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Burning biodiversity: Woody biomass use by commercial and subsistence groups in western Uganda's forests

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ABSTRACT

Woodfuels are the most heavily used energy source in sub-Saharan Africa. We analyzed the ecological impacts and modes of access of five user groups (domestic consumers, gin distillers, brick manufacturers, charcoal producers, and tea companies) drawing biomass energy from natural forests in western Uganda. While domestic consumers use the most species for fuelwood (>50), their consumption is likely sustainable because they generally harvest fast-growing species from fallows on their own land or their neighbors'. Charcoal producers prefer old-growth hardwood species and are responsible for the greatest loss of natural forests. They access forests by finding landholders who, either willingly or through coercion, allow trees on their lands to be cleared. The impact of charcoal production is exacerbated by a license system that undervalues natural forests and rewards rapid harvests across large areas. The tea industry consumes mainly eucalyptus wood (*Eucalyptus* spp.) from corporate plantations, but they indirectly create pressure on natural forests by hiring immigrants who subsequently settle in and clear forest remnants. If such practices continue, forest remnants will soon be exhausted, leaving Kibale National Park as the last natural forest in the region. Forest remnants are a vital source of water, medicinal plants, and energy for local citizens and to protect them from over-exploitation, policy makers should target the charcoal and tea industry for reform. Support for local land management institutions governing access to fallows and successional forests will inevitably enhance the policy interventions.

1. Introduction

1.1. *Woodfuel consumption and forest ecosystems*

Approximately half of the wood cut annually worldwide is used as fuel, and of this amount, nearly 90% is produced and consumed in developing countries, where firewood and charcoal constitute the primary source of energy for the poor (Okello et al., 2001; Parikka, 2004; Dovie et al., 2004). This reliance is even more pronounced in sub-Saharan Africa, where woodfuels are the dominant energy source, both in terms of primary energy supply and the number of people relying on

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them (Bailis et al., 2005). Even in countries with large endowments of fossil fuels like Gabon and Nigeria, woodfuels are a significant energy source. Heavy reliance on woodfuels can result in a range of negative environmental impacts, with both local and global consequences, including forest loss and degradation, health problems for charcoal producers and households where biofuels are combusted (Ezzati and Kammen, 2002), and increased greenhouse gas emissions (Bailis et al., 2005). In addition, the expenses associated with both collected and purchased woodfuel are a major economic burden on the poor (Ezzati et al., 2001). The African humid tropics may not yet suffer the acute fuelwood shortages common in arid African regions, but fuelwood harvesting in these regions is extensive and significantly impacts biodiversity.

It is estimated that the extraction of wood from tropical forest for timber, charcoal burning and fuelwood constitute 68% of the proximate causes of deforestation in Africa, 89% in Asia and 51% in Latin America (Geist and Lambin, 2001). Even if forest is not entirely cleared, selective harvesting may change forest composition and ecosystem function (see Ndangalasi et al., this volume). For example, the harvesting of trees from old-growth forest may result in slow growing species being replaced with faster growing secondary species. Secondary growth is more susceptible to fire. If the burn frequency is sufficiently high, these disturbed forested areas, which were originally mature forest, can be converted to grassland that can be maintained indefinitely by fire. Unlike other tropical regions, many African mid-elevation secondary growth species do not provide food for frugivorous birds or primates (Struhsaker, 1997). Thus the replacement of old-growth trees with secondary growth reduces populations of many frugivores (Struhsaker, 1997). This reduction has been documented to last for over 30 years (Chapman et al., 2000) and is speculated to last much longer (Chapman and Chapman, 2004). Depending on the extent of disturbance produced through harvesting, plant evolutionary characteristics such as timing of reproduction, resource allocation, reproductive value, seed size, seed crop size, and seed germination may be significantly altered (Silvertown and Lovett-Doust, 1993). This may lead to the disruption of ecosystem, community or population structure and changes in resource and substrate availability or the physical environment. Changes in ecosystem characteristics such as species diversity, nutrient output, and biomass as well as changes that reset succession in one or more sites may be significantly disturbed (Mooney and Godron, 1983; White and Pickett, 1985; Turner et al., 1993; Burrows, 1993). In this paper, we measure patterns of fuelwood extraction in the moist, evergreen forests of western Uganda and discuss its effect on biological diversity.

1.2. *Woodfuel consumption in Uganda*

The forests of western Uganda contain biological diversity of global importance (Struhsaker, 1987) and are vital to local populations for sustaining ecosystem processes and providing multiple resources, especially fuelwood (Chapman and Chapman, 1996). Yet rapid population growth (3.3% per year), expanded commercial charcoal and brick production, as well as urban and industrial fuelwood demands are fundamentally altering the relationship between forests and forest users with resultant negative impacts on the forest resource base. In addition, the demand for forest products has intensified in the context of insecure property rights. The resulting rapid deforestation in Uganda (~600 km^2 per year) is threatening the long-term sustainability of land use in the region (Banana and Gombya-Ssembajjwe, 1996).

Given Uganda's poor record of state-centered forest conservation policies, contemporary researchers and practitioners alike are calling for new approaches to forest management (Banana et al., 2004). Community-based forest management has become a popular model, bolstered by political and ethical arguments regarding local resource access and self-determination (Agrawal and Gibson, 1999). At the heart of the community-based approach is the question of resource access—who has the ability and the right to use and benefit from forest resources? Throughout Uganda, community-based forest management is promoted with a vague concept of who constitutes "the local community" (Mugisha, 2002). To evaluate the feasibility of community-based management, local forest conditions and the ecological impacts of various user groups need to be thoroughly studied and understood in a holistic resource availability and use framework. Customary and formal forest access rules must also be accounted for, as well as the influence of national policies on local forest management.

Here we analyze the ecological impacts and modes of access by five user groups drawing biomass energy from natural forests in western Uganda. The five groups are (1) domestic consumers, (2) gin still operators, (3) brick manufacturers, (4) charcoal producers, and (5) tea companies. We selected these groups because they are embedded differently in markets and regulatory systems. Each has varying ability to benefit from forest resources by means of transport, labor, capital, and political power. Together, these oft-reinforcing factors shape fuelwood consumption patterns and the resulting impacts on ecosystems. They also influence how each user group responds to growing resource scarcity. By identifying species preferences of these groups, the volumes and rates of fuelwood harvest, and source forests, we aim to identify activities that most immediately threaten biodiversity. Thus we hope to guide efforts to promote sustainable community-based forest management in western Uganda and other African forests that are under similar pressure to supply fuelwood.

2. Study area

2.1. *Ecological characteristics*

The study area is located around Kibale National Park (795 km^2), in the Kabarole District in western Uganda, lying immediately northeast of the Rwenzori Mountains. Kibale National Park holds the last substantial tract of premontane forest in East Africa (Chapman and Chapman, 1996) (Fig. 1). Surrounding Kibale National Park is a mosaic of grasslands, smallholder agriculture, papyrus swamps, tea, eucalyptus plantations, and patches of natural forests. These forest patches average 32 ha in size (range 3 to 350 ha) and are located almost entirely in wet lowlands or steep slopes.

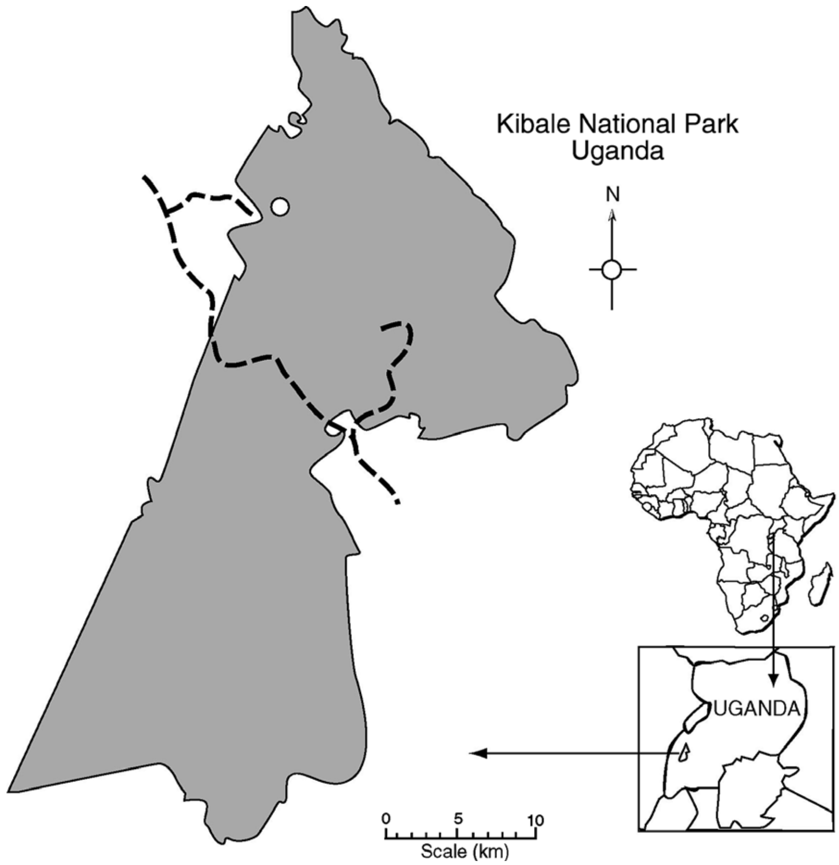

Fig. 1 – Map of study area, Kibale National Park in western Uganda.

Foresters have classified the forest in this region as a *Parinari* forest, distinguished on photo aspect maps by large spreading crowns of *Parinari excelsa* (Skorupa, 1988; Kingston, 1967). At this elevation (1370–1525 m), the presence of *P. excelsa* and the subdominants (*Pouteria altissima*, *Olea capensis*, *Newtonia buchananii*, and *Chrysophyllum gorungosanum*) is associated with old-growth forest (Osmaston, 1959). When discussing specific tree species used as fuelwood, we indicate if they are old-growth, mid-successional, early successional, or exotic species following Zanne and Chapman (2005) and Hamilton (1991). As is typical of many tropical tree communities, tree growth rates in the region are highly variable among species (Chapman and Chapman, 2004). Species typically found in old-growth or mature trees have growth rates of between 1 and 3 cm diameter at breast height (DBH) per year, while species colonizing gaps or disturbed areas can have growth rates exceeding 10 cm DBH/year and can reach >15 m in height and >10 cm DBH in just 5 years (Chapman, unpublished data). While rates of seed dispersal into areas of disturbed forest are not reduced, recruitment of seedlings and saplings is very poor, due to competition with grasses and an aggressive herbaceous layer (Chapman and Chapman, 1997; Paul et al., 2004). Areas of mature forest are not typically susceptible to fire, while areas of degraded forest are (Chapman et al., 1999; Lwanga, 2003).

2.2. *Social context and rules of forest access*

The dominant ethnic group in the area is the Batoro people. Since their arrival in Kabarole District[1] during the 19th century (Naughton-Treves, 1999), the Batoro have developed a local system of ownership and forest use, incorporating both spatially explicit resource domains (e.g., royal and village forests) and user rights to specific tree species (Kaipiriri, 1997). Royal forests are managed similarly to village forests except that a special tax is levied on any commercial users of the forest and is collected by a representative of the *Omukama* (king) (Kasenene, J., pers. comm.). As is common in East Africa, forest access rules are complex and include overlapping tenure claims (Rocheleau and Edmunds, 1997). Most forest patches and swamp forests are considered village property that is subdivided into individually managed parcels. Few individuals have legal title to their land; they claim it instead under customary rules. Some elements of communal ownership persist. Individual owners are typically obligated to give kin and neighbors permission to use natural forests and old fallows for cooking fuelwood, medicinals, drinking water, and other subsistence purposes.

[1] Prior to independence, the region was known as the Toro Kingdom.

Traditional forest property regimes were undermined by state-imposed regulations and commercial timber markets during and immediately after the colonial period. During this time, the Ugandan Forest Department assumed ownership of all large blocks of forests (including Kibale Forest in 1932) and managed them for timber extraction. Local people were prohibited from harvesting resources in state forests and were expected to rely instead on surrounding forest patches. Following independence, between 1971 and 1986, Uganda experienced war, severe economic recession, and the disintegration of the state. The Forest Department lost control of Kibale and other forest reserves (Hamilton, 1984), and during this turbulent period, the population density in Kabarole District tripled (from 27 to 97 people per km^2) due to high fertility rates and the immigration of tens of thousands of Bakiga people from southwestern Uganda (World Bank, 1993). In 1990, the post-war Ugandan government "upgraded" Kibale from a reserve to a National Park and used force to control illicit use of park resources (Feeny, 1998). More recently, park managers and local leaders have begun to discuss collaborative management at Kibale, and to allow some neighboring communities to use non-timber forest products within specified zones (KNP General Management Plan 2005). Outside the park, the continued rapid population growth (3.4%, among the fastest in Uganda) and high demand for fuelwood and charcoal has intensified pressure on forests (Government of Uganda, 2002).

2.3. Current fuelwood use and patterns of deforestation

Over 95% of Kabarole's people rely exclusively on wood for energy (Government of Uganda, 2002). Charcoal production for regional and national urban markets is expanding (Chapman and Chapman, 1996). As elsewhere in East Africa, charcoal is produced by burning logs in oxygen-restricted pyrolytic conditions inside earth kilns (known locally as 'heaps') averaging 5.7 m^3 in size (range 1.7–10.9 m^3). Brick production is also growing to meet construction demands of growing urban and semi-urban areas. The commercial production of banana beer and gin also requires fuelwood resources (~60% of smallholder land is cultivated with brewing bananas) (Naughton-Treves, 1998). The area devoted to tea cultivation in Kabarole has expanded by 2000 ha (~10%) in the past 40 years (Mulley and Unruh, 2004), much of this within 10 km of Kibale Park, where tea production expanded six fold between 1955 and 1988 (Mugisha, S., unpublished data). Mulley and Unruh (2004) explain that this expansion intensifies pressure on forests in two ways: first, tea companies require significant amounts of eucalyptus to dry their tea (roughly one hectare of eucalyptus is needed per every three hectares of tea), and second, they import laborers from outside Kabarole,[2] many of whom eventually leave the tea companies and establish homesteads on land near the park boundary.

Amidst growing demands for forest resources and uncertain access rules, deforestation in Kabarole has continued apace. According to remote sensing analysis by Mulley and Unruh (2004), between 1955 and 2001 forest declined by 7967 ha outside of Kibale National Park, while increasing by 10,823 ha within the Park, due to forest regrowth in formerly cultivated areas. A similar analysis by Naughton-Treves et al. (unpubl.) along the western boundary of Kibale showed that forest loss inside the park within 500 m of the boundary proceeded at 0.2% per year between 1995 and 2001. During this same period, forest declined outside the park by 2.3–3.8% per year, with the fastest rates occurring within 1 km of the park boundary. This peak in deforestation rates near the park was similarly observed for other forest reserves of the Albertine Rift (Plumptre, 2002, and see Plumptre et al., this volume). The accelerated deforestation near the park boundary is cause for concern given the deleterious effects of isolation on biodiversity conservation (Brooks et al., 1999). As in the case of other African forest parks, the pattern of deforestation also portends heightened pressure on Kibale in the future if surrounding forests are exhausted (Struhsaker et al., 2005).

3. Methods

We focused our monitoring and interviews along the western side of Kibale National Park, up to 10 km from the boundary (Fig. 1). Due to our long history (15+ years) of working in this area and our basic knowledge of the Toro language, citizens were generally comfortable discussing their fuelwood uses and opinions about forest management with us. We also assured respondents we would protect their anonymity. Expert help from local resident field assistants (both Batoro and Bakiga), further improved the data quality. Despite these advantages, illicit uses were likely underestimated by some respondents.

3.1. Survey

To obtain a rough estimate of the proportion of the local residents that belonged to different fuelwood user groups, we surveyed people from 160 households divided into three groups: those located adjacent to a natural forest patch, adjacent to Kibale National Park, or in the second or third row of properties away from any forest edge. This sampling design was sensitive to the strongly spatial underpinnings of traditional forest access rules. We asked each respondent if anyone in the household had engaged in cooking, producing gin, or brick making during the past year. We also noted if they had a woodlot on their property.

3.2. Monitoring fuelwood use

Between 2000 and 2001, using a participant observer approach, we monitored 86 fuelwood combustion "episodes", including 32 domestic cookers, 18 brick makers, 26 charcoal producers, and 24 banana gin distillers. We used a stratified semi-random method to select individuals lying along a continuum of increasing distance from Kibale. This design was easy to follow in the case of domestic cookers who are present throughout the landscape (Table 1). Sampling the other fuelwood user groups was more difficult given their non-random distribution on the landscape. For example, only

[2] Roughly half of the local tea labor force is recruited from areas beyond Kabarole District (Lameck, K., Manager, J. Finlay Tea Ltd., pers. comm., 2006).

Table 1 – A description of the sample of informants used to describe patterns of fuelwood use in the region adjacent to Kibale National Park, Uganda

User group	Total sample size	% Women sampled (as % of people actively involved)	No. of samples			Average duration of each combustion episode (i.e., period monitored, in hours)
			<1 km from Kibale National Park	<1 km from other natural forest	Kibale or other natural forest	
Domestic consumers	28	96	7	13	8	4
Brick makers	22	7	0	6	16	44
Gin distillers	22	0	13	8	1	13
Charcoal producers	26	5	12	14	0	128

one still and no charcoal heaps were found >500 m from the edge of Kibale or another patch of natural forest. Conversely, all but two brick kilns were located within 100 m of a major road, and thus >5 km from the park.

In each case, we identified and weighed all logs and wood pieces designated for use in a particular combustion episode. Logs <40 kg were weighed (wet weight). The mass of larger logs was estimated from measuring the volume (length $\times \pi r^2$) and multiplying this by the wood density for the 12 frequently used species: *Vernonia* spp., *Acanthus pubescens*, *Maesa lanceolata*, *P. excelsa*, *Bridelia micrantha*, *Macaranga schweinfurthii*, *Eucalyptus* spp., *Olea welwitschii*, *Diospyros abyssinica*, *Fagaropsis angolensis*, *N. buchananii* and *Prunus africana*. This resulted in more precise estimates for smaller pieces than for large logs. Wood density for these 12 species was calculated by volumetric displacement of water by fresh wood pieces. For other species, we used wood density listed in Brown (1997). We identified the species of wood by visual observation. If we did not recognize the species, the fuelwood users assisted in its identification. The final proportion of "unknown" species varied among fuelwood uses. Seven percent of fuelwood pieces used in domestic cooking could not be identified, 7% of pieces used to make charcoal were also not identified, 2% remained unidentified for stills, and <1% for brick kilns. These field methods were inappropriate for measuring fuelwood use by tea processing factories, given the industrial scale of their operation. Instead we relied on the records of the single tea processing plant in the study area (Kiko processing plant of Rwenzori Highland Tea Company, later purchased by James Finlays (U) Ltd.).

3.3. *Semi-structured interviews*

We took advantage of the many hours spent monitoring fuelwood use to conduct in-dept, semi-structured interviews with individuals from each of the user groups. We asked people where they had obtained each piece of fuelwood, if/how they negotiated access to the fuelwood, if they perceived any shortage of fuelwood, and if so, who or what they thought was to blame for the shortage. We also tallied outputs of the combustion episode (e.g., volume of gin or charcoal produced, number of bricks, number of meals cooked). To obtain a broader picture of forest access rules, we interviewed 11 key informants, including four local council chairmen, two Forest Department officials in the regional municipal office (Fort Portal), three charcoal transporters, and two small-scale charcoal vendors.

3.4. *Data analysis*

Descriptive statistics was the major source of analysis. However, non-parametric statistics (e.g., Kruskall–Wallis and Mann–Whitney *U*-Test) were used under various regimes. The Kruskall–Wallis test was used to compare the differences in the amount of wood utilized by the five groups as well as the number of species used by the user groups in each combustion episode. The Mann–Whitney *U* test was to ascertain the differences in the mean biomass consumption between the user groups. We used the CITES classification to identify the threat status of species.

4. Results

The composition of the 160 respondents in our field survey roughly accords with the make-up of Kabarole's general population. There were 48% women and 52% men, and 29% Kiga, 68% Toro and 3% 'Other ethnicity' (compared to 28% Kiga, 70% Toro and 2% 'Other' according to the 2002 Ugandan government census of Kabarole).

4.1. *Physical patterns of use and sustainability*

The results of the survey of 160 residents reveal that all respondents rely on firewood for cooking, no matter where they live (Table 2). Charcoal production was the second most frequent use (17.8%), but this activity was confined largely to natural forest edges and was especially prevalent around village-managed forest patches. Those who distilled banana gin resided mainly along the edge of forest remnants and Kibale Park and comprised 14.4% of the total respondents. Only 2.5% of respondents baked bricks. Overall the amount of biomass harvested per combustion episode differed significantly amongst the different users (Kruskall–Wallis = 68.01, $P < 0.001$), with charcoal using more biomass than any other group (Mann–Whitney tests between pairs $P < 0.02$ or less). Brick making used more woody biomass than stills ($P = 0.003$) or women collecting cooking firewood ($P < 0.001$), and biomass collection for stills being more than collection for cooking firewood ($P < 0.001$).

As a group, women gathering firewood for cooking ('domestic consumers') used the greatest number of woody species (50) (Table 3). At the other extreme was the tea processing plant, which relied entirely on one species of eucalyptus (*Eucalyptus grandis*) to fuel its tea leaf driers. Brick makers, gin distillers, and charcoal producers all used a comparable number of species (~26). The number of woody species used

Table 2 – The results of the survey of fuelwood use by residents (N = 160) near Kibale National Park, Uganda

Households' location	N	% Ethnic group[a]	% Women interviewed	During past year, % using fuelwood			
				Cook	Distill gin	Bake bricks	Produce charcoal
Household adjacent to Kibale National Park	52	35 K 62 T 3 O	42	100	26.9	1.9	9.6
Household adjacent to forest patch	56	18 K 77 T 5 O	43	100	16	4	21
Household in second or third 'row' from forest	51	35.3 K 60.7 T 4.0 O	58.8	100	7.8	0	2.0
Total	160	28.8 K 66.2 T 5.0 O	48.1	100	14.4	2.5	17.8

a T = Batoro people, K = Bakiga people, O = other ethnicity (includes people of Nyoro, Ankole, Hutu and other ethnic heritages).

Table 3 – A description of the woody species used and annual combustion of five groups of fuelwood users adjacent to Kibale National Park, Uganda

Fuelwood user (*n*)	Total no. of spp used	Top species (by % total weight for those accounting for >2%) and successional stage[a]	Annual combustion[b] (tons/yr/user)
Domestic consumer (28 households)	50	*Vernonia* spp. (14.8%) – ES *Acanthus pubescens* (10.9%) – ES *Maesa lanceolata*(6.5%) – ES *Parinari excelsa* (4.3%) – OG *Bridelia micrantha* (3.9%) – ES *Psidium guavaja* (3.9%) – EX *Ficus brachylepis* (3.2%) – ES *Sesbania sesban* (3.2%) – ES	4.3
Brick maker (18 kilns)	22	*Eucalyptus* spp. (78.4%) – EX *Persea americana* (5.6%) – EX *Sapium ellipticum* (4.4%) – ES	96.4
Gin distiller (22 stills)	27	*Prunus africana* (33.2%) – ES *Parinari excelsa* (11.1%) – OG *Macaranga scheiwinfurthii* (4.8%) – ES *Olea welwitschii* (2.3%) – MS	6.1
Charcoal producer (26 heaps)	26	*Diospyros abyssinica* (18.1%) – MS *Olea welwitschii* (12.0%) – MS *Fagaropsis angolensis* (10.3%) – MS *Newtonia buchananii* (7.8%) – OG *Parinari excelsa* (6.1%) – OG	50.8
Tea factory (1)	1	*Eucalyptus* spp. (100%) – EX	2535–3000

a Successional status of species as per Zanne and Chapman (2005) with OG: old growth, MS: mid-successional, ES: early successional, EX: exotic.
b Calculated by multiplying biomass used per burning episode by number of burning episodes every year, as estimated by informants.

during each combustion episode also differed significantly among the five user groups (Kruskal–Wallis = 9.264, $P = 0.026$). The number of species burned during an average brick-making project was less than that taken to fuel stills (pairwise comparison using Mann–Whitney, $Z = 3.1$, $P = 0.008$), produce charcoal ($Z = 3.3$, $P = 0.002$), and cook food ($Z = 3.4$, $P < 0.002$). Fueling stills typically involved a species harvest that was comparable to charcoal production and used marginally more species than the average used during a day's cooking ($Z = 1.98$, $P = 0.054$). Finally, the number of species used in charcoal production was similar to that collected by women for fuelwood. The major difference seems to be that

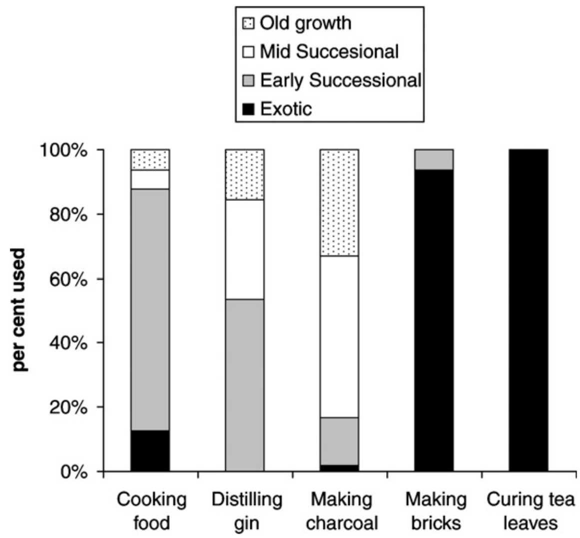

Fig. 2 – Type of woody species used in Kabarole, Uganda.

in producing bricks people are more selective and only use trees found near roads (e.g., *Eucalyptus* spp. and other exotic species).

More important than a simple tally of the average number of species used per combustion episode is the *type* of species harvested by the different groups (Fig. 2). Women relied mainly on fast-growing early successional species like *Vernonia* spp. for cooking food (Table 3). In previous research (Naughton-Treves and Chapman, 2002), we calculated that each household in the study area would require roughly 0.5 ha of land fallowed for ~4 years to meet their fuelwood needs for cooking (8.4 kg per day). Brick makers meanwhile primarily harvested eucalyptus trees. By contrast, gin distillers and charcoal producers burned slow-growing hardwood species such as *P. excelsa*, *N. buchananii*, and *O. welwitschii*. These species are rapidly disappearing from forests outside the park and provide important food resources for frugivores in the region. During interviews, respondents ranked these three old-growth species as "most scarce" along with two early successional species: *B. micrantha* and *P. africana*. *P. africana* is listed in Appendix II of CITES and is highly valued for its medicinal properties (Anonymous, 2005; Fashing, 2004).

4.2. Forms of acquiring access to fuelwood and coping with scarcity

Table 4 reveals the distinct pattern of extraction for each user group. On average, women collect just over half their firewood for cooking from fallow land and woodlots on their own property. Their second major source is woody species growing on their neighbors' land. During interviews, women explained that this is customary and that it would be rude for their neighbor to refuse them "small sticks" for cooking. Women also collected fallen branches of hardwoods from forest remnants, especially when they needed to prepare slow-cooking food. Average time spent searching for and collecting firewood was 1.1 h/day (range 0.5–3), a relatively low value compared to the travel and collection times of nearly 5 h/day recorded in some other parts of Africa (Kammen, 1995).

The brick makers relied primarily on eucalyptus trees grown on neighbors' woodlots. They obtained this wood by bargaining with their neighbors and offering them a percentage of the profit from the sale of the bricks. Due to the significant cost of transporting bricks, brick makers located their kilns near major roads and thus they were too far from natural forest remnants to draw on them. Transport costs apparently did not constrain other fuelwood extractive activities, such as gin distillation and charcoal manufacturing.

Gin distillation is typically a group project in which various individuals contribute banana mash, distillation equipment (barrel and pipes), and labor. Distillers pay 15,000/= (~US $8.1 in 2003) each year to the subcounty tenderer for the right to produce gin. Distillation is typically carried out where banana fields abut natural forest, and where a small stream flows. Small fires need to be maintained continuously for 12 h, thus slow-burning hardwood logs are favored. These are mainly drawn from fallen branches or logs within an area <500 m of the still, including within the Park occasionally. If logs are drawn from forest belonging to a neighbor, that neighbor receives a portion of gin sale profits.

Charcoal production is officially regulated by a license system where individuals pay 26,800/= per month (equivalent to ~US $14.60, comprised of a $8.70 transport fee, $5.88 burn fee) to produce as much as they can from anywhere in the District. There is an active, illicit trade in sharing and duplicating these licenses. Individuals living in remote forested areas do not buy licenses; rather, it is the intermediary who buys and transports the charcoal to town must have the license.

Table 4 – Source of fuelwood by land property type for four use groups

Use groups	Total kg traced to source	Own property		Neighbors' property		Village forest patch[c]	Kibale National Park
		Fallow[a]	Woodlot[b]	Fallow[a]	Woodlot[b]		
Domestic cookers	483.2	38.2%	18.5%	23.4%	4.8%	13.1%	1.6%
Gin distillers	2829.3	5.8%	2.6%	2.0%	0%	80.5%	9.1%
Charcoal manufacturers	28,190.8	0%	0%	7.3%	0%	92.3%	0.4%
Brick makers	19,320.6	3.9%	12.4%	16.0%	67.2%	0.2%	0%

a "Fallow" is a broad category including naturally regenerating fallows 4–20 years old as well as areas of brush managed amidst sparsely planted banana fields.
b "Woodlot" refers to planted areas of exotic trees, primarily *Eucalyptus grandis*.
c Includes royal patches. See Naughton-Treves (1999) for a history of royal claims to wildlife and forests in Kabarole.

Certain individuals (often Kiga immigrants) specialize in manufacturing charcoal, an arduous job commonly referred to as "poor man's work". The access rules for charcoal producers are often unclear. In fact, during several interviews, landowners asked the first author to explain who had the right to produce charcoal. Most typically, landowners who agree to have charcoal produced from a portion of their territory of village forest receive one or two sacks of charcoal (each worth ~2500/= or ~$1.40 US) as payment (average yield per "heap" is 17 sacks). Individuals residing on Royal forested land officially have no right to demand payment or to deny permission to charcoal producers. In such cases, the King's representative collects one or two sacks of charcoal per heap. Some individuals, single women in particular, complained that they could not refuse "men who come with papers" (i.e., licenses). Evidently, customary norms of access do not govern the charcoal business, but neither do legal codes. For example, it is illegal to clear forest alongside streams, yet the majority of charcoal production episodes occurred close to water given that this is where the last natural forest grows.

Unlike the other fuelwood uses described so far, tea is part of the formal national and international economy. Tea processing factories in Kabarole appear to abide by environmental laws. Most keep careful records of their fuelwood use. Some publicly post-rules for environmental stewardship, and one company, J. Findlay (U), attained accreditation for Environmental Management under the ISO 14001 system. The tea factory in the study area now burns only eucalyptus trees grown on their private property (Table 4). But some other factories continue to buy eucalyptus from local farmers. Moreover, as tea production continues to expand in Kabarole, more land for raising eucalyptus is required, which the tea companies acquire by buying land from local people. Under this practice, eucalyptus is often planted in wetlands, although this latter practice is illegal (Mulley and Unruh, 2004).

5. Discussion

5.1. Proximate concerns for loss of biological diversity

The patterns of fuelwood extraction we observed in western Uganda accord with studies elsewhere in tropical Africa (Parrotta et al., 2002). Woodfuels continue to provide nearly all the energy required for cooking and heating in rural and urban households in Uganda (Ugandan National Forestry Authority Report, 2004, cited in GTZ, 2005). The high household demand for fuelwood and charcoal coupled with industrial demands (including expanded cultivation of tea) is driving rapid deforestation. Using old growth, hardwood species as fuel is not sustainable, particularly for the manufacture of charcoal, given the large volumes of wood consumed. The regeneration of hardwoods on fallow land is very slow (Chapman et al., 1999; Naughton-Treves and Chapman, 2002). For example, to perpetually supply a charcoal manufacturer with 50 tons of native hardwoods per year would require an extremely large area—depending on regeneration and growth rates possibly as much as 1000 km^2 of land area. This represents the standard accumulation of native hardwoods on fallow land managed by smallholders. If lands were to be managed specifically for hardwood production (e.g., liberation thinning, enrichment planting) biomass accumulation would be substantially higher. At present, however, local citizens cannot afford to manage land for such long time horizons, or they are too uncertain of their long-term ownership of forests. Thus, even though home cooking consumers outnumber charcoal producers by >5–1, it is the charcoal producers' activities that immediately threaten natural forests.

Meanwhile, women's use of firewood around Kibale appears to be sustainable due to their reliance on early successional species from fallow lands. The campaign to privatize land in Uganda could potentially undermine women's access to firewood given that they now rely on customary access rules to use wood from one another's fallows and fields (Rocheleau and Edmunds, 1997). Supporting these customary access rules is in the best interest of forests and local communities.

At the other extreme, the tea industry's impact on forests is shaped by formalized national and international regulations. Some companies are attempting to produce tea according to international fair-trade criteria, which include protecting natural forests. While this is a laudable goal, the tea industry will still indirectly threaten Uganda's western forests as long as companies buy up fallow land for eucalyptus plantations and import large numbers of workers for their plantations and processing plants.

5.2. Policy and management implications

As in many tropical regions (Parrotta et al., 2002), much of western Uganda's natural forests are not being "managed" so much as "mined" for fuelwood (charcoal in particular). Similar patterns have been observed in neighboring Tanzania, where commercial harvesting for charcoal overrides ecological impacts from all other harvesting purposes because of powerful economic incentives and the wide range of species and size classes used to produce charcoal (Luoga et al., 2002). In western Uganda, as elsewhere in Africa, local citizens obtain negligible income from charcoal production. Instead, profits accrue to charcoal transporters and wholesale traders, as well as to those engaged in the illicit "license" trade (Brouwer and Falcao, 2004).

Policy reform aimed at improving the sustainability of charcoal manufacture is urgently needed to slow biodiversity loss and protect ecological services and local livelihoods. Such reform may be complex due to the fact that while charcoal has negative environmental impacts, using charcoal instead of firewood has positive consequences for human health. Compared to wood, charcoal use contributes much more to biodiversity loss and climate change (Bailis et al., 2005). On the other hand, charcoal burns more cleanly than wood and switching from wood to charcoal can reduce a household's levels of particulate matter and carbon monoxide by as much as 90% (Ezzati and Kammen, 2002). This in turn can decrease the incidence of respiratory illness in children by 50%. Thus, although choosing charcoal over wood can negatively impact the environment, it can also reduce the incidence of illness in the household.

Management strategies that encourage more sustainable charcoal production, transport, and end-use are only in their infancy. Many experts call for more efficient, modern kilns (Okello et al., 2001). Others argue that marketing and license rules should be reformed to foster prices that better reflect charcoal's inherent ecological and social costs (Lew and Kammen, 2005; Ribot, 1998). Such reform is often politically difficult due to urban consumers' demand for cheap energy. For example, Nigeria's efforts to slow fuelwood consumption have been "unsuccessful" due to the high costs of alternative fuels (Kersten et al., 1998). These experiences have lead some analysts to call for greater subsidies for electric power for urban consumers, as a way to alleviate some of the pressure on forests (Ministry of Agriculture, 2004).

5.3. *Concluding remarks*

At present, the greatest threat to Uganda's natural forests is charcoal production, an economic activity that at present does not conform to customary forest access rules or codified legal regulations. Because of abundant, inexpensive access, Ugandans have one of the highest levels of consumption of firewood and charcoal in Africa (1.77 m^3 fuelwood per person per year, Brouwer and Falcao, 2004). However, this access comes at the expense of the country's natural forests and biological diversity, and the long-term maintenance of local ecosystem services (e.g., watershed and soil protection). Outside of national parks, old-growth species are becoming increasingly rare because harvest patterns favor short-lived, early successional tree species or grasslands (Okello et al., 2001). The Ugandan National Forest Authority projects that the current national consumption rate of 20 million tons of wood per year will triple by 2025 (GTZ, 2005). Under such a scenario, old-growth forests will likely be extirpated outside of parks and reserves. To conserve Uganda's remaining natural forests, reform in the charcoal sector is urgently needed, as well as coordination of policies across nations due to illicit wood harvesting. National energy plans ought to incorporate biodiversity and livelihood concerns.

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