INBAR Working Paper

Technical Report

Country Profile of Climate Change Mitigation Potential of Implementing Sustainable Management for Bamboo Forests in Kenya

Mbae Muchiri[1], Meshack Muga[1]

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[1] Kenya Forestry Research Institute

About the International Bamboo and Rattan Organisation

The International Bamboo and Rattan Organisation, INBAR, is an intergovernmental organisation dedicated to the promotion of bamboo and rattan for sustainable development. For more information, please visit www.inbar.int.

About this Working Paper

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International Bamboo and Rattan Organisation

P.O. Box 100102-86, Beijing 100102, China Tel: +86 10 64706161; Fax: +86 10 6470 2166
Email: info@inbar.int

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Acronyms

BTCL	Bamboo Trading Company
CFA	Community Forest Association
CO_2	Carbon dioxide
Dbh	Diameter at breast height
DRSRS	Department of Resource Survey and Remote Sensing
GO	Governmental Organisation
GPE	Green Pot Enterprises
GPS	Global Positioning Systems
GSP	Generalised System of Preferences
Ha	Hectares
INBAR	International Bamboo and Rattan Organisation
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KEBS	Kenya Bureau of Standards
KEFRI	Kenya Forestry Research Institute
KFS	Kenya Forest Service
KSh	Kenyan Shilling
KWS	Kenya Wildlife Service
ME&F	Ministry of Environment and Forestry
NEMA	National Environmental Management Authority
NGO	Non Governmental Organisation
NTFP	Non Timber Forest Products
R&D	Research and Development
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SD	Standard Deviation
SEM	Standard Error of the Mean
SMEs	Small Medium Enterprises
SU	Suppressed
SWOT	Strength Weakness Opportunity and Threat

T	Tonnes
UNFCCC	United Nations Framework Convention on Climate Change
UoE	University of Eldoret

Table of Contents

1. Introduction **1**

2. Materials and methods **4**

2.1 Desk study 4
2.2 Bamboo status data 4
2.3 Estimation of carbon stock and carbon conversion to CO_2 6
2.4 Bamboo management practices 8

3. Results and discussion **9**

3.1 Sample plots location 9
3.2 Stocking density and diameter of culms 10
3.3 Oven dry weight 12
3.4 Biomass and carbon stock 13
3.5 Climate change mitigation potential of *Oldeania alpina* bamboo forest in Kenya 15
3.6 Current status of bamboo management 17
3.7 Key players/actors/stakeholders dealing with natural bamboo 18
3.8 Benefits derived from natural bamboo forest 20
3.9 SWOT analysis 21

4. Conclusions and recommendations **24**

4.1 Conclusions 24
4.2 Recommendations 24

References **26**

Appendix **30**

List of figures

Figure 1. Distribution of indigenous bamboo in Kenya.. 2
Figure 2. Mature *Oldeania alpina* culm (left), young culm (centre) and old culm (right). 6

List of tables

Table 1. *Oldeania alpina* culm maturity classes.. 6
Table 2. Geographic location of the sample plots 9
Table 3. Stocking density of *O. alpina* in Kenya 10
Table 4. Diameter (Dbh) of *O. alpina* culms in Kenya 12
Table 5. Oven dry biomass of *O. alpina* culms up to a height of 2.5 cm diameter......................13
Table 6. Biomass and carbon stock of *O. alpina* in five ecosystems in Kenya 14
Table 7. Carbon in dead culms 14
Table 8. *Oldeania alpina* aboveground carbon stock removal in Kenya for product development 16
Table 9. Key players/actors/stakeholders dealing with natural bamboo in Kenya 19
Table 10. Economic and environmental benefits from the current management practice on natural bamboo forest 20
Table 11. SWOT analysis of sustainably managing natural bamboo forests to enhance economic development and environmental conservation 21

Executive Summary

The bamboo sector can significantly contribute to climate change mitigation because bamboo is a fast-growing plant that generates substantial amounts of biomass in a short time. *Oldeania alpina* is the indigenous bamboo species in Kenya and covers an area of 133,273 ha distributed in five ecosystems: Mt Elgon, Cherang'any, Mau, the Aberdare Range and Mt Kenya (INBAR, 2018). The species plays a critical role in the regulation of water flow, soil erosion control, socio-economic development, biodiversity conservation, provision of ecosystem services and improved local livelihoods. Recent research by the International Bamboo and Rattan Organisation (INBAR) has shown that the bamboo sector can significantly contribute to climate change mitigation through the storage of carbon in forest ecosystems and its products. The purpose of this report is to assess the climate change mitigation potential of implementing sustainable forest management in the indigenous bamboo forests in Kenya.

The field data collection was conducted in accordance with the protocol approved by Kenya Forest Service (KFS) and in partnership with Kenya Forestry Research Institute (KEFRI), Department of Resource Surveys and Remote Sensing (DRSRS), University of Eldoret (UoE) and Luke (Natural Resources Institute Finland). Data were collected from 43 randomly selected plots in natural unmanaged bamboo forests in four ecosystems: the Mt Kenya, Mt Elgon, Mau and Aberdare ranges. All culms were assessed for maturity class (young, mature, old, suppressed and dead) and diameter at breast height (Dbh) within two subplots of a 2 m radius and 5 m apart from the centre of a 10 m radius plot. Plot means were calculated and applied to estimate stocking ha^{-1}, mean diameter at breast height (Dbh), carbon stock and carbon sequestration potential by bamboo maturity classes. Allometric equations developed by Muchiri and Muga for *O. alpina* (Muchiri and Muga, 2013) were used to estimate the oven dry weight, which was subsequently applied to calculate biomass and carbon stock. A questionnaire was designed and administered to 15 stakeholders in the bamboo sector to obtain information on current management practices. A Strength, Weakness, Opportunity and Threat (SWOT) analysis was carried out based on the obtained information, literature review and the consultants' experience and knowledge.

The culm mean stocking density ranged from 18,711 culms ha^{-1} in Mau to 35,496 culms ha^{-1} in Mt Kenya. The proportion of dead bamboo was very high, between 8% and 21%, and was highest

in Mau and lowest in the Aberdares. The highest proportion of mature bamboo culms was 82% in the Aberdares and the lowest was 29% in Mt Elgon. The bamboo culm mean Dbh ranged from 1.7 cm in Mt Kenya to 5.3 cm in the Aberdares. Significant variations ($P<0.05$) were noted in culm Dbh within maturity classes and among ecosystems. The large size of the mature culms in the Aberdares may be attributed to selective cutting of mature culms and removal of dead culms.

The *O. alpina* culm oven dry biomass ranged from 1.0 kg per sample for the suppressed class to 4.9 kg for the mature class. The mean aboveground bamboo carbon stock was estimated as 20.5 to 49.4 t C/ha. More than half of the *O. alpina* biomass was located in the Aberdare ecosystem, even though the stocking was about half of that of Mt Kenya and Cherang'any.

If bamboo is sustainably harvested and value-added into durable products, the annual carbon locked into durable products will be 509,778 tC/ year (1,870,885 tCO_2/ year). If harvested bamboo is used for bioenergy, the annual carbon emission reduction will be 2,164,604 tCO_2.

No consistency currently exists on the legal status, definition and classification of bamboo in the laws and policy frameworks in Kenya. The focus of bamboo management is on its conservation and protection values, and this management is under the strict control of the KFS. There has been a 'presidential ban' on harvesting and transportation of bamboo, which has continued to hamper development of the bamboo sector. The only cost to the government associated with the management of natural bamboo forests is enforcement of compliance with protection laws, fire surveillance, negligible rehabilitation of degraded areas and revenue collection.

The major challenges of managing natural bamboo forests in Kenya are forest fires, poor accessibility to the areas with bamboo, inadequate baseline information, limited government support programmes, an undeveloped market and weak trade linkages. However, strong opportunities exist for developing the bamboo sector by expanding plantations, making durable bamboo products (e.g. construction and building materials, furniture and panel products), developing a pulp and paper industry, and using bamboo as bioenergy (resulting in a reduction in deforestation).

The amount of mature and dead culms is very high, creating a fire risk. Dead and mature culms should be sustainably harvested and utilised for product development and biomass energy to reduce fire risks in the forests. The recommended harvesting regime is a one- or two-year cycle; between 30 % and 40 % of the mature culms could be harvested and all dead culms should be removed. Further development of the natural bamboo sector can be accelerated by finalisation of the Bamboo National Strategy, including adoption and implementation of bamboo management guidelines.

1. Introduction

Global climate change mitigation has received much more attention from scientists, resource managers and policymakers in recent years. The Intergovernmental Panel on Climate Change (IPCC) has promoted strategies for climate change mitigation and adaptation (IPCC, 2014). Forests can mitigate climate change by reducing carbon in the atmosphere (Zhang et al, 2007; Jackson and Baker, 2010; Canadell and Raupach, 2008), and the carbon sequestration potential of forests can be exploited by involving communities in activities that promote forestry practices that provide climate change mitigation benefits (UNFCCC, 2007). Bamboo forests have strong potential for carbon sequestration to mitigate climate change. Over 1600 species of bamboo grow on over 35 million hectares across the tropical and sub-tropical regions of Africa, Asia and South America (Vorontsoa et al, 2016; FAO, 2020). Bamboo is one of the fastest growing plants on earth and generates substantial amounts of biomass within a short period (Yiping et al, 2010). Bamboo has multiple economic and ecological benefits, and the internal production and consumption was valued globally at USD 68 billion in 2019, with over 10,000 documented products and applications.

Recent research has shown that the bamboo sector can significantly contribute to climate change mitigation, both through ecosystem carbon reduction and storage of carbon in durable products (Lugt et al, 2018; Lugt and King, 2019; King et al, 2021). The expansion of markets for bamboo products, culminating in the restoration of large areas of degraded land with bamboo forests, has created a large carbon sink in China. In 2010, China's bamboo forests stored 727 million tonnes of carbon, and this is projected to increase to over one billion tonnes by 2050 (INBAR, 2014).

Most of the bamboo resources in Kenya comprise one indigenous species, *Oldeania alpina,* formerly known as *Arundinaria alpina* and later *Yushania alpina*. Unsustainable exploitation of forests and conversion of forestland into agricultural land has resulted in the disappearance of vast areas of indigenous bamboo in Kenya, which had 450,000 ha in 1940 but only 150,000 ha in 2010 (Kigomo, 2007; FAO, 2010; Ndirangu, 2017). Kenya currently has about 133,273 ha of *O. alpina* (INBAR, 2018), which is almost equivalent to the area of commercial tree plantations. The bamboo forests are distributed in the following five ecosystems: Mt Elgon (18,893 ha), Cherang'any (8,180 ha), Mau (30,196 ha), the Aberdare Range (50,038 ha) and Mt Kenya (25,966 ha) (Figure 1).

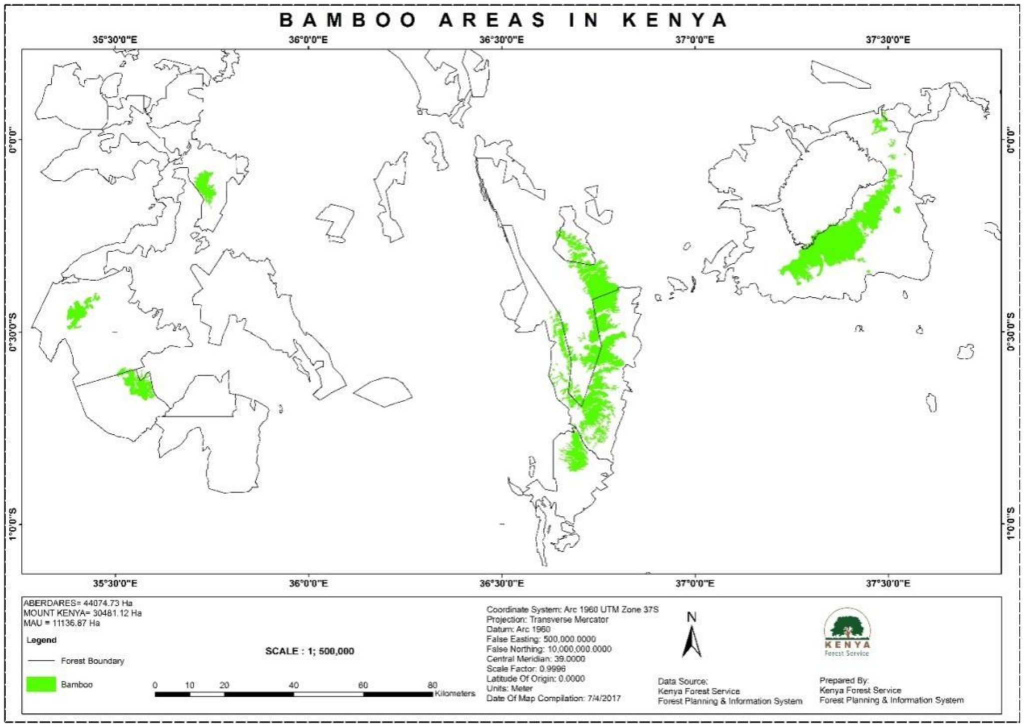

Figure 1. Distribution of indigenous bamboo in Kenya.

Administratively, the counties with the greatest amounts of bamboo resources are Tharaka-Nithi, Nyeri, Muranga, Kiambu, Nyandarua, Nakuru, Narok, Trans Nzoia, Uasin Gishu and Nakuru.

The indigenous bamboo in Kenya plays a critical role in the regulation of water flow and in soil erosion control. It is also vital in socio-economic development, provision of ecosystem services and biodiversity conservation as habitat for herbivore wildlife, including elephants and buffalos, which are a major tourist attraction in Kenya. Bamboo contributes to local livelihoods, with an estimated 3.2 culms being used for fencing, construction, props in the flower industry, edible shoots, toothpicks, skewers, baskets and handicrafts (Ongugo et al. 2000).

Although a presidential ban is in place on the harvesting of natural bamboo in Government forests, substantial illegal cutting of indigenous *O. alpina* is resulting in losses of revenue to the government and reduction of the bamboo carbon sequestration potential.

At present, Kenya does not have national standards for quantifying and monitoring its bamboo carbon sinks, despite the fact that bamboo forests provide vital ecosystem services and effectively mitigate land degradation. Therefore, huge opportunities exist for using bamboo to meet some of the country's Nationally Determined Contributions under the Paris Climate Change Accord. Developing these opportunities would entail building channels to secure funds from REDD+ initiatives and voluntary markets.

A need therefore exists to increase information on the status of bamboo forests, management practices, carbon stocks, and the potential for climate change adaptation and mitigation by bamboo forests in Kenya.

2. Materials and methods

2.1 Desk study

A desk study was conducted to review relevant literature, develop a field protocol for the establishment and assessment of field plots and formulate a questionnaire for collecting information on the management practices of indigenous bamboo forests in Kenya. The field protocol is outlined below, and a copy of the questionnaire is attached (Appendix1). Reference was also made to the study by INBAR on the areas covered by bamboo in Kenya and its distribution (INBAR, 2018).

2.2 Bamboo status data

The procedure for field data collection is based on the approved framework by the Kenya Forest Service (KFS), in partnership with the Kenya Forestry Research Institute (KEFRI), Department of Resource Surveys and Remote Sensing (DRSRS), University of Eldoret (UoE) and Natural Resources Institute Finland (Muchiri et al, 2016).

The data used in this study were obtained from four ecosystems: Mt Kenya, Mt Elgon, Mau and the Aberdare Range. The Mau Ecosystem contained three sites: Kiptuget Forest Station in Baringo County, Lorenges Forest Station in Uasin Gishu County and Longman Forest Station in Nakuru County; the Mt Kenya Ecosystem contained the Chogoria Forest Station in Tharaka Nithi County; the Mt Elgon Ecosystem contained the Kimothon and Kiptogot Forest Stations in Trans Nzoia County; and the Aberdare Ecosystem contained the Kieni Forest Station (Figure 1).The field data on bamboo forests for the Cherang'any ecosystem were not collected due to time and budget limitations, but the information for Cherang'any was considered to be the same as that of the neighbouring Mt Elgon Ecosystem.

Study sites were chosen in consultation with forest station managers and were easily accessible and fairly representative of the bamboo forest. Sample plots were randomly located about 50 to 250 m from the edge of a road for ease of access, due to time and financial constraints. The plots were circular, with a radius of 10 m, and the locations were recorded using GPS. In all the plots, the bamboo culms were evenly distributed, and enumeration was undertaken in two subplots with a 2 m radius and 5 m apart in the west and east directions from the sample plot centre. The mean number of culms in the two sub-plots (each 2 m in radius) was obtained and multiplied by 25 to get the number of culms in a sample plot (of 10 m radius).

All culms and shoots in a plot were identified and classified into four age categories: young (including shoots), mature, old and dead based on the colour and texture (Muchiri and Muga, 2013). The young culms were green in colour and vigorously growing, mature culms were greenish brown, old culms were brown and covered with moulds, and dead culms were dry and without foliage (Table 1 and Figure 2). Diameter at breast height (Dbh) was measured during the maturity classification. The culm average mean height for each sub-plot was determined using a Suunto height clinometer.

The data were organised using Excel spreadsheets and a fifth category, suppressed (SU), was introduced for culms with a Dbh less than 1 cm. The data were analysed using the Statistical Package for the Social Sciences (SPSS) Programme (Version 22). The culm stocking data for each plot were segregated into the five maturity classes, and the percentage proportion of each class was calculated. The plot stocking means were applied to calculate the average stocking for each maturity class in the three study sites. The culm mean heights for plots were determined in the field. The mean height of the culms for each of the study sites was calculated as the average of the plot mean heights in the study area. Muchiri and Muga (2013) obtained the respective figures for the Aberdare ecosystem from a study. The mean, standard deviation and standard error of Dbh were calculated for the four study sites, and significant differences in these parameters within maturity classes and ecosystems were tested at the 95 % confidence level using sample plot means.

Table 1. *Oldeania alpina* culm maturity classes

Code	Description	Explanation
S	Shoots	Emerging and without leaves
SU	Suppressed	Young or mature, but with a Dbh of less than 1 cm
Y	Young	Green in colour, but leaves not yet developed
M	Mature/ Old	Brown in colour, and with leaves and branches
O		Greyish in colour, with mould on the culms. Leaves are still green
D	Dead	Greyish in colour, with mould on the culm. Leaves are dry or completely dropped

Figure 2. Mature *Oldeania alpina* culm (left), young culm (centre) and old culm (right).

2.3 Estimation of carbon stock and carbon conversion to CO_2

Wood carbon density is usually calculated as 50% of the tree oven dry biomass (Basuki et al, 2009), while that of bamboo is 47 % (Bao and Trinh, 2019), but direct estimation of biomass is time-consuming, expensive and destructive (Rowell, 1984). This has resulted in the use of allometric equations to estimate biomass. The equations are developed by establishing a relationship between the various physical parameters of the trees, including the diameter at breast height, height of the tree trunk, total height of the tree, crown diameter and tree species. The developed equations give estimates of biomass for specific sites and regions. A study by Muchiri and Muga (2013) developed allometric equations for estimating *O. alpina* culm biomass to a length top diameter of 2.5 cm. In this study, the *O. alpina* culm biomass was estimated to a culm length top diameter of 2.5 cm by applying the following equations:

$W = -1.11 + 0.36 D^2$ ……………………………….. *Equation 1*

where W = culm merchantable green weight (kg), D = culm Dbh (cm).

$ODW = 1.04 + 0.06(Dbh*gw)$……………………….*Equation 2*

where ODW = culm merchantable oven dry weight (kg), Dbh = diameter at breast height (cm) and gw = green weight (kg).

Analysis of 225 bamboo culms from 25 plots in the Kiandongoro Forest Station, the Aberdare ecosystem (Muchiri and Muga, unpublished data) showed that the biomass of an *O. alpina* culm portion above 2.5 cm diameter and with foliage (leaves and branches) accounts for 17.5 % of the culm biomass portion to the top diameter of 2.5 cm. The total aboveground biomass of a culm was obtained by multiplying its culm biomass up to a length of 2.5 cm diameter by 1.175. The plots' aboveground bamboo biomasses were obtained by adding the individual culm aboveground biomass. Plot means for each ecosystem were calculated and applied to estimate the aboveground carbon stock ha^{-1} for each respective ecosystem, as shown below:

$C = B \times 0.475)$ ----------- *Equation 3* (Magnussen and Reed, 2004)

where C = carbon stock ha^{-1}; B = biomass ha^{-1}, 0.475 = conversion factor of *O. alpina* biomass to carbon stock

The total aboveground carbon stock for an ecosystem was calculated by multiplying the ecosystem's mean aboveground carbon stock ha^{-1} by its bamboo forest area.

The morphological characteristics of an *O. alpina* culm are close to those of *Oxytenanthera abyssinica,* and the results of a study in Western Ethiopia (Gurmessa, 2016) showed that the belowground carbon stock of the latter was 20% of aboveground carbon stock. The total carbon stock of *O. alpina* culms in this study was therefore calculated as 120% of the aboveground carbon stock. The total carbon stock ha^{-1} in an ecosystem was obtained by multiplying its plot means by the respective stocking density. The culm total carbon stock in an ecosystem was calculated by multiplying its carbon stock $ha^{-1}$by its bamboo forest area. The total carbon stock for the country was obtained by summing up the individual ecosystem values.

Carbon conversion to CO_2: C=3.67 CO_2

2.4 Bamboo management practices

A questionnaire (Appendix 1) was designed and administered to various stakeholders in the bamboo sector to obtain information on current management practices. Based on this information, literature review and the consultants' experience and knowledge, a SWOT analysis was carried out.

3. Results and discussion

3.1 Sample plots location

A total of 43 sample plots (Table 2) were established and enumerated in the three ecosystems studied. The information for the Abedare plots was extracted from a study by Muchiri and Muga (2013). All the plots were located at elevations between 2,232 to 2,752 m above sea level, which is within the range (2,200–3,500 masl) for natural bamboo forests in East Africa (Scribd Inc., 2018).

Table 2. Geographic location of the sample plots

Ecosystem	County	Forest station	E	N	Altitude, m
Mt Elgon	Trans Nzoia	Kiptogot	03444426	0108526	2520
		Kimothon	03446639	0106036	2485
		Kimothon	03443622	0106092	2501
		Kimothon	03444144	0106377	2433
Mt Kenya	Tharakanithi	Chogoria	037506279	0251172	2232
			037498125	0245314	2306
			037491793	0231874	2366
			037491289	0232315	2553
			037490826	0229154	2553
			037490826	0228813	2366
Mau	UasinGishu	Lorenge	03527456	360773602(UTM)	2752
	Baringo	Kiptuget	03543386	360803128(UTM)	2933
			03543167	360802724 (UTM)	2930
			03542705	360801862 (UTM)	2930
	Nakuru Nakuru	Logoman	03553764	0028164	2673
			03553758	0028141	2672
			03553785	0028151	2658
Aberdares	Kiambu	Kieni	03641920	00 51750	2467
		Kieni	03641920	00 51782	2479
		Kieni	03641227	00 51817	2459
		Kieni	03643135	0051796	2401
		Kieni	03641239	0051807	2460
		Kieni	03641136	0051776	2484
		Kieni	03640270	0051464	2509
		Kieni	03640299	0051447	2511
		Kieni	03640295	0051441	2521
		Kieni	03640596	0051258	2537
		Kieni	03640525	0052306	2516
		Kieni	03640556	0052403	2543
		Kieni	03640476	0052449	2553

		Kinale	03640449	0052526	2552
		Kieni	03640238	0052541	2566
		Kieni	03640136	0052550	2517
		Kinale	03640128	0052610	2540
		Kieni	03640390	0052619	2562
		Kieni	03640013	0052599	2566
		Kieni	03639893	0052643	2558
		Kamae	03638122	0050872	2612
		Kamae	03638171	0050903	2611
		Kamae	03638223	0050921	2643
		Kamae	03638265	0050908	2622
		Kamae	03638291	0050866	2628

3.2 Stocking density and diameter of culms

The bamboo culm mean density ha^{-1} in Mt Elgon, Mt Kenya and Mau was 34,634, 35,496 and 18,711 culms, respectively (Table 3 – dead culms are not included). The respective mean density in the Aberdares was 19,159 culms, derived from 25 plots (Table 2). Bamboo stocking density is higher in Mt Kenya and Mt Elgon than in the Aberdares and Mau. Stocking density was lowest in the Aberdares because of the occasional removal of bamboo culms for use in horticulture-related activities, the major economic enterprise in this ecosystem. The other probable reason is that the culms have larger Dbh than in the other ecosystems. Stocking in Mau was low because the local community cuts bamboo culms for domestic use and to open areas for livestock grazing.

Table 3. Stocking density of *O. alpina* in Kenya

Ecosystem	Number of plots	Maturity class	Number of culms ha^{-1}	Proportion, %
Mau	8	Dead	5,026	21
	8	Mature	17,367	73
	8	Young	1,344	6
	8	All classes	23,736	100
Mt Kenya	6	Dead	6,502	15
	6	Mature	17,184	40.9
	6	Suppressed	2123	5.1
	6	Young	16,919	40
	6	All classes	41,998	100

Mt Elgon	4	Dead	6,668	16
	4	Mature	11,943	29
	4	Suppressed	3,881	9
	4	Young	18,810	46
	4	All classes	41,401	100
Aberdares	25	Dead	1,757	8
	25	Mature	17,088	82
	25	Young	2,071	10
	25	All classes	20,916	100

The culm mean density ha^{-1} in Mt Kenya, Mt Elgon and Cherang'any, the Aberdares and Mau were 35,496, 34,634, 34,634, 19,159 and 18,711, respectively. The proportion of mature bamboo culms was 82% in the Aberdares, 73% in Mau, 41% in Mt Kenya and 29% in Mt Elgon. The reason for the high proportion of mature culms in the Aberdares and Mau is that the two ecosystems are not as affected by fire compared to the others. The proportion of the young culms, which reflects the stands' regeneration potential, was 8 % in Mau, 10 % in the Arberdares, 40 % in Mt Kenya 40% and 45 % in Mt Elgon. The average annual regeneration was 25.75 %. No suppressed bamboo culms were detected in Mau and the Aberdares, compared to 2 % in Mt Kenya and 9 % in Mt Elgon. The reason for the non-existence of suppressed culms in Mau and the Aberdares is that stocking was lower than in Mt Kenya and Mt Elgon

The proportion of dead culms was 8 % in the Aberdares, 15 % in Mt Kenya, 16 % in Mt Elgon and 21 % in Mau (Table 3). The high proportion of dead bamboo in Mau is because bamboo in this area occupies rugged steep terrain with very poor access roads, and no enterprises require bamboo culms. Another reason is that the local community had cut bamboo culms to open areas for livestock grazing. The existence of substantial amounts of dead culms in Mt Kenya and Mt Elgon is a result of occasional fires and the lack of enterprises that require dead culms.

The culm mean Dbh ranged from 1.7 cm in Mt Kenya to 5.3 cm in the Aberdares (Table 4). Significant variations ($P<0.05$) were detected in culm Dbh within maturity classes and among ecosystems (Table 4). The large size of mature culms in the Aberdares may be attributed to selective removal of the dead culms, as already mentioned, and other factors, including climate and site conditions.

Table 4. Diameter (Dbh) of *O. alpina* culms in Kenya

Ecosystem	Maturity Class	Mean	N	SD	SEM	Min	Max
Mau	Dead	3.738	101	1.0280	.1023	1.3	6.7
	Mature	3.949	348	1.4808	.0794	1.1	8.7
	Young	3.685	27	2.1910	.4217	1.3	7.1
	All classes	3.881	477	1.4564	.0667	1.1	8.7
Mt Kenya	Dead	2.116	96	.5693	.0581	1.0	3.5
	Mature	1.930	257	.6033	.0376	1.0	3.3
	Suppressed	.795	37	.1026	.0169	.5	.9
	Young	1.549	239	.3159	.0204	1.0	2.7
	All classes	1.747	629	.5819	.0232	.5	3.5
Mt Elgon	Dead	2.138	65	1.1748	.1457	1.0	6.9
	Mature	2.569	120	1.1355	.1037	1.1	5.4
	Suppressed	.607	40	.2485	.0393	.2	.9
	Young	1.921	189	.6458	.0470	.1	4.2
	All classes	2.016	414	1.0338	.0508	.1	6.9
Aberdares	Dead	5.2	18	-	-		-
	Mature	5.3	150	0.75	0.1	3.3	7.4
	Suppressed	-	-	-	-		-
	Young	5.2	69	1.0	0.1	2.8	7.0
	All classes	5.3	237				

3.3 Oven dry weight

The culm mean oven dry biomass to top height of 2.5 cm varied from 1.00 kg for the suppressed class to 4.9 kg for the mature class (Table 5).

Table 5. Oven dry biomass of *O. alpina* culms up to a height of 2.5 cm diameter

Ecosystem	Maturity class	Stem oven dry biomass, kg
Mau	Dead	1.92
	Mature	2.10
	Young	1.88
Mt Kenya	Dead	1.10
	Mature	1.06
	Suppressed	1.00
	Young	1.01
Mt Elgon	Dead	1.10
	Mature	1.24
	Shoot	1.01
	Suppressed	1.00
	Young	1.07
Aberdares	Dead	4.6
	Mature	4.9
	Young	2.3

3.4 Biomass and carbon stock

The mean carbon stock calculated from the data in Table 6 is 38.25 tonnes ha^{-1}. The biomass and carbon stock of *O. alpina* in the Aberdare ecosystem was the highest with 59.28 t C/ ha, even though the culm density is more than double that of Mt Kenya, Mt Elgon and Cherang'any 24.57 tC ha^{-1}, 25.99 tC ha^{-1} and 25.99 tC ha^{-1} respectively (Table 6). The reason is that the size of culms (Dbh) in the Aberdares was almost double that in the other ecosystems. The number of dead culms in the Aberdares was also between one-fourth and one-third of that in the other ecosystems (Table 7). Thus, removal of dead and selective cutting in the Aberdares enhanced the diameter growth of the remaining stock. As most of the ecological factors are similar in these ecosystems, one possible explanation is that the size of the bamboo culms and carbon stock can be substantially improved by selective cutting and maintaining a stocking level of about 20,000 culms ha^{-1}.

Table 6. Biomass and carbon stock of *O. alpina* in five ecosystems in Kenya

Ecosystem	Maturity class	Forest area, ha	Culms ha^{-1}	Above-ground biomass, tonnes ha^{-1}	Above-ground carbon, tonnes ha^{-1}	Below-ground carbon, tonnes ha^{-1}	Total carbon, tonnes ha^{-1}	Total carbon, tonnes
Mau	Mature	30,193	17,367	42.9	20.3775	4.0755	24.453	738,309.43
	Young	30,193	1,344	3	1.425	0.285	1.71	51,630.03
	Total	**30,193**	**23,737**	**45.9**	**21.8025**	**4.3605**	**26.163**	**789939.459**
Mt Kenya	Mature	25,966	17,184	21.4	10.165	2.033	12.198	316,733.27
	Suppressed	25,966	2,123	2.5	1.1875	0.2375	1.425	37,001.55
	Young	25,966	16,189	19.2	9.12	1.824	10.944	284,171.90
	Total	**25,966**	**41,998**	**43.1**	**20.4725**	**4.0945**	**24.567**	**637906.722**
Mt Elgon	Mature	18,893	11,943	17.4	8.265	1.653	9.918	187,380.77
	Suppressed	18,893	3,881	4.6	2.185	0.437	2.622	49,537.45
	Young	18,893	18,810	23.6	11.21	2.242	13.452	254,148.64
	Total	**18,893**	**41,302**	**45.6**	**21.66**	**4.332**	**25.992**	**491066.856**
Cherang'any	Mature	8,180	11,943	17.4	8.265	1.653	9.918	81,129.24
	Suppressed	8,180	3,881	4.6	2.185	0.437	2.622	21,447.96
	Young	8,180	18,810	23.6	11.21	2.242	13.452	110,037.36
	Total	**8,180**	**41,302**	**45.6**	**21.66**	**4.332**	**25.992**	**212614.56**
Aberdares	Mature	50,038	17,088	98.4	46.74	9.348	56.088	2,806,531.34
	Young	50,038	2,071	5.6	2.66	0.532	3.192	159,721.30
	Total	**50,038**	**20,916**	**104**	**49.4**	**9.88**	**59.28**	**2966252.64**
Kenya	**Total**	**133,273**						**5,097,780.24**

Table 7. Carbon in dead culms

Ecosystem	Maturity class	Forest area, ha	Culms ha^{-1}	Above-ground biomass, tonnes ha^{-1}	Above-ground carbon, tonnes ha^{-1}	Below-ground carbon, tonnes ha^{-1}	Total carbon, tonnes ha^{-1}	Total carbon, tonnes
Mau	Dead culms	30,193	5,026	11.3	5.4	1.1	6.5	195,157.80
Mt Kenya	Dead culms	25,966	6,502	8.4	4	0.8	4.8	124,382.00
Mt Elgon	Dead culms	18,893	6,668	8.6	4.1	0.8	4.9	92,811.50
Cherang'any	Dead culms	8,180	6,668	8.6	4.1	0.8	4.9	40,184.10

Aberdares	Dead culms	50,038	1,757	9.5	4.5	0.9	5.4	270,858.40
Kenya	**Total**	**133,273**						**723,393.80**

3.5 Climate change mitigation potential of *Oldeania alpina* bamboo forest in Kenya

Bamboo has good potential for climate change mitigation because it is a good carbon sink and has a high rate of carbon dioxide removal. Table 8 shows that the *O. alpina* mean carbon stock varies from 24.567 to 59.28 tonnes C ha^{-1} (90.16 to 217.56 tonnes CO_2 ha^{-1}). The carbon storage is high when compared to a 9- or 10-year-old Moso bamboo (*P. pubescens*) plantation in China (25 to 32 tonnes ha^{-1}) (Lou et al, 2010). The mean aboveground carbon, at 38.0 tonnes C ha^{-1}(calculated from the results in Table 8), is much lower than for a 4-year-old bamboo plantation (*B. vulgaris, B. balcooa* and *B. cacharensis*) (61.1tonnes C ha^{-1}) in India (Nath et al, 2009) and *O. alpina i*n Ethiopia (Teshoma 2019) (72.3 t C ha^{-1}). This is understandable, as the bamboo forests in Kenya are unmanaged, so the stands contain many dead and suppressed culms, which lead to low carbon storage in bamboo forests.

According to Tran (2010), the cutting cycle of some species of the *Dendrocalamus* family in Vietnam is one or two years, depending on cultivation levels. . In India, a three or four year cutting cycle is recommended for common bamboo species according to Negi and Naithani (1994). If a one-year cutting cycle is applied, 30% of the total number of bamboo culms can be harvested, whereas a percentage of 40% is recommended for a two-year cutting cycle The harvested bamboo biomass will be replaced by new culms within the same year; thus, the biomass and carbon stock of the bamboo ecosystem will be stable. *Oldeania alpina* generates annually; therefore, we recommend a one-year harvesting cycle with a removal fraction of 30% of the culms. Thus, the estimated annual aboveground bamboo stock removal is between 6.1 and 14.8 tCha^{-1}. Total bamboo biomass can be taken out annually is 2,711,585 t biomass or 1,274,445 t C (Table 9).

Table 8. *Oldeania alpina* aboveground carbon stock removal in Kenya for product development

Ecosystem	Forest area, ha	Culms ha-1	Aboveground carbon tC ha^{-1}	No. of Culms harvested / ha	Annual aboveground carbon removal, tC ha^{-1}	Total above-ground carbon removal tC
Mau	30,196	23,737	21.80	7,121	6.54	197,485
Mt Kenya	25,966	41,998	20.47	12,599	6.14	159,477
Mt Elgon	18,893	41,302	22	12,391	6.5	122,767
Cherang'any	8,180	41,302	22	12,391	6.5	122,767
Aberdares	50,038	20,916	49.4	6,275	14.8	741,563
Kenya	133,273					1,274,445

The lifecycle of bamboo culms is short, between 5 and 10 years (Lou et al., 2010). Under normal condition, harvested or dead bamboo culms will release carbon to the atmosphere in few years through burning and/or decomposing. However, the bamboo carbon sequestration potential can be improved by making durable bamboo products, including construction and building materials, furniture, and laminated panel, strand woven and other engineered products, (Düking et al, 2011; Liese, 2009). These products can contribute significantly to the economic and social well-being of remote rural people who are mainly involved in the manufacturing process. Importantly, carbon will be locked into these durable products, which can last for 30 years or more (Van der Lugt et al, 2018)

Scenario 1: Harvested bamboo biomass is value-added into durable products; based on experience from bamboo processing in China, 40 % of the bamboo biomass and/or carbon can be locked into durable products. Annual carbon locked into durable products will be 509,778 tC/year. Over the period of 30 years, carbon storage in bamboo products will be 15,293,341 tC (56,126,560 t CO_2)

Using bamboo as bioenergy also has good potential and can result in a reduction of deforestation caused by supplying household energy (INBAR, 2014). Reducing deforestation will, in turn, increase forest carbon and carbon sequestration. Thus, expansion of the bamboo sector, coupled with the production of broad durable products, will greatly contribute to climate change mitigation. Converting bamboo biomass into biochar also has great potential to store carbon in the soil.

Harvesting of mature culms for product manufacturing creates space for coppicing of new culms that grow faster, thereby enhancing carbon sequestration. Most importantly, the waste generated from value-addition or industrial processing can be further value added into bio-energy and bio-char.

Scenario 2: Harvested bamboo is used for gasification for electricity production. The gasification of 1 kg of dry bamboo produces 0.72 kWh/kg dry bamboo plus approximately 0.1 kg of charcoal (Van der Lugt et al, 2018). A total biomass of 2,711,585 kg can produce 1,952,341 kWh of electricity and 271,158.5 kg of biochar. If the generated electricity can be used as a substitute for grid electricity in Kenya, where the grid emission factor is 0.599 kg CO_2/kWh, then the emission savings from bamboo biomass energy will be 1,169,452 t CO_2 per year. Together with carbon emission savings from biochar (271,158.5 t/C equal to 995,152 tCO_2), the total annual carbon emission reductions from using bamboo biomass would be 2,164,604 tCO_2

3.6 Current status of bamboo management

No consistency yet exists on the legal status, definition or classification of bamboo in the laws and policy frameworks in Kenya. Bamboo is classified as 'indigenous forests', 'grass' and 'cane' in different statutes. Forests are classified in three categories: public forest, community forest and private forest (Constitution of Kenya, 2010), and an additional category, 'indigenous forests', which enables maintenance and conservation (including sustainable production of wood and non-wood products of indigenous forests within the jurisdiction of the local authority). Bamboo forests are found mainly in 'indigenous forests' in the five major water towers of Kenya and are under strict control. The management focus is conservation and protection under strict control of the KFS (Oduor et al, 2018). A 'presidential ban' has been placed on harvesting and transportation of bamboo, and this has continued to hamper development of the bamboo sector. However, controlled harvesting of bamboo occurs through a special user licence or harvesting permit that has, so far, been issued to one company, Bamboo Trading Company Limited (BTCL). Transportation of bamboo does not require proof of origin if it is less than one tonne or one m^3.

The draft National Forest Policy (2015) lacks synchronisation of different laws and policy guidelines in relation to bamboo management and utilisation; however, it recognises the role of bamboo forests in the protection of water catchments. It also has provisions for 'Joint

Management Agreement' or Special User Rights for the private sector. Community Forest Associations (CFA) close to bamboo forests provide mechanisms to promote investments in forestry activities, including sustainable utilisation of bamboo (Oduor et al, 2018).

Natural bamboo forests in Kenya have not been managed or harvested for several years, resulting in congestion, poor regeneration, incidences of diseases and fire. The bamboo in the general plantation areas is also not managed. The silvicultural management of bamboo is based on its growth habit, and particularly the way the underground rhizome develops and leads to the formation of culms. Effective management involves systematic selective cutting of mature culms, thereby harvesting a crop that is valuable and useful (Kigomo, 2007). Field observations showed that removal of dead, old and mature culms, either by harvesting or fire, improved bamboo growth vigour or allowed regeneration of new shoots. The improved growth vigour and the offshoot of new shoots increase the carbon sequestration potential.

Kenya has a history of restricted utilisation of its indigenous bamboo for industrial purposes, although the Mt Kenya Ecosystem Management Plan (2010–2019) and the Aberdares Ecosystem Management Plan (2010–2019) provide for the development of bamboo resources (Oduor et al, 2018). The plans indicate that bamboo dies after it attains biological age and the resulting accumulation of the dry dead material is a recipe for forest fires, which are very difficult and expensive to control. The two management plans noted the high rate of bamboo regeneration and that controlled exploitation does not have any negative impact on ecosystem conservation values.

Results of questionnaires administered and interviews with bamboo sector stakeholders in this study revealed an absence of management practices for the indigenous bamboo forest in Kenya, apart from the general protection for soil and water conservation and minimal planting to rehabilitate degraded areas.

3.7 Key players/actors/stakeholders dealing with natural bamboo

The key players/actors/stakeholders and their roles are presented in Table 9 and in Appendices 2 and 3.

Table 9. Key players/actors/stakeholders dealing with natural bamboo in Kenya

Stakeholder /Actor	Roles/activities
Communities	• Protection • Utilisation of bamboo for construction, fodder, energy and shoots for food • Processing of various bamboo products and trading
Ministry of Environment and Forestry	• Policy
National Environmental Management Authority	• Oversee conservation and management of bamboo resources
Kenya Forest Service	• Protection against human activities • Rehabilitation of degraded areas • Control of fires • Licensing • Extension and education
Kenya Forestry Research Institute (KEFRI)	• Undertake research on natural bamboo in areas related to product development, agronomy, environmental conservation, socio-economic issues • Training entrepreneurs and farmers on bamboo growing, processing and product development
Kenya Wildlife Service (KWS)	• Protection • Feed for wildlife • Control of fires
Kenya Water Towers Authority	• Protection
Entrepreneurs and NGOs	• Support both small and large reforestation programs involving local community groups and farmers. These include: • Bamboo propagation • Ecosystem Rehabilitation • Environmental Education • Ecotourism

	• Training in bamboo processing • Bamboo processing mainly for handicrafts and furniture • Fostering democratic space and sustainable livelihoods
Farmers	• Bamboo propagation • Bamboo processing mainly for handicrafts and furniture • Planting bamboo as an alternative crop and enhancing livelihoods to tobacco small-holder farming
Universities, including: The Cooperative University of Kenya, Maseno, South Eastern, Eldoret, Karatina, Egerton	• Research, education and extension

3.8 Benefits derived from natural bamboo forest

The benefits derived from the natural bamboo forest involved economic importance and environmental conservation (Table 10).

Table 10. Economic and environmental benefits from the current management practice on natural bamboo forest

Ecosystem	Economic	Environmental
Mt Elgon	Forest-adjacent communities use bamboo for construction, fodder, energy and shoots for food	• Protection of catchment areas • Climate change mitigation('carbon sink', soil conservation)
Mt Kenya	• Tourism • Acts as an indicator that the area is conducive for bamboo growing • If promoted, a bamboo industry can thrive in the region	• Preservation of the water catchment • Climate change mitigation ('carbon sink', soil conservation)
Mau	• Cottage industry, fencing, horticulture	• Water catchment protection • Soil and water conservation

	• Conserve water sources and Lake Victoria because the Nyando River drains into the lake	• Carbon sink • Wildlife habitat
Aberdares	• Tourism • Acts as an indicator that the area is conducive for bamboo growing • If promoted, a bamboo industry can thrive in the region	• Preservation of the water catchment • Climate change mitigation ('carbon sink', soil conservation)

3.9 SWOT analysis

The results of a SWOT analysis showing that sustainably managing natural bamboo forests enhances economic development and environmental conservation are presented in Table 11.

Table 11. SWOT analysis of sustainably managing natural bamboo forests to enhance economic development and environmental conservation

Strengths	Weaknesses
• Existence of large areas of undisturbed bamboo forests of O. *alpina* with high stocking of 21,000–42,000 culms ha^{-1} • Existence of draft guidelines on harvesting and management of indigenous bamboo in Kenya • KEFRI and other actors have capacity and experience in bamboo handicraft and furniture making • Urban people are relatively aware of the value of bamboo products • Products made from natural material similar to bamboo are already being sold in Kenyan markets • High return on investment in bamboo • Exposure of a good number of stakeholders and staff of the Ministry of Environment and Forestry (ME&F), KEFRI and KFS to advanced technology for	• Bamboo resources in government forests are not managed due to lack of management and harvesting prescriptions and are therefore of poor quality • More than 99% of bamboo resources are under government control, and getting a licence for harvesting or a movement permit is cumbersome • Multiple payment of cess fees for a single load of bamboo across counties is costly and discouraging to entrepreneurs • Inadequate technology in harvesting and processing of bamboo in the country • Inadequate information and awareness on benefits and demand for bamboo services and products • Very weak forward and backward linkages of the enterprises (Enterprises are standalone) • Low investment capacity and business literacy among entrepreneurs

processing and utilisation of bamboo in China • Willingness by KFS to develop a National Programme for Bamboo • Bamboo is clearly mentioned in the draft Forest Policy as a priority species for promotion for growing on farms and plantations and for charcoal and energy production and increased forest cover • Ongoing evaluation of various properties of *O. alpina* in China will provide useful information on potential uses • Bamboo can be used for rehabilitation of degraded sites for water and soil conservation	• Poor accessibility in the areas hosting natural bamboo • Inadequate funding for facilitation of bamboo research and development • Inadequate technical knowhow for bamboo processing research • Undeveloped/poor market/trade linkages • Poor coordination among different stakeholders in bamboo research and development in the country • Inadequate policy and legislation on bamboo management and utilisation • Limited government support programmes • Inadequate skilled human resources for processing of bamboo in construction at local and regional levels • Bamboo is susceptible to borers requiring treatment • No standards on utilisation of bamboo • Farmers solely depend on one or two companies
Opportunities	**Threats**
• Total trade values of in bamboo products reached USD 60 billion in 2017 • A lot of interest in commercialisation of production and utilisation of bamboo by the private sector and farmers • Generation of employment opportunities at local level • Tourism industry offers large scope for construction of ecotourism resorts • Kenya Vision 2030, which is the government development blueprint, has identified bamboo development as one of the flagship projects, thus elevating the status of bamboo among the government priorities • Forest Policy 2014 calls for diversification of species range outside the traditional forest plantation species • The Forest Conservation and Management Act 2016 has identified bamboo as one of the key species that should be promoted • KFS is promoting development of the bamboo value chain through issuance of licences and encouraging farmers and	• There is a belief that unmanaged bamboo forest is a habitat for poisonous snakes • Cheap and fancy products made from plastic can overtake the market for bamboo handicrafts and furniture • Forest fires can wipe out bamboo stock • Illegal extraction leads to unsustainable bamboo forest management • Import of comparatively cheaper bamboo products from abroad (especially Asia, with its advanced technologies)

private organisations to invest in bamboo development • Local research and development of appropriate technologies for bamboo re-stocking, management, processing, chemical treatment and utilisation (e.g. KEFRI & JKUAT) • Entrepreneurial opportunities based on new products from bamboo, such as timber, fuel, food, pulp, beverages, clothing, bags to replace plastic bags and carbon trade • Job opportunities, especially for the youth, across the bamboo value chain • Climate change mitigation, adaptation and carbon trade • Provisions for a Joint Management Agreement or Special User Rights for the private sector; Community Forest Associations (CFA) for communities close to bamboo forests are mechanisms to promote investments • 'Forest Management and Conservation Fund' and 'Water Tower Funds' when fully operationalised	

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4. Conclusions and recommendations

4.1 Conclusions

This study on bamboo biomass and carbon stock in Kenya was conducted in rich bamboo regions in Kenya. A total of 43 circular plots were established in four regions: Mau, Mt Elgon, Mt Kenya and the Aberdares. The data collected in Mt Elgon were adopted for estimation of carbon stock in Cherang' any because the two regions are similar. The result shows that more than 5 million tC is present in bamboo forests in the five regions.

The potential for carbon emission reductions by *O. alpina* is very high. If bamboo forests are sustainably managed for durable product development or biomass energy, the annual carbon emission reductions can reach approximately 2 million tCO_2/year.

Bamboo forests are currently not managed; consequently, they are in very poor condition and contain a high proportion of dead and mature culms. Culm density is very high in some regions, which results in a high proportion of suppressed culms.

4.2 Recommendations

- Bamboo forests should be brought to management to make use of the potential of bamboo for climate change mitigation and socio-economic development. All dead culms, suppressed culms and 20–40 % of the mature culms should be removed. This will help prevent fire and diseases, while simultaneously stimulating the regeneration of healthy culms.
- Trial plots should be set up to study the annual carbon sequestration, harvesting cycle and harvesting volume of different management practices of bamboo forests.
- The government should undertake a national inventory of *O. alpina* and determine its carbon storage potential.
- The capacity of key stakeholders should be built up for production, management and utilisation of bamboo.
- The Government should lift the unofficial ban on harvesting of bamboo and provide policies and legislation on inclusion of *O. alpina* in national development.

- The Government should finalise and implement a National Bamboo Strategy and Action Plan.

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Appendix

Appendix 1: Bamboo Management Practices Questionnaire

KENYA FORESTRY RESEARCH INSTITUTE

Tel: +254 20 2010651/2
+254 722 157 414
+254 724 259 781/2
+254 734 251 888
Email: director@kefri.org

P.O Box 20412
00200, Nairobi
Kenya

Bamboo management practices Questionnaire

Name of respondent:____

Telephone No:____

Email address:____

Institution: ____

County: ____

Date:____

Objective:

Report on bamboo management practices to identify best practice, benefits derived from the best practices in terms of economic and environmental factors

1. What are the current management practices of natural bamboo forests in Kenya/your region?

2. Who are key players/actors/stakeholders dealing with natural bamboo in Kenya and what are their roles?

Stakeholder /Actor	Roles/activities

3. What are the key activities undertaken by KFS, Communities and Entrepreneurs in natural bamboo forests in Kenya/your region?

Organisation	Key activities
KFS	
Communities	
Entrepreneurs	

4. Does KFS have any management prescriptions for natural bamboo forests in Keya/your region?

5. What are the economic benefits derived from the current management practice on natural bamboo forest in Kenya/your region?

6. What are the environmental benefits derived from the current management practices of natural bamboo forest in Kenya/your region?

7. Are there costs of managing natural bamboo forest in Kenya/your region? If yes, list.

8. What are the challenges of managing natural bamboo forest in Kenya/your region?

9. Are there any risks associated with management of natural bamboo forest in Kenya/your region?

10. Are there opportunities for involving communities and entrepreneurs in managing natural bamboo forest in Kenya/your region?

11. What are the best practices suitable for sustainable managing of natural bamboo forests that promote economic and environmental interests in Kenya/your region?

12. Are there NGOs participating in natural bamboo forest activities Kenya/your region?

Name of NGO	Activity

13. State any recommendations on cost-effective and sustainable best practices on the landscape scale.

Appendix 2: Contacts of the organisations consulted

Name, Location and Contact	**County**	**Type of Organisation**	**Key Interests**
Tiriki Tropical Gardens and Farm Shamakhokho Market	Vihiga	Social enterprise	• Bamboo propagation • Growing bamboo • Bamboo processing • Training in bamboo processing • Rehabilitating degraded areas
Eco Green	Busia	Community Based Organisation	• Ecosystem Rehabilitation (ER) • Environmental Education (EE) • Ecotourism (ET) Consultancy • Non Timber Forest (NTFP) Products • On farm bamboo farming
Waterstone Resource Fibre, Ngong Road, Karen,	Nairobi	This is a subsidiary of Waterstone Norway based in Kenya	• Supports the production and sustainable use of bamboo along the whole value chain – from certified seedlings to advanced industrial bamboo products, such as furniture and flooring, panels and countertops • Supports both large and small afforestation and reforestation programmes involving local community groups and farmer cooperatives
Nyabera ICL Awendo	Migori	An Agronomy investment	• Bamboo propagation • Growing bamboo • Vision of having a bamboo workshop to offer training • Promoting bamboo in land rehabilitation
Elegance Bamboo Ventures, Donholm	Nairobi	Enterprise	Making handicrafts and furniture from bamboo
MadoyaTumaini Youth Group Huruma,	Nairobi	Enterprise	Making handicrafts and furniture from bamboo
Kenya Bamboo Centre, Jamuhuri	Nairobi	Enterprise	Making handicrafts and furniture from bamboo
Comboni Catholic Sisters Karen	Nairobi	Enterprise	Bamboo culm production

Kitil Farm	Kajiado		• Grow and sell bamboo seedlings on 2 acres • Sell culms • Has a breeding laboratory
Kuria Bamboo Farmers' Cooperative Society Manager Mr. Tegere Gimonge Tel. 0710724339			• Started planting bamboo (*Dendrocalamus giganteus* and *Bambusa vulgaris,* among other species) in 2008 • Bamboo as an alternative crop (20 clumps per farmer) • Enhancing livelihoods of tobacco small-holder farmers • They have established Bamboo Nurseries • Bamboo on farming mostly on land edges • Bamboo species planted
Homa Bay Bamboo Farmers Cooperative Society, Limited	Homa Bay	Cooperative Society	• Planting bamboo as alternative crop and enhancing livelihoods to Tobacco Small holder farming • Bamboo handicraft making
Migori Bamboo Farmers Cooperative Society Limited	Migori	Cooperative Society	• Production of bamboo as alternative crop • Enhancing livelihoods to Tobacco Small holder farming
Suba Bamboo Farmers Cooperative Sindo Market, Suba	Migori	Cooperative Society.	• Production of bamboo as alternative crop • Enhancing livelihoods to Tobacco Small holder farming
The Bamboo Trading Company	Kiambu and Nyandarua	Company	• Involved in sustainable bamboo harvesting and utilisation (*Oldeania alpina)* of bamboo chips and culms for biomass energy
Farmers	UasinGishu, Busia, Siaya, Bungoma, Nyeri, Kiambu, Kakamega,	Famers.	Growing various bamboo species on farms
Global bamboo solutions	Kisii	Farmer	5000 seedlings of *Bambusa vulgaris* and *Dendrocalamus giganteous*

Green Pot Enterprise	Narok, Bomet and TharakaNiithi	An integrated bamboo company, On farm bamboo *Dendrocalamus asper* and has a bamboo nursery	• Establishment of bamboo plantations • 100 acres of *Dendrocalamus asper* and *Oldeania alpina* • Plans to set a number of factories in diverse parts of the country to produce various bamboo products
The Green Belt Movement	Nairobi	NGO	• Promote environmental conservation • Build climate resilience and empower communities, especially women and girls • Foster democratic space and sustainable livelihoods • Promotion of bamboo planting in Muranga County
Climate Change Mitigation Initiative	Embu	NGO	• Introduce bamboo production in Kirinyaga County. • Use bamboo for soil conservation, water retention and as a 'carbon sink' • Enhance livelihood opportunities through bamboo production, processing and utilisation.

Appendix 3: Key people interviewed

Name	Designation	Institution	County	Telephone contact	Email address
Nicodemus Mwatika	Ecosystem Conservator	Kenya Forest Service	Trans Nzoia	0721357392	nmwatika@yahoo.com
Simon Kinyanjui	Forester, Komothon	Kenya Forest Service	Trans Nzoia	0720344736	simukinya@gmail.com
Lawrence Andati	Forester, Kiptogot	Kenya Forest Service	Trans Nzoia	0721452442	Andati72@gmail.com
Julius K. Sawe	CFA Chairman	Community Forest Association, Mau	Baringo		
Tobias Achungo	Forester, Lorenge	Kenya Forest Service	UasinGishu	0722-286872	
Paul Kipkoech	Forest Ranger, Logman	Kenya Forest Service		0724-369-578	
Harrison Wainaina	Forester, Kiptuget	Kenya Forest Service			
Mukira	Deputy Head of conservancy, Mau	Kenya Forest Service		0722-889-830	
Robert Sunya		Eco Green		0724788564	robertsunya@yahoo.com

Prof. Jacob K. Kibwage		The Coop University of Kenya		0722479061	jkkibwage@yahoo.com
Rose A. Olang		Maseno Tree Nursery, Farmers' community based organisation		0719676124	matnufo101@yahoo.com

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