STATUS AND DISTRIBUTION OF MONTANE BAMBOO IN ECHUYA CENTRAL FOREST RESERVE, S.W. UGANDA

By

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May 2013

Acknowledgements

This study was supported by ***Nature***Uganda with funds from DANIDA through Dansk Ornitologisk Forening (DOF) and implemented by the Institute of Tropical Forest Conservation (ITFC). Fieldwork was carried out by ITFC staff, namely, Christopher Byaruhanga, Narsi Owoyesigire, May Murungi and Fredrick Ssali. We are grateful to NFA staff especially Venancio Barugahare, Echuya Forest Supervisor, who hosted and guided the field team.

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Executive summary

This report is a study of the bamboo population structure, disturbance factors affecting bamboo forest regeneration and the management options for the recovery of the dwindling bamboo stock in Echuya Central Forest Reserve. The study was carried out as part of ***Nature***Uganda's Echuya Forest Conservation Project (EFCP) that aims at reconciling the needs of local people neighbouring the forest with the sustainable conservation of the forest. We used a stratified systematic sampling design of line transects laid out across the forest running in an East–West. A total of 100 circular plots were laid out along ten transects in a systematic grid at 100 m intervals. In addition, 100 larger circular plots for assessing trees associated with bamboo were also established at each sampling point.

Results show that bamboo in Echuya is "unhealthy" since most of the stems were in an old age class category. There is a also a considerably high intensity of bamboo harvesting with 33.8% of total stems having been harvested in the pure bamboo and 23.6% of total stems having been harvested in mixed bamboo forest. Tendencies of over-harvesting bamboo were observed especially in the pure bamboo where as high as 73.9% of stem counts in a sample plot were recorded as cut stems. In addition, there was a high prevalence of bamboo stem damage caused by borer infestation, woody climbers and feeding by monkeys. Tree colonization and root expansion were also a threat to the bamboo.

We recommend urgent attention to allow for the recovery of the existing bamboo stock by, among others, regulating and enforcing bamboo off-take quotas which were recommended by other researchers such as Bitariho & McNeilage (2006). We further recommend participatory review of the existing bamboo off-takes, reducing the number of harvesters at any given time, strengthening the bamboo domestication program, putting in place bamboo recovery periods of at least 4–5 years between harvests where no harvesting is allowed and banning commercial harvesting of bamboo.

Introduction

This report has been prepared by ITFC for ***Nature***Uganda in fulfilment of a contract to assess the status and distribution of bamboo in Echuya Central Forest Reserve funded through Dansk Ornitologisk Forening (DOF). ***Nature***Uganda (NU) has been implementing the Echuya Forest Conservation Project (EFCP) since 2004 with the aim of reconciling the needs of local people neighbouring the forest with sustainable conservation of the forest. National Forest Authority (NFA) with the assistance of NU has been implementing a Collaborative Forest Management (CFM) program in Echuya forest for the past eight years. The Echuya CFM program involves local people harvesting bamboo stems for livelihoods and income.

The bamboo found in Echuya forest reserve is a montane bamboo (*Yushania alpina* K. Schum.) and occurs naturally in other mountain forests in Uganda including Bwindi Impenetrable, Mgahinga, Rwenzori and Mt Elgon National Parks (Howard, 1991; Bitariho, 1999). It is a typical high altitude and tropical woody grass and occurs gregariously within mountain forests in tropical Africa (Wimbush, 1945; Kigomo, 1988; Bystriakova *et al*., 2004). The bamboo is a perennial woody grass with woody culms growing from underground rhizomes and forming clumps. It belongs to the family gramineae and sub-family bambusoideae. The bamboo is one of the fastest growing perennial plants. Once established, new bamboo shoots can attain full heights and diameters within 2-3 months and by 2-3 years are mature and strong enough to be utilised (Bystriakova *et al*., 2004).

Bamboo forest is a rare habitat and has a wide range of functions for biodiversity conservation and human well being (Kigomo, 1988; Bitariho, 1999; Embaye, 2000; Bystriakova *et al*., 2004; Sheil *et al*., 2012). For instance, it protects water catchments, prevents soil erosion and provides food for animals of global conservation concern such as mountain gorillas (*Gorilla beringei beringei*), golden monkeys (*Cercopithecus mitis kandti*) and blue monkeys (*Cercopithecus mitis*) that consume young bamboo sprouts. As well as these ecological functions, bamboo is widely used in homesteads around protected areas. It is the single-most important plant resource, with a multitude of uses including building poles, bean stakes, granaries, basketry and fuel (Bitariho, 1999). However, most national parks restrict use of bamboo by local people and this leaves

Echuya as the sole source of bamboo for both subsistence and commercial use which may deplete its dwindling bamboo stocks.

Problem statement

Bamboo stem harvesting in Echuya is as old as mankind that has lived there. The bamboo forest has always been a source of building poles, fuel wood and materials for weaving baskets and food storage granaries for the local people adjacent to the forest. The scenario in the past two decades has led to a concern by conservationists and local people alike that the bamboo forest is declining because of overharvesting caused by commercialization of the bamboo stems (e.g. Bitariho & McNeilage, 2007; Bitariho & McNeilage, 2004; Banana & Tweheyo, 2001). Moreover, bamboo harvesting is not permitted by the Uganda Wildlife Authority in other forests such as Bwindi and Mgahinga where local people used to access bamboo before the parks were created. Additionally, efforts at planting bamboo outside the forest by development organizations as a way of reducing pressure from the forest started only recently (Bitariho, 2008). This therefore makes Echuya forest to be the only source of supply of bamboo in southwestern Uganda. The implication of this is that bamboo from Echuya forest is highly demanded for both local and commercial use.

Due to overharvesting, much of the bamboo forest in Echuya forest looks ‘unhealthy’ with many old stems and few young stems. This was a different scenario some forty years ago when the bamboo looked healthier with many tall and green young bamboo stems dominating the forest (Kingston, 1968; Bitariho & McNeilage, 2007). The declining bamboo forest is a cause for concern among conservationists and development practitioners since bamboo supports biodiversity and the rural economy near Echuya. The Bamboo is consumed by blue monkeys and baboons alike in Echuya and by Mountain gorillas, golden monkeys, elephants and buffaloes in the neighboring national parks of Bwindi and Mgahinga. People use bamboo for building poles, bean-staking and basket weaving. However, harvesting bamboo from Echuya has been reported to be unsustainable due to poor harvesting methods such as clear cutting of bamboo and over-harvesting.

Taking a long-term outlook based on the ever increasing demand for bamboo for subsistence and commercial exploitation while also considering other threats including climate change, the considerable pressure exerted on the bamboo in Echuya may deplete the bamboo forest (see Bitariho & McNielage, 2004; Banana & Tweheyo, 2001). With the continuing diminishing of bamboo from Echuya forest, there is a dire need by conservationists and local people to find a long term strategy of mitigating the effects of the bamboo forest loss. This can be through determining sustainable harvest levels of the bamboo and planting of bamboo in local community homesteads. The subsequent loss of the bamboo forest from Echuya forest will not only lead to the loss of fauna and flora that depend on it but also loss of rural income for the local people that depend on it.

Studies on the status of bamboo in Echuya forest have been carried out by Bitariho & McNeilage, (2007); Bitariho & McNielage, (2004); Banana & Tweheyo, (2001). Bitariho & McNeilage (2007) established Permanent Sample Plots (PSPs) in Echuya forest and recommended an annual monitoring system of the PSPs to determine the rate of bamboo forest loss in Echuya. However due to financial constraints, no subsequent studies have been carried out in Echuya to determine the status of bamboo in Echuya and therefore determine the rate of bamboo loss. Little information is currently available on the status of bamboo in Echuya upon which NFA can base its actions to better manage bamboo in Echuya Forest Reserve. Thus, this study forms a basis for the wider management of Echuya Central Forest Reserve since bamboo is the major vegetation type in Echuya.

Objectives

This study assessed the status of bamboo in Echuya and the possible threats that may cause its further decline within Echuya. The specific objectives were;

1. To determine stem density, diameter class distribution and age class distribution of the bamboo (population structure)
2. To assess the disturbance factors that affect bamboo forest regeneration (borer infection tree colonization and harvest intensities)
3. To map bamboo abundance and distribution
4. Recommend management options for existing bamboo stock to allow its recovery
5. Recommend sustainable harvesting regimes and off-take quotas for the bamboo

Methods and materials

Echuya forest reserve is located in south-west Uganda in Bufumbira County, Kisoro District and Rubanda County, Kabale District. It lies between 1°14'–1°21'S and 29°47'–29°52'E (Banana & Tweheyo, 2001; Bitariho & McNeilage, 2007). Echuya is under the management of National Forest Authority. It is one of the natural forest reserves situated at high altitude (2270–2570 m above sea level) running between Lake Bunyonyi, Mgahinga Gorilla National Park and Bwindi Impenetrable National Park (Fig 1). The forest reserve covers an area of 34 km^2 and like most natural forest areas of south-west Uganda, Echuya is surrounded by a high human population density of about 500 people per km^2 (Uganda Population Census, 2002; Bitariho & McNeilage, 2007). In the 1960s, Echuya forest had big, tall and dense bamboo stems with occasional hardwood trees and shrubs scattered in a few places (Kingston, 1968). But presently bamboo in Echuya is less dominant although it is still the major vegetation type with 12.7% and 26.2% of the forest being pure bamboo forest and mixed bamboo forest respectively.

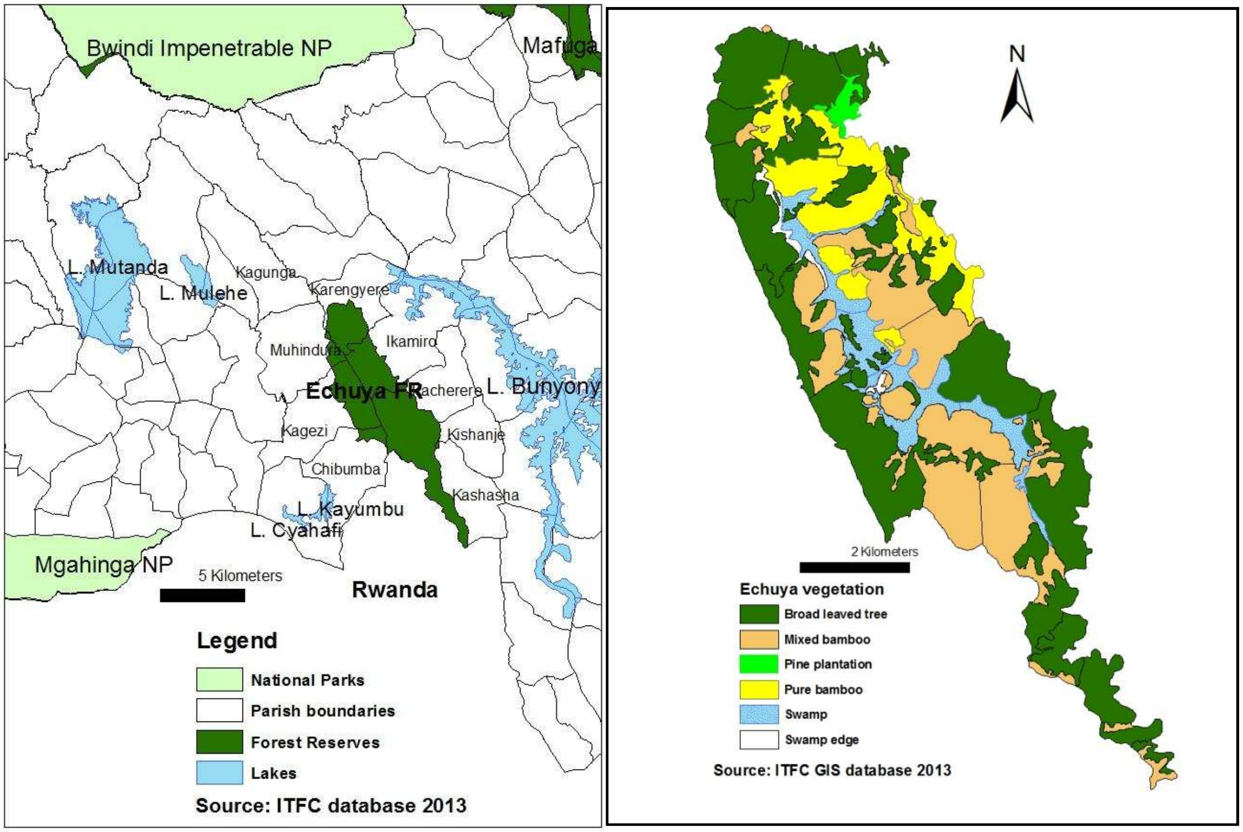

Fig 1: The location and vegetation zones of Echuya Central Forest Reserve

Echuya forest reserve is an afromontane forest with a rugged terrain and steep sided slopes and valleys. Random sampling in such areas is almost impossible and can be time consuming, labour intensive and costly for vegetation surveys. A stratified systematic sampling design was used following Bitariho & McNeilage (2007) and Wong (2003). Line transects were laid out across the forest running in an East–West direction and covering two bamboo strata of pure bamboo and mixed bamboo. A total of 100 circular plots with 5m radius (50 plots in each stratum) were located along ten transects in a systematic grid at 100 m intervals using a GPS and compass. In addition, circular plots of radius 10 m were established along the line transects at each sampling point to assess trees associated with bamboo.

In each bamboo assessment plot, we categorized the bamboo stems as ‘sprouts’, ‘young’, ‘mature’, ‘old’ and ‘dead’ (see Wimbush, 1945; Scott, 1994; Bitariho, 1999; Bitariho & Mosango, 2005; Bitariho & McNeilage, 2007; Sheil *et al*., 2012). We measured the diameter (midway between the first two nodes above the ground) of all stems in each plot using calipers and recorded bamboo stem damage (caused by insect borer attacks, animals, climbers). Cut stems were also recorded. 'Broken stems' were recorded if the break occurred below 2 m in height. Furthermore, we recorded individual tree species with dbh >10 cm in the tree assessment plots.

Data analysis was done using Microsoft Excel and Minitab version 14. Following Bitariho and McNeilage (2004), bamboo stem density was calculated for each age class in pure bamboo and mixed bamboo strata. Stems were then grouped according to their sizes using upper class limits. To determine the level of bamboo damage, the stems were categorized as cut stumps, damaged stems and undamaged stems and their percentages calculated. Data for each bamboo stratum is presented in form of tables, bar-graphs and pie-charts. In addition, we tested for statistical differences among populations of bamboo categories such as cut stems versus uncut stems and young stems versus old stems using Mann-Whitney tests, Kruskal Wallis tests and Spearman rank correlations. Such tests were also used by Sheil *et al*., (2012).

Results

Bamboo stem density and age class distribution in Echuya Central Forest Reserve

In the pure bamboo forest, old bamboo stems had the highest stem densities and the young bamboo stems the least (Table 1 and Figure 1). The sprouts constituted 4.7% and young stems 13.1% compared to the old stems which constituted 45.2% and mature stems 39.3% of total stems.

Table 1: Bamboo stem density in the pure bamboo forest of Echuya

Measure	**Sprouts**	**Young**	**Mature**	**Old**	**Dead**	**Total**
N all plots	50	50	50	50	50	50
N plots with bamboo	30	42	50	50	29	50
Bamboo density (stems ha^{-1})	371.6	1,030.9	3,082.5	3,540.7	185.8	7,840
Minimum (stems ha^{-1})	0	0	254.5	127.3	0	1,145.5
Maximum (stems ha^{-1})	1,909.1	3,818.2	12,345.5	12,218.2	1,145.5	21,254.5

In the mixed bamboo forest, 11 out of 50 plots were empty i.e. had no bamboo. The age classes were distributed as “mature” > “old” > “young” > “dead” > “sprouts” as shown in table 2. This was a similar scenario observed in the pure bamboo.

Table 2: Bamboo stem density in the mixed bamboo forest of Echuya

Measure	**Sprouts**	**Young**	**Mature**	**Old**	**Dead**	**Total**
N all plots	50	50	50	50	50	50
N plots with bamboo	26	38	33	31	19	39
Bamboo density (stems ha^{-1})	224.0	977.5	1,758.9	1,389.8	252.0	4,378.2
Minimum (stems ha^{-1})	0	0	0	0	0	0
Maximum (stems ha^{-1})	3,436.4	6,363.6	7,127.3	8,781.8	1,781.8	19,981.8

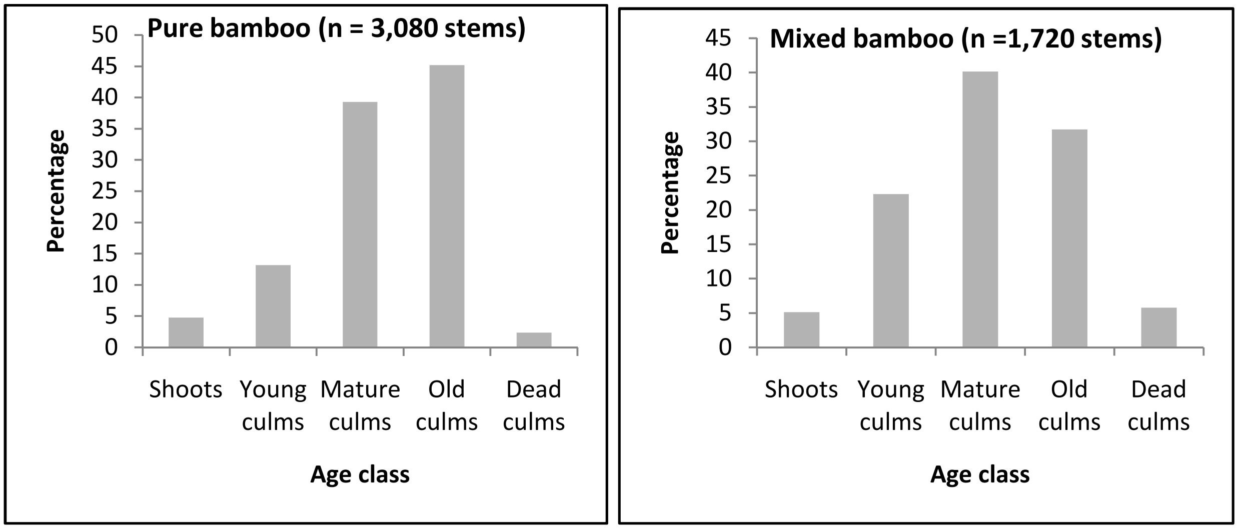

Figure 1: Bamboo age class distribution in the pure and mixed bamboo forest strata of Echuya

The size class distribution of bamboo in Echuya Central Forest Reserve

The distributions of bamboo size classes in the pure and mixed bamboo strata of Echuya are shown in Fig 2. Stem sizes were significantly different among young, mature and old bamboo stems (Mann-Whitney test, $P < 0.05$). There is a higher occurrence of thick bamboo stems (> 40.5 mm) in the pure bamboo forest than in the mixed bamboo forest. The thickest bamboo stems were in the pure bamboo forest and had diameters reaching the upper class limit of 102.5 mm while those in the mixed bamboo area did not exceed the upper class limit of 80.5 mm.

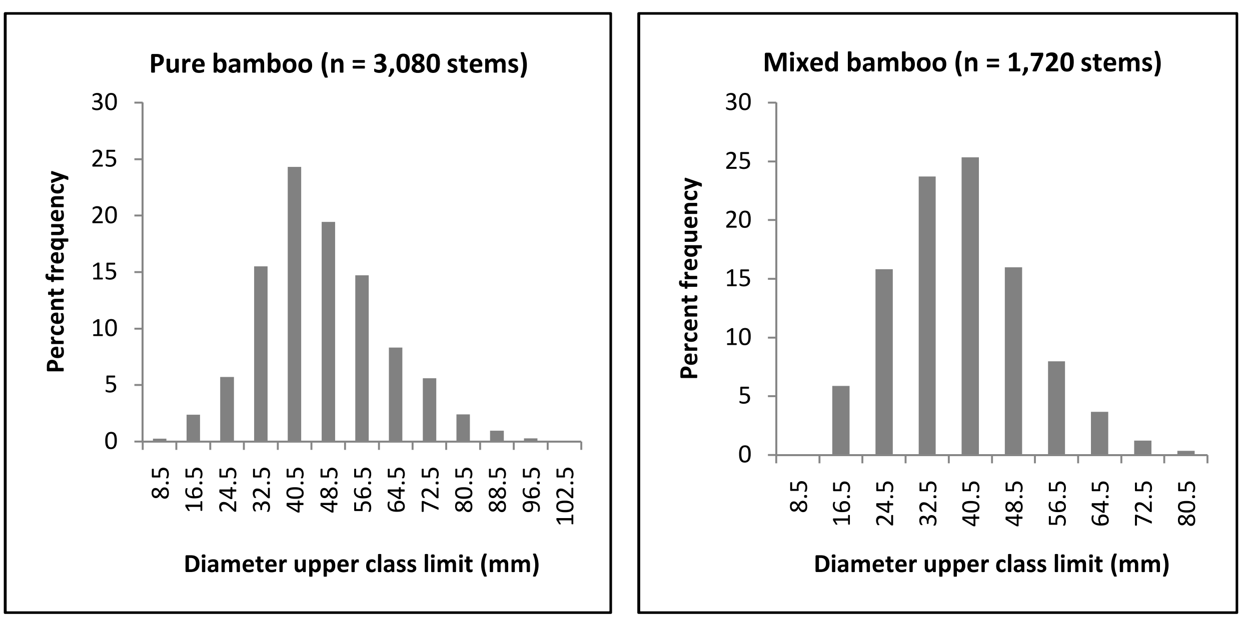

Figure 2: Diameter class distribution of bamboo in pure and mixed bamboo strata of Echuya

Disturbance factors affecting bamboo forest regeneration in Echuya

Bamboo harvest intensities

The intensity of harvesting bamboo in Echuya is considerably high (see Figure 4 and pictures 1 and 2) and yet bamboo regeneration is poor in many areas of Echuya CFR (Figure 5). Per-plot analyses showed that the highest percentage of bamboo stems cut in any plot was 73.9% of the total stems (Table 3). In pure bamboo, cut stems made up 33.8% and uncut stems 66.2 % of all stems in pure bamboo. When compared with young stems in all plots combined together, the cut stems were nearly four times the population of young bamboo (i.e. there were 1,564 cut stems compared to 405 young stems). In addition, the population of cut stems exceeded that of mature stems; even old stems (see Table 3 and Figure 3). The average diameter of cut stems is comparatively closer to that of old stems suggesting that harvesters target older bamboo used for building poles (Table 3). However, no correlation was detected between density of cut stems and the mean diameter per-plot of mature stems, old stems and old and mature stems combined together (Spearman rank correlation, r_s = 0.023, $^{-}$0.004 and 0.025, p = 0.877, 0.979 and 0.864, respectively). In addition, there was no correlation between the density of cut stems and the density of sprouts among the plots in pure bamboo (Spearman rank correlation, r_s = 0.266, p = 0.163).

Table 3: Population of cut stems compared to uncut stems in the pure bamboo forest

Population	N	% all plots	Highest % per plot	Lowest % per plot	Mean diameter
Cut	1,564	33.8	73.9	0	48.9
Uncut	3,067	66.2	100	26.1	43.0
Dead	73	1.6	12.5	0	43.9
Mature	1,211	26.1	65.5	1.8	41.5
Old	1,391	30.0	59.4	4.3	47.6
Young	405	8.7	27.1	0	32.2
Broken	163	3.5	25.4	0	41.2
Combined	4,631	100	100	100	44.9

In the mixed bamboo forest, cut stems made up 23.6% and uncut stems 76.4% of total stems (Table 4). Per-plot analyses showed that the highest percentage of bamboo stems cut in any plot was 50% of the total stems. When compared with different categories of uncut bamboo, the cut stems (n=522) were fewer than mature (n=691) and old stems (n=546) but their population exceeded that of young stems (n=384). Their average diameter (D = 37.9 mm) was substantially less than that of old stems (D = 41.8 mm) but greater than the average diameters of other population categories (Table 4). In addition, there was no correlation between the density of cut stems and the mean diameter per-plot of any of the age classes: old, mature and young (Spearman rank correlation, r_s = 0.230, 0.119 and $^{-}$0.079, p = 0.279, 0.563 and 0.721, respectively). However, there was a positive correlation between the density of cut stems and the density of sprouts among the plots in mixed bamboo (Spearman rank correlation, r_s = 0.756, p = 0.002).

Table 4: Population of cut stems compared to uncut stems in the mixed bamboo forest

Population	N	% all plots	Highest % per plot	Lowest % per plot	Mean diameter
Cut	522	23.6	50.0	0	37.9
Uncut	1,692	76.4	100	0	34.8
Dead	99	4.5	37.5	0	34.4
Mature	691	31.2	62.5	0	34.2
Old	546	24.7	71.4	0	41.8
Young	384	17.3	40.0	0	25.9
Broken	105	4.7	50.0	0	35.6
Combined	2,214	100	100	100	35.5

Combining data from pure and mixed bamboo forests revealed that harvesting of bamboo in Echuya is less selective based on stem sizes since all size classes, with the exception of the largest size class of 96.5-104.5 mm, had cut bamboo stems (see Figure 3). Nonetheless, the most affected size class was the 64.5-72.5 mm diameter class which had 35.3% cut stems. Other classes with at least 25% cut stems were the 16.5-24.5 mm, 56.5-64.5 mm, 64.5-72.5 mm, 72.5-80.5 mm, 80.5-88.5 mm and 88.5-96.5 mm diameter classes (see Appendix 1).

Further, a comparison with past studies in Echuya and Mgahinga revealed that bamboo stem densities have decreased since 2004 and are considerably lower in Echuya in both pure and mixed bamboo (Table 5). For example, comparing the 2004 data by Bitariho & McNeilage (2004) with this study, the density of live stems in pure bamboo (i.e. young, mature and old bamboo stems) has decreased by nearly 5,000 stems per hectare (i.e. 38.3%) and the density of dead stems has decreased ten times in pure bamboo and nearly two-fold in the mixed bamboo area. However, the density of cut stems has remained relatively stable in the pure and mixed bamboo strata over the same period of time (Table 5).

Table 5: Mean stem density of live, cut and dead stems in Echuya in 2013 and 2004, and in Mgahinga in 2005 and 1997

Study	**Stems per hectare in the Pure bamboo stratum**		
	Live stems	Dead stems	Cut stems
Echuya 2013	7,651 ± 16.2	186 ± 4.7	3,996 ± 90.9
Echuya 2004	12,394 ± 49	1,422 ± 14	4,199 ± 18.3
Mgahinga 2005	30,408 ± 79	44,656 ± 314	1,005 ± 4.6
Mgahinga 1997	34,430 ± 155	7,420 ± 74.9	No data
	Stems per hectare in the Mixed bamboo stratum		
	Live stems	Dead stems	Cut stems
Echuya 2013	4,125 ± 12.4	252 ± 7.9	2,075 ±16.2
Echuya 2004	3,090 ± 23	499 ± 5.5	2,099 ± 11.6
Mgahinga 2005	19,720 ± 64	22,646 ± 120	814 ± 4.7
Mgahinga 1997	39,600 ± 261	6,800 ± 55	No data

The Echuya 2004, Mgahinga 2005 and Mgahinga 1997 data is from Bitariho and McNeilage, (2005)

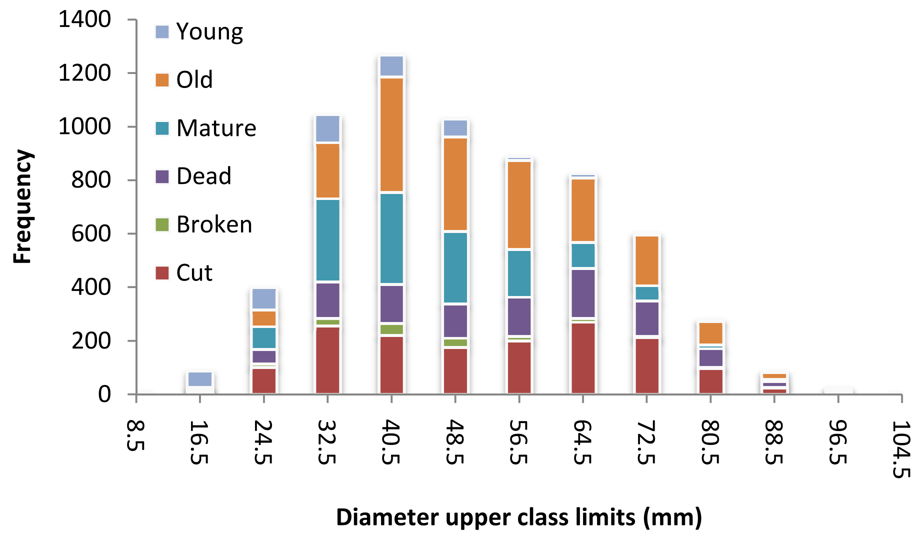

Figure 3: The distribution of cut stems among diameter classes compared to other bamboo population categories (pure and mixed bamboo data combined)

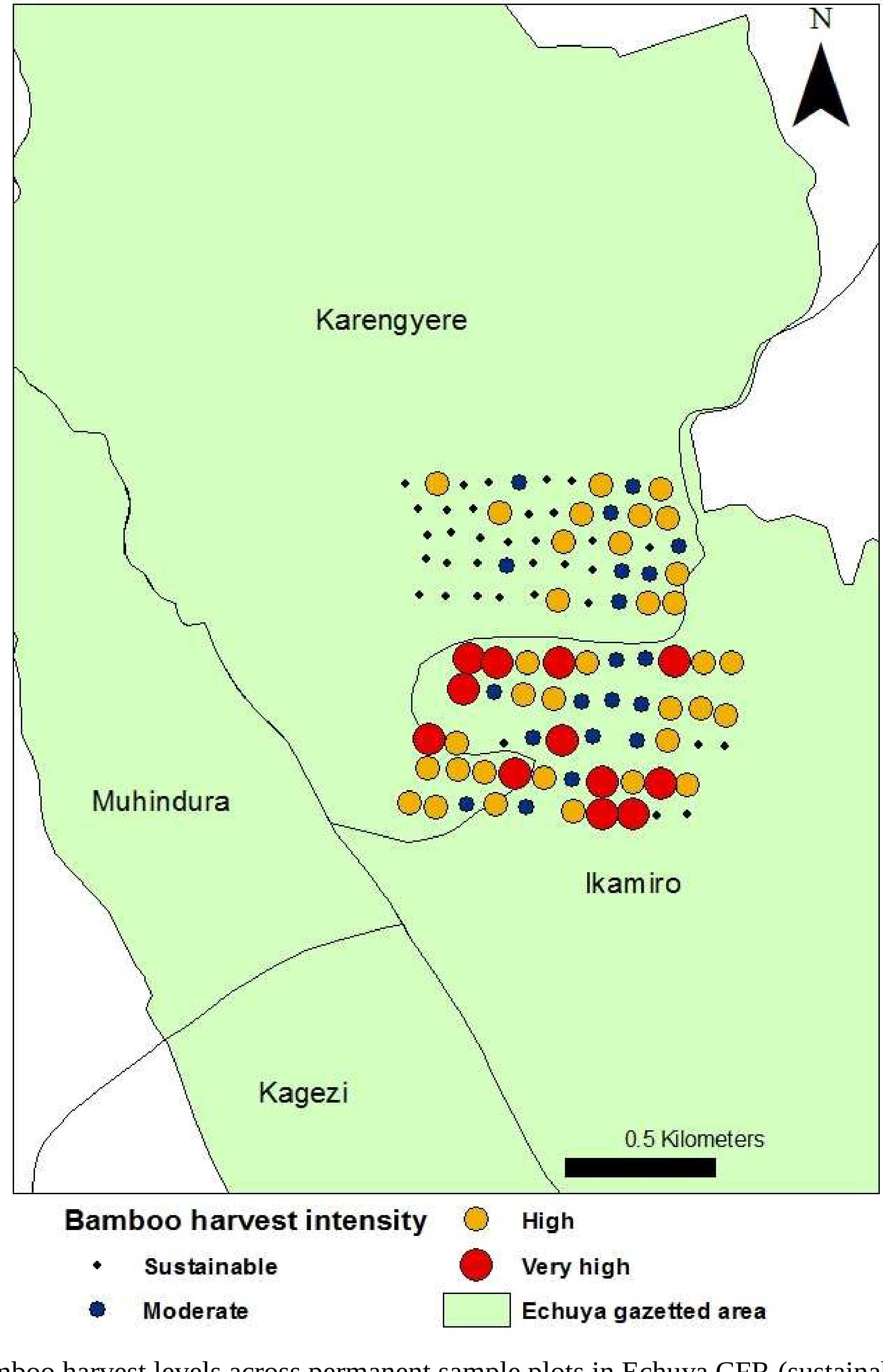

Fig 4: Bamboo harvest levels across permanent sample plots in Echuya CFR (sustainable harvest = less than10%, moderate = 10-25%, high = 25-50% and very high = greater than 50% of all bamboo stems in a plot were cut)

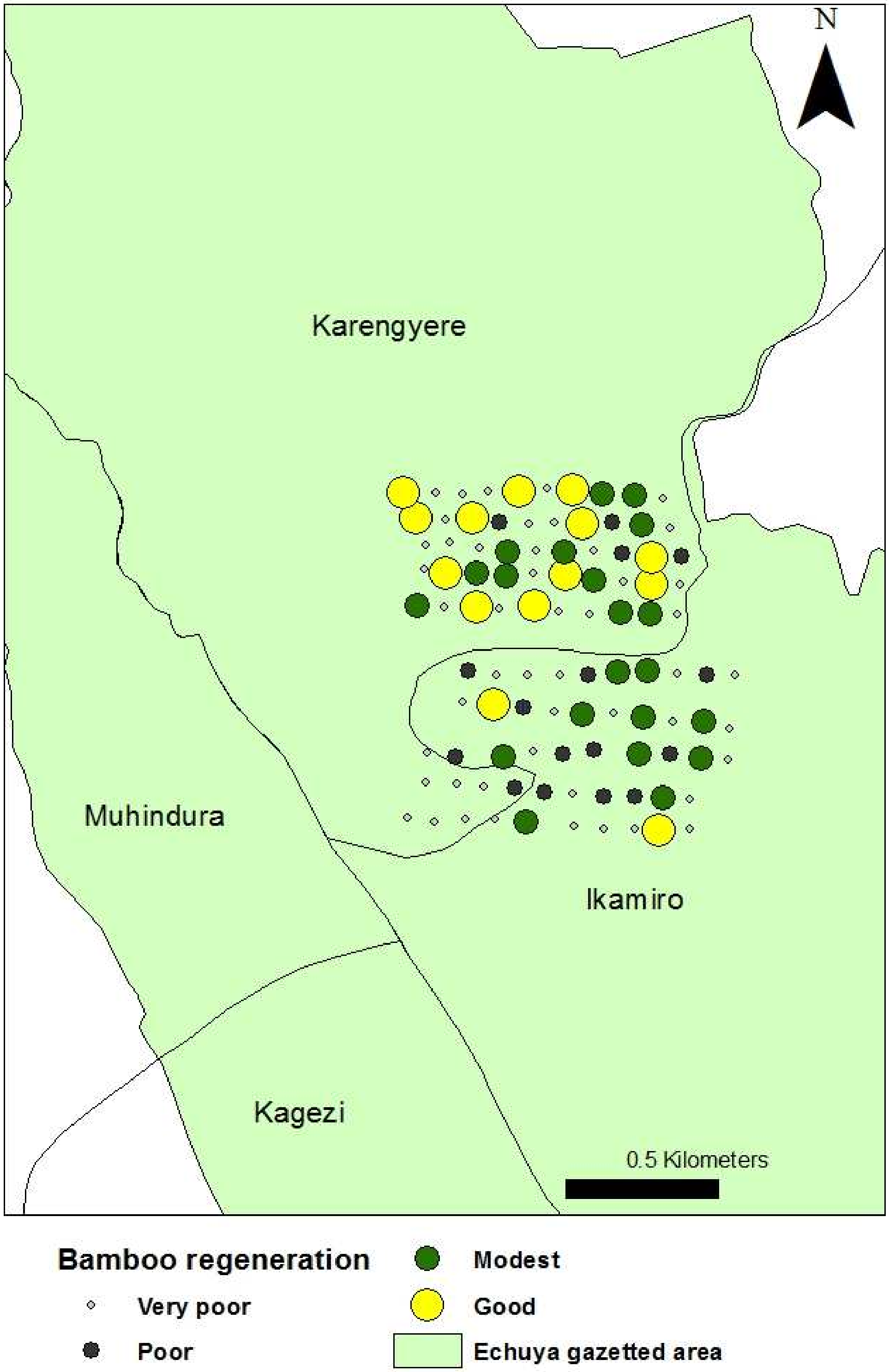

Fig 5: Bamboo regeneration across permanent sample plots in Echuya CFR (Very poor = less than 5%, Poor = 5-10%, Modest = 10-25%, Good = greater than 25% of all bamboo stems in a plot were young)

Plate 1 **Plate 2**

Plate 1: Cut bamboo stems in a pure bamboo area of Echuya that was subjected to a high intensity of bamboo harvesting

Plate 2: Roadside bundles of bamboo harvested from Echuya forest before being loaded on the trucks plying the Kisoro-Kabale road

Bamboo damage levels

Bamboo stems were categorized as cut stumps, damaged stems and undamaged stems. Stems were considered damaged if they were crooked, attacked by insect borers, covered by woody climbers and had their tops broken by heavy winds or monkeys feeding on them. From Figure 6, it is evident that the level of bamboo damage is considerably high both in the pure and mixed bamboo forests of Echuya. Cut stumps made up 34% and 24% of all bamboo in the pure and mixed bamboo forests respectively. Stems damaged by borer infestation, woody climbers and monkeys made up 54% and 71% in the two bamboo strata respectively (Figure 6).

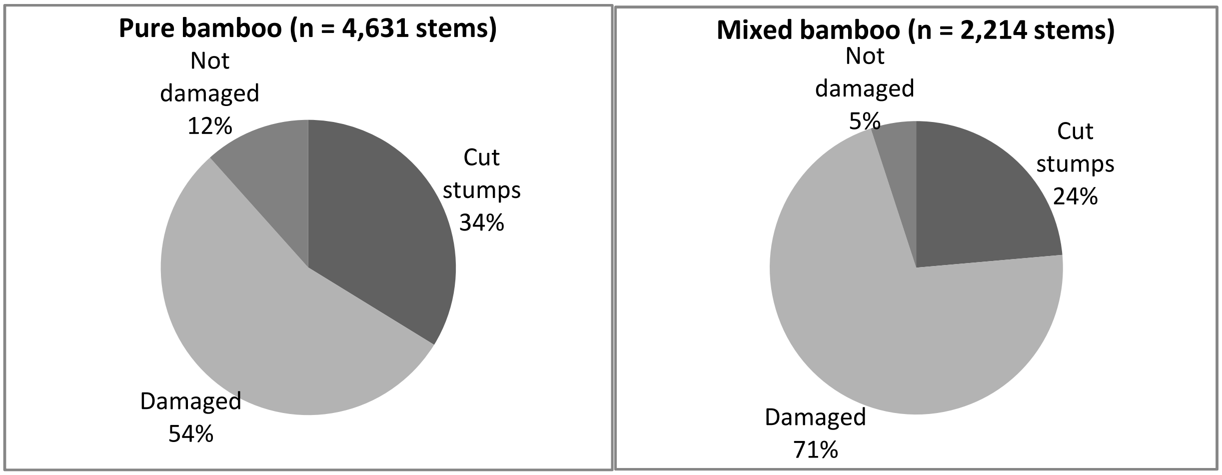

Figure 6: Bamboo stem damage levels in Echuya CFR

Trees colonizing bamboo in Echuya CFR

More than 50% of the plots in pure bamboo forest (i.e. 26 plots) and more than 80% of the plots in mixed bamboo forest (i.e. 42 plots) contained trees with a diameter at breast height (dbh) exceeding 10 cm. Trees were associated with significantly thinner mature and old bamboo in the pure and mixed bamboo strata (Kruskal Wallis tests, $p < 0.05$). The most abundant tree species in pure bamboo stratum were *Macaranga kilimandscharica* (26.8%), *Dombeya torrida* (18.6%) and *Allophylus macrobotrys* (12.4%; see Fig 7). The most abundant tree species in mixed bamboo stratum were *Macaranga kilimandscharica* (31.7%), *Neoboutonia macrocalyx* (19.7%) and *Psychotria mahonii* (18.4%; see Figure 8). The mixed bamboo stratum had more and bigger trees compared to the pure bamboo stratum (see Fig 9). Nonetheless, tree cover is increasing in many parts of the pure bamboo forest (Figure 10).

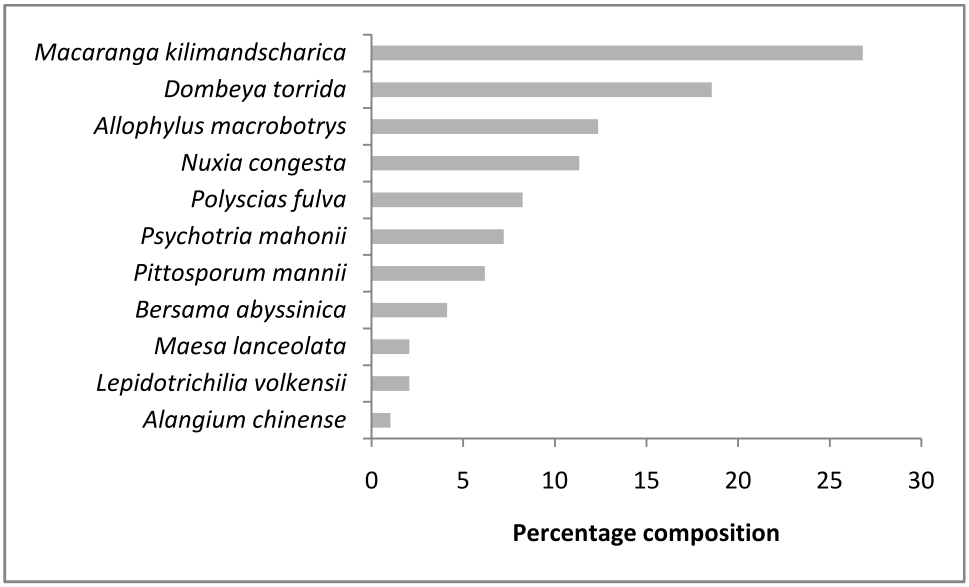

Figure 7: Tree species composition in the pure bamboo forest in Echuya (n = 11 species)

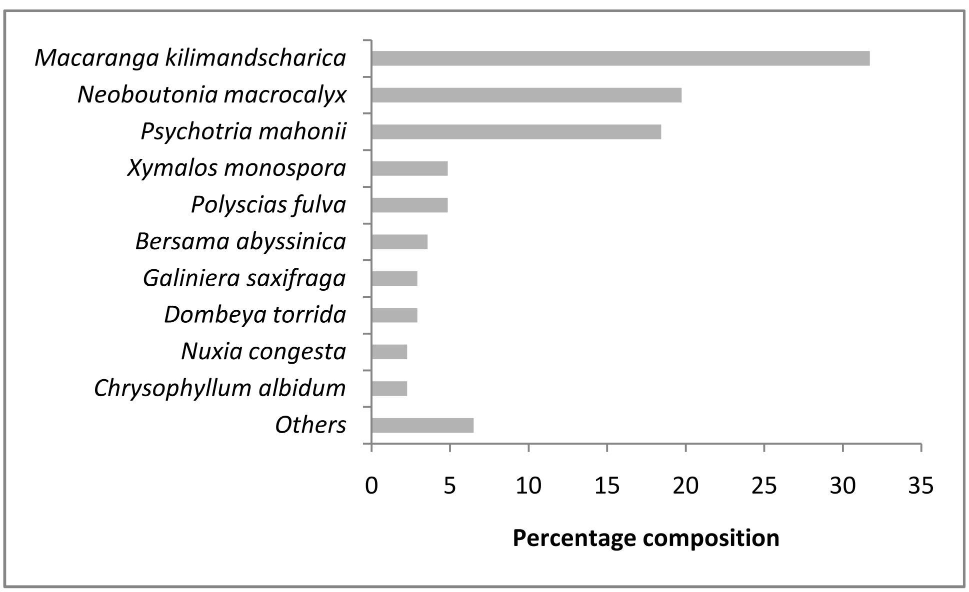

Figure 8: Tree species composition in the mixed bamboo forest of Echuya (n = 15 species)

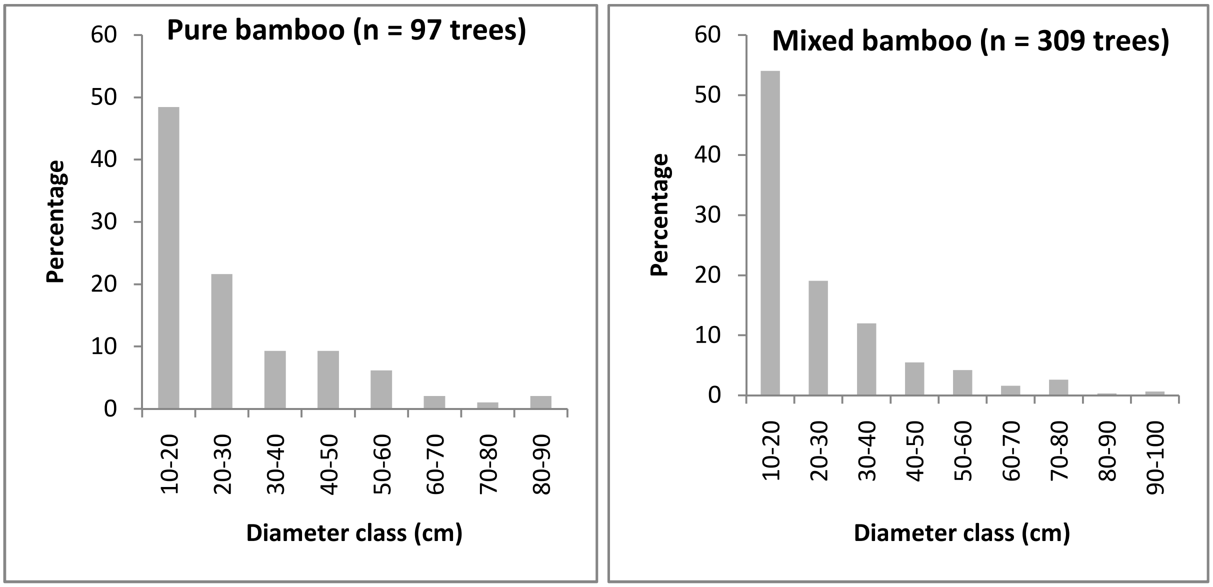

Figure 9: Diameter class distribution of trees in pure and mixed bamboo strata of Echuya CFR

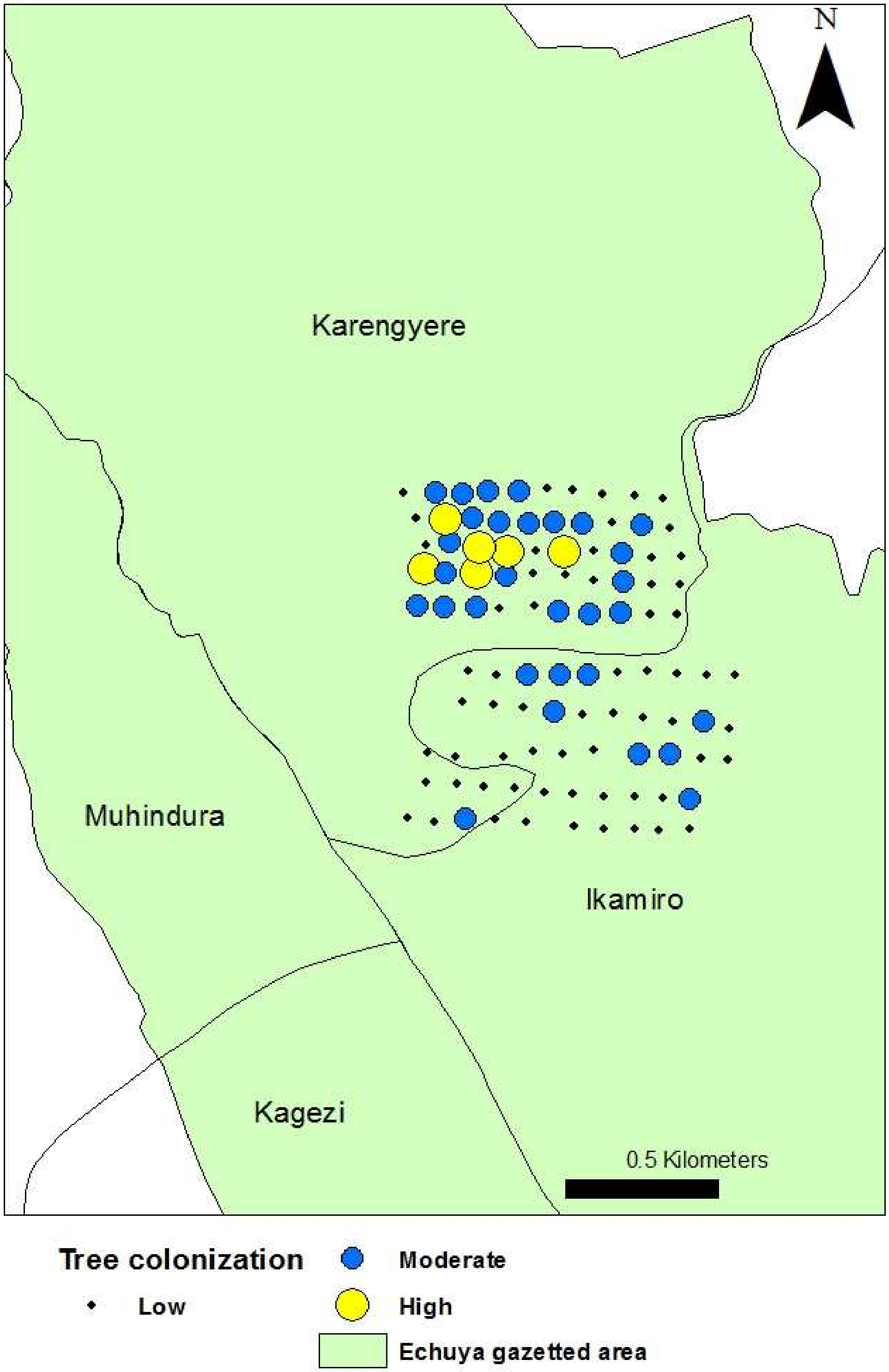

Figure 10: Tree colonization across permanent sample plots in Echuya CFR (Low = less than 127 trees ha^{-1}, Moderate = 127-382 trees ha^{-1} and High = 382-668 trees ha^{-1})

Discussion and recommendations

The state of bamboo in Echuya

Our study shows that the bamboo in Echuya forest looks “unhealthy” as stated nine years ago by Bitariho and McNeilage (2004). The bamboo forest is mainly with stems of old age class category and the young stems the least. In addition, the density of young, old and dead stems has noticeably declined in the two bamboo strata but more so in pure bamboo. This could be attributed to the high intensity of harvesting which was evident given that 33.8% of total stems in pure bamboo and 23.6% of total stems in mixed bamboo were cut stems exceeding the sustainable harvest figure of between 1-10% of the bamboo stock recommended by Bitariho & McNeilage (2006). Moreover, as high as 73.9% of stem counts in a sample plot were cut stems. This means that there is over-exploitation of bamboo in Echuya which may be driven by the high demand for bamboo since Echuya is the major source of bamboo in the region. Such over-harvesting of bamboo in Echuya may also be attributed to illegal harvesters and the use of poor harvest methods especially the clear cutting of bamboo when harvesting bamboo for bean-stakes and building poles (Bitariho, 1999; & McNeilage 2006). In addition, the lack of alternatives like vines, lianas and woodlots for the local people adjacent to the forest may also have caused massive harvesting of bamboo stems there (Bitariho 1999; Bitariho and Mosango, 2004). As such, there is need to address the high demand of bamboo from Echuya by ensuring compliance with sustainable harvesting methods and developing alternatives to the bamboo resource.

The study also shows that the diameter class distributions in both pure and mixed bamboo forest types in Echuya show a normal distribution curve. This kind of distribution is typical of bamboo populations with equal number of thick and thin bamboo stems (Hall and Bawa, 1993; Bitariho and McNeilage, 2004). In addition, our data show that pure bamboo forest has thicker stems than the mixed bamboo. The occurrence of thinner stems in the mixed bamboo forest when compared to the pure bamboo forest may be as a result of increasing competition from the increasing tree cover given that bamboo is heliophilous in nature and competes for light and soil nutrients with tree species in the mixed bamboo forest (Reid *et al*., 1991; Bitariho, 1999; Bitariho and McNeilage, 2004). Could this distribution have a bearing on the choices of the bamboo harvesters? Bitariho (1999; Bitariho and McNeilage, 2004) found out that local harvesters adjacent to Bwindi and Mgahinga tend to harvest bamboo stems for bean-stakes in the mixed bamboo forest type while the harvesting of bamboo for building poles and basketry is done in the pure bamboo forest. It is therefore plausible that bamboo harvesters in Echuya target the mixed bamboo forest for thinner stems used as bean-stakes and the pure bamboo for the thicker stems which are used as building poles, materials for basketry and firewood.

On the other hand, the density of sprouts in pure and mixed bamboo strata was higher than that recorded by Bitariho and McNeilage (2004). Compared to the neighboring forests of Bwindi and Mgahinga National Parks where bamboo harvesting has not been permitted (Mgahinga has only recently allowed controlled bamboo harvesting), sprout densities in Echuya are much lower than those in Bwindi and Mgahinga (Bitariho, 1999; Sheil *et al*., 2012). The comparatively lower density of sprouts in Echuya seems to suggest that bamboo harvesting may not stimulate bamboo sprout production, growth and survival. However, this finding remains more suggestive than conclusive given our small data set and the likelihood that some sprouts may have come up after the survey or have been already eaten by animals before our study and remained undetected.

Bamboo disturbance factors

Almost all bamboo stems in the mixed bamboo stratum (i.e. 95%) and most of the bamboo in pure bamboo stratum (i.e. 88%) were damaged by human harvesting, borer infestation, woody climbers and monkeys. Similarly, Bitariho and McNeilage (2004) found a high level damage in the mixed bamboo (i.e. 96%) but less damage in the pure bamboo (i.e. 69%). From these data, overall bamboo damage in Echuya has increased from 74.7% to 90.5% over the past decade. There is also clear evidence that bamboo harvesting is taking a huge toll on the forest considering that many areas inside the pure bamboo forest have almost been cleared of bamboo. Such hotspots of clear-cutting though not widespread point to illegal bamboo harvesting or non-compliance with the set guidelines for sustainable harvesting of bamboo in Echuya (Bitariho, 2007) which can be attributed to the tendency for bamboo harvesters to repeatedly converge in certain areas especially those near the road where they gather and bundle together the cut bamboo stems before carrying them out of the forest (Venancio Barugahare, pers.comm). As such, our data coupled with the study findings of Banana and Tweheyo (2001) which showed that in Echuya tree cover increased from 16% to 51% in 50 years raise serious concerns for the conservation of bamboo in Echuya CFR. If the presently high levels of bamboo damage mainly due to over-harvesting of bamboo stems are not checked, there is an increased likelihood of bamboo being wiped out of Echuya forest.

We also found 309 tree stems (greater than 10 cm dbh) representing 15 tree species in the mixed bamboo and 97 tree stems representing 10 tree species in pure bamboo (see Appendix 2). About a decade ago, Bitariho and McNeilage (2004) found no tree species in pure bamboo and identified 19 tree species in the mixed bamboo stratum. All the trees species in this study are among the 19 tree species identified by Bitariho and McNeilage (2004) and all the trees are secondary forest tree types (Hamilton, 1991) which like bamboo are heliophilous and major colonizers in Echuya forest (Banana and Tweheyo, 2001; Bitariho and McNeilage; 2004). Tree colonization and expansion in the pure and mixed bamboo strata pose a major threat to bamboo in Echuya since bamboo may not compete favourably with trees for the available resources including light, soil nutrients and water. Tree canopy cover impedes light penetration to the bamboo stems and tree species root system may impede bamboo rhizome expansion thereby affecting bamboo establishment (Bitariho, 1999). Thus, it is likely that in the long term bamboo in Echuya will be taken over by tree cover thereby changing the composition and structure of the forest.

Recommendations

Bamboo in Echuya is in an unhealthy state and needs urgent attention to allow for the recovery of the existing bamboo stock. We offer the following suggestions;

- Bamboo harvesting requires careful management, supervision and monitoring. As such, NFA should ensure that bamboo off-takes are regulated and enforced.
- There is need to improve compliance with the existing allowable off-takes i.e. annual bamboo harvest quotas of up to 10% for the harvest of young and mature bamboo stems and harvest quotas of up to 50% for the harvest of old/dry bamboo stems.
- There is also a need to regularly review the existing bamboo off-takes with a view of reducing the harvesting pressure being exerted on the deteriorating bamboo stock in Echuya. This requires full participation of all stakeholders including bamboo harvesters, NFA and ***Nature***Uganda. In addition, bamboo harvesters, NFA and ***Nature***Uganda Staff should meet regularly to monitor bamboo off-takes and devise means of enforcing compliance with the recommended procedures.

- Bamboo harvesters should be discouraged from repeatedly congregating in the same area to avoid cases of clear cutting of bamboo. Each resource user group, usually a small group of about 12 people (Bitariho & McNeilage, 2006), should be allowed to enter the forest separately for harvesting at any given time so that they can be adequately supervised by NFA staff. Furthermore, harvesting by breaking dry bamboo stems with hands as opposed to cutting with pangas can reduce the incidence of clear-cutting bamboo stems. As such, the use of pangas in harvesting dry bamboo should be minimized.
- The domestication of bamboo around Echuya forest as has been initiated by ***Nature***Uganda should be promoted further as a way of decreasing the demand of bamboo from the forest and at the same time providing the local communities with a means of income from selling the bamboo stems.
- Bamboo restoration through enrichment planting should also be promoted especially where bare patches exist. This could be undertaken by CFM members and NFA.
- There is also need to clearly mark areas where bamboo harvesting is allowed and others where harvesting cannot be allowed due to the presently high levels of damage. We suggest that no harvesting should be allowed where at least 25% of bamboo stems have been harvested. Harvested areas should be rotated to allow for recovery of the bamboo forest with at least 4–5 years between harvests. In addition, regeneration of bamboo in the harvesting and non-harvesting zones should be regularly monitored by recording the population of sprouts and young bamboo stems. Furthermore, harvesting must avoid sprouting seasons to avoid damaging the tender sprouts and young bamboo stems.
- Finally, there should be a ban on commercial harvesting of bamboo including the use trucks which often ferry bamboo from Echuya. The diminishing bamboo in Echuya cannot satisfy the ever-increasing demand especially for commercial purposes.

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Appendix 1: The size class distribution of bamboo in Echuya

Pure bamboo stratum						
Diameter upper class limit (mm)	Young	Mature	Old	Dead	Broken	Cut stems
8.5	9	0	0	0	0	1
16.5	61	9	6	3	1	7
24.5	84	84	63	55	13	100
32.5	104	310	210	136	29	255
40.5	83	343	431	146	45	219
48.5	67	272	352	128	34	175
56.5	14	178	334	146	17	199
64.5	16	97	241	187	14	269
72.5	7	57	189	132	4	212
80.5	7	14	88	69	5	96
88.5	1	8	27	21	1	25
96.5	2	0	8	6	0	6
104.5	0	0	4	0	0	0
Mixed bamboo forest						
Diameter upper class limit (mm)	Young	Mature	Old	Dead	Broken	Cut stems
8.5	1	0	0	0	0	0
16.5	85	14	3	19	6	15
24.5	124	151	26	53	11	75
32.5	93	252	107	106	23	135
40.5	66	222	194	101	31	103
48.5	24	123	131	87	21	72
56.5	11	48	80	64	7	57
64.5	1	18	42	42	5	35
72.5	0	3	21	16	0	18
80.5	0	0	9	9	1	11
88.5	0	0	0	1	0	1

Appendix 2: Tree species list of Echuya

Trees in the Mixed bamboo stratum			
Tree species	N tree stems	% composition	Mean DBH
Alangium chinense	5	1.6	25.0
Allophylus macrobotrys	3	1.0	36.4
Bersama abyssinica	11	3.6	13.2
Chrysophyllum albidum	7	2.3	28.1
Dombeya torrid	9	2.9	48.1
Galiniera saxifrage	9	2.9	25.6
Lepidotrichilia volkensii	6	1.9	12.4
Macaranga kilimandscharica	98	31.7	18.9
Maesa lanceolata	5	1.6	28.8
Neoboutonia macrocalyx	61	19.7	28.1
Nuxia congesta	7	2.3	17.3
Polyscias fulva	15	4.9	42.0
Psychotria mahonii	57	18.4	46.3
Syzygium guineense	1	0.3	18.2
Xymalos monospora	15	4.9	18.0
Trees in the Pure bamboo stratum			
Tree species	N tree stems	% composition	Mean DBH
Alangium chinense	1	1.0	26.9
Allophylus macrobotrys	12	12.4	20.0
Bersama abyssinica	4	4.1	19.6
Dombeya torrid	18	18.6	21.6
Lepidotrichilia volkensii	2	2.1	18.5
Macaranga kilimandscharica	26	26.8	12.8
Maesa lanceolata	2	2.1	28.8
Nuxia congesta	11	11.3	43.5
Pittosporum mannii	6	6.2	45.5
Polyscias fulva	8	8.2	25.1
Psychotria mahonii	7	7.2	36.7