

Assessing the Economic Value and Credit Market Potential of Carbon Stock in South Nandi Forest, Kenya

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Abstract

Provision of information about carbon stock and potential carbon market for tropical forests ecosystem is an important knowledge base, which is scarce in developing countries, for decision making in carbon trade. Financial benefits of the carbon market, which has not been developed before, in which this study focuses would not only lead to poverty alleviation among local communities but also serve as an incentive for better management of the forest ecosystem. This study aimed at assessing the economic value of carbon stock in South Nandi forest towards securing its credit market for the forest adjacent communities. South Nandi forest is among the few remaining tropical rainforests in western Kenya, and it is a major source of livelihoods for forest adjacent communities. This protected ecosystem hosts a variety of endangered plants, animals and endemic bird species. This study comprised of two forest surveys: Participatory Forest Resource Assessment (PFRA) and carbon assessment survey. Results indicated a total carbon store of 2.8 ± 0.8 million tons of carbon (equivalent to 10.5 ± 2.9 million tons CO_2). The findings showed that more open forest areas had lower carbon densities. The study found that there was potential for tree planting projects in and around the South Nandi Forest to attract carbon funding either through the regulated carbon credit market under the Clean Development Mechanism (CDM) or through the voluntary carbon market. One option would be to reforest degraded or cleared areas within the forest boundaries with indigenous species. Tree planting projects outside of the forest boundary, such as trees planted on farms, could apply for carbon based funding depending on their management. Activities that reduce deforestation in the South Nandi Forest could also attract REDD (Reduced Emissions from Deforestation and Degradation) project funding.

Key words: Carbon credit market, Carbon emission, Carbon sequestration, Carbon stock, Poverty alleviation.

INTRODUCTION

Many developing countries, especially in the African continent, are experiencing negative impacts of climate change on agricultural production and food security. Higher temperatures, drying up of soils, increased pests and disease effects, shift in suitable areas for livestock production and growing crops, increased desertification in the Sahara region, floods, deforestation, and soil erosion have also been experienced (Tadesse, 2010). The main causes of climate change are emission of greenhouse gases (GHGs) out of industrialization mainly from developed nations, while on the other hand, increasing forest degradation in developing nations, which is exacerbated by poverty, evidenced by demand in construction timber, woodfuel, honey and herbal medicine needs (GOK, 2011). Greenhouse gases such as carbon dioxide (CO₂), methane, nitrous oxides and chlorofluorocarbons absorb huge thermal radiation emitted by the earth's surface, leading to global warming (Lasco *et al.*, 2006). Rising concentration of GHGs in the atmosphere will significantly change the world's climate before 2100, where CO₂ is the most important GHG accounting for more than 50% of radioactive forces associated with anthropogenic GHG emissions (IPCC, 2001). Forests on the other hand, being public goods, suffer the tragedy of the commons problem, where users act independently according to their self-interest of the shared forest resource, contrary to the common good of all users by degrading it. Rain-fed agriculture is estimated to be the proximate driver of about 80% of deforestation globally, while timber extraction and logging activities, fuel wood collection, charcoal production, and to a lesser extend livestock overgrazing in forests are most important drivers of degradation in Africa (Kissinger *et al.*, 2012). This has implied that in Africa, felled trees are economically valued much more than standing trees (GOK, 2011), wherefore, the deforestation leads to carbon emission back to the atmosphere.

As important globally carbon stores, forests play a significant role in promotion of sustainable development in influencing climate change (Busienei, 2010), whereby carbon stock refers to a reservoir or system that has capacity to accumulate or release carbon (FAO, 2005). The carbon reservoir in the world's forests is higher than that in the atmosphere (Oli Bishwa and Shrestha, 2009). Forests mitigate climate effects of the ever-increasing atmospheric carbon dioxide concentrations by removing carbon from the atmosphere through photosynthesis and convert it into sugars used to grow leaves, wood and roots (Broadmeadow and Matthews, 2003). Forests also release carbon dioxide to the atmosphere through respiration and decay of dead wood, litter, and organic matter in soils. About two-thirds of the globe's terrestrial carbon, exclusive of that stored in rocks and sediments, is sequestered in the standing forests, leaf and forest debris and in forest soils (Waran, 2001). The world's forests and forest soils currently store more than 1 trillion tonnes of carbon, which is twice the amount in the atmosphere (Oli Bishwa and Shrestha, 2009). This is because plants store carbon in terms of live biomass for as long as they live. Once they die, the biomass eventually enters the soil as soil carbon. The carbon is re-emitted into the atmosphere if the biomass is incinerated and is free to move in the carbon cycle (Waran, 2001). Forest fires and timber harvesting release stored carbon to the atmosphere, although some of it is stored in wood products or used to produce energy, replacing fossil fuel use (Ryan *et al.*, 2010). When older forests which normally have a large quantity of stored carbon are harvested, replacing the lost carbon from the site can take more than a hundred years (Harmon *et al.*, 1990). Since climate change is one of the biggest human and environmental

concerns of the 21st century (IPCC, 2001; Tadesse 2010), developing nations like Kenya having an opportunity of benefitting from their forests in a sustainable manner. This is because in developing nations, forest products are the main sources of livelihoods for forest adjacent communities living within a radius of 5 km from forest boundary (Sumukwo, 2013). The Forest adjacent communities heavily rely on the forest resources for income through unsustainable means of charcoal making, illegal logging, poor honey harvesting, that includes the felling of trees for access especially on the western side of the South Nandi forest (KFS, 2011). This is in contradiction of the Government of Kenya's Forest Act 2005, section 40, and stipulates that all indigenous forests and woodlands shall be managed on a sustainable basis for purposes of carbon sequestration and other environmental services (GOK, 2005).

The carbon market is based on the "polluter pays" principle, whose objective is to reduce emission of greenhouse gases through application of market law, which brings together voluntary organizations that exchange the rights to emit carbon dioxide (Rudolph *et al.*, 2011). Carbon markets originated from the Kyoto Protocol, which introduced three market-based mechanisms designed and created to tackle climate change and assist with sustainable development namely: Emissions Trading Scheme (ETS), Clean Development Mechanism (CDM) and Joint Implementation (JI) (Murdiyarso and Herawati, 2005). Two of these mechanisms, the CDM and JI are project-based. They are designed to help reduce GHG emissions through project activities involving *inter alia* renewable energy (including fuel switching), energy efficiency, reforestation/ afforestation, and low-emission public transportation, and more (GOK, 2010). The CDM is relevant to Kenya as it applies to non-Annex 1 countries, which are developing countries that have undertaken to tackle climate change, but are not obliged to take on legally binding GHG emission reduction targets (Carraro and Favero, 2009; GOK, 2010). Carbon markets can be both regulated and voluntary. The voluntary markets are aimed at generating GHG emissions reductions not required by the Kyoto Protocol's derived regulation (Murdiyarso and Herawati, 2005). Currently, the most liquid markets are the European Union Emissions Trading Scheme (EU ETS) and the global Kyoto compliance market. The European CO₂ price is the global benchmark price because the European Union adopted a CO₂ market as the centrepiece of its own strategy for regulating emissions, thus creating the largest emissions market in the world (Carraro and Favero, 2009). There is also a voluntary market which is increasing in volume. Hence, even if the Kyoto Protocol failed to introduce a global emission trading system, separate market fragments with different price ranges have evolved in different countries. This implies that there is no single price for carbon across the world. Additionally, even if developing countries, like Kenya, have not capped their emissions, they participate in emissions trading through CDM (GOK, 2010). Thus, the linkages and market forces created by emissions trading can introduce a price for carbon even in countries that have not capped their emissions (Carraro and Favero, 2009).

Nandi County has in recent years had climate-related impacts ranging from frost that led to huge losses and adversely impacted on food security, hailstorms, extreme flooding, landslides, receding river levels, and drying rivers leading to large losses and adversely impacting on food security (KFS, 2015a). Many of these extreme climate events have led to displacement of communities to safer grounds (GOK, 2012). South Nandi forest, especially the western side of the forest, is faced with destructive activities, that comprise of overgrazing, increased demand for land for settlement resulting to excisions

and illegal occupation, charcoal making, illegal timber logging in the forest reserve and soil erosion (KFS, 2015a). The challenges in conservation of the forest are insecure forest boundaries due to encroachment and excisions, undervaluation of the forest resources, degradation due to human factors, inadequate awareness of the biodiversity value, unsustainable extraction levels and lack of clear forest zonation (KFS, 2011). Some 2,241.8 ha of the forest (equivalent to 9%) have so far been excised for settlement (KFS, 2011; KFS, 2015a). There are also illegal settlements in the forest, where approximately 552 families are illegally settled on 910.6 ha of the forest which is not excised (KFS, 2015b). An exchange programme in Chepkumia block of the South Nandi forest resulted to securing of 440 ha of water catchment area in 1990 by the KFS, but which since then, approximately 300 ha of it is still bare due to financial constraints for its rehabilitation, hence affecting its role of being a catchment for Yala and Nyando rivers which drain their water into Lake Victoria, and also a habitat and corridor to wild animals (hyenas, wild pigs, antelopes, cerval cats, snakes, monkeys, baboons and some reptiles) and 83 species of birds, among them, the globally endemic and endangered *Turners' eremomela*, as well as regional endemics such as *Hartlaubs Turaco* and the range restricted *Hunter's Cisticola* (Musila *et al.*, 2011). As much as South Nandi forest adjacent communities stand to benefit from carbon trade, especially the communities having signed forest management agreements with the KFS through their Kobujoi Community Forest Association (CFA) on 3rd March 2014 for co-management of the forest resources and carrying out of site-specific forest management plans, among the activities being carbon trading, they have not benefitted from carbon markets (KFS, 2015a). This is because of the complexity of the trade, trading conditions and general lack of capacity and knowledge on carbon trading among the local communities and decision-makers.

Management strategies that increase carbon sequestration or decrease carbon loss in South Nandi forest are important. These will enable managers to know what practices are likely to promote carbon storage or minimize losses during critical time periods as shall be informed by this study. The academia will learn new practical theoretical and conceptual models of establishing carbon baselines in similar forests as South Nandi. This study will also inform the forest adjacent communities on potential carbon markets and hence enhance benefits on payment for ecosystem services, leading to poverty alleviation and reduction on forest degradation. The overall objective of this study was to conduct economic valuation of carbon stock in South Nandi forest towards securing its credit market for the forest adjacent communities leading to their poverty alleviation and subsequent reduction of South Nandi forest degradation.

MATERIALS AND METHODS

Theoretical Framework

In the study, linear regression analysis approach was used in biomass estimation. Biomass of tropical forests were estimated using regression equations of biomass as a function of diameter at breast height (DBH) as shown in the allometric equations in Table 1 (Brown, 1997; Cairns, 1997).

Table 1: Estimation of biomass of South Nandi forest using regression equations of biomass as a function of Diameter at Breast Height (DBH)

Selected Aboveground Biomass Allometric Equations		
Allometry for:	Equation formula	Source
Mixed species of tropical trees in moist conditions (mean annual rainfall 1500-3000 mm)	$B = \exp [-2.134 + 2.53 \ln D]$	Brown 1997
<i>Prestoea montana</i> (palm) - for all palms, Brown 1997	$B = 4.5 + 7.7 H$	Frangi and Lugo, 1985
Mixed tropical liana species	$B = 10^{(0.12 + 0.91 \log A)}$	Putz 1983
<i>Eucalyptus grandis</i>	$B = 2.3229 D^{0.2214}$	Birk and Turner 1992
<i>Eucalyptus saligna</i>	$B = 0.167 * D^{2.21}$	Specht and West, 1998
<i>Pinus patula</i>	$B = \exp [-1.170 + 2.119 * \ln D]$	Brown, 1997
<i>Cypressus lustanica</i>	$B = 4.5966 - 2.364 D + 0.411 D^2$	Monteith, 1979
Selected Belowground Biomass Allometric Equations		
Allometry for:	Equation formula	Source
Mixed species of tropical trees	$B = \exp [-1.0587 + 0.8836 \ln AB]$	Cairns 1997
Belowground Biomass Allometric Equation		
Allometry for:	Equation formula	Source
Mixed species of tropical trees	$B = \exp [-1.0587 + 0.8836 \ln AB]$	Cairns 1997
Biomass to Carbon Allometric Equation		
Allometry for:	Equation formula	Source
Conversion of dry weight biomass to carbon	$C = B / 2$	Brown 1997

Where,

B = biomass (kg); D = dbh (cm); H = height (m); p = wood density (g/cm³); A = basal area (cm²); C = circumference (cm); AB = aboveground biomass density (tons/ha); Carbon = carbon (kg).

Conceptual Framework

The following two equations by Pukkala (1991) were used to calculate the volume of trees in all vegetation types:

$$\ln(y) = -1.64932 + 2.39924 \ln(x) \dots\dots\dots (1) \text{ for closed forest}$$

$$\ln(y) = -1.64932 + 2.24063 \ln(x) \dots\dots\dots (2) \text{ for other vegetation types}$$

where, y = stem volume (dm^3)
 x = diameter at breast height (cm)

The first equation was suitable for stems with clear boles with light branches and the second for multi-stemmed trees and those with a clear bole and multiple branches. The use of these equations was justified because the form of the trees encountered in South Nandi forest was similar to those used by Pukkala to derive the equations. The equations gave stem volume from the stump height to a top diameter of 2 cm, a limit at which the tree is utilized for firewood. The volume of each tallied tree was summed to calculate the volume of the sample plot, which was converted into stand volumes ($\text{m}^3 \text{ha}^{-1}$). The stand volumes were used to calculate the average stand volume in each forest type. Calculations of the Mean Annual Increment (MAI) were theoretical and based on the assumptions made in the inventories by Pukkala (1991).

Description of the Study Area

The study was conducted in South Nandi forest, Kenya. The South Nandi Forest reserve is located in western Kenya within Nandi South and Nandi Central sub-counties. The forest adjacent Constituencies are Emgwen, Aldai and Chesumei. It lies on latitude $0^{\circ}18'$ N and $0^{\circ}32'$ N and longitude $37^{\circ}05'$ E to $37^{\circ}23'$ E, in Rift Valley region (KFS, 2011). It lies west of Kapsabet town and south of the main Kapsabet-Kaimosi road. The forest comprises of two forest stations: Kobujoi and Kimondi.

The South Nandi Forest Reserve covers 24,001.3 hectares out of which Kobujoi currently measures 18,000 ha after 1,500 ha were excised for settlement, while Kimondi station measures 6,001.3 ha after 741.8 ha were equally excised for settlement (KFS, 2011; KFS, 2015a). The forest comprises of 20,084.4 ha of closed-canopy forest, 2,266.2 ha of exotic trees plantations, 610 ha planted with tea in the Nyayo tea zone and 1,040.7 ha of scrub, grassland, or under cultivation. It was gazetted vide legal notice number 76 of 1936 (KFS, 2015a). The Forest Reserve is defined by boundary plan no.75/68 LN 89 of 1937 (Muchiri and Mbuvi, 2012). The forest elevation is between 1700 to 2000 meters above sea level and receives average annual rainfall between 1600 and 1900 millimeters, which makes it classified as a 'moist forest' (forests with 1500 to 3000 mm mean annual rainfall) under the Food and Agricultural Organization (FAO) guidelines of the United Nations (KFS, 2015a). The forest is in a transitional area between the lowland forests of West and Central Africa and the montane forests of central Kenya (KFS, 2011). Common tree species found within the forested area include *Tabernaemontana stapfiana*, *Macaranga kilimandscharia*, *Croton Megalocarpus*, *Croton macrostachyus*, *Drypetes gerrardii*, *Celtis africana*, *Prunus africana*, *Neoboutonia macrocalyx*, and *Albizia gummifera* (Muchiri and Mbuvi, 2012). Figure 1 shows location of the forest in Kenya.

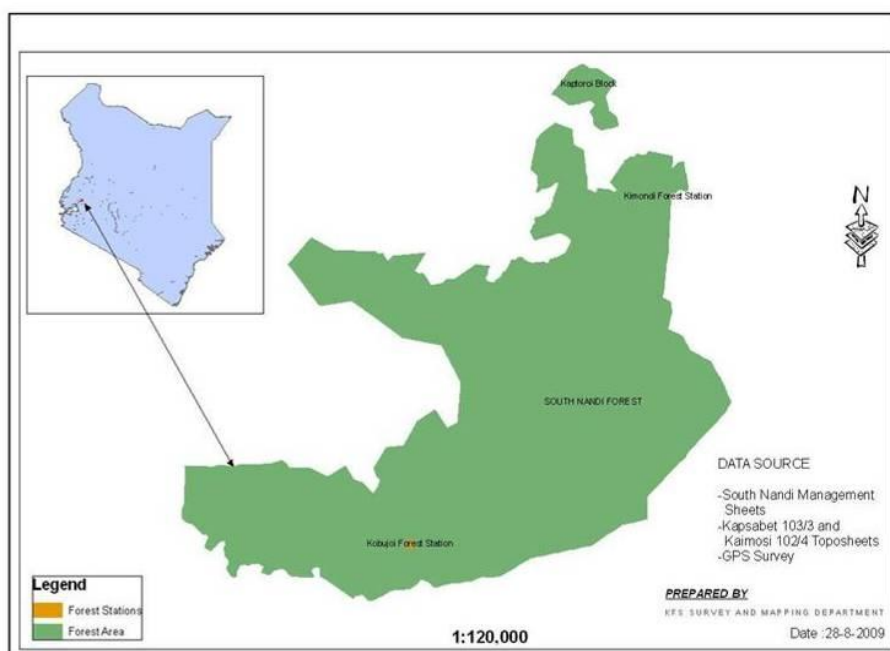


Figure 1: Location of South Nandi forest

Socioeconomic Characteristics of the South Nandi Forest Adjacent Communities

Agriculture contributes 42% of the total household income of the forest adjacent communities in South and Central Nandi sub-counties. The average household farm size is 1 ha (2.5 acres) while average number of cattle is two, that at times graze in the forest after paying some fee; though households to the west of the forest have lesser land holdings (Mbuvi and Gichuki, 2009). Hence, there is a lot of pressure on the forest resources on the western side. The arable land of the two sub-counties is 330.9 Km², while the area of cash crops grown is 32,700 ha and food crops 36,700 ha; the annual milk production is 16,237,398 litres (GOK, 2012). However, there are no clear mechanisms of community access to the forest and/or the activities that bring income to the community are not allowed under the Forests Act 2005. The absolute poverty level is 42% while 66% of people who live near the forest are below the poverty line (Mbuvi and Gichuki, 2009).

Empirical Design, Sampling Method and Data Collection

Two separate forest surveys, the Participatory Forest Resource Assessment (PFRA) and the Carbon Assessment Survey (CAS), were conducted within the South Nandi Forest. The results from these two surveys were assessed to determine the mean carbon storage in tree biomass for the South Nandi Forest.

Participatory Forest Resource Assessment (PFRA) survey

A three-day training for data collection assistants was conducted with emphasis on practical exercises to ensure quality data were collected. The trainees comprised of 10 local community members, two Nature Kenya Project staff and two officers of Kenya Forest Service. Training included establishing plots, taking measurements of various parameters of trees and shrubs, preparing plants specimen and using Geographical Positioning System (GPS) handsets.

A systematic sampling design was used in the allocation of sample plots on the administrative map of South Nandi forest on a scale of 1:50,000. The total number of plots was determined by superimposing a 2 km x 2 km grid squares (400 ha) over the map of South Nandi forest. The size of each sample plot was 10 m x 200m and the first corner was placed systematically at 50m east and 50m south of the intersections points of the 2 km x 2 km grids. The sampling design resulted in a sampling fraction of 0.05 %.

Locating of sample plots in the field was by GPS and conventional survey methods. The four corners of the plot were established using the conventional chain surveying method and temporarily marked with clearly visible wooden posts.

The parameters measured or observed in every plot were as follows:

Tally of herbs (non-woody plants) in a sub-plot of 2 m × 2 m covering an area of 0.0004 ha (sub unit 1a);

Tally of tree seedlings and saplings in a sub-plot of 2m × 25m (sub unit 1b) covering an area 0.005 ha. Seedlings were defined as the regeneration of woody species with a height more than 0.5m and less or equal to 1.5m; and saplings as young trees with a height more than 1.5m and dbh less than 5.0cm;

Diameter at breast height (dbh) of all trees more than 5 cm in sub units 1a, 1b and 1c covering an area of 0.05 ha;

All trees with dbh more than 10 cm in the sub units 1a, 1b, 1c and unit 2 covering an area of 0.1 ha;

All trees with dbh equal or more than 20 cm in all the four units (an area of 0.2 ha);

Total height from the ground level to the tip of the crown for the two dominant trees in sub units 1a to 1c, and in units 2 to 4;

Bole height (stem height from the ground level to the lowest point of the tree crown) for the two dominant trees in sub units 1a to 1c, and in units 2 to 4;

Tree mortality, forest uses and disturbance

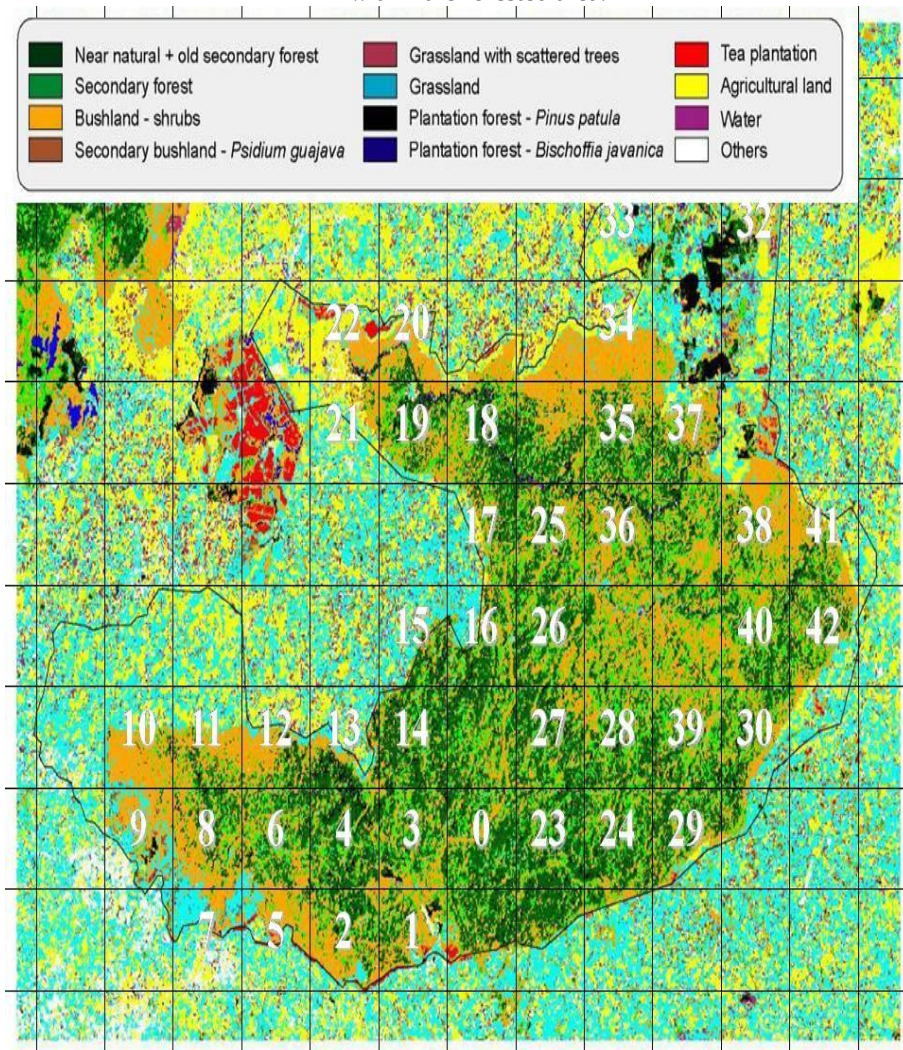
This forest assessment identified the vegetation type (indigenous forest verses plantation, open verses closed canopy), tree species, herbaceous species, seedling density, and noted signs of degradation. It was conducted over the extent of the South Nandi Forest by dividing the forest into a grid. The forest covered 41 blocks of this grid, with a single plot conducted within each block

Figure 2). Of the 41 plots, 35 plots were indigenous forests and the remaining 6 plots were forest plantations. Each plot was divided into six nested subplots, in which diameter at breast height (dbh) measurements were conducted in four subplots (Figure

3). Within all subplots, trees with diameters greater than 20 cm were recorded. Trees with a dbh greater than 10 cm but less than 20 cm were recorded for nested subplot 2, and trees with a dbh greater than 5 cm but less than 10 cm were recorded for nested subplot 1.

Figure 2: PFRA plot location grid:

The South Nandi Forest was divided into a grid, with a plot taken within each grid within the forested area.



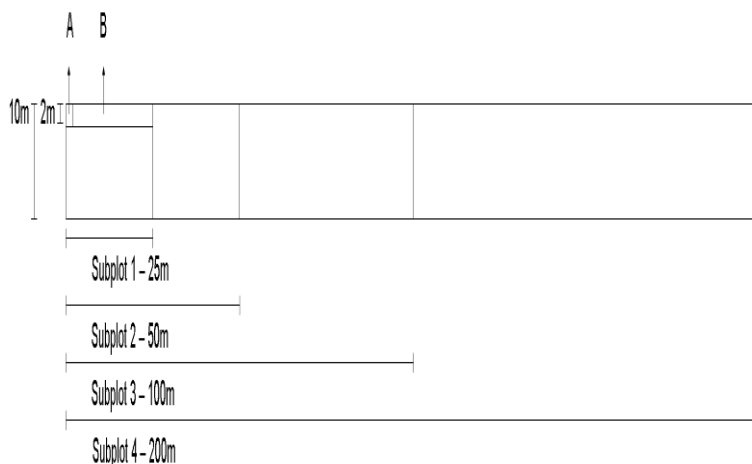


Figure 3: Plot layout for PFRA: Each plot was divided into six subplots. Subplot A (2 x 2 m), subplot B (2 x 25 m), subplot 1 (10 x 25m), subplot 2 (10 x 50m), subplot 3 (10 x 100m), subplot 4 (10 x 200m)

Carbon Assessment Survey (CAS)

The Carbon assessment survey relied upon the data provided by the PFRA survey in quantification of the carbon stocks for the South Nandi forest. The biomass for each tree was calculated using published allometric equations that relate diameter at breast height (dbh) values to tree biomass (Table 1). Tree specific allometric equations were used for exotic plantation species (*Eucalyptus saligna* and *Cupressus lusitanica*) while generalized tropical moist forest equations were used for indigenous species. The belowground biomass was calculated using an allometric equation based upon biomass density in tons per hectare (Cairns, 1997). Carbon is estimated as half of the tree biomass (Brown, 1997). Carbon density was estimated for each sample plot by scaling tree biomass by the area of the subplot in which a tree of that size was measured. Average carbon density for the forest was calculated as the arithmetic mean of all forest plot carbon densities.

Data analysis

Data were analysed using the Microsoft excel 2010 and SPSS Version 17.0 computer programmes. The dbh data were analysed to compile a list of all species measured, the number of times each species was recorded and the percentage that it represented out of the total records of trees more than 5 cm dbh. The seedlings and saplings data were analysed to show the status of the regeneration of the species with trees more than 5 cm dbh. All the herbs recorded were identified and compiled into a list. The dead wood data were not analysed because the number of the dead trees enumerated was negligible.

RESULTS AND DISCUSSION

Key Carbon Sinks in South Nandi Forest

South Nandi forest is dominated by evergreen hardwood species such as *Funtumia africana*, and *Croton* and *Celtis* species. The remaining area is covered with agriculture or plantations. Carbon densities found in the sample plots in South Nandi Forest plantations showed that eucalyptus plots had a carbon density of 44 tonsC/ha while *Cupressus lusitanica* (cypress) plots had a carbon density of 58 tonsC/ha. Indigenous hardwood species plantations had the highest carbon densities of all plantation types: *Olea welwitschii*, 104 tonsC/ha, *Prunus africana*, 87 tonsC/ha.

The indigenous forest had higher carbon density than plantation areas. The indigenous forests (open and closed) had a mean carbon density of 220 tonsC/ha in comparison to a mean carbon density of 59 tonsC/ha across all plantation types. The open canopy forests also had a greater carbon density (165 tonsC/ha) than the *Olea welwitschii* indigenous plantation (104 tonsC/ha), which had the highest carbon density amongst all plantation types within the forest.

Therefore, the indigenous *Olea welwitschii* and *Prunus africana* were the key carbon sinks with highest carbon densities (104 and 87 tonsC/ha respectively) than the non-indigenous eucalyptus and *Cupressus lusitanica* plantations (44 and 58 tonsC/ha respectively) (Figure 4). The statistical significance of these differences cannot be measured due to the low number of plots. Additionally, differences in carbon densities may be due to other factors, such as plantation age.

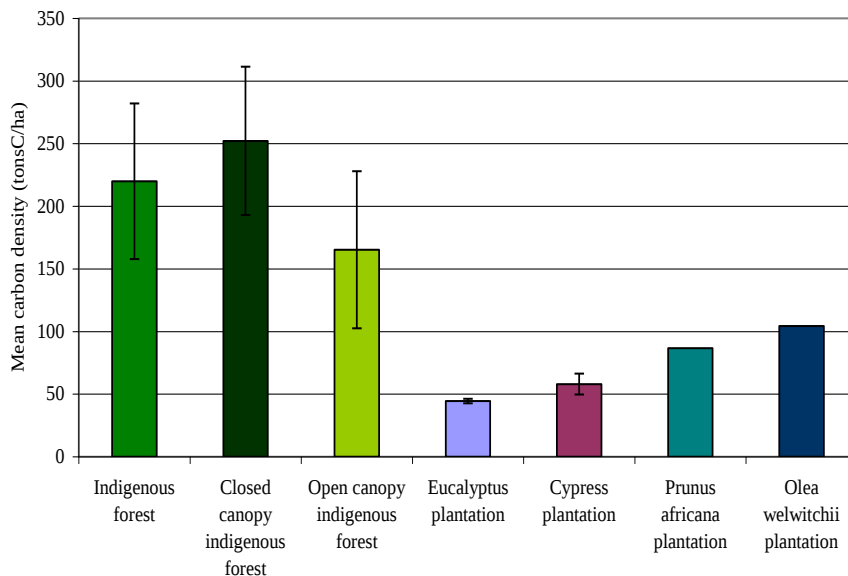


Figure 4: Carbon densities (in tree biomass) of cover types

Quantification of Amount of Carbon in South Nandi Forest

The total number of trees measured to quantify carbon was 1,538 (Table 2).

Table 2: Tree species with the diameter at breast height (dbh) more than 5 cm in 41 sample plots

Species	Forest type	(n)	%(n) (1538)	Species	Forest type	(n)	%(n) (1538)
<i>Cupressus lusitanica</i>	Plantati on	15	0.9	<i>Pennisetum</i>			
<i>Tabernaemontana</i>		3	0.2	<i>cladestinum</i>	open	6	0.4
<i>stapfiana</i>	closed	13	0.8	<i>Sapium</i>			
		9	0.6	<i>ellipticum</i>	open	6	0.4
<i>Strombosia scheffleri</i>	closed	12	0.8	<i>Vernonia</i>			
		3	0.2	<i>amyddalina</i>	open	6	0.4
<i>Croton megalocarpus</i>	closed	10	0.7	<i>Coffea</i>			
<i>Macaranga</i>		2	0.1	<i>eugenioides</i>	closed	5	0.3
<i>kilimandscharica</i>	closed	14	0.9	<i>syzygium</i>			
		0	0.0	<i>guineense</i>	closed	5	0.3
<i>Olea capensis</i>	Closed	77	5.0	<i>Kapkilalialwe</i>			
<i>Casaeria</i>				<i>t</i>	closed	4	0.3
<i>battiscomberi</i>	closed	71	4.6	<i>Markhamia</i>			
	Plantati on			<i>lutea</i>	plantation	4	0.3
<i>Eucalyptus</i>		67	4.4	<i>Sakamwet</i>	closed	4	0.3
<i>Drypetes gerrardii</i>	closed	54	3.5	<i>Sokomwet</i>	closed	4	0.3
				<i>Vernomonia</i>			
<i>Polyscias fulva</i>	closed	57	3.7	<i>amygdlinia</i>	open	4	0.3
				<i>Xymalos</i>			
<i>Dracaena steudneri</i>	Open	45	2.9	<i>monospora</i>	closed	4	0.3
	Plantati on			<i>Cordia</i>			
<i>cheparusiot</i>		37	2.4	<i>Africana</i>	closed	3	0.2
<i>Prunus africana</i>	open	36	2.3	<i>Mbereriat</i>	closed	3	0.2
<i>Macrorungia</i>							
<i>pubinervia</i>	closed	33	2.1	<i>Borkoyet</i>	closed	2	0.1
<i>Neoboutonia</i>	Plantati on			<i>Craibia</i>			
<i>macrocalyx</i>		30	2.0	<i>brownie</i>	open	2	0.1
				<i>Fagarapsis</i>			
<i>Diospyros abyssinica</i>	closed	29	1.9	<i>angolensis</i>	closed	2	0.1
				<i>Nuxia</i>			
<i>Solanum mauritianum</i>	Closed	27	1.8	<i>congesta</i>	open	2	0.1
<i>Aningeria altissima</i>	open	24	1.6	<i>Pitpitet</i>	open	2	0.1
				<i>Clerodendru</i>			
<i>Croton macrostachyus</i>	Closed	21	1.4	<i>m johnstonii</i>	closed	1	0.1
<i>Cassipoura</i>				<i>Clerodendru</i>			
<i>ruwensoriensis</i>	Closed	19	1.2	<i>m johnstonii</i>	closed	1	0.1
				<i>Dracaena</i>			
<i>Ehretia cymosa</i>	closed	18	1.2	<i>steudneri</i>	open	1	0.1
				<i>Ehretia</i>			
<i>Albizia gummifera</i>	closed	17	1.1	<i>cymosa</i>	closed	1	0.1
<i>Ibisia gummifera</i>	closed	17	1.1	<i>Lamaiyet</i>	closed	1	0.1
<i>Bersama abyssinica</i>	Open	16	1.0	<i>Mbarkaiyat</i>	closed	1	0.1

	Plantati						
<i>Pinus patula</i>	on	14	0.9	<i>Mibeset</i>	closed	1	0.1
<i>Schefflera volkensii</i>	closed	13	0.8	<i>Mimosaceae</i>	closed	1	0.1
<i>Zathoxylum guleti</i>	closed	13	0.8	<i>Namkoiyet</i>	closed	1	0.1
<i>Vernonia auriculifera</i>	open	12	0.8	<i>Ocoba</i>			
<i>abustanyet</i>	open	11	0.7	<i>routledgei</i>	open	1	0.1
<i>Ensete edule</i>	Open	9	0.6	<i>Olea</i>			
<i>nyastabiny</i>	closed	9	0.6	<i>welwitchii</i>	closed	1	0.1
<i>Celtis gomphophylla</i>	open	8	0.5	<i>Psidium</i>			
<i>Gouania longispicata</i>	closed	7	0.5	<i>guajava</i>	closed	1	0.1
<i>Casuarina equisetifolia</i>	open	6	0.4	<i>Ritchiea</i>			
				<i>albersii</i>	closed	1	0.1
				<i>Rubia</i>			
				<i>cordifolia</i>	open	1	0.1
				<i>Schefflera</i>			
				<i>volkensii</i>	closed	1	0.1
				<i>Tekestet</i>	open	1	0.1
Total 34 species		1,454 trees	94%	34 species		84 trees	6%

Table 2 shows that there were 68 species and most of them were commonly used for firewood, poles, timber, medicine, fodder and bee forage. The most widely distributed species, with observations ranging from 140 to 153, were *Cupressus lusitanica*, *Tabernaemontana stapfiana*, *Strombosia scheffleri*, *Macaranga kilimandscharica* and *Croton megalocarpus* accounting for 42.6 % out of measured trees with more than 5 cm dbh.

Table 3: Descriptive statistics of selected parameters for sampled trees with more than 5 cm dbh in 41 sample plots

Parameter	No. of cases	Minimum	Mean	Maximum	S.E
DBH, cm	1538*	5	33.0	400	
No. of trees ha ⁻¹	41*	40	182	380	
Basal area m ² ha ⁻¹	41*	2	26	122	
Volume, m ³ ha ⁻¹	41*	23	116	489	

*Number of trees, **Number of sample plots

Source: Survey data, 2015

From Table 3, out of the 1,538 trees measured to quantify carbon, it was found that the stocking varied from 40 to 380 trees ha⁻¹, dbh from 5.0 cm to 400 cm, while the mean basal area ranged from 2 m² ha⁻¹ to 122 m² ha⁻¹ and volume of trees per hectare ranged from 23 m³ ha⁻¹ to 489 m³ ha⁻¹.

Table 4: 10 most abundant tree species with dbh more than 5 cm in 41 sample plots

Species	Forest type	(n)	%(n)1538	Cumulative(%)
<i>Cupressus lusitanica</i>	plantation	153	9.9	9.9
<i>Tabernaemontana stapfiana</i>	closed	139	9.0	18.8
<i>Strombosia scheffleri</i>	closed	123	8.0	26.9
<i>Macaranga kilimandscharica</i>	closed	140	9.1	36.0
<i>Croton megalocarpus</i>	closed	102	6.6	42.6
<i>Olea capensis</i>	Closed	77	5.0	47.6
<i>Casaeria battiscomberi</i>	closed	71	4.6	52.2
<i>Eucalyptus</i>	Plantation	67	4.4	56.6
<i>Drypetes gerrardii</i>	closed	54	3.5	61.1
<i>Polyscias fulva</i>	closed	57	3.7	63.8
Total			63.8	63.8

Source: Survey data, 2015

Table 4 shows the 10 most abundant tree species with dbh more than 5 cm were *cupressus lusitanica*, *tabernaemontana stapfiana*, *strombosia scheffleri*, *macaranga kilimandscharica*, *croton megalocarpus*, *olea capensis*, *casaeria battiscomberi*, *eucalyptus*, *drypetes gerrardii* and *polyscias fulva*. The 10 most abundant species accounted for 63.8 % of the total number of trees measured.

Based on calculations using the published allometric equations that relate diameter at breast height (dbh) values to tree biomass as shown in Table 1, the closed canopy carbon density was at 252 ± 59 tons C/ha, while the secondary forest had a carbon density of 165 ± 62 tonsC/ha for open canopy forest. The mean carbon density for all indigenous forest plots (closed and open canopy) for the PFRA dataset was 220 ± 62 tons of carbon per hectare (tons C/ha, given as value $\pm$ standard error). Extrapolating this figure to an estimated 13,000 ha of indigenous forest yields a total carbon store of 2.8 ± 0.8 million tons of carbon (equivalent to 10.5 ± 2.9 million tons CO₂). In comparison, the Carbon Assessment Survey found a similar value, with a mean carbon density of 235 ± 39 tons C/ha for the indigenous forest areas sampled. The PFRA data indicates that the closed canopy forest had a greater mean carbon density, 252 ± 59 tonsC/ha for closed versus 165 ± 62 tonsC/ha for open canopy, but the difference was statistically insignificant (2 tail t-test p-value of 0.11).

Major Constraints and Opportunities in Carbon Trading in South Nandi forest

Through a survey conducted by Mwatete and Koech (2015) in 1,278 households, alongside the PFRA, on interests of South Nandi forest adjacent communities in conserving the forest, it showed that their interests were linked to the services they get from the forest (Table 5).

Table 5: Main reasons why forest adjacent communities are interested in conserving the South Nandi forest

Goods/service	No. of respondents	% of total Respondents
Firewood	934	73
Herbal medicine	455	36
Grazing	359	28
Rain	830	65
Fruits	34	3
Timber	65	5
Charcoal	99	8
Honey	55	4
Pleasant air	10	1
Strict law	11	1
Tourism	6	<1
Carbon trading	2	<1
Soil conservation	6	<1
Stop extinction	1	<1
Farming	1	<1

Source: Survey report, 2015

Firewood was rated the highest, followed by rainfall for their rain-fed agricultural production, then herbal medicine and lastly grazing of their livestock in the forest as the top four major incentives for conserving the forest. The survey therefore indicated that the interest among the community to co-manage the forest with KFS is high. This is an opportunity which could be utilized to introduce and implement carbon trading. With the signed forest management agreement, the forest adjacent communities have legal right to conduct carbon trade with the available global carbon trade schemes.

However, carbon trading was rated among the bottom three incentives because the community had never benefitted from carbon trading. Secondly, the community had no knowledge about the possibility of them benefitting from the trade as an incentive, apart from the two community members that knew about that opportunity. Other challenges faced which lead to degradation of the forest are overgrazing, increased demand for land for settlement resulting to excisions and illegal occupation, charcoal making, illegal timber poaching in the forest reserve, soil erosion, inadequate utilization of the indigenous knowledge on sustainable forest conservation, increased pressure from the neighbouring communities and increased risks of further encroachment. The challenges in conservation of the forest are insecure forest boundaries due to the encroachment and excisions, undervaluation of the forest resources, degradation due to anthropogenic factors, inadequate awareness of the biodiversity value, unsustainable extraction levels and lack of clear forest zonation.

CONCLUSIONS AND RECOMMENDATIONS

The study shows a relatively high carbon density of the indigenous forest within the South Nandi Forest area (220 ± 62 tonsC/ha). Carbon densities estimated for the South Nandi Forest are on a par with those found in rainforests in other regions such as

Ecuador in South America at 200 – 300 tonsC/ha in the aboveground biomass as agreed by Butler (2007). This indicates that projects in South Nandi Forest would have a good chance of attracting carbon funding.

There is potential for tree planting projects in and around the South Nandi Forest to attract carbon funding either through the regulated carbon credit market under the Clean Development Mechanism (CDM) or through the voluntary carbon market. The area is well positioned to initiate such projects as many community groups (e.g. South Nandi Biodiversity Conservation Group, Cham Education group and Genesis multipurpose youth group) have already established successful tree nurseries. One option would be to reforest degraded or cleared areas within the forest boundaries with indigenous species. These areas may eventually regain mature forest cover and reach carbon densities of 220 tons C/ha. To determine how much additional carbon this would sequester the exact number of hectares of deforested area to be planted needs to be determined and mapped and the current existing carbon storage in these areas needs to be sampled. The amount of time needed to accumulate this carbon would also need to be determined. Carbon trading projects typically have 20 year commitment periods and it is unlikely that a forest would grow to maturity in this time. Therefore, good estimates of biomass accumulation rates are important to determine project income and payment schedule. Local forest growth rates are not readily available, but could be estimated by sampling and calculating biomass for secondary forests of known ages or individual indigenous trees of known ages for the species to be planted.

Tree planting projects outside of the forest boundary, such as trees planted on farms, could also apply for carbon based funding depending on their management. If the trees were intended for harvest for fuel wood and/or timber, both the tree growth rates and the harvesting rates would need to be determined to find the net carbon store increase. Trees planted that are not to be harvested (e.g. for windbreaks, shade, fruit, medicinal use) will be more simple to account for. Because the trees planted in such projects will be scattered over many properties, formation of cooperatives to apply for and monitoring the project will be necessary.

Activities that reduce deforestation in the South Nandi Forest could also attract REDD (Reduced Emissions from Deforestation and Degradation) project funding. REDD projects are currently only funded through the voluntary carbon market (companies and agencies interested in reducing carbon emissions, but not mandated to do so by their governments). The REDD projects may eventually be able to earn carbon credits included in the formal CDM market. To determine carbon emissions prevented by REDD projects, current and predicted future deforestation rates (i.e. hectares of forest lost per year) in South Nandi Forest need to be estimated. This can be done by assessing satellite images or aerial photos of the region in recent years and by assessing wood use, demand, and sources and population growth patterns in the surrounding areas. The proponents of a REDD project will also have to show how the project activities would prevent future deforestation. Such activities could include reducing need for fuel wood through alternative energy, fuelwood saving stoves, and on-farm woodlots, reducing need for forest timber through alternative livelihoods and on-farm woodlots and improved forest monitoring and management.

Forest carbon projects, either tree planting or REDD projects, are more likely to receive funding if they have been certified through an established certification scheme. The two main certifications currently operating are the Voluntary Carbon Standard (VCS) and Climate Community and Biodiversity (CCB) Standard. Both standards give detailed, step-by-step guidance for project establishment and monitoring which are freely available online. Currently VCS is the only certification for REDD projects.

Other steps for the managers and stakeholders of the South Nandi Forest would be to create initial project proposals and present these to the National Environmental Management Authority (NEMA) Climate Change Office, non-governmental organizations seeking to establish carbon projects, and/or companies interested in acquiring carbon credits. Organizations that may be of assistance in seeking potential donors include the World Wildlife Foundation (WWF) and the World Agroforestry Center (ICRAF), both of which have headquarters in Nairobi. There may also be potential to attract funds from local industries interested in offsetting their carbon emissions despite the fact that they are not currently required to do so. For example, Kenya Airways gives its passengers the option to pay into a carbon project fund to offset flight emissions.

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REFERENCES

- Birk EM and Turner J (1992). Responses of flooded gum (*E. grandis*) to intensive cultural treatments: biomass and nutrient content of eucalypt plantations and native forests. *Forest Ecology and Management* 47, 1-28.
- Broadmeadow M and Matthews R (2003). Forests, carbon and climate change: The UK contribution. Information Note. Forestry commission. 231 Corstorphine Road Edinburgh. EH127AT.
- Brown S (1997). *Estimating Biomass and Biomass Change of Tropical Forest: a Primer*. Food and Agriculture Association of the United Nations (FAO), Rome.
- Busienei VJ (2010). Potential economic value of carbon sequestration in Kakamega forest and surrounding farms. Masters' degree Thesis in Agriculture and Applied Economics, Egerton University.
- Butler RA (2007). Amazon rainforest locks up 11 years of CO₂ emissions.
- Cairns MA, Brown S, Helmer EH and Baumgardner GA (1997). Root biomass allocation in the world's upland forests. *Oecologia* 111, pp. 1-11.
- Carraro C and Favero A (2009). The Economic and Financial determinants of Carbon prices. *Journal of Economics and Finance*, 59, 2009. No. 5.
- FAO (2005). Global forest resources as updated in 2005.
- Frangi JL and Lugo AE (1985). Ecosystem dynamics of a subtropical floodplain forest. *Ecological Monographs* 55, 351-369.
- Government of Kenya (2009). Kenya National Bureau of Statistics, Kapsabet office.
- Government of Kenya (2011). Kenya State of the Environment and Outlook, 2010. Supporting the delivery of Vision 2030. A publication of the National Environment Management Authority (NEMA). ISBN 9966 – 7460 – 5 – 6.
- Government of Kenya (2012). National Climate Change Action Plan.
- Government of Kenya (2010). National Climate Change Response Strategy.
- Government of Kenya (2005). The Forests Act, 2005.

- Harmon ME, Ferrell WK, Franklin JF (1990). Effects on carbon storage of conversion of old-growth forests to young forests. *Science*, 247: 699-702.
- IPCC (2001). The Scientific Basis. Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change- IPCC (eds. J.T. Houghton, Y. Ding, D.J. Griggs, M. Nogner, P.J. van der Linden and co-editors). Cambridge University Press, Cambridge.
- KFS (2011). Integrated Forest Management Plan for South Nandi Forest, 2011 – 2020. Produced with financial assistance of United Kingdom's Department for International Development (DFID) through Nature Kenya and Kenya Forest Service through Green Zones Development Support Project (GZDSP).
- KFS (2015a). North and South Nandi Forests Strategic Ecosystem Management Plan 2015 – 2040. Plan development supported by Global Environment Facility (GEF) and United Nations Development Programme (UNDP) through the "Strengthening Protected Areas Network within the Eastern Montane Forest Hotspot of Kenya Project" coordinated by Nature Kenya. Published by Kenya Forest Service, Nairobi, Kenya.
- KFS (2015b). Participatory Forest Management Plan for Kimondi Forest Station, Kenya (Revised Version). Unpublished.
- Kissinger G, Herold M, Veronique D (2012). Drivers of deforestation and forest degradation: A synthesis report for REDD+ policymakers. Lexeme consulting, Vancouver, Canada. August 2012.
- Lasco RD, MacDicken KG, Pulhin FB, Guillermo Q, Sales RF and Cruz RVO (2006). Carbon stocks Assessment of a Selectively Logged Dipterocarp Forest and Wood Processing Mill in the Philippines. *Journal of Tropical Forest Science*. 18(4) – 172 (2006).
- Mbuvi MTE and Gichuki J (2009). Socioeconomic Report for South Nandi Forest Adjacent Communities: Towards Participatory Forest Management Implementation in South Nandi Forest. Produced with financial assistance of United Kingdom's Department for International Development (DFID) through Nature Kenya (Unpublished).
- Monteith D (1979). Whole-tree weight tables for New York. Applied Forestry Research Institute. Research Report 40.
- Muchiri MN and Mbuvi MT (2012). Tree Resources Inventory of South Nandi Forest Reserve. Produced with financial assistance of United Kingdom's Department for International Development (DFID) through Nature Kenya.
- Murdiyarso D and Herawati H (2005). Carbon Forestry: Who will benefit? Proceedings on Workshop on Carbon Sequestration and Sustainable Livelihoods. Published by Centre for International Forestry Research.
- Mwatete GK and Koech CK (2015). Socioeconomic report for South Nandi forest communities. Produced with financial assistance of Global Environment Facility (GEF) and United Nations Development Programme (UNDP) through Nature Kenya (Unpublished).
- Musila W, Malombe I, Mwachala G (2011). A Rapid Biodiversity Survey of Nandi Hills and Cherangani Hills forests. Report produced by National Museums of Kenya, through financial support from Global Environment Facility (GEF) and United Nations Development Programme (UNDP) through the "Strengthening Protected Areas Network within the Eastern Montane Forest Hotspot of Kenya Project" coordinated by Nature Kenya.
- Oli Bishwa N and Shrestha K (2009). Carbon status in Forests of Nepal: An overview. *Journal of Forest and Livelihood*. 8(1). February 2009.
- Pukkala T (1991). Nakuru and Nyandarua intensified extension project, Technical report No 2: Woody biomass baseline survey. FINNIDA in cooperation with the Ministry of Environment and Natural Resources, Forest Department, Kenya. 37 p.
- Putz F (1983). Liana biomass and leaf-area of a "Tierra Firme" forest in the Rio-Negro Basin, Venezuela. *Biotropica* 15 (3) 185-189.
- Rudolph S, Lenz C, Lerch A and Volmert B (2011). Towards sustainable carbon markets: Requirements for ecologically effective, economically efficient and socially just emissions trading schemes. Joint discussion paper series in Economics, by the universities of Aachen, Gießen, Göttingen, Kassel, Marburg and Siegen. ISSN 1867 – 3678.
- Ryan, MG, Harmon ME, Birdsey RA, Christian CP, Heath LS, Houghton RA, Jackson RB, Duncan DC, Morrison JF, Murray BC, Pataki DE and Skog KE (2010). A synthesis of the science on forests and carbon for U.S. forests. Issues in Ecology, Report number 13. Ecological Society of America.
- Sumukwo J, Adano Wario R, Kiptui M, Cheserek GJ and Kipkoech AK (2013). Valuation of natural insurance demand for non-timber forest products in South Nandi, Kenya. *Journal of emerging trends in economics and management sciences (JETEMS)* 4 (1): 89 – 97.
- Tadesse D (2010). The impact of climate change in Africa. ISS Paper 220. November, 2010.
- Waran A (2001). Carbon sequestration potential of trees in and around Pune city. M.Sc. Thesis submitted to Department of Environmental Science, University of Pune. Published.