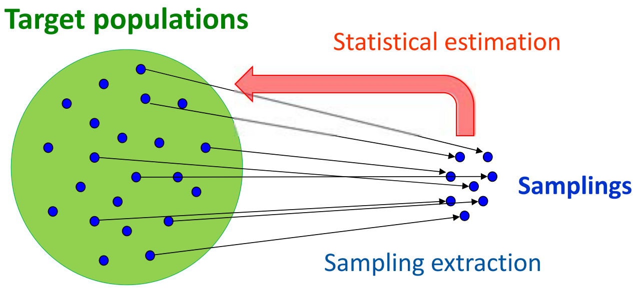
➢ Statistical sampling design & mehodology

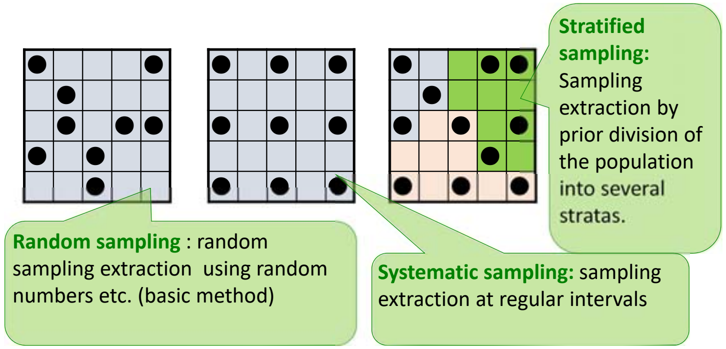
- It is not possible to examine all elements of the target populations.
- Statistical estimation : conduct sampling to determine the trend of target population.



➢ Statistical sampling design & methodology

- **Sampling extraction methods**

As simplified method, we have random sampling, systematic sampling, stratified sampling etc.

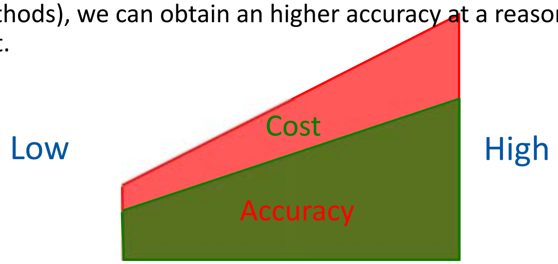


➢ Statistical sampling design & methodology

- **Planning a survey**

The cost for NFI implementation is proportional to the level of data accuracy. The more data is accurate and true , higher is the cost.

However, thanks to ingenious ideas (e.g: combination of methods), we can obtain an higher accuracy at a reasonable cost.



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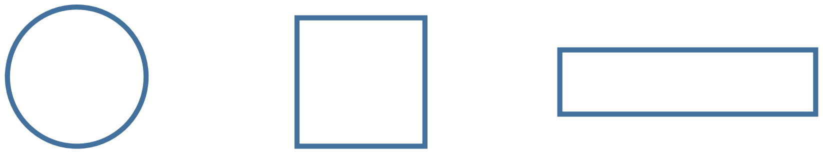
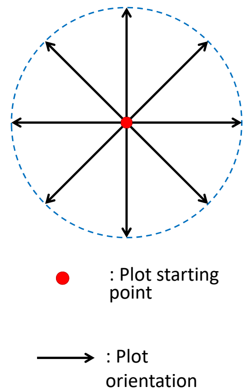
➢ Sampling Plot shape

- There are circular, square, rectangular etc.. plots.



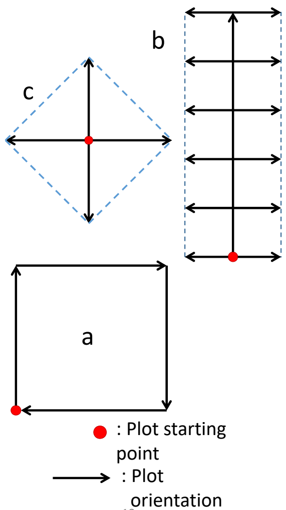
✓ Circular plot

- Strengths :
  - Theoretically, this is the shape that minimizes more the edge effects.
  - It is not necessary to measure the perimeter
  - That is to say, one can easily determine whether a tree is inside or outside the plot using a pole etc.. once the center position of the plot is determined (using Vertex, one can effectively know if the tree is inside / outside).
  - By changing the plot radius according to the slope, we can maintain the central projection area.
- Weaknesses :
  - The perimeter is a curved line (arc), it is possible to allow (without noticing) trees on the edge if you do not check the location of the tree inside/ outside this area.



✓ Rectangular plot

- Strengths :
  - The perimeter is a straight line, it is easy to see if the trees are inside / outside the edge
  - Type c on the left, determines more effectively the plot contrarily to a circular shape (however, it is not possible to provide a plot with significant area)
- Weaknesses:
  - Topographic survey of the perimeter being necessary, the efficiency of determining the type A plot is reduced
  - Theoretically speaking, the edge effect is more important than in the circular plot



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➢ Example of NFI in different countries

- NFI varies according to countries.

Table 2.3 Features of probability-based sampling designs used by NFIs

Country	Systematic grid spacing for plots or clusters of plots (km × km)	Strata criteria for stratified sampling	Random component in plot location	Number of field plots per cluster	Permanent plots (proportion of all plots)	Last NFI cycle	Current/ future NFI cycle
Austria	3.889 × 3.889	–	–	4	1.00	2000–2002	2007–2009
Belgium (Walloon Region)	1 × 0.5	–	–	1	1.00	1994–2008	2008–2018
Brazil	20 × 20	–	–	4	–	–	2009–
Canada	20 × 20	Terrestrial ecozone	–	1	1.00	2000–2006	2007–
China	–	–	–	1	1.00	2004–2008	–
Cyprus	–	–	–	1	1.00	2001–2005	–
Czech Republic	2 × 2	–	Within 300 m of grid point	1	1.00	2001–2004	–
Denmark	2 × 2	–	–	4	Approximately 0.33	2002–2006	2007–2011
Estonia	5 × 5	–	–	16	0.25–0.50	2004–2008	2009–2013
Finland	3 × 3 to 10 × 10	In North Lapland[a]	No	9–14	Approximately 0.25	2004–2008	2009–2013
France	1.41 × 1.41	–	Within 900 × 900-m cell	2	0.00	2004–2009	–
Germany	2 × 2 to 4 × 4	–	–	4	1.00	2000–2002	2011–2012
Great Britain	–	Forest type	Within polygons	1	–	1995–1999	2009–2013
Iceland	0.5 × 1 to 1.5 × 3	Plantation and birch	–	1	1.00	–	2005–2009
Ireland	2 × 2	–	Within 100 m of grid point	1	1.00	2004–2006	–
Italy	1 × 1	Administrative region and land cover	–	1	0.00[b]	2003–2007	–
Japan	4 × 4	–	–	1	1.00	2004–2008	–
Korea	4 × 4	–	–	4	1.00	1996–2005	2006–2010
Latvia	2 × 2 to 4 × 4	–	–	1	1.00	2004–2008	2009–2013

(continued)

➢ Example of NFI in different countries

- NFI varies according to countries.

Table 2.3 (continued)

Country	Systematic grid spacing for plots or clusters of plots (km × km)	Strata criteria for stratified sampling	Random component in plot location	Number of field plots per cluster	Permanent plots (proportion of all plots)	Last NFI cycle	Current/ future NFI cycle
Lithuania	4 × 4	–	–	1	0.75	2003–2007	2008–2012
Luxembourg	1 × 0.5	–	–	1	1.00	1999–2001	2008–2010
Netherlands	1 × 1	–	Within 1 × 1-km grid cell	1	0.5	2001–2005	2010–
New Zealand	4 × 4 and 8 × 8	Forest category	–	1 or 4	1.00	1945–1955	2002–2010
Norway	3 × 3			4	Some	2000–2004	2005–2009
Poland	4 × 4			1	1.00	–2001	–2009
Portugal	2 × 2			1	0.00	2005–2006	
Romania	2 × 2 to 4 × 4			4		2007–2008	
Slovak Republic	4 × 4			1	0.00	2005–2006	
Slovenia	4 × 4			5	1.00	2007	
Spain	1 × 1			1	1.00	1997–2007	2008–2018
Sweden	varying			4–12	Approximately 0.60	1993–2002	2003–2012
Switzerland	1.41 × 1.41			1	1.00	2004–2006	
USA	2,400 ha systematic hexagonal tessellation		Within 2,400 ha hexagon	4	1.00	2004–2008	2009–2013

[a] Percent non-productive forest land, volume, cumulative day-time temperature.
[b] All plots marked for possibility of future measurement.

NFI in France

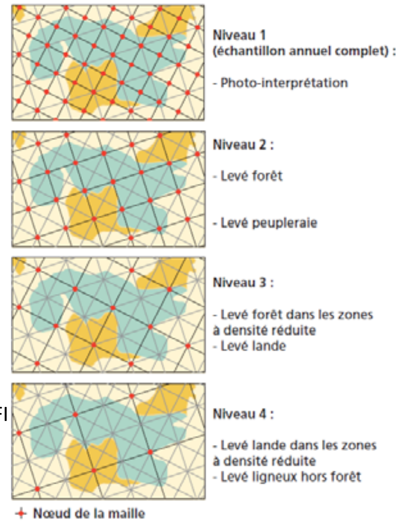
INVENTAIRE FORESTIER NATIONAL

- Beginning of the survey : 1958,
  since 1981 (Improved system)
  since 2004 (Current system)
- Most recent survey: NFI5 (from 2004 to 2009)
- NIF cycle: 10 to 12 years
- Survey unit : Division
- Body, staff and budget
  - National institute of forest resource research
  - About. 130 experts (2003)
  - Approx. 6,000 billion CFAF (2003)

fig. 4 - L'occupation du sol photo-interprétée en 2009

NFI in France

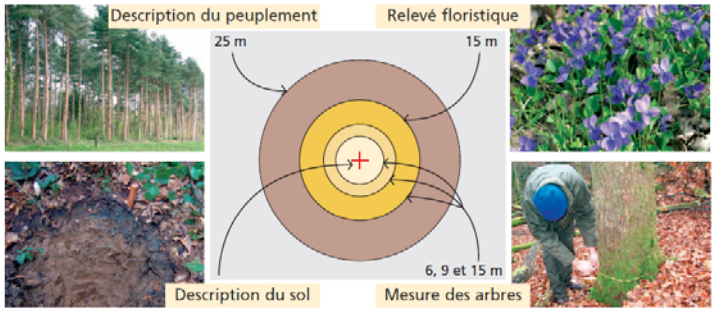
- Sampling method
  Sample is systematic in space and time.
  Level 1 : 1 node / 1000 ha
  Level 2 : 1 node / 2000 ha
  Level 3 : 1 node / 4000 ha
  Level 4 : 1 node / 8000 ha
- Develop forest maps using aerial photos
- Verification of information on the field
  About 9000 points of the inventory grid are checked each year by the NFI field teams (2 or 3 agents).



NFI in France

- Points in production forest are the subject of many comments on forest population, vegetation and stationary conditions (slope, aspect, soil, etc.).. This also goes with measures taken on trees (height, diameter, etc.)..

Quadruple circular plot



NFI in Germany

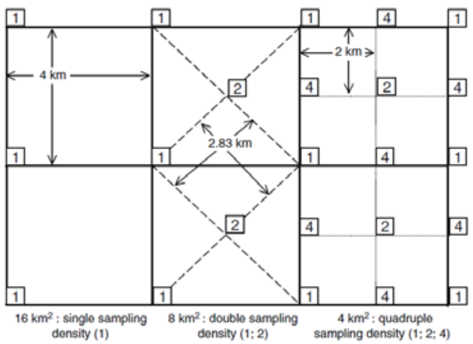
- Beginning of the survey : 1st inventory : from 1986 to 1990,
  2nd inventory : from 2000 to 2002
- Most recent survey : 3rd inventory : from 2011 to 2012
- NFI cycle: 10 to 12 years
- Survey unit: Region
- Body, Staff and Budget
  - Ministry of Agricİture and food
  - Carried out by forest agents or consultant under

  the supervision of the Region

NFI in Germany

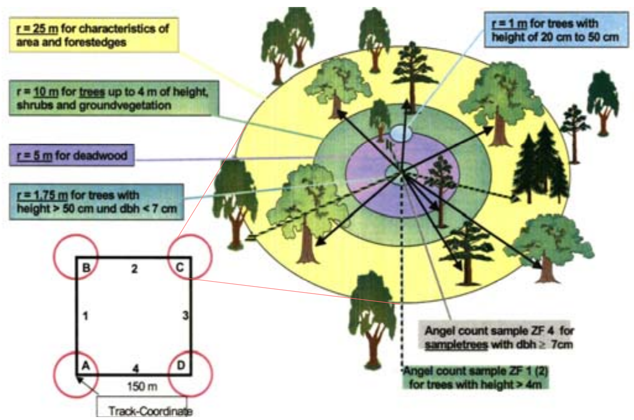
- Sampling method

The density of systematic sampling differs from one region to another:
3 types of sampling density
- 4 km x 4 km (x1)
- 2.83 km x 2.83 km (x2) and
- 2 km x 2 km (x4)



NFI in Germany

- Node structure : 150 m x 150 m
- Circular plots (Radius r=25 m) at the 4 corners



NFI in Germany

- « Invisible plot » :
  The metallic rod is pushed into the soil. It will be found using metal detector during the next inventory.

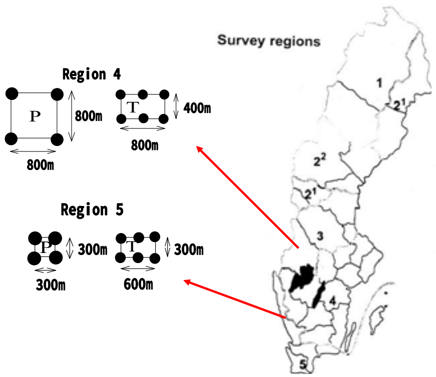
NFI in Sweden

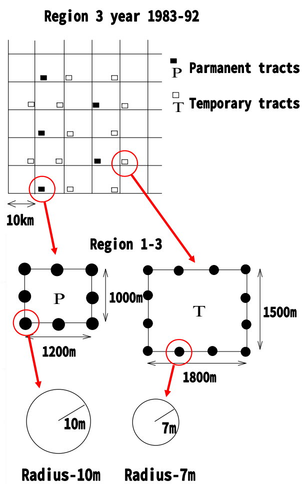
- Beginning of the survey : since 1923
- Carried out more than 6 times
- Body, staff and budget
  - National University of Agriculture Faculty of forests
  - About 2 billion CFAF per year (2003)

NFI in Sweden

- Systematic sampling method
- Large sampling units
- Combination of permanent and

  temporary units

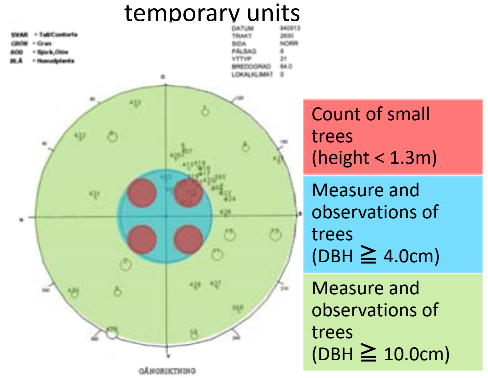


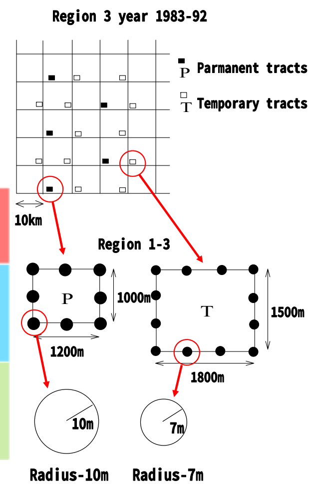


NFI in Sweden

- Systematic sampling method
- Large sampling units
- Combination of permanent and

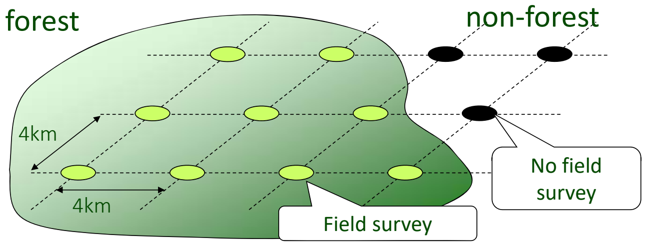
  temporary units





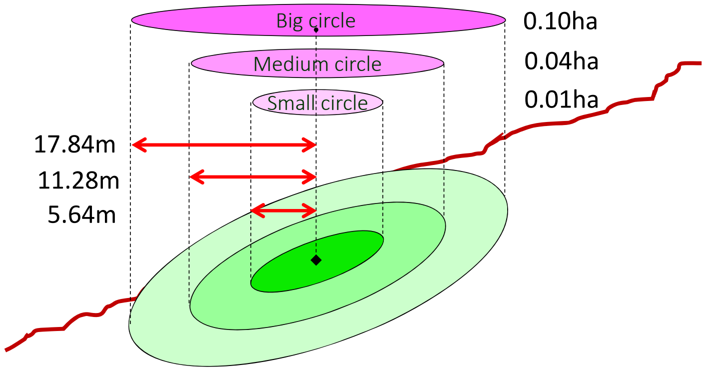
NFI in Japan

- **Beginning of the survey**: 1st inventory : from 1999 to 2004,
  2[nd] inventory: from 2004 to 2009
- **Sampling design** :
  Grid sampling : A grid (of 4 km x 4 km) covering the whole country was developed. Field plots extracted among 23,500 coordinates are approximately 15,000 coordinates (covering forest part).

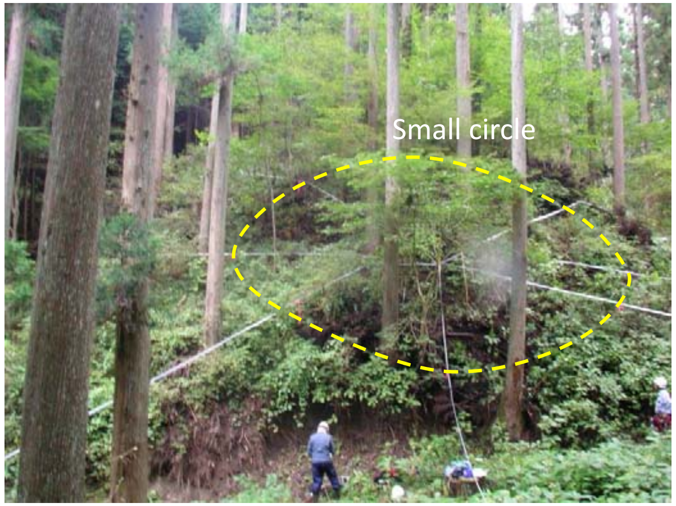


NFI in Japan

- Plot : 0.1 ha / Nested structure (triple circles)
- Determining a plot so that the horizontal projected surface is equal to 0.1 ha



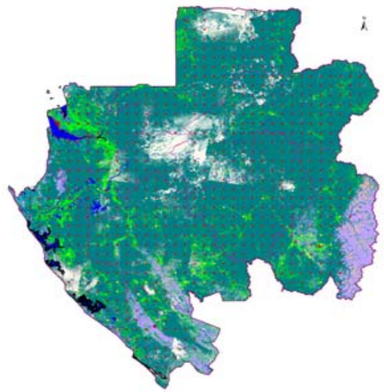
NFI in Japan



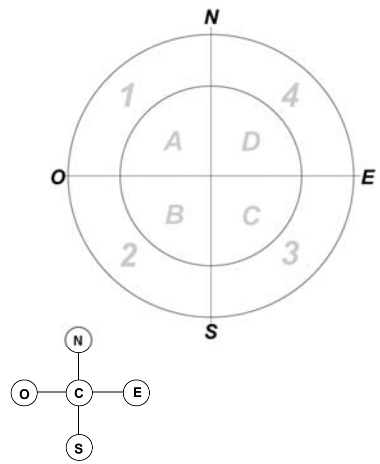
NFI in Gabon

Number of plots per province

Province	Number of plots
Estuaire	62
Haut-Ogooué	73
Moyen-Ogooué	41
Ngounié	107
Nyanga	40
Ogooué-Ivindo	119
Ogooué-Lolo	91
Ogooué-Maritime	60
Woleu-Ntem	95
Total	**688**



Plot shape

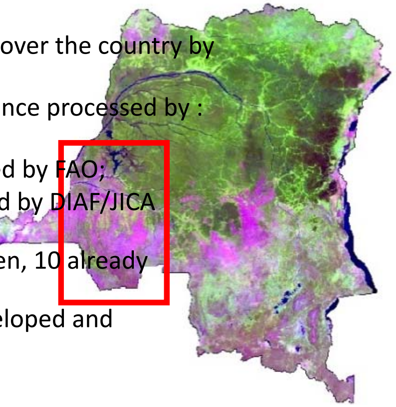


Draw the location of trees with a diameter (DBH≥ 60 cm) relatively larger than the other trees of the plot.
(this makes checking and sketching of the processed plot easier to the verification team.)

Large Circular Plot
- radius=17.84m
- surface area=0.1ha

Little Circular Plot
- radius=11.28m
- surface area=0.01ha

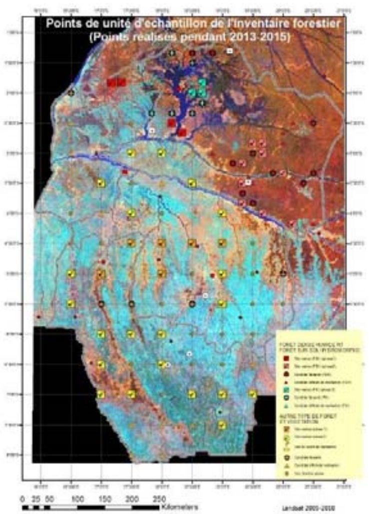
NFI in DRC



- 65 randomly distributed sites over the country by the FAO:
- 6 Sites in the Bandundu Province processed by : la DIAF/JICA;
- The remainder to be processed by FAO;
- Inventory work already started by DIAF/JICA in Bandundu province, more than 90 sites are foreseen, 10 already achieved.
  The methodoly has been developed and validated.

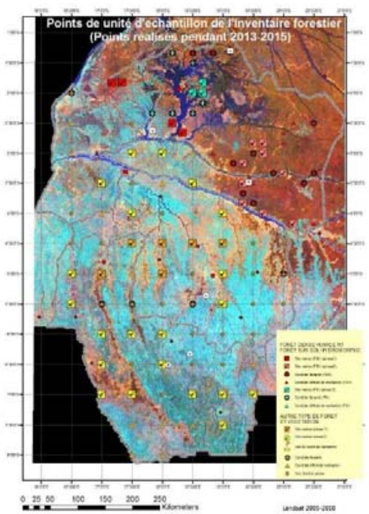
The project inventory methodology

- The sampling method is systematical and stratified
- Sampling spots are located each 10' in evergreen rainforest and rainforests with hydromorphous soils , and each 30' in other types of forests.
- The spots are selected within a radius of 10km from roads, rivers/lakes based on safety and effectiveness.

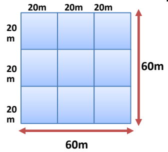


Project inventory methodology

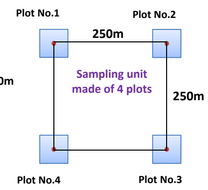
- Plots are arranged in groups (a group of plots makes a sampling unit).
- In majority type forests, (evergreen rainforests and rainforest with hydromorphous soils), we have square plots of 60m x 60m area.
- In other types of forests such as dry forests and savanah, there are circular plots of 30m diameter.

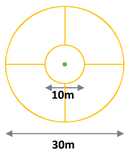


Project inventory methodology

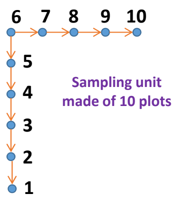


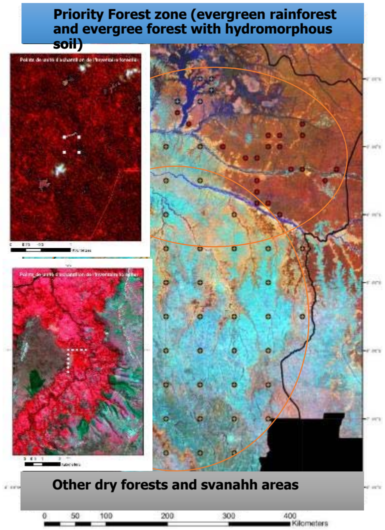
Square Plot of 60m x 60m





Circular plot of 30m diameter





Inventory plots of the project

Number of plots per province and foprest type (by the end of 2014)

Plt type and forest type	Kwango	Kwilu	Mai-Ndombe	Total
Square plot				
Mature rainforest			20	20
Mature forest on hydromorphous soil			19	19
Secondary forest			1	1
Total Square Plots	**0**	**0**	**40**	**40**
Circular Plots				
Crops	18	17	2	37
Mature rainforest		1	8	9
Mature forest on hydromorphous soil	1	4	2	7
Dry forest / Light Forest	11			11
Secondary Forest	20	28	11	59
Mosaic of cropped lands / natural vegetation (shrubs and wooded)	2	3	1	6
Aquatic graaslands	1			1
Wooded savanah	69	3		72
Shrub savanah	7	7	9	23
Grassland	3	10		13
Total Circular Plot s	**132**	**73**	**33**	**238**

Data to be collected

DBH

TREE HEIGHT

Diameter of fallen tree

Sample and borderline

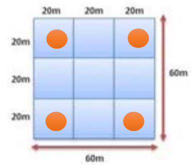
Data on wildlife and local communities

Tree species

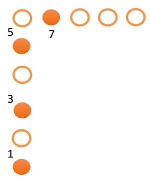
Item	Description
DBH	All trees (of 10cm diameter or above)
Tree species	All trees (of 10cm diameter or above)
Tree height	Some trees with regard to the diameter class
Fallen tree diameter	All fallen trees with 60 m length (10cm diameter or above)
Other data	Forest type, topography, erosion, soil texture, human activity, etc.

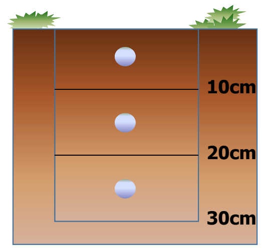
Data to be collected

B3, B5, B7 and B9 square plots and circular plots in 1, 3, 5, and 7. Three soil samples are taken at various depths.



4-spot soil sampling

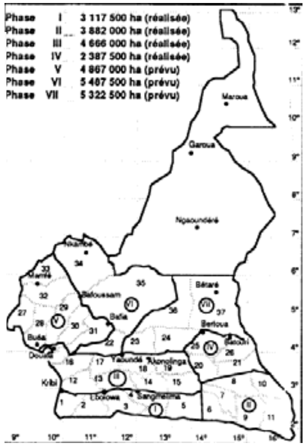




Soil sampling cylinder

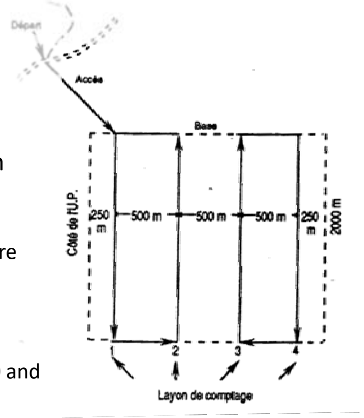
NFI in Cameroon

- Twice : 1991-1995 supported by Canada
  2003-2005 supported by FAO
  - First NFI
    - Compilation Unit (UC)
      NFI's target territory is divided into many UC.
      (approx. 500.000 to 600.000 ha)
    - Primary Unit (UP)
      The central point of each UP is systematically localized
      (UTM grid).
      Their number is set to 25 at least per UC.
      They are squares of 2 km x 2 km



NFI in Cameroon

- 2 times : 1991-1995 supported by Canada
  2003-2005 supported by FAO
  - First NFI
    - Primary Unit (UP)
    - 4 parallel strips per UP :
      2000 m x 25 m width
    - 10 sampling-tracts for each parallel strip :
      200 m x 25 m width (0.5 ha)
      All living trees (DBH ≧ 20 cm) are identified
    - 4 first meters of PE :
      4 m x 25 m width (0.01 ha)
      All living trees (DBH between 10 and 20 cm) are identified.



FAO method (2008)

- Basic method for programs supporting the implementation of survey plans on national forest resources in developing countries
- Minimum unit of a square grid in which one side is a latitude and longitude degree
- Square cluster of 1km in a point in which there are 4 plots of 20 x 250km

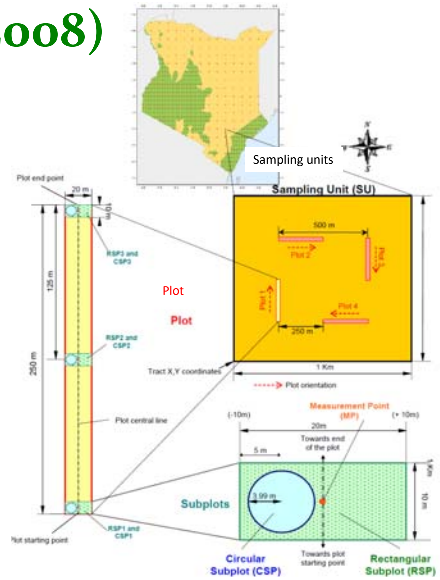


Table of Contents

➢Kenya's NFI

Kenya's NFI

- Stratification: SLEEK stratification will be used

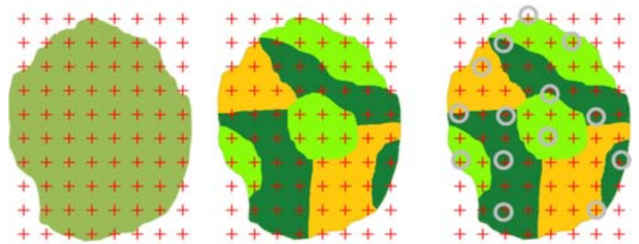
forest classe		Canopy coverage classe	
Montane Forest, Western Rain Forest and Bamboo Forest	X	Dense	= 12 forest types
Mangrove Forest and Coastal Forest		Moderate	
Dryland Forest		Open	
Plantation			

Kenya's NFI

- NFI is utilized for developing EF

Sampling Design of NFI

1 Systematic sampling method: Distance of 2km-by-2km: (4km^2 grids) over the whole country
2 Stratified sampling method: SLEEK stratification (12 forest types)
3 Random sampling method: The number of clusters to be calculated based on the SLEEK stratification.



Systematic sampling method Stratified sampling method Random sampling method

Kenya's NFI

- Sampling Design of NFI

ICFRA proposal: Cluster sampling method

- Cluster design is as follows. However, since SLEEK stratification is used that means, it is needed to decide how the cluster design will be adjusted, e.g. left side figure is for forest except for mangrove, right side figure is for mangrove. In addition, cluster method itself should be re-considered whether it is applied or not because of possibility that more than two forest types are mixing in a cluster.

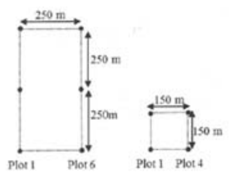


Figure . Cluster designs in Strata 1-3 (left) by ICFRA and in Stratum 4 (right).

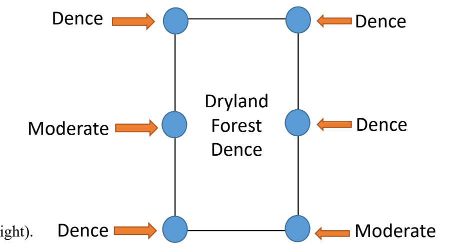


Figure . Example of cluster with more than two forest type mixed

In this case, how can the data be compiled? Moderate data is compiled as Dense forest or moderate forest? Otherwise no cluster method applied?

Kenya's NFI

- **Plots shape**

ICFRA proposal: Cercle shape is used as mentioned in the following figure. However, since SLEEK stratification is used, it is needed to decide how each shape will be applied to the SLEEK stratification, e.g. left side is for non-forest, right side is for forest.

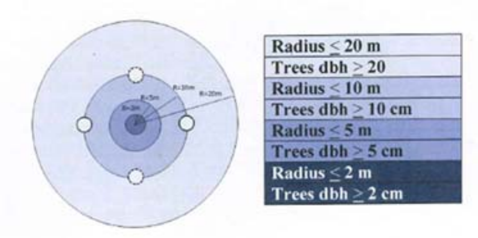


Figure . Sample plot design for Stratum 1 and 3

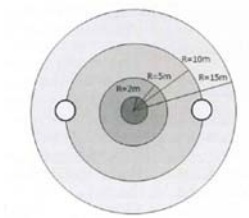


Figure . Sample plot design for Stratum 2 and 4

*ICFRA 2016. Proposal for National Forest Resources Assessment (NFRA) in Kenya

Kenya's NFI

- **Measurement method in the plots:**

- ICFRA proposal: As mentioned in the table

Table .Measurement on the circular sample plots.

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

*ICFRA 2016. Proposal for National Forest Resources Assessment (NFRA) in Kenya.

Thank you for your attention.

DATA REQUIREMENTS FOR EFFECTIVE MRV FRAMEWORK

J. K. Ndambiri
Head: FP & FIS

Lets start here!!!!

1.0 Introduction

- Data and information are important requirements for assessing existing and desired conditions in any planning .
- Approved Forest Management Plans implementation require to be monitored by generating data that continually inform on the MRV

2.0 Justification

- The implementation of MRVs require contribution of data from all stakeholders with interest in forests and include forest adjacent community's , foresters and all concerned from KFS..
- Primary source of forest data in our country rests with foresters at the station and sub-county level
- Data Flows from Forest station forms the core of all monitoring, Reporting and Verification frameworks in the whole of the reporting chain hence need fro accurate, timely and verifiable data collection at the station and Sub-county level.
- Need to develop and incorporate an appropriate Data collection Monitoring and Evaluation Framework at the station considering activities undertaken by all including Community groups and CFAs
- Need to standardize M& E framework in the Management plans being developed

CORE CHALLENGES IN DATA COLLECTION

- Data types from forests station not defined as per the objectives
- Weak Protocols to track workplan process and progress
- Analogue structure of data generation and reporting
- Data generation poorly aligned with KFS strategic objectives.

CHALLENGES CONTD

- Duplication of reporting systems due to overlap on mandates of various programmes.
- Inadequacy of foresters to embrace digital technology.

DATA REQUIREMENTS FOR MRV AS PER KFS STRATEGIC OBJECTIVES

Objective 1-Intensify conservation and management of strategic forest resources for environmental and economic growth. (Data Collected to Answer the following:

- Level of forest degradation
- Endangered rare tree species and mitigations
- Status of biodiversity
- Existing undergrowth
- Fire breaks and their maintenances
- Geo reference location of invasive species and invasive species type.

DATA REQUIREMENTS FOR MRV AS PER KFS STRATEGIC OBJECTIVES Contd

Objective2-Enhance forest productivity of industrial forest plantations and increase efficiency in wood utilization for wealth creation.

- Nursery operations: planting stocks, seeds, seed stands, psps etc
- Sawmills and their efficiencies, intakes/offtakes conversion efficiencies etc
- Data on outcomes of integrated harvesting to maximize revenue.
- Materials exploited from farmlands ,monthly quantities and areas.
- Workforce employed in industrial plantations
- Value addition of products-(Furniture industries and contribution to livelihood.
- Location of sawmills, timber traders, and retailers at the County levels.
- Livelihood activities in the Plantations by communities e.g. Area under PELIS, number of farmers quantities of products including Conservation oriented IGAs

DATA REQUIREMENTS FOR MRV AS PER KFS STRATEGIC OBJECTIVES Contd

Objective3- Promote forest extension on farm to increase tree cover for sustained timber, woodfuel and environmental conservation.

- Acreage of farms under trees.
- Non-wood products types and income generated
- Sensitization campaigns for farm forestry.
- Volume of products from farms
- Rate of growth by ecozones(data on date planted, annual growth rates,etc)
- Tree resources use (Timber, poles, fuel wood, carbon farming)
- Area of farm protected from erosion
- Area covered by invasive species

DATA REQUIREMENTS FOR MRV AS PER KFS STRATEGIC OBJECTIVES Contd

Objective4-Develop and disseminate technologies in forest management ,on farm tree planting.

- Number of farmers involved in environmental services e.g carbon sequestration
- Biodiversity conservation Area/numbers involved. Acreage of farms under trees.
- Adherence to forest management practices(thinning schedules, harvesting , planting and site preparation.
- Age groups of farmers involved in tree planting.

DATA REQUIREMENTS FOR MRV AS PER KFS STRATEGIC OBJECTIVES Contd

- *Objective 5-Enhance revenue generation thro sustainable forest based industries ecotourism and payment for environmental services:*
  - Number of Ecotourism sites
  - Payments done for environmental services e.g Way leaves camping studies etc
  - Communication systems e.g roads, airstrips,
  - Hydrology :-rivers, lakes volume of water offtakes etc

DATA REQUIREMENTS FOR MRV AS PER KFS STRATEGIC OBJECTIVES Contd

- *Objective Improve Institutional capacity and infrastructure thro collaborations, training and Development:*
  - Number of staff by categories and skills.
  - Training requirements e.g gis and digital technology
  - Buildings, roads status, electricity connections etc
  - Hardware/softwares and capacities for usage
  - Internet connectivity

DATA REQUIREMENTS FOR MRV AS PER KFS STRATEGIC OBJECTIVES Contd


25/03/2013 00:00



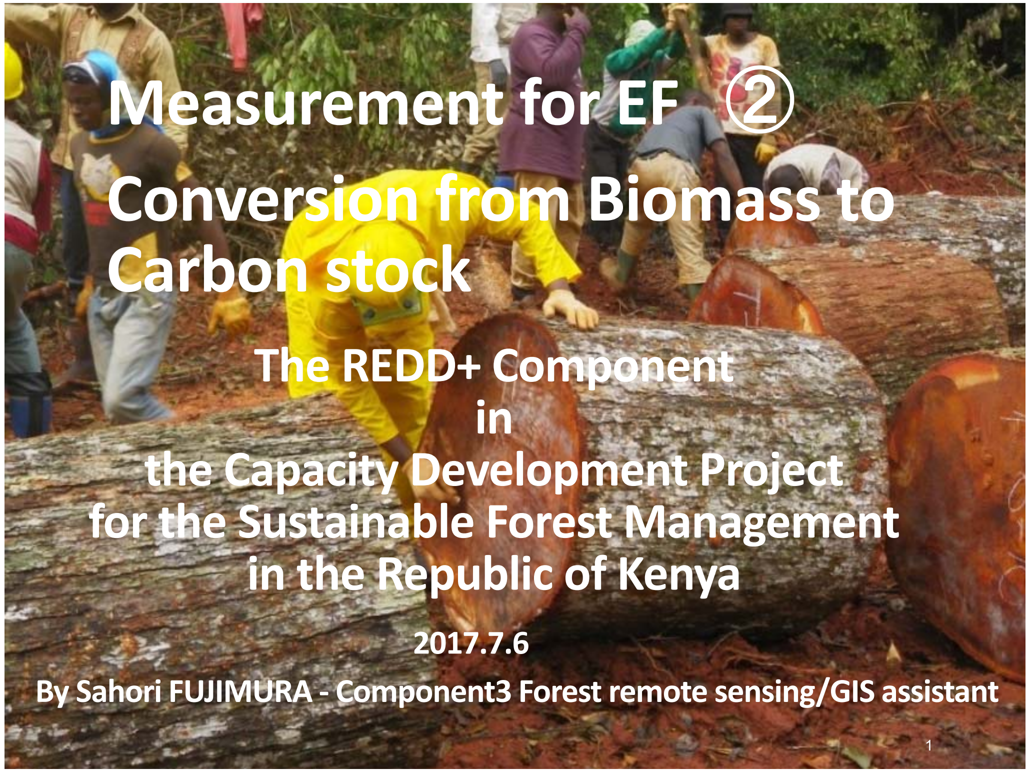
6.0 Contents of Reporting Tool

Management Objective/Programme	Objective	Activity	Unit	Target	Indicator	No. of beneficiaries	Annual Targets (YRS) 1	2	3	4	5	Achievement	Variance	Remarks
Natural forest conservation	Rehab	planting	ha	20			0	5	5	5	5			
	Protection	Fencing	ha	200			200							

7.0 CONCLUSIONS AND RECOMMENDATIONS

1. All officers dealing with management plans implementation at different levels to be sensitized on its application.
2. Need to customize to the forest station level to incorporate the specific details in their AWP so that the forester and communities make monthly, quarterly and annual reports to the relevant offices for accurate implementation of MRV

Thank you for listening



Estimating Carbon Emissions with IPCC Guidelines

Basic equation to estimate carbon emission from land use related activities is:

Activity Data		Emission Factor		Emission Estimate
Map Area (ha)	X	Forest Inventory Biomass survey	=	CO_2

Carbon Estimation

A monitoring system under UNFCCC will have to provide data on carbon stock and carbon stock changes as well as forest area and forest area changes

AD

【Data Collection】
- **Map**
- **statistical information**
- **satellite images**
- **aerial photographs**

【Analysis of remote sensing data】
- **Preprocessing of remote sensing data**
- **object classification**
- **pixel classification**

The area trend by each forest type

EF

【Data Collection】

Forest inventory
- species
- tree height
- diameter
- volume

Biomass survey
- allometric equation
- coefficients

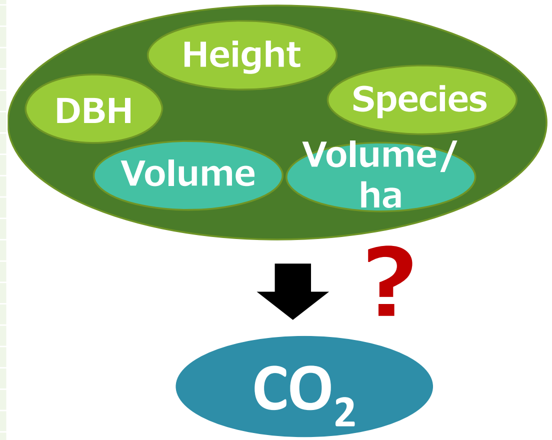
【Analysis of Inventory result】
- **Biomass and carbon stock estimation**

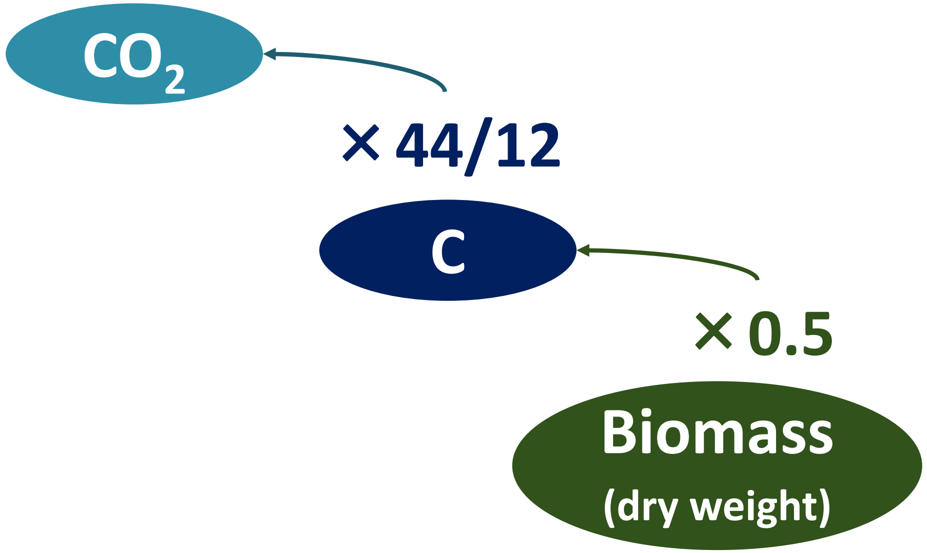
The trend of emission factor (carbon stock per unit area) by forest type

【Historical trend in carbon stocks】
Carbon stock change

Species	DBH(cm)	Height(m)
Treculia obovoidea	10	3.4
Drypetes sp.	13	3.8
Irvingia gabonensis	15	6.0
Plagiostyles africana	18	8.3
Strombosia grandifolia	20	10.5
Allanblackia floribunda	21	9.2
Desbordesia glaucescens	24	12.0
Beilschmiedia obscura	26	14.3
Desbordesia glaucescens	33	16.8
Guarea thompsonii	35	15.5
Treculia obovoidea	40	19.2
Strombosia grandifolia	46	18.1
Allanblackia floribunda	52	14.4
Drypetes sp.	52	15.9
Irvingia gabonensis	55	22.5
Blighia welwitschii	64	18.4
Strombosiopsis tetrandra	67	24.2
Irvingia gabonensis	68	20.3
Strombosiopsis tetrandra	69	21.1
Diospyros suaveolens	70	28.9
Treculia obovoidea	73	24.4
Strombosia grandifolia	74	19.5
Anthonotha ferruginea	79	25.5
Coelocaryon preussii	81	20.7
Strombosia grandifolia	81	22.4
Scyphocephalium mannii	82	19.8
Angylocalyx zenkeri	85	28.3
Strombosia pustulata	90	22.0
Treculia obovoidea	98	25.9
Cyrtogonone argentea	101	26.8

After the National Forest Inventory, How we can calculate carbon stock form the result of the Inventory??





Carbon fraction

- The ratio of the carbon in the dry weight of the plant is around 50%
- This ratio is called as carbon fraction and the value is around 0.5 (it change depend on the location and species)
- So the forest carbon stock is around half of the forest biomass.

What is the biomass?

What is the biomass in the forestry science ?

-Timber volume?

-Wet weight?

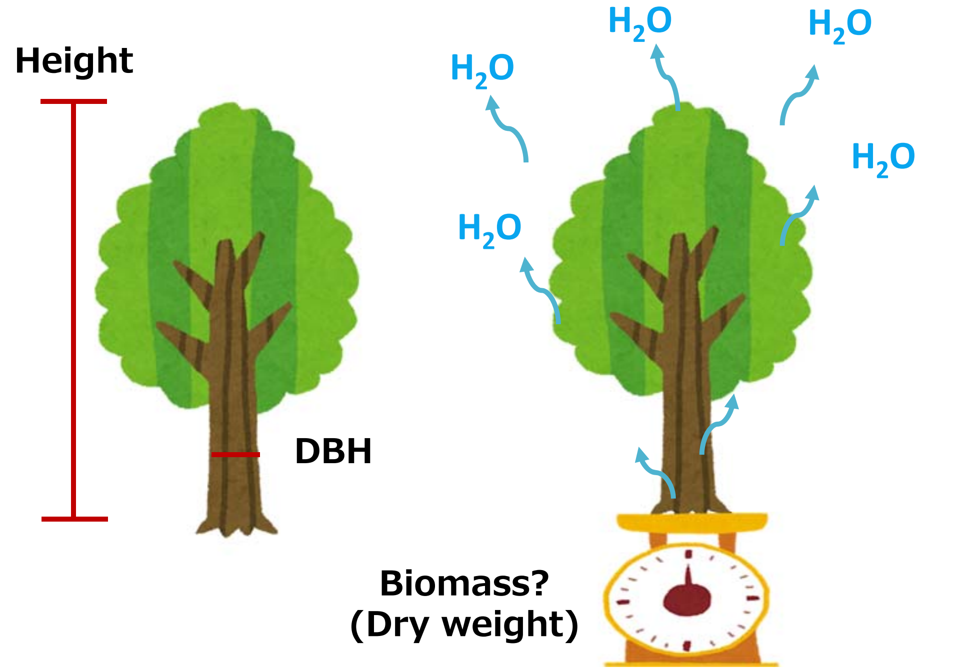
-Dry weight?

Biomass : The total amount , weight or volume of plants and amimals in an area.

In forest science, biomass is the **dry weight** of trees and other plants in the forest.

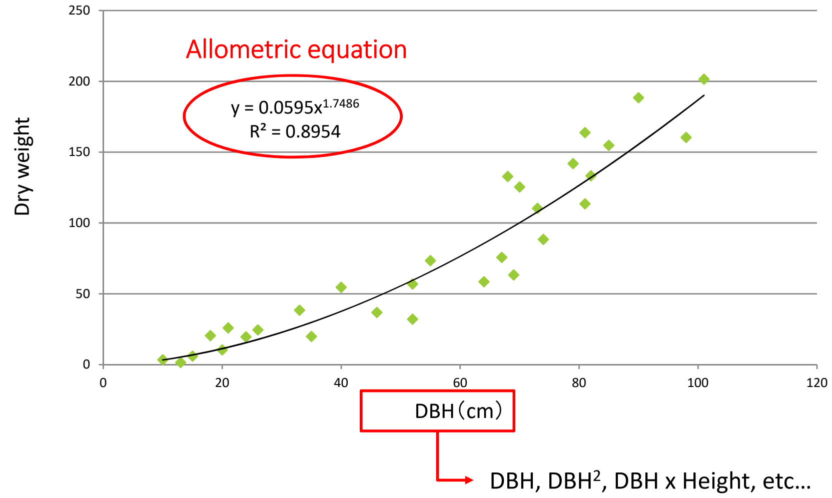
- If we know the dry weight of each tree, we can calculate the amount of CO_2 which is stored in the forest.

- But from the result of National Forest Inventory, we can not have the data of dry weight of each tree

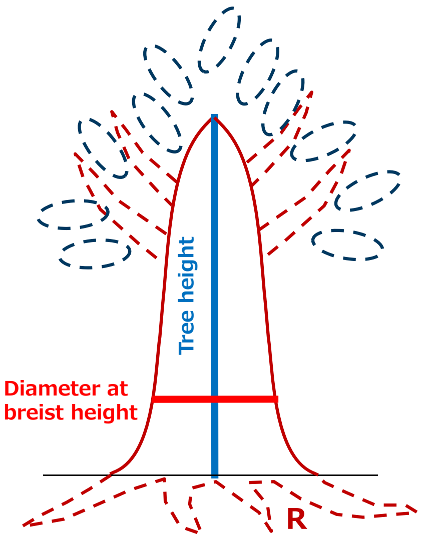


- To know dry weight of each tree, Biomass survey which is called as Destructive sampling is needed

Allometric equation



BEF and BCEF



Biomass Expansion Factors (BEF) :
expand merchantable volume to total volume to account for non-merchantable components of the tree, stand and forest

Biomass Conversion Expansion Factors (BCEF) :
convert directly merchantable volume to total biomass(Dry weight) to account for non-merchantable components of the tree, stand and forest

Biomass survey

1. Analysis of the result of NFI and design the sampling
2. Select sample trees in the field
3. Measure total fresh weight of sample trees
4. Collect sub-sample from sample tree
5. Dry the sub-sample
6. Measure the dry weight of sub-sample
7. Calculate total dry weight of sample tree
8. Develop allometric equation, BEF and BCEF

1. Analysis of the result of NFI and design the sampling

Species	DBH(cm)	Height(m)
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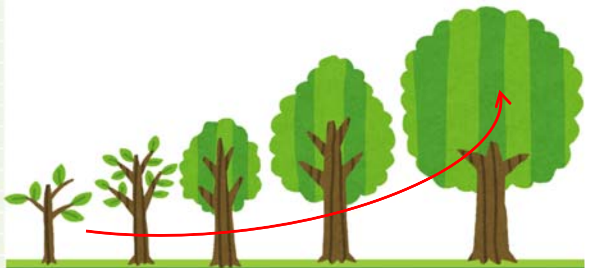
Desbordesia glaucescens	33	16.8
Guarea thompsonii	35	15.5
Strombosia grandifolia	46	18.1
Allanblackia floribunda	52	14.4
Drypetes sp.	52	15.9
Irvingia gabonensis	55	22.5
Blighia welwitschii	64	18.4
Irvingia gabonensis	68	20.3
Strombosiopsis tetrandra	69	21.1
Diospyros suaveolens	70	28.9
Treculia obovoidea	73	24.4
Strombosia grandifolia	74	19.5
Anthonotha ferruginea	79	25.5
Coelocaryon preussii	81	20.7
Strombosia grandifolia	81	22.4
Scyphocephalium mannii	82	19.8
Angylocalyx zenkeri	85	28.3
Strombosia pustulata	90	22.0
Treculia obovoidea	98	25.9
Cyrtogonone argentea	101	26.8

✓ The biggest DBH
✓ Representative species
✓ Sample size interval
✓ Scope of the survey



2. Select sample trees in the field

Go to the field and select the sample trees measuring the DBH.

3. Measure total fresh weight of sample trees

Dig up root


Dig up around the sample tree to expose the roots and mark the boundaries of the position of the ground level.

3. Measure all fresh weight of sample trees

Fell tree





Fell the sampler tree .

3. Measure total fresh weight of sample trees

Select steam and separate branches




Select the most thickest and straight steam as a steam, and separate the other branches from stem. Measure the length of Steam and mark at the point of 1.3m above the ground level , then mark every 2m up to the top of the stem.

2. Measure total fresh weight of sample trees

Cut the Stem and measure the Diameter


Cut the steam


Numbering


Measure the diameter

3. Measure total fresh weight of sample trees

Separating branch and leaves

3. Measure total fresh weight of sample trees

Measure fresh weight of each organ

Measure total fresh weight by each organ(stem, branch, leaf).

3. Measure total fresh weight of sample trees

Dig up and clean all root, then measure the weight

Measure total fresh weight by each organ(stem, branch, leaf).

3. Measure total fresh weight of sample trees

Collect small roots which are remained in the soil

4. Get sub-sample from sample

Get sub-samples by each organ and measure the sub-sample fresh weight

Sub-sample of branch

Sub-sample of root

Sub-sample of leaves

5. Dry the Sub-sample

Put sub-sample in the dry machine

Sub-sample in the dry machine

6. Measure the weight of Sub-sample

Measuring dry weight of sub-sample

7. Calculate total dry weight (biomass) of sample tree

$$TDW = TFW \times \frac{SDW}{SFW}$$

TDW: Total dry weight of each organ
TFW: Total fresh weight of each organ
SDW: Sub-Sample dry weight of each organ
SFW: Sub-Sample fresh weight of each organ

Dry weight = Biomass

7. Calculate total dry weight (biomass) of sample tree.

Example of calculation

	Stem	Branches large+small	Leaves	Roots large+small	Total
Total fresh weight of sample trees by tree organs (kg)	7,650.5	3,241.9	140.7	692.0	11725.0
Fresh weight of Sub-Sample (g)	1,989.8	1,343.5	483.0	1,677.3	
Dry weight of Sub-Sample (g)	1,301.2	862.3	246.5	1,118.4	
Dry weight/Fresh weight of sub-samples	0.654	0.642	0.510	0.667	
Total dry weight by tree organs (kg/tree)	5,002.9	2,080.7	71.8	461.4	7616.9

Total dry weight of sample tree
= Biomass of sample tree

8. Develop allometric equation, BEF and BCEF

Allometric equation $y = a X^b$

y : Biomass

X : Parameter

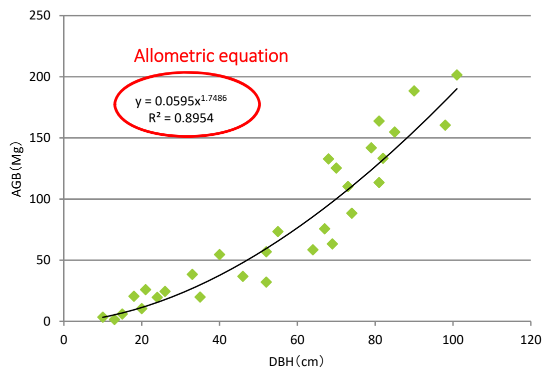
(e.g. DBH, DBH^2, D^2H etc.)

◦ a, b : Coefficient

8. Develop allometric equation, BEF and BCEF

sample tree No.	DBH (cm)	AGB (Mg)
1	10	3.4
2	13	1.5
3	15	6
4	18	20.5
5	20	10.4
6	21	25.9
7	24	19.6
8	26	24.5
9	33	38.4
10	35	19.9
11	40	54.6
12	46	36.8
13	52	56.9
14	52	32.1
15	55	73.4
16	64	58.5
17	67	75.7
18	68	132.8
19	69	63.3
20	70	125.4
21	73	110.3
22	74	88.4
23	79	141.9
24	81	113.5
25	81	163.8
26	82	133.3
27	85	154.8
28	90	188.4
29	98	160.4
30	101	201.5

Sample trees data

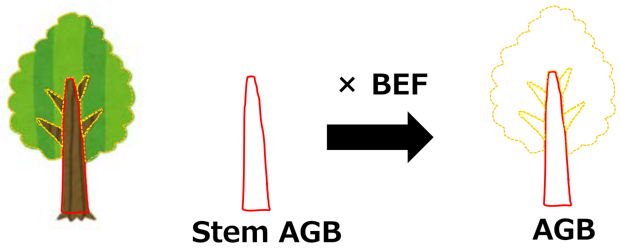


for example…

- Making equations from data of diameter and biomass.
  - DBH; Diameter at Breast height
  - AGB; Above Ground Biomass

8. Develop allometric equation, BEF and BCEF

- BEF is Biomass expansion factor
- BEF is the coefficient for estimation of AGB from stem biomass.



- BEF is the ratio of AGB to stem biomass.

BEF: Total AGB (stem + branches + leaves) / stem AGB

8. Develop allometric equation, BEF and BCEF

Biomass Expansion factor:

A factor that coverts the stem biomass into the biomass of the whole tree, including branches, leaves etc.

$$\text{BEF} = \frac{TDWa}{TDWs}$$

BEF: Biomass Expansion Factor

TDWa : Total dry weight of AGB

TDWs : Total dry weight of Stem

8. Develop allometric equation, BEF and BCEF

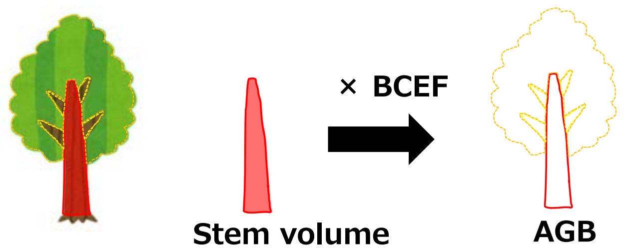
Calculation of Carbon stock with BEF

$$C = (V \times WD \times BEF) \times CF$$

C: Carbon stock (Mg-C)
V : Volume (m3)
WD : wood density (Mg/m3)
BEF : Biomass Expansion Factor
CF : Carbon factor

8. Develop allometric equation, BEF and BCEF

- BCEF is Biomass conversion expansion factor
- BCEF is the coefficient for estimation of AGB from stem volume.



- BCEF is the ratio of AGB to stem volume.

BCEF: Stem volume / AGB

8. Develop allometric equation, BEF and BCEF

Biomass Conversion and Expansion factor:

A factor that coverts directly the trunk volume into the biomass of the whole tree etc.

$$\text{BECF} = \frac{AGB}{V} = \frac{V \times WD \times BEF}{V} = WD \times BEF$$

BECF: Biomass Conversion and Expansion Factor

AGB : Above Ground Biomass V : volume

WD : wood density BEF Biomass Expansion Factor

8. Develop allometric equation, BEF and BCEF

Calculation of Carbon stock with BCEF

$$C = (V \times BCEF) \times CF$$

C : Carbon stock (Mg-C)
V : Volume (m3)
BCEF : Biomass Conversion and Expansion Factor
CF : Carbon factor

8. Develop allometric equation, BEF and BCEF

Default value of carbon fraction of AGB

TABLE 4.3
CARBON FRACTION OF ABOVEGROUND FOREST BIOMASS

Domain	Part of tree	Carbon fraction, (CF) [tonne C (tonne d.m.)$^{-1}$]	References
Default value	All	0.47	McGroddy *et al.*, 2004
Tropical and Subtropical	All	0.47 (0.44 - 0.49)	Andreae and Merlet, 2001; Chambers *et al.*, 2001; McGroddy *et al.*, 2004; Lasco and Pulhin, 2003
	wood	0.49	Feldpausch *et al.*, 2004
	wood, tree d < 10 cm	0.46	Hughes *et al.*, 2000
	wood, tree d ≥ 10 cm	0.49	Hughes *et al.*, 2000
	foliage	0.47	Feldpausch *et al.*, 2004
	foliage, tree d < 10 cm	0.43	Hughes *et al.*, 2000
	foliage, tree d ≥ 10 cm	0.46	Hughes *et al.*, 2000
Temperate and Boreal	All	0.47 (0.47 - 0.49)	Andreae and Merlet, 2001; Gayoso *et al.*, 2002; Matthews, 1993; McGroddy *et al.*, 2004
	broad-leaved	0.48 (0.46 - 0.50)	Lamlom and Savidge, 2003
	conifers	0.51 (0.47 - 0.55)	Lamlom and Savidge, 2003

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, 4.48, Table 4.3.

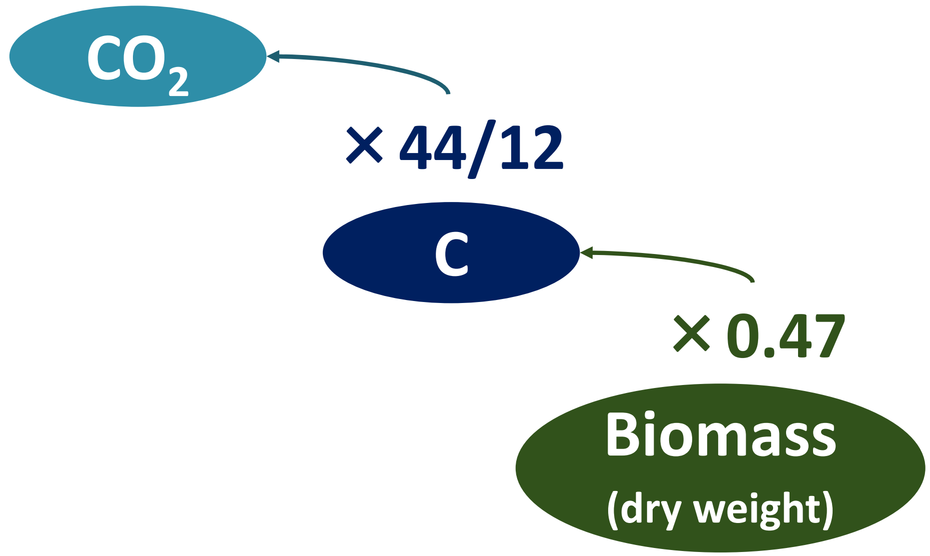
8. Develop allometric equation, BEF and BCEF

Root –Shoot ratio (R)

Root - Shoot ratio (R) is a ration of BGB to AGB. It is difficult to directly measure BGB. After the R is obtained in advance by biomass survey the BGB can be estimated based on the ABG

$$R = \frac{BGB}{AGB}$$

R : Root – Shoot ratio
AGB : Above ground biomass
BGB : Below ground biomass



Estimation of Emission

Direct Estimation

Result of NFI (DBH, Height…) ✖ Allometric equation ✖ FC 0.47 = Carbon stock

Indirect Estimation

Stem Volume ✖ Coefficients BCEF ✖ FC 0.47 = Carbon stock

Kenya's Methodology

Kenya has not yet developed country neither allometoric equation nor BEF,BCEF

For developing FRL in Kenya, Kenya has selected some common equations for AGB

Forest type, Species	Equation
for common trees, *Acacia spp.* and plantation species (*Pinus patula, Eucalyptus and Cupressus*)	$AGB=0.0673*(0.598*D^2H)^{0.976}$ (kg) (Chave et al. 2009, 2014)
Rhizophra spp	$AGB = 0.128 \times DBH^{2.60}$ (Fromard et al. 1998, Komiyama et al. 2008)
Agro-forest	$AGB_{Agro\text{-}forest}=e^{(0.93*\log((d\wedge 2*h))-2.97)}$ (Henry et al. 2009)

For calculation of BGB, Kenya use the root /shoot ratio of BGB to AGB which is provided by IPCC

Forest type	Root/Shoot ratio
Montane Forest	0.27
Coastal forest	0.20 (AGB ≤ 125 (ton/ha) 0.24 (AGB ＞125 (ton/ha)
Mangrove Forest	0.37 and 0.20 (AGB ≤ 125 (ton/ha)), 0.24 (AGB＞125 (ton/ha))
Dryland Forest	0.40 (Kibwezi), 0.27 (Baringo)
Plantation	0.27

CF which Kenya uses is provided by IPCC

Biomass	CF
AGB	0.47 (tonne C (tonne d.m.)$^{-1}$
BGB	0.50 (tonne C (tonne d.m.)$^{-1}$

Kenya's Emission estimate

For develop FRL, Kenya develop country data using result of ICFRA inventory and Additional inventory

Kenya's Carbon Stock

Class	Canopy coverage	Volume**	AGB		BGB		TOTAL	
			Biomass stock	Carbon stock	Biomass stock	Carbon stock	Biomass stock	Carbon stock
Montane Forest & Western Rain Forest	Dense	437.86	344.75	162.03	93.08	46.54	437.83	208.57
	Moderate	69.59	58.36	27.43	15.76	7.88	74.12	35.31
	Open	26.23	23.02	10.82	6.22	3.11	29.23	13.93
Coastal forest & Mangrove forest	Dense	97.35	92.82	43.62	27.39	13.70	120.21	57.32
	Moderate	64.53	60.45	28.41	13.64	6.82	74.09	35.23
	Open	41.92	35.24	16.57	7.48	3.74	42.72	20.30
Dryland Forest	Dense	98.55	79.27	37.26	31.29	15.64	110.56	52.90
	Moderate	38.74	33.83	15.90	12.72	6.36	46.55	22.26
	Open	16.00	14.26	6.70	3.85	1.93	18.12	8.63
Plantation	Dense	539.23	436.68	205.24	117.90	58.95	554.58	264.19
	Moderate	137.79	113.54	53.36	30.66	15.33	144.20	68.69
	Open	174.54	138.22	64.96	37.32	18.66	175.54	83.62
*(Agro-forestry)		106.98	74.23	34.89	20.04	10.02	94.27	44.91

* The class of Agro-forestry has been considered to apply for setting FRL. **Volume does not include volume of Climber.

But NFI has not been implemented so the accuracy of the country data is not high because of the small number of inventory data.