Population structure of montane bamboo and causes of its decline in Echuya Central Forest Reserve, South West Uganda

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Abstract

Montane bamboo is of immense importance to the people living adjacent to Echuya Forest Reserve. It is used for building poles, bean-staking and basket weaving. The bamboo in Uganda occurs mostly in protected areas. Over the past 50 years, the bamboo forest cover has been declining. This study aimed at determining bamboo density and distribution and the possible causes of its decline within Echuya. We used exploratory inventories, bamboo assessment plots and village interviews to determine bamboo population structure and possible causes of its decline in Echuya. Bamboo forest decline in Echuya may be blamed on several factors that interplay together. Poor harvest methods especially during the clear cutting of bamboo for bean-stakes and stakes for house wefts seems to be the remote cause of the bamboo forest decline. Other causes for the bamboo forest decline are damages caused by insect borers and climber loads on the bamboo stems. The remote causes have been exacerbated by the invasion of secondary forest tree species such as *Macaranga kilimandscharica* that have slowly taken over areas previously occupied by the bamboo forest. Seventy per cent of the local people interviewed agree that over-harvesting of bamboo is the major reason for its decline.

Key words: bamboo strata, Echuya forest, montane bamboo

Résumé

Le bambou de montagne est extrêmement important pour les gens qui vivent près de la Réserve Forestière d'Echuya. Il sert à faire des charpentes, des tuteurs pour les haricots et des paniers tressés. En Ouganda, le bambou pousse surtout dans les aires protégées. Les surfaces occupées par les bambous ont décliné depuis 50 ans. Cette recherche visait à déterminer la densité et la distribution des bambous et les causes probables de leur déclin à Echuya. Nous avons réalisé des inventaires exploratoires, des plots pour l'évaluation des bambous et des interviews dans les villages pour déterminer la structure des populations de bambous et les causes du déclin. Ce déclin peut être attribué à plusieurs facteurs interactifs à Echuya. Des méthodes de récoltes malencontreuses, spécialement lorsque les gens font des coupes à blanc pour des perches à haricots ou la charpente des maisons, semblent une raison ancienne du déclin de la forêt de bambou. D'autres causes sont les dommages causés par les insectes térébrants et par le poids de ceux qui marchent sur les jeunes pousses. Les causes anciennes ont été exacerbées par l'invasion d'espèces d'arbres de forêts secondaires comme *Macaranga kilimandscharica* qui ont peu à peu gagné des zones occupées auparavant par la forêt de bambou. Soixante-dix pour cent des personnes interrogées ont reconnu que la surexploitation du bambou était la raison principale du déclin constaté.

Introduction

Montane bamboo grows gregariously within most mountain forests of tropical Africa and Asia (Wimbush, 1945; Kigomo, 1988; Bitariho & Mosango, 2005). It is a tropical high altitude woody grass of the family Poaceae and subfamily Bambusoideae (Kigomo, 1988; Bystriakova, Kapos & Lysenko, 2004; Bitariho & Mosango, 2005). The bamboo has recently been described taxonomically as *Yushania alpina* K. Schumann (Embaye, 2000; Bystriakova *et al.*, 2004). Previously it was taxonomically described by several authors as *Arundinaria alpina*, *Synarundinaria alpina* and *Sinarundnaria alpina* (Wimbush, 1945; Kigomo, 1988; Scott, 1994; Bitariho, 1999; Bitariho & Mcneilage, 2004;

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Bitariho & Mosango, 2005). In Uganda, the bamboo occurs in Bwindi, Mgahinga, Rwenzori and Mt Elgon National Parks and Echuya Central Forest Reserve.

Like most other bamboos, the montane bamboo takes long to flower (over 30 years) and it is believed when it flowers, it does so massively and in a gregarious manner (Wimbush, 1945; Huberman, 1959). There are no records available to show the massive and gregarious flowering of bamboo in south western Uganda although some patches of bamboo were observed in flower on slopes of Mt Sabinyo in Mgahinga National Park and Echuya Central Forest Reserve (Bitariho & Mcneilage, 2004). Bamboo forests prefer deep volcanic soils; especially Andosols and shoots can reach a maximum height and diameter of 18 and 10 cm respectively (Embaye, 2000; Bussmann, 2004). Average annual stem increment of unmanaged natural bamboo is about 8.5–10 tonnes of dry matter per hectare (Embaye, 2000).

Bamboo is of great importance to rural economies of Uganda and many other African and Asian countries. It is used as buildings poles for houses and basket weaving by the people living adjacent to Echuya. In addition to its economic importance, the bamboo is an important ecological habitat for many species. For example, the blue monkeys (*Cercopithecus mitis*) and baboons (*Papio anubis)* in this forest consume significant quantities of bamboo shoots during the wet seasons (Bitariho & Mcneilage, 2004; Bitariho & Mosango, 2005).

Kingston (1968) reported 39 years ago that Echuya forest had big, tall and dense bamboo stems with occasional hardwood trees and shrubs, but this is not the case today (Bitariho & Mcneilage, 2004). Over the past 50 years, about half of the bamboo stands in Echuya have been replaced by trees and the bamboo is slowly but surely becoming a minor component of the understory (Banana & Tweheyo, 2001; Bitariho & Mcneilage, 2004; Bitariho & Mosango, 2005). Local bamboo harvesters have indicated that some tree species such as *Macaranga kilimandscharica* and *Nuxia congesta* suppress the growth of bamboo where they grow (Bitariho & Mcneilage, 2004; Bitariho & Mosango, 2005). These are pioneering secondary forest trees, which could reflect the fact that bamboo is being lost and replaced by trees.

Bamboo stem cutting in the nearby National Parks (Mgahinga and Bwindi) is not permitted, and therefore people living in these areas are increasingly demanding bamboo from Echuya (Bitariho & Mcneilage, 2004; Bitariho & Mosango, 2005). The bamboo can be resilient to harvesting and bamboo stem harvest stimulates the growth of new shoots (Cunningham *et al.*, 1993). However poor harvest methods such as clear cutting of bamboo and over-harvesting have been observed to be detrimental to bamboo growth leading to its decline (Huberman, 1959; Kigomo, 1988; Bitariho & Mcneilage, 2004; Bitariho & Mosango, 2005).

If bamboo in Echuya continues to decline at this rate it could have a significant impact not only on biodiversity but also on the livelihoods of surrounding communities. In light of the apparent decline of bamboo in Echuya, and the heavy dependence of the local communities on bamboo, it is vital for both the conservationist and the long-term livelihoods of the local population that we ensure that bamboo harvest is sustainably managed. However, little information is currently available on bamboo ecology and population dynamics, to assess sustainable harvest of bamboo. We undertook to determine the population structure of the bamboo and the reasons for its decline in Echuya forest.

Materials and methods

Study area

Echuya forest reserve is located in south-western part of 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, 2004). Echuya is under the management of National Forest Authority. It is one of the natural forest reserves situated at a high altitude (2270–2570 m above sea level) running between Lake Bunyonyi, Mgahinga National Park and Bwindi Impenetrable National Park in S.W. Uganda. The forest reserve covers an area of 34 km^2 and like most natural forest areas of S.W. Uganda, is surrounded by a high human population density of about 500 people per km^2 (Uganda Population Census, 2002).

Sampling design

Two types of sampling designs were used: Exploratory inventory (EI) and bamboo assessment plot designs. The EI has been recommended by the National Forestry Authority for vegetation sampling and was used to determine the density and distribution of bamboo in relation with other vegetation types across Echuya (Wong, 2003). The bamboo assessment plot design was used to assess specifically the population dynamics of the bamboo forest (Wong, 2003).

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 in this case (Bitariho & Mcneilage, 2004; Bitariho & Mosango, 2005). Aerial photographs of Echuya forest of 2003 were analysed together with local knowledge of bamboo harvesters and forest guards. Three bamboo strata were identified (Bitariho & Mcneilage, 2004; Bitariho & Mosango, 2005):

- Pure bamboo (bamboo occurs as the only dominant vegetation type).
- Mixed bamboo (bamboo occurs mixed with other tree species).
- No bamboo (areas with no bamboo but with trees and open/closed forest types).

Plot layout and sizes

For the EI, six line transects separated from each other by a distance of 1000 m were laid out across the forest running in an east–west direction and covering the different bamboo strata (Van Wyk *et al.*, 1996; Bitariho, 1999; Banana & Tweheyo, 2001; Bitariho & Mcneilage, 2004; Bitariho & Mosango, 2005). On each transect concentric circular plots of radius 10 and 5 m were set up for assessment of trees and bamboo, saplings and climbers/shrubs respectively (Wong, 2003). The concentric plots were located at intervals of 200 m on the line transects. A total of 67 plots were set up in the entire forest, ten plots in each stratum of pure bamboo and mixed bamboo and 47 plots in the no bamboo vegetation type. From the plots, data on plant species and their densities were obtained. This sampling design provided a sampling intensity of 0.02% and 0.06% for bamboo and trees respectively.

For the bamboo assessments plots, line transects running from the east–west direction were established in two bamboo strata of pure bamboo and mixed bamboo (Van Wyk *et al.*, 1996; Bitariho, 1999; Banana & Tweheyo, 2001; Bitariho & Mcneilage, 2004; Bitariho & Mosango, 2005) running from an available human trail into the forest and located at every 100 m interval within the strata. The first transect was randomly selected and thereafter other transects established systematically (Bitariho, 1999; Bitariho & Mcneilage, 2004; Bitariho & Mosango, 2005). On each transect, circular plots of radius 5 m were set up and located at 100 m intervals (Wong, 2003). A total of 120 plots were established (60 in each of the two bamboo strata). In the mixed bamboo forest, circular plots of radius 10 m were also established along the line transects at each sampling point to assess trees associated with bamboo.

In each of the plots, data on bamboo diameter at breast height (dbh), age-class distribution (identified by specialists' bamboo harvesters and also validated from Wimbush, 1945; Scott, 1994; Bitariho, 1999 and Bitariho & Mosango, 2005), bamboo stem damage (caused by insect borer attacks, animals, climbers) and signs of harvesting/cutting of bamboo were recorded. Furthermore, individual tree species with dbh >10 cm were recorded in the mixed bamboo strata. The bamboo assessment plot design provided a sampling intensity of 0.03% and 0.05% for bamboo stems and trees respectively. The forest survey data (EI and bamboo plots) were analysed using Microsoft Excel and Systat 10.2 statistical packages.

Village interviews

Three parishes adjacent to Echuya forest and known to be traditional users of bamboo were identified together with forest rangers and selected bamboo specialists' harvesters. From the three parishes, six villages were randomly selected from the villages adjacent to Echuya. Then from each of the six villages, fifteen homesteads were visited without prior notification of the people visited and if people were found at home interviews were carried out (Bitariho, 1999; Bitariho & Mosango, 2005). A semi-structured questionnaire was administered to the bamboo harvesters. The information sought from the interviews was; whether they have cultivated bamboo in their homesteads and reasons for the decline of bamboo in Echuya. We used Microsoft Excel 2003 to analyse the village interview data.

Results and discussions

Interaction of bamboo with other vegetation types

Three bamboo strata were identified during the EI; pure bamboo, mixed bamboo and areas with no bamboo. Bamboo stems density in Echuya is 17,481 and 14,020 stems per hectare for the pure and mixed bamboo strata respectively (Table 1). Stem density of other plant types (trees, saplings and climbers/shrubs) was lower than that

Table 1 Mean stem density of plant life forms in Echuya forest

	Bamboo	Tree saplings	Climbers/ shrubs	Trees
Pure bamboo strata				
No. plots	10	10	10	10
Mean	137.4	16.2	16.1	1.3
No. stems/hectare	17,481	2062	2048	41
SD	93.38	17.29	13.35	2.11
Mixed bamboo strata				
No. plots	10	10	10	10
Mean	110.2	21.2	28.3	26.5
No. stems/hectare	14,020	2697	3600	843
SD	78.88	7.32	22.29	8.61
No bamboo strata				
No. plots	47	47	47	47
Mean	0	4.04	2.14	3.75
No. stems/hectare	0	514	272	119
SD	0	14.07	7.14	11.67

of bamboo in all bamboo strata except for the no bamboo strata (Table 1). The stems density of climbers/shrubs, saplings and trees increased from the pure bamboo to the mixed bamboo strata. In the no bamboo strata, the stem density of most plant life-forms was lower than in the other bamboo strata (Table 1). This is because some forest areas of Echuya are open with herbaceous vegetation and are just being colonized by trees and climbers. The open forest areas of Echuya could be a result of secondary succession in areas previously occupied by the bamboo forest. Even in areas dominated by bamboo, tree saplings and climbers and shrubs are slowly taking over the bamboo (Table 1). Banana & Tweheyo (2001) also noted that the area under tree cover in Echuya has increased from 16% to 51% during the past 50 years. It is therefore apparent that bamboo in Echuya is reducing in area although it is still the major vegetation type there.

Bamboo age-class distribution and stem density

The bamboo age classes can easily be distinguished from each other in the forest. Bamboo shoots are 6 months or less old and are very soft and eaten by monkeys, the young stems are green and soft (1–4 years old), the mature stems are light green and tough (5–7 years old) while the old stems are yellowish and sometimes grey and tough (over 8 years old) (Wimbush, 1945; Scott, 1994; Bitariho, 1999 and Bitariho & Mosango, 2005).

Table 2 shows the mean stem densities of bamboo age classes and their distribution in the pure bamboo and mixed bamboo strata. Overall mean bamboo stem density as expected is the highest in the pure bamboo stratum (Bitariho, 1999; Bitariho & Mosango, 2005), and bamboo shoot density is also the highest in the pure bamboo. The mean stem density of bamboo in the two strata was significantly different with more bamboo stems occurring in the pure bamboo than in mixed bamboo (Yates corrected, $\chi^2_{\text{(d.f. = 1)}} = 10.51$, $P < 0.001$). The most dominant age-class type of bamboo is the old stem type while young stem type is the least (Table 2). This is in agreement with the fact that the much of the bamboo forest in Echuya looks 'unhealthy', with most of the stems old and grey in colour. Bitariho (1999) and Bitariho & Mosango (2005) observed a similar kind of age-class distribution of bamboo in a nearby Mgahinga and Bwindi National parks in 1999. Kingston (1968) reported 39 years ago that the bamboo looked healthy with many tall and green young bamboo stems dominating the forest. Therefore, this is an indication that the bamboo forest is declining and will continue to decline over the years with more of the old stems replacing the young ones and that there is poor bamboo regeneration.

Huberman (1959) noted that the failure to produce new stems has often been held to be a reliable sign of pro-

Table 2 Mean stem density of bamboo age classes in Echuya forest

Statistic	Shoots	Young	Mature	Old	Dead	Total
Pure bamboo						
No. plots	60	60	60	60	60	60
Mean	1.27	14.38	23.32	59.73	11.18	109.88
Stems/hectare	161.5	1829.5	2966.9	7599.2	1422.4	13,979
SD	2.47	11.47	14.94	32.58	13.96	54.78
Mixed bamboo						
No. plots	60	60	60	60	60	60
Mean	0.1	8.17	5.5	10.62	3.92	28.30
Stems/hectare	12.7	1039.4	699.7	1351.1	498.7	3600
SD	0.66	8.73	6.18	11.94	5.53	26.71

spective flowering and this could be the case of the bamboo forest in Echuya. Small patches of bamboo were observed flowering during this study. Moreover, bamboo flowering was observed on the slopes of Mt Sabinyo in Mgahinga National Park (near Echuya forest) in the early 1980s (Bitariho & Mcneilage, 2004). That part of the Mt Sabinyo no longer has bamboo on it, but other parts of the mountain and Mgahinga Park do still have extensive areas of bamboo. The bamboo flowering in Echuya is therefore likely to occur only in small patches like that observed in Mgahinga and during this study.

Bamboo diameter class distribution

The diameter class distribution of bamboo in both pure and mixed bamboo forest strata shows a bell shaped kind of distribution characteristic of a normal curve (Fig. 1). This kind of distribution is typical of a bamboo population with equal number of thick and thin bamboo stems (Hall & Bawa, 1993). The diameter class distribution of the bamboo stems in the two strata is significantly different with greater proportions of small stems found in the mixed bamboo strata (Yates corrected, $\chi^2_{\text{(d.f. = 1)}} = 9.31$, $P < 0.001$). More thick bamboo stems are found in the pure bamboo strata than in the mixed bamboo and vice versa (Bitariho, 1999; Bitariho & Mosango, 2005). Thick bamboo stems (>32.5 mm) are used for basket weaving and building poles while thin bamboo stems (<24.5 mm) are used for bean-stakes and stakes for house wefts (Cunningham *et al.*, 1993; Bitariho, 1999). Bamboo harvesters therefore will concentrate on harvesting bamboo for bean-stakes and house wefts in the mixed bamboo forest and basket weaving and building poles in the pure bamboo forest (Cunningham *et al.*, 1993; Bitariho, 1999; Bitariho & Mosango, 2005).

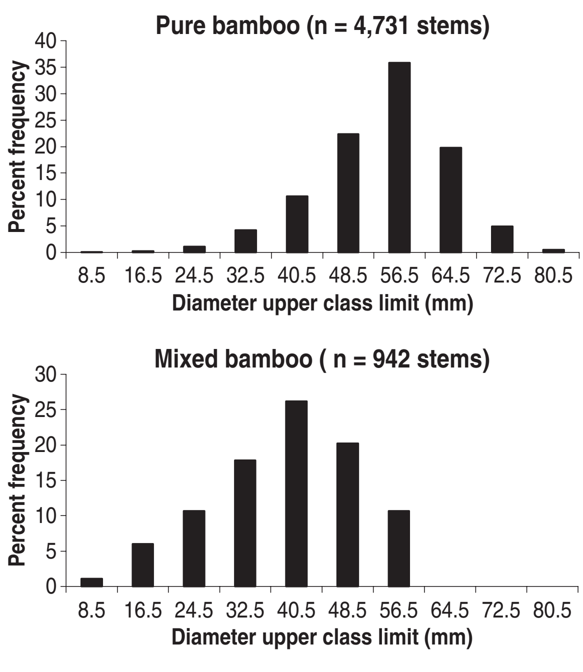

Fig 1 Diameter class distribution of bamboo in Echuya forest

Bamboo is heliophilous in nature and therefore competes for light and soil nutrients with trees in the mixed bamboo forest (Reid, Jinchu & Zisheng, 1991; Bitariho, 1999; Bitariho & Mosango, 2005). Tree canopy cover impedes light penetration to the bamboo stems and this is probably the reason why bamboo in the mixed bamboo forest is thinner than in the pure bamboo, where canopy cover is low. Furthermore, bamboo rhizome expansion may be impeded by the tree species root system and this may affect bamboo establishment in the mixed forest (Reid *et al.*, 1991; Bitariho, 1999).

Bamboo stem damage levels

Bamboo stems are damaged by humans during harvesting (stem cutting), monkeys during feeding and natural causes such as insect borer attacks and climbers. Damage levels of bamboo in Echuya are high (Fig. 2), with more than 60% of the bamboo stems damaged or cut. In the mixed bamboo forest, almost all the bamboo stems encountered were damaged (96%) with equal levels of damage caused by humans and natural factors (Fig. 2). This study encountered intense levels of bamboo cutting by humans in the mixed bamboo forest (46%). This is because bamboo stems used for bean-stakes and stakes for house wefts (harvested in large bundles) tend to be concentrated more in the mixed bamboo forest. As a result, bamboo in the mixed bamboo forest is losing vigour, which would be consistent with tree species opportunistically taking over the areas occupied by the bamboo. This kind of scenario is also likely to happen in the pure bamboo forest, as more bamboo stems get damaged, especially if exacerbated by over-harvesting.

Tree species associated with bamboo

Nineteen tree species were identified in the mixed bamboo stratum, all of which were secondary forest trees

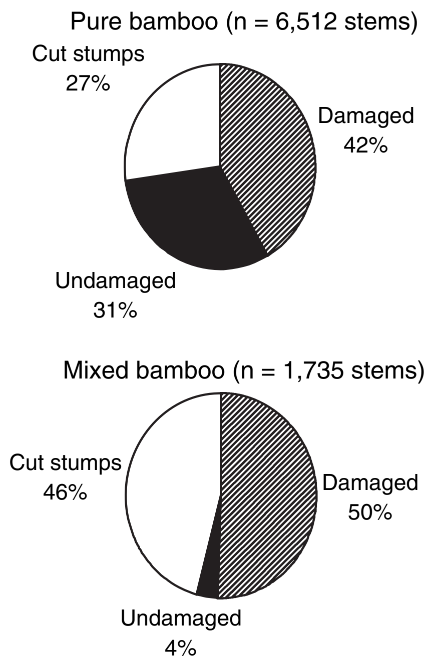

Fig 2 Bamboo damage levels in Echuya forest

(Hamilton, 1991). The most common tree species in the mixed bamboo were *M. kilimandscharica*, *N. congesta* and *Maesa lanceolata* (Fig. 3). The fact that these are secondary and pioneering tree species consistent with trees colonising the areas previously occupied by bamboo. These trees like bamboo are heliophilous and major colonizers in Echuya forest (Reid *et al.*, 1991; Chandrasheraka, 1996; Banana & Tweheyo, 2001). It is therefore likely that the secondary forest tree species in Echuya forest are contributing to a decline in bamboo forest cover.

Local community use of bamboo

There is a high level use of bamboo by the local communities living adjacent to Echuya. Ninety-six per cent of the people interviewed had not planted bamboo in their homesteads and yet admitted that they depended on Echuya bamboo for their household use (Fig. 4). Bamboo harvesters interviewed noted that high-level use of bamboo from Echuya is caused by lack of bamboo gardens. Seventy per cent of the interviewed bamboo harvesters said that they do not think of establishing bamboo gardens in homesteads because they could easily access it from Echuya forest (Fig. 4). Others cited land shortage and lack of bamboo planting skills the reason for not having bamboo gardens in their homesteads. Seventy-eight per cent of the interviewed people agree that the bamboo forest decline is caused by over-harvesting of bamboo stems (Fig. 4).

Why bamboo forest in Echuya is declining

Bamboo forest cover decline may be a result of poor harvest methods such as the clear cutting of bamboo in some areas (as practised when cutting bamboo for bean-stakes and stakes for house wefts) combined with other natural causes such as borer attacks and climber loads that seem to make bamboo lose vigour. Huberman (1959) noted that

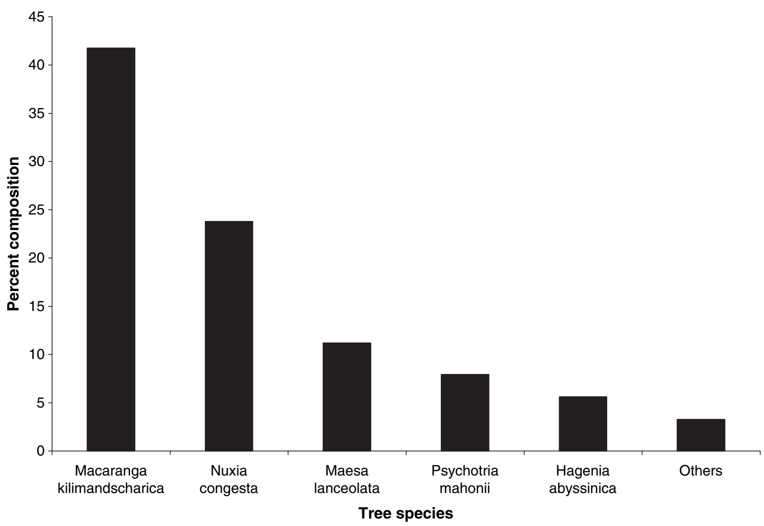

Fig 3 Tree species associated with bamboo in Echuya forest

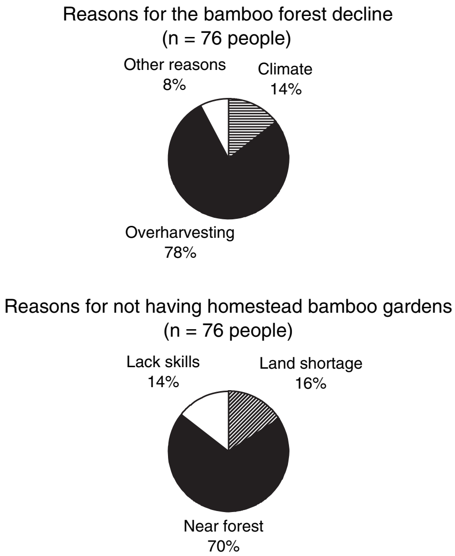

Fig 4 Local peoples' attitudes on bamboo forest in Echuya

continuous clear cutting of bamboo, particularly in unfavourable soils and climate, causes bamboo to deteriorate or to become eliminated altogether. The clear cutting of bamboo is further exacerbated by the invasion of secondary forest trees such as *M. kilimandscharica* and *N. congesta* that seem to out-compete bamboo for resources such as light and soil nutrients. Bamboo forest cover decline may also be as a result of an eminent flowering of the bamboo that is likely to occur in small patches. Climate change may also have led to a decline in bamboo forest. Most areas of south western Uganda have had an increase in temperature over the past 30 years because of clearings of forests and swamp drainages (Butynski, 1984; Bitariho, Babaasa & Kasangaki, 2000). This has led to major changes in most vegetation cover of south western Uganda and with increase in temperatures locally and globally bamboo forest cover may also have been affected (Romme & Turner, 1991; Smith, 1996 Bitariho *et al.*, 2000).

Acknowledgements

This study was funded by the European Development Fund/European Union through the National Forest Authority (NFA), and implemented by the Institute of Tropical Forest Conservation (ITFC). Technical advice was provided by Dr Jenny Wong and James Acworth of NFA. The research would not have been possible without the support in the field of ITFC Field assistants led by Herbarium technician Robert Barigyira and NFA field staff of Echuya.

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(Manuscript accepted 8 August 2007)

doi: 10.1111/j.1365-2028.2007.00840.x

