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LAND-USE AND COVER CHANGES (1988–2002) AROUND BUDONGO FOREST RESERVE, NW UGANDA: IMPLICATIONS FOR FOREST AND WOODLAND SUSTAINABILITY

E. N. MWAVU*,† AND E. T. F. WITKOWSKI

Restoration and Conservation Biology Research Group, School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Johannesburg, PO WITS 2050, Johannesburg, South Africa

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ABSTRACT

Land-use and cover changes around Budongo Forest Reserve (BFR) were analysed from multi-temporal LandSat images (1988 and 2002) and associated field-based studies in 2003–2004. Three major land-use and cover classes: forest/woodland, sugarcane plantations and grassland/shifting-cultivation/settlements were clearly discriminated. The area under sugarcane cultivation increased over 17-fold, from 690 ha in 1988 to 12729 ha in 2002, with a concomitant loss of about 4680 ha (8·2 per cent) of forest/woodland, mainly on the southern boundary of BFR. Land-use and cover changes were a result of (a) agricultural expansion, (b) increasing human population, exacerbated by large influxes of refugees, (c) conflicts of interest and political interference in the management of BFR and (d) unclear land tenure. Agriculture is the main land-use practice and source of income to local people, with commercial sugarcane and tobacco as the primary cash crops. Individual smallholder sugarcane plantations covered distances ranging from 30 to 1440 m along the BFR edge, with no buffer zone, resulting in direct conflicts between farmers and forest wild animals. There is an ever-increasing need for more land for agricultural expansion, resulting in continued loss of forest/woodland on private/communal lands and encroachment into BFR. This unsustainable agricultural expansion and the local people's perception of BFR as an obstacle to agriculture, threatens the conservation of its threatened wild plants (e.g. *Raphia farinifera*) and the endangered chimpanzees. Therefore, their sustainable management for both development and conservation will require strong and incorruptible institutions that will seek a balance between resource exploitation and conservation. Copyright © 2008 John Wiley & Sons, Ltd.

KEY WORDS: agricultural practices; change-detection; forest/woodland loss; forest management; land-tenure; institutional framework; political interference; remote sensing; Uganda

INTRODUCTION

In developing countries where a large proportion of the human population depends almost entirely on natural resources for their livelihoods, there are increasing competing demands for utilisation, development and sustainable management of the land resources (e.g. natural vegetation), resulting in land-use and cover changes. Land use is defined as the manner in which human beings employ the land and its resources (e.g. for agriculture, grazing, logging, etc.), while land cover is the ecological state and physical appearance of the land surface (e.g. closed forests, woodlands or grasslands) (Turner and Meyer, 1994; Brandon, 2001). The primary cause of land-cover change worldwide is through changes in the way people use and manage land (Dale *et al*., 2000; Gobin *et al*., 2001; Millennium Ecosystem Assessment (MEA), 2005a). The most potent forces affecting natural vegetation arises from the direct effects of an expanding human population (e.g. habitat destruction for agriculture, human settlement, land for grazing, etc.) and indirect effects (e.g. pollution) (Grime, 1997; UN/ECE, 2002; MEA,

* Correspondence to: E. N. Mwavu, Restoration and Conservation Biology Research Group, School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Johannesburg, PO WITS 2050, Johannesburg, South Africa.
E-mails: edwardm@gecko.wits.ac.za; emwavu@forest.mak.ac.ug
† Present address: Department of Forest Biology and Ecosystems Management, Makerere University, P.O. BOX 7062, Kampala, Uganda.

2005b). Hence, land use directly and indirectly influences environmental conditions, which play a major role in landscape change.

Forests worldwide have been disappearing at an alarming rate, with an estimated 86 per cent of the original forest cover already lost by 1993 (WRI, 1994). Total forest area continues to decrease, with each year about 13 million ha of forest lost due to deforestation, particularly in the tropics, mainly as a result of conversion to agricultural land (FAO, 2005; MEA, 2005b). According to the MEA (2005b) forests have completely disappeared in 25 countries and another 29 have lost more than 90 per cent of their forest cover. A crucial link between forests and sustainable development has been recognised in the Millennium Development Goals. The area of forest cover is one of the indicators for the 7th Goal to 'ensure environmental sustainability' (Hoare, 2005). However, as humans try to meet their daily needs, they are subjecting forests, woodlands and grasslands to the highest rates of change that have ever been recorded for large regions (FAO, 1996; MEA, 2005b), and Uganda's forests and other natural vegetation types are no exception. Uganda lies within the region in which at least 30 per cent of the landscape (by area) comes under cultivation in any particular year (MEA, 2005a). However, the disappearance of tropical forests is a result of many pressures, both local and regional, acting in various combinations in different geographical locations (Geist and Lambin, 2002). While it is possible to identify with some certainty the factors underlying tropical deforestation in a general sense, it is very difficult to pinpoint a uniform set of drivers/causes and their relative contributions that apply generally at a global or even regional level (MEA, 2005b). Deforestation is a location specific problem, with the effects and magnitude of each identified factor differing between countries and regions (NRC, 1999). Furthermore, a complicated combination of economic and social development factors, levels of agricultural productivity and urbanization, climatic and geographical peculiarities, and historical factors, together determine the rates of deforestation in any particular place (Luoga *et al*., 2005; MEA, 2005b).

Uganda is a developing country with a largely agrarian economy, where over 90 per cent of the human population rely heavily on natural resources for livelihood needs (NEMA, 1998), leading to varying impacts on its forests (Mwavu and Witkowski, 2008). However, these impacts and changes have not been well documented and quantified, particularly for important natural tropical forests such as Budongo Forest Reserve (BFR), the largest forest reserve in Uganda (Plumptre, 1996). BFR is a semi-deciduous forest in the NW, and of considerable value for both biodiversity conservation (with probably the largest wild chimpanzee population in Africa and several threatened plant species, Plumptre *et al*., 2007), as well as for local livelihood activities. Forests and woodlands are central to Uganda's three national pillars of sustainable development—the economy, society and environment. But according to MEA (2005b), the overall state of knowledge on the condition and changes of forests/woodlands in many regions of the world is incomplete. With the increasing human population in Uganda, both indigenous and migrant, and the shrinking extent of natural habitats, it is important to evaluate the magnitude, pattern and type of land-use and cover changes that are occurring within and surrounding the BFR. These data may help to project the consequences of these changes on the conservation of natural resources, and with appropriate action, contribute to sustainable management (Petit *et al*., 2001). Furthermore, the increasing concerns for the consequences of both global environmental change and local development have brought land-use and cover research to the forefront of the international agenda (Turner, 1997; WRI, 1997; Dale *et al*., 2000). The changes in land-use and cover due to natural and human activities can be observed using current and archived remotely sensed data at very high spatial, spectral and temporal resolutions (Luong, 1993).

Over the years, remote sensing has emerged as the most useful data source for quantitatively measuring land-use and cover changes at the landscape scale (Hudak and Wessman, 1998). Satellite remote sensing in conjunction with GIS has been widely applied, and recognised as a powerful and effective tool in detecting land-use and cover change (Meaille and Wald, 1990; Weng, 2002). It can help decision makers to develop effective land management plans (Mongokolsawat and Thirangoon, 1990). Remote sensing and GIS-based change-detection studies can, therefore, be utilised to provide information on how much, where and what type of land-use and cover change has occurred. Satellite remote sensing provides cost-effective, multi-spectral and multi-temporal data, and turns them into information valuable for understanding and monitoring land development patterns and processes for building land-use and cover data sets (Sunar *et al*., 1996; Weng, 2002).

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In this study, land-use and cover changes within and around BFR were analysed from multi-temporal images and field based studies, with a view to understand the dynamics of land-use and cover changes, especially deforestation and associated agricultural developments from 1988 to 2004. Multi-temporal analysis of satellite imagery is effective for change detection because there is a high correlation between spectral variation in the imagery and land cover change (Green *et al*., 1994). The area studied lies between 31 20′–31 50′E and 1 29′–2 0′N. The main focus was on determining patterns of change within two ecologically important land-use and cover types, namely forest/woodland and commercial sugarcane plantations. The time period investigated encompassed the rehabilitation and expansion of the Kinyara Sugar Works Ltd (KSWL), a sugarcane growing and processing factory. Information on land-use and cover changes and their causes/drivers may provide a better understanding of land utilization, and play a vital role in the formulation of policies and programmes required for development planning at both local and national levels. In addition, understanding the function and structure of landscapes, primarily in terms of human impacts, also requires the integration of biological and socio-economic knowledge (Grundy *et al*., 2000; Botha *et al*., 2004; Dovie *et al*., 2005; Palmer *et al*., 2005). Hence, an assessment of socio-economic conditions that local households face was undertaken through field observations, household interviews and key informants.

METHODS

Description of Study Area

BFR, located in Masindi District, North Western Uganda, is situated on top of the escarpment, east of Lake Albert on the edge of the western Rift Valley, at 1°37′–2°03′N, and 31°22′–31°45′E. It was gazetted as a Central Forest Reserve (CFR) in 1932, and covers about 825 km^2. The reserve is contiguous with the Murchison Falls National Park to the North, Bugungu Game Reserve to the Northwest and Karuma Game Reserve to the Northeast. On the southern side, it borders villages, inhabited by subsistence farmers of mixed language, culture and nationality. They are entirely dependent on the land resources for their daily livelihoods and income. In addition, there is the developing Kinyara Sugar Works Ltd (KSWL), fully owned by the Ugandan Government, which engages in commercial sugarcane growing and processing. Its out-growers' scheme had a modest start in the 1980s, but has picked up momentum over the years following the rehabilitation of KSWL in 1995. It is aimed at addressing the problems of the rural poor by making them stakeholders in the sugar industry by growing and selling sugarcane to the factory. The human population of Masindi District nearly doubled between 1991 and 2002, from 260 796 to 466 204, a mean annual growth rate of 5 per cent. For example, the population of Budongo and Bwijanga sub-counties, the closest to BFR, increased from 44 054 to 76 929 (75 per cent increase; NEMA, 1998, 2001; National Population and Housing Census, http://www.ubos.org/fullreport.html).

Land-use and Cover Change Analysis

To detect changes in land-use and cover, at least two time-period data sets are required (Jenson, 1986). In this study, land-use and cover changes and forest/woodland loss were assessed using two date ortho-rectified, Landsat 742 RGB combination UTM/WGS84 images, one from 1988 (Landsat TM5), the other from 2002 (Landsat ETM7).

Image classification

The typical approach in developing land-use and cover maps with satellite imagery involves defining spectral classes by clustering the image data and assigning pixels into classes (Hlavka *et al*., undated: http://geo.arc.nasa.gov/sgez/applitech/autoproc.html; accessed 27th Oct. 2004). ERDAS IMAGINE 8·7® image processing software was used for all image data processing. The *Iterative Self-Organizing Data Analysis Technique* (ISODATA) algorithm was used to perform an unsupervised classification, with Maximum Iterations set at 99, the Convergence Threshold set at 0·95 and the number of classes set at 36. This initial run revealed spectral confusion in some classes of the classified images. Hence, masking out of these land-use and cover classes was implemented. Known areas (based on other reliable sources) were excluded from automatic processing, then 'pasted' in later.

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A broad level classification was adopted by mainly focusing on the more clearly defined forest vegetation classes and the commercial sugarcane cultivation as the areas of interest (AOI), aided by information from field surveys (Mwavu *et al*., in press) and expert knowledge of the region. By restricting the classification to the AOI, which was manually created as a mask prior to unsupervised classification, classification accuracy was enhanced. For each date, the resultant classified image was recoded to its respective classes. A 3×3 majority filter was passed once over the resulting land-use and cover images to eliminate noise and to show only the dominant classification.

Classification accuracy assessment

An accuracy assessment of the derived land-use and cover map was also conducted for the classified imagery based on how well it matched observations at sample points on the ground, by employing the positional accuracy method. Using 42 ground-truthed GPS points (32 inside and 10 outside the BFR boundaries) and relating them to what was classified on the images, a statistical test of the classification accuracy of the whole image was performed by using the Kappa Index that accounts for chance agreement.

Change detection

The smoothed classified images were then subjected to a post-classification change-detection process. The post-classification approach to change-detection was deemed suitable since the images were from different sensors, taken on different dates and had been independently classified and labelled. The changes in land-use and cover that were recorded included change from forest/woodland to commercial/subsistence agriculture, shifting cultivation to commercial cultivation and from grassland/woodland to forest.

Drivers/Causes of Land-Use and Cover Change

Data on land-use practices, land cover changes, relevant socio-economic parameters, and the perceptions of the households in villages surrounding BFR were determined through field observations, as well as interviews with local residents and key informants. Thirty-eight (38) households and four key informants, namely the District Environment Officer, Local Government District Forest Officer, KSWL Out-growers Scheme Manager and Central Government District Forest Officer were interviewed. Households were selected systematically in order to obtain a representative sample in terms of ethnicity, wealth, gender and age classes. Semi-structured interviews (SSI) and questionnaire interviews were conducted on an individual basis to minimise peer influence and improve the quality of data (Phillips and Gentry, 1993). The SSI guide served only as a checklist, delimiting the issues to be considered in the interview to ensure that the same information was obtained from a number of people (Inglis, 1992; Chambers, 1994). Key informant interviews were also used to obtain information that would assist in clarifying or improving understanding of particular issues or problems that were raised in the household interviews. The interviews were conducted between December 2003 and January 2004. Human population data for the adjoining villages were obtained from the 1980 and 2002 national population censuses, and utilised to give an indication of the gender, family size, livelihoods and employment situation in the area. Data from interviews were analysed by using both descriptive and inferential statistics. A null hypothesis: '*The benefits of the forest to the local people do not outweigh the obstacle it poses to their agricultural production*', was tested by cross-tabulation using Fisher's Exact test in SPSS ver.13®. Surrounding sugarcane plantations were identified and their sizes, distances along the edge and from the boundary of BFR measured. Differences in their sizes, distances along the edge and from the boundary of BFR were compared by one-way ANOVA.

RESULTS

Land-Use and Cover Changes

The land-use and cover classification clearly discriminated two classes: forest reserve and commercial sugarcane plantations. However, shifting cultivation plots and grassland areas were difficult to clearly discriminate from each other as they had similar spectral classes and were, therefore, recoded into one class. The major land-cover

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Table I. Changes in the major land-use and cover classes within and around Budongo Forest Reserve between 1988 and 2002

Land-use/cover type (class)	Area (ha)		Change	
	1988	2002	Absolute (ha)	Per cent
Forest/woodland	57 079	52 399	−4680	8·2
Sugarcane plantations	690	12 729	12 039	1745
Grassland/shifting cultivation/settlement	127 016	110 903	−16 112	12·7

conversions were from forests/woodlands and grasslands to sugarcane plantations, settlements and shifting cultivation. The grassland/shifting cultivation/settlement cover decreased from about 127 016 ha in 1988 to 110 903 ha in 2002, a 12·7 per cent loss. The area under sugarcane increased considerably from 690 ha in 1988 to 12 729 ha in 2002, with a concomitant loss of about 4680 ha of forest/woodland (Table I), all outside the BFR and mostly on the southern boundary of BFR (Figures 1 and 2). The 4680 ha of forest/woodland lost all went to cultivation of sugarcane and other crops. Thus, forest/woodland cover decreased from 57 079 ha in 1988 to 52 399 ha in 2002, an 8·2 per cent loss in a 14 year period (Table I). However, the 2002 map shows an increase in forest cover within the northern part of BFR. This increase is probably due to the protection that the nature reserve, under the management of the Uganda Wildlife Authority (UWA) and National Forestry Authority (NFA), provides within this area, as well as its greater distance from human settlements. The overall accuracy of the classification was 97·6 per cent, with a Kappa coefficient of 92·7 per cent.

Field surveys and observations undertaken in 2003–2004 corroborated the image classification analysis results for 2002, and revealed the destruction of forests/woodlands, particularly outside the boundaries of BFR. Records from KSWL showed that sugarcane plantations (including those owned by KSWL and private farmers) on the southern side of BFR increased over 10-fold, from 1368 ha in 1996 to 15 347 ha in 2004. In 2004, the out-growers sugarcane plantation area was 5423 ha, about 35 per cent of the total area, further supporting the Landsat analysis results. The out-growers' scheme had a significant expansion between the 1995 and 2001 financial years (Figure 3). Similarly, there was an increase in the planted area of about 4560 ha between the 2001/2002 and 2003/2004. This increase was due to a strategy adopted by the company to outsource sugarcane production from self-employed farmers (out-growers) having land within a reasonably close distance of 25 km from the factory. No data are available prior to 1996 as a result of national political upheaval and the consequent economic decline that resulted in the closure of the factory in 1985, which only returned to production in March 1996. The future expansion of the sugar industry is focussed on the out-growers' scheme. The out-growers state that they each need a minimum of 5–7 ha of cultivated land to make sufficient income to sustain themselves.

Although image analysis for the period 1988–2002 (Figures 1 and 2) showed that the BFR had not been encroached by agriculture, field surveys and observations in 2003–2004 revealed that illegal harvesting of trees for timber had nonetheless, degraded the forest (Mwavu and Witkowski, 2008). There were numerous signs of illegal pitsawing, even in the so-called 'nature reserve' (no harvesting allowed) part of the forest. In addition, outside the BFR there were encroachments from settlements, as well as sugarcane and tobacco growing at the forest edges.

Socio-Economic Issues Acting as Drivers of Land-Use and Cover Changes

Both the local people and key informants were concerned that land-use and cover changes in the area have occurred with the increase in sugarcane plantations and deforestation, threatening the availability of land for further increases in crop cultivation. This change was attributed to a number of factors/drivers, including the rapid human population increase, which is associated with agricultural expansion (e.g. commercial sugarcane and tobacco growing, and subsistence crop cultivation), unclear land tenure and political interference in the management of forests/woodlands on both private and gazetted reserves.

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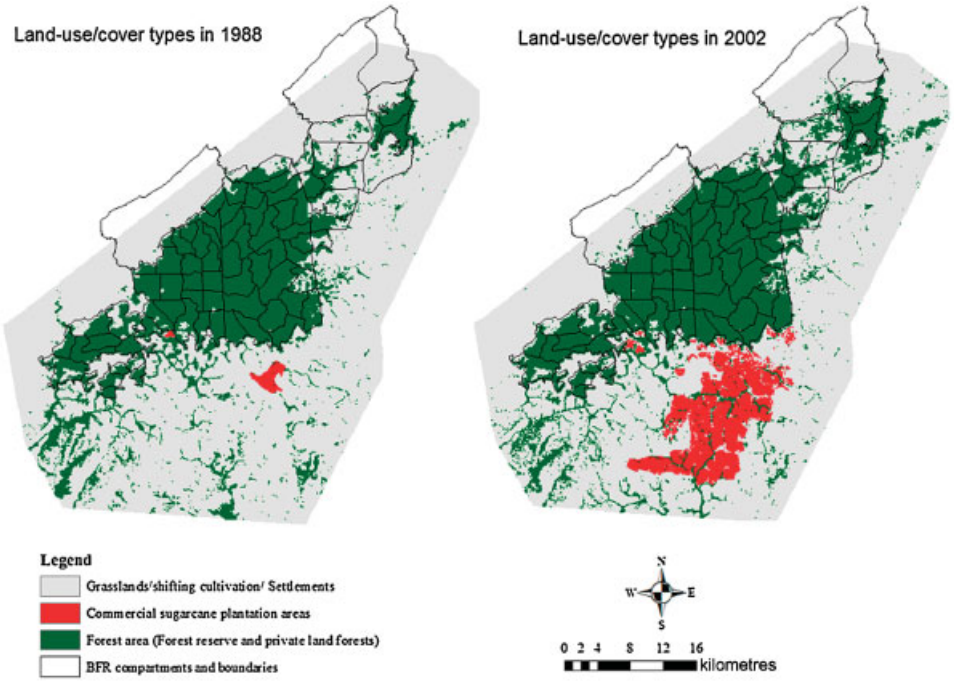

Figure 1. Extent of forest/woodland cover and sugarcane plantations in 1988 and 2002, for the area within, and surrounding Budongo Forest Reserve, NW Uganda.

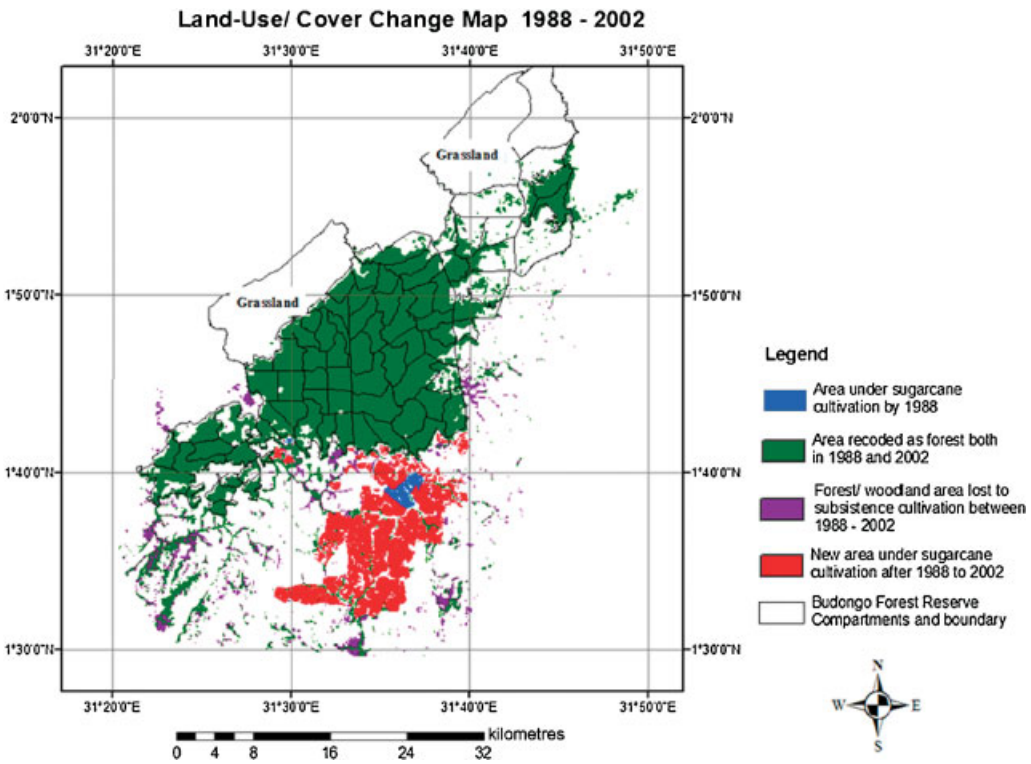

Figure 2. Map of change detection in the major land-use and cover categories surrounding Budongo Forest Reserve, NW Uganda, from 1988 to 2002.

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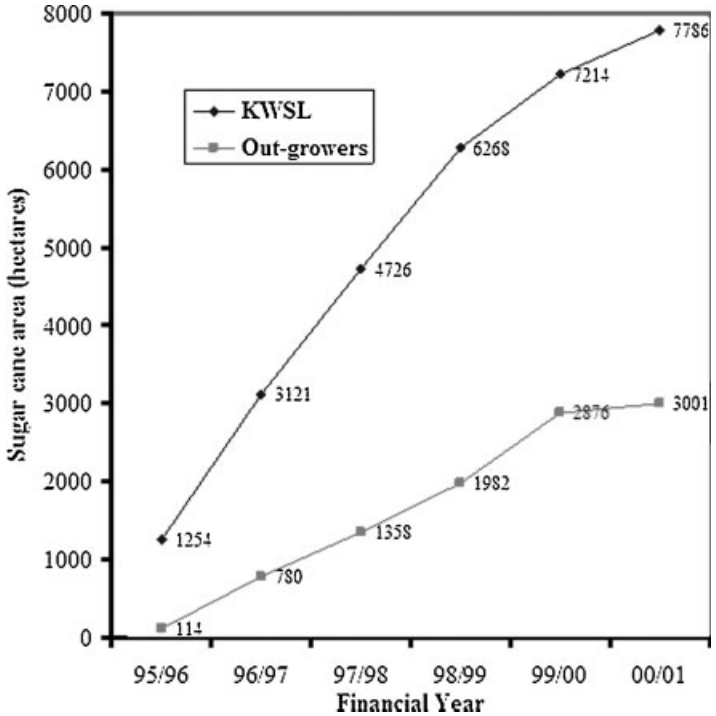

Figure 3. Cumulative sugarcane area planted (ha) by (a) the Kinyara Sugar Works Ltd (KWSL) and (b) the out-growers scheme, between the 1995/1996 and 2000/2001 financial years.

Agricultural expansion

Agriculture is the main land-use practice and the main source of income for the local population and, consequently, for the local governments in terms of tax. According to both the local communities and the key informants, commercial sugarcane and tobacco growing were the primary economic activities, followed by maize cultivation. In 2001, sugarcane farmers recorded a net annual income of about Uganda Shs. 600 000 ha^{-1}, equivalent to US \$351 ha^{-1}. Field surveys (2003/2004) revealed that the out-growers' sugarcane areas were expanding so fast that plantations were being established close to the BFR boundaries, with little or no buffer zone between the two on the southern part of BFR (Table II). This expansion can also be attributed to the presence of predominantly sandy clay loam soils that are more suitable for productive arable agriculture, as compared to those on loose sandy sediments in the northern part of BFR (Figure 4). The expansion of the sugarcane plantation area was primarily due to the introduction and strengthening of the out-growers scheme, with soft loans and ready market incentives. Distances of adjoining plantations from the BFR boundary ranged from -1 (one metre inside the forest) to 30 m, while distance along the boundary ranged from 30 to 1440 m.

Of 40 surveyed sugarcane plantations, totalling 208 ha, 9 (30 ha in total, and each with 100–550 m of forest edge) were 0 m from, and 2 were 30 m from the boundary, while 2 were 1 m inside the BFR boundary. Generally, many of the sugarcane plots covered long distances along the forest edge, with 32 (80 per cent) being ≥ 100 m in length along the boundary. However, among the nine villages surveyed (Table II), there were no significant differences in plantation sizes ($p = 0{\cdot}649$), length along the forest edge ($p = 0{\cdot}305$) or distance from the BFR boundary ($p = 0{\cdot}572$). These results suggest that many of these plots were established within what was previously a buffer zone between the agricultural areas and the BFR. Given the increasing shortage of land in the region, it is likely that all remaining strips of land adjoining the forest will be converted to agriculture. Instead of using fertilizers, tobacco farmers resort to clearing forest/woodland patches every other growing season in the belief that they are more fertile than the already cleared agricultural land and to avoid buying fertilizers. This has resulted in the loss of numerous

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Table II. Extent and size of sugarcane plantations along the Budongo Forest Reserve (BFR) boundary from a 2003 survey

Village	Number of surveyed plots	Size (ha) (mean ± SE)*	Distance (m) from forest boundary (mean ± SE)*	Distance (m) along forest edge (mean ± SE)*
Kyarugangara	2	4·7 ± 0·7	5·0 ± 0·0	155 ± 45
Kirema	9	3·4 ± 0·9	4·4 ± 1·8	181 ± 39
Kiswata	1	9·4	5	300
Kijaikwe	5	5·0 ± 0·1	12·0 ± 7·3	274 ± 75
Kapeka II	6	3·2 ± 0·6	4·0 ± 1·0	216 ± 72
Kapeka III	7	4·7 ± 2·9	4·3 ± 0·7	189 ± 69
Wafala	7	1·9 ± 0·1	3·9 ± 0·4	91 ± 10
Nyabyeya II	2	1·2 ± 0·2	6·0 ± 4·0	110 ± 10
Kanyege	1	65·3	−1	1440
Total	40	207·8	—	7960

All the villages surveyed are located on the southern side of the BFR.
*Size of sugarcane plantations, their distance from BFR boundary, and distance along the BFR edge were not significantly different among the villages (ANOVA, $p \gg 0{\cdot}05$).

forest and woodland patches, particularly outside BFR, but also sometimes even within remote parts of BFR. Farmers also destructively cut down whole palm (*Raphia farinifera*) stems in BFR to access branches to peel off the woody material used in the drying of tobacco leaves.

On the question of whether land available for cultivation expansion has been decreasing over the years, about 55 per cent of the 38 respondents were affirmative, concurring with all the key informants, while 24 per cent had no comment. To alleviate land shortage for agricultural expansion, they made a number of recommendations that interestingly included providing part of BFR for agriculture (Table III). Yet, they recognised that the forest offers

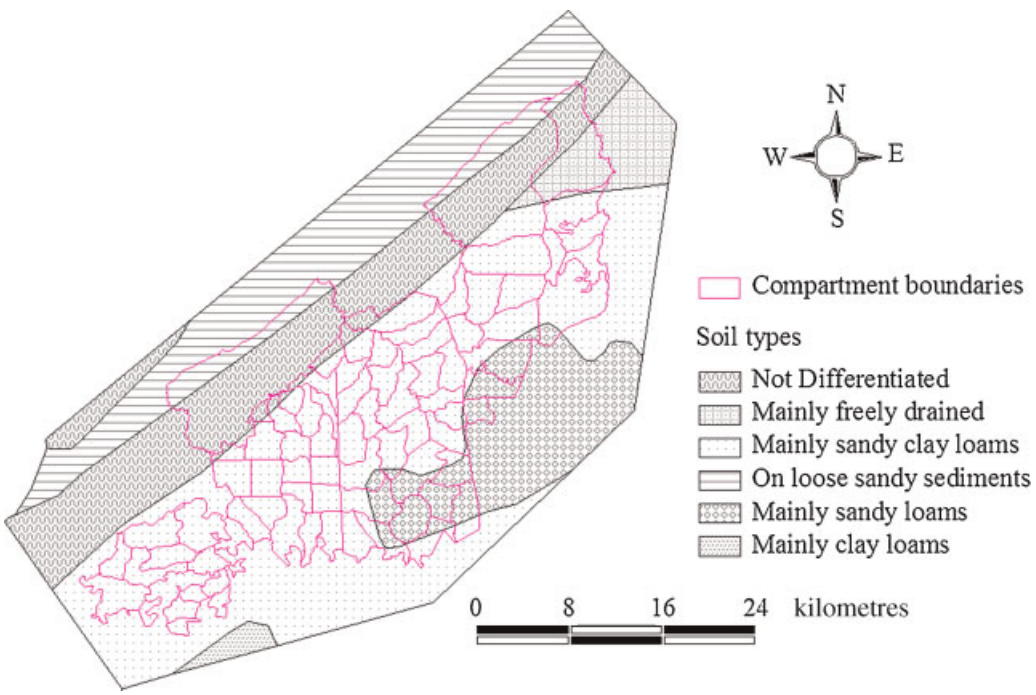

Figure 4. Map of soil types in and around Budongo Forest Reserve (BFR), NW Uganda. This figure is available in colour online at www.interscience.wiley.com/journal/ldr

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Table III. Local people's suggestions/recommendations for alleviating the decreasing land availability for agricultural expansion and settlements

Suggestions/recommendations	Responses (per cent of respondents, $n = 38$)
1. Find land elsewhere	15·8
2. Provide part of the Budongo Forest Reserve	10·5
3. Population control (e.g. through family planning)	7·9
4. Employ better methods of farming and modernise agriculture	7·9
5. No comment	50·0

them benefits, which they ranked on the basis of importance in the order; rainfall catchment (60·5 per cent), building materials (15·8 per cent), commercial timber (7·9 per cent) and fuelwood (7·9 per cent) (Figure 5). No respondent ranked water catchments, furniture materials or wild fruits as the most important benefit from the forest. A cross-tabulation (Fisher's exact test) of the forest benefits and responses to the question: whether the presence of a forest near the homestead was a threat to agriculture, revealed that actually the benefits do not outweigh the threats ($p = 0{\cdot}53$). This suggests that agriculture is more valued than forest conservation, even if it may contribute to rain-fed agricultural productivity.

Population increases

The 38 households interviewed constituted a total of 305 people, with an average of 8 (±0·81 SE) and a range of 2–25 people/household, and hence, large families. Local respondents and key informants concurred that the local human population in the area has increased over the years. Comparisons of the 1990 and 2002 census data showed dramatic increases, ranging from 135 to 835 per cent for the villages on the southern boundary of BFR and within a radius of 25 km from the KSWL. The highest increase of 835 per cent was for the villages Bulyango I and II, which are close to the factory, and where most of the casual labourers for the factory live. Of the 38 household heads, 14 (36·8 per cent) had settled in the area between 1988 and as recently as 2001, 7 (18·4 per cent) were already

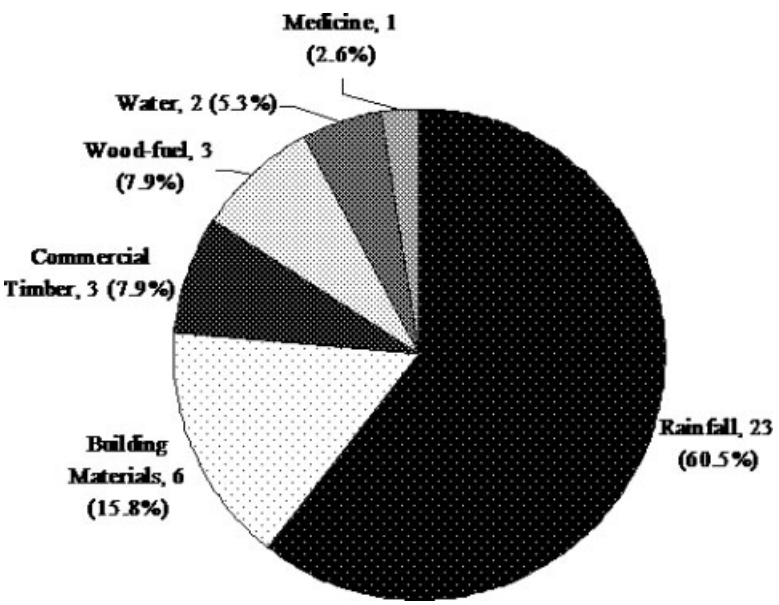

Figure 5. Number of respondents ranking each selected forest benefit as the most important to them (percentage of respondents ($n = 38$) in parentheses).

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resident prior to 1988, while 17 (44·7 per cent) did not respond. The two major reasons cited for settling were (a) finding fertile land for agriculture (32·4 per cent) and (b) employment (18·4 per cent). Indeed, the soils in the southern part of BFR are mainly sandy clay loams that are more suitable for arable agriculture (Figure 4).

Of the 305 people in the 38 interviewed households, 51·5 per cent were males and 48·5 per cent females, with low levels of education, lack of employment opportunities and all relying mainly on agriculture for subsistence and monetary income to meet their daily needs. Even for the 15·8 per cent of respondents that had some sort of formal employment (all males), they also practiced subsistence agriculture because their salaries were insufficient to support all their household needs. Among them were primary school teachers, builders and KSWL casual workers, none of whom were paid substantial salaries, lack social benefits and were faced with increasing food prices due to the promotion of sugarcane production instead of traditional food crops. Alternative sources of income were pitsawing (2·6 per cent of the respondents), charcoal production (5·3 per cent), bee-keeping (2·6 per cent) and formal employment (2·6 per cent). Others were rattan cane and pole harvesters, with BFR being the main source. However, the number obtaining income from pitsawing may be higher than reported as many may have been doing it illegally. Hence, there were few alternative sources of monetary income for the local population in the area, and two of those mentioned were entirely reliant on the woodlands and forests.

Land tenure system

On the southern border of BFR, the major land tenure systems are leaseholds and freeholds, with very little customary land, as most of the population is immigrant. The leaseholds are mainly held by Indians, most of whom are absentee landlords. Of the 38 households, 8 (21 per cent) explicitly stated that they were squatters who actually had no legal ownership right over the land. Though the rest of the households claimed ownership of the land they occupied, they were not clear on the type of land tenure they possessed, and indeed, it is also possible that some of them might not actually have legal ownership. It was also noted that the local people did not clearly know the position of the forest reserve boundaries.

Management, regulation and enforcement

Local respondents were aware that rules and regulations pertaining to the use of the forest reserve do indeed exist. Considering whether a permit is required in order to harvest/extract some forest products, 37·7 per cent responded 'yes', 48·8 per cent 'no', while 13·5 per cent had no comment. Agricultural encroachment, illegal pitsawing, charcoal production and pole and rattan cane harvesting were cited as the major threats to the conservation of forests and woodlands in the area (Table IV). Interestingly, one respondent cited poverty as the major threat.

On the major challenges to forest/woodland management, key informants cited the increased immigrant human population as leading to forest encroachment, as well as illegal pitsawing (in BFR), political interference and the limited capacity (manpower and financial resources) to enforce by-laws. Confiscated timber planks were observed in a local leader's house, indicating a lack of collaboration with the Forest Department (presently NFA) to help stop

Table IV. Local people's perceived threats to the sustainable management of communal forests/woodlands and Budongo Forest Reserve, NW Uganda

Threats	Responses (per cent of respondents, $n = 38$)
Illegal pit-sawing and pole-cutting	92·1
Agricultural expansion and encroachment (e.g. tobacco and sugarcane growing)	31·6
Harvesting for charcoal production	15·8
Poaching and hunting	10·5
Poverty	5·3
Rattan cane harvesting	5·3
Unsustainable resource harvesting	5·3
Fires along the forest edge	2·6
Lack of sensitization to protect forest/woodlands	2·6
Lack of tree planting	2·6

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illegal activities. Although there are legal instruments, through the local government councils to enact by-laws, no legal protection of forests/woodlands on private/communal lands around BFR occurs. Key informants stated that the best institutional/organizational arrangement for the management of forests in order to benefit both local people and meet conservation requires the involvement of the District Council and the NFA, which both have the structure and capacity. For the communal forests/woodlands, it was suggested that NGO's be mandated, as they have the capacity to mobilise the local people.

DISCUSSION

Land-Use and Cover Changes

The land-use and cover changes involving a decrease in vegetation cover corresponded to patches of deforestation and sugarcane plantations, and were outside and at the boundaries of BFR. Similarly, studies from other parts of Uganda report that the extent of forest decline is much greater outside permanent forest estates, due to changes in land-use and cover from tropical forest or savannah woodlands to cultivated and/or grazed land (Plumptre, 2002). With agricultural expansion being the major driver of deforestation in the area, our findings are similar to those from other parts of the world. Agricultural expansion is by far the leading land-use change associated with deforestation in Asia, Africa and Latin America (Geist and Lambin, 2002; MEA, 2005a, 2005b). Based on aerial photographs, Campbell *et al.* (1993) noted that deforestation in Zimbabwe had been largely a result of clearing land for cultivation. Similarly most of the deforestation in Tanzania stems from activities related to agricultural expansion and harvesting for fuelwood (Bagachwa *et al*., 1995; Luoga *et al*., 2000, 2002, 2005). Anthropogenic factors, which favour arable land-use, are reported to be the drivers of change on the South Downs landscape, United Kingdom (Burnside *et al*., 2003).

Land-Use and Cover Change Drivers

Presently, in the study area, sugarcane growing is highly preferred to other traditional crops as well as plantation forests (which require long growing periods), as it is more profitable and economically valuable. The valuing of agriculture over forest conservation shows why forests/woodlands, particularly outside the BFR, are being converted into sugarcane plantations. Thus, these land-use and cover changes are the result of landowner decisions and reflect the ranking of possible land-uses in the area. Similarly, studies elsewhere indicate that ecological dynamics in human-influenced landscapes are strongly affected by socio-economic factors that influence land-use decision-making (Berry *et al*., 1995). Kajembe *et al.* (2005) noted that people carry out activities that degrade forests/woodlands because of the high economic benefits they obtain from these activities. They often see little immediate economic gain from conserving forest/woodland resources or assuring their sustainable utilization. Increases in prices of agricultural produce (Angelsen *et al*., 1999; Angelsen and Kaimowitz, 1999; Chipika and Kowero, 2000), fertilizers (Barbier and Burgess, 1996), and export goods (Reed, 1989) may also lead to an increase in areas under cultivation, probably resulting in more deforestation. For example, in Sudan, increased producer prices of export crops encouraged woodland clearing for crop cultivation, resulting in significant deforestation (Stryker *et al*., 1989). The increasing agricultural expansion mainly in the southern part as compared to the northern part could also be attributed to differences in soil types. The sandy clay loams that predominate the southern side have desirable infiltration rates and facilitate water uptake by plants than the heavy texture soils (e.g. clay loam, clay and soils on loose sandy sediments) (Petry *et al*., 2002). Hence, they are more suitable for productive arable agriculture.

Although the expansion in sugarcane growing has had some positive impacts for rural development, such as improved road infrastructure and household income, it has also had attendant negative impacts. Plantation sugarcane growing conflicts with other agroforestry practices, as standing trees are usually removed in a plantation. The KSWL does not cover afforestation among its environmental protection and rehabilitation initiatives. Road construction is reported to play a crucial role in deforestation as it provides access to previously inaccessible forest areas (Dudley *et al*., 1995; Bryant *et al*., 1997; MEA, 2005b) and in the case of BFR, probably facilitates illegal

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harvesting of timber and palms for tobacco drying. In a study of the causes of deforestation based on analysis of economic models, Angelsen and Kaimowitz (1999) concluded that more roads, higher agricultural prices, lower wages and shortages of off-farm employment generally led to more deforestation. Similarly, our study area was characterised by these socio-economic conditions, as alternative sources of income are very few and most of the employment is on farms with low wage returns. Similar considerations may also be important in developed countries. For example, Allison and Hobbs (2004) report that in the Western Australian agricultural region, land-use and cover changes and ensuing natural resource degradation are rooted in the economic, demographic and social changes that link variables in the ecological system to those in the social system.

Increasing human population

The increasing human population in the villages adjoining BFR is also leading to deforestation as both the immigrants and indigenous people seek to expand land for food crops and tobacco cultivation and settlements. It is currently estimated that over 100 000 people, mainly non-indigenous, are living in Uganda's forest reserves, with Masindi District, in which BFR lies being the most affected (*The NewVision* Newspaper, 19th May, 2005). The occupation of tropical rainforests by large- and small-scale non-indigenous resource users often leads to widespread deforestation and resource depletion, primarily because the productive choices of the people concerned often require replacing the forest/woodland with other land-uses (Sierra, 1999). Place and Otsuka (2000) revealed that population pressure, market access and land tenure are also important factors affecting land use and resource management in east-central Uganda. Similarly, deforestation continues to accelerate in tandem with poverty and high levels of population growth in many parts of the developing world (MEA, 2005b).

Land tenure system

The Uganda Constitution of 1995 and the Land Act of 1998 spells out four general legal land tenure systems namely: customary, freehold, *mailo* (the registered owner holds the land in perpetuity, but is subject to customary and statutory rights of lawful and *bonafide* occupants) and leasehold land. Thus all land is owned, including the trees growing on it, whether government or private land (The Uganda Forestry Policy, 2001). This has various management implications for the forest/woodlands depending on the nature of ownership and management goals. Deliberate protection of forests/woodlands on private lands in the study area, particularly those with absentee landlords, has not been seriously addressed due to unclear ownership and lack of secure tenure, resulting in deforestation. Whereas absentee owners tend to use land less intensively and manage tree resources less effectively (Place and Otsuka, 2000), it is widely accepted that the resource-use strategy of recent migrants to tropical rainforests results in extensive deforestation and other negative environmental impacts (Sierra, 1999). In other parts of Uganda, customary land tenure institutions have been found to provide strong rights in terms of agricultural land, but are relatively weak in collective management of other resources, such as woodlands (Place and Otsuka, 2000). It is also reported that conversion of land for agricultural use is greater under the customary tenure system compared with freehold and *mailo*. Similarly in the Ivory Coast, the lack of a consistent and secure land tenure system contributed to deforestation to a greater extent than the effects of price increases of export goods (Reed, 1989). Studies of land cover change in forest-dominated landscapes in the USA (Spies *et al*., 1994; Turner *et al*., 1996) and Brazil (Dale *et al*., 1993) also demonstrated that land ownership greatly affects landscape dynamics. Thus, land ownership is an important determinant of landscape pattern (Gobin *et al*., 2001), and security of tenure is important in shaping who uses the land resources and how.

Management, regulations and enforcement

Worldwide, societies have rules to protect the collective welfare from harmful actions perpetrated by individual members of society. However, the successful implementation of these rules will depend on an enabling environment, the willingness of all stakeholders to uphold them and reflection of societies' conscious and unconscious ideologies entrenched through history. In Uganda, Environmental Impact Assessment (EIA) is a legal requirement for any large-scale development project. However, the establishment of sugarcane plantations in the study area have not been subjected to EIAs. Yet, this type of agricultural practice has serious implications for

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the regional environment. This illustrates that despite the presence of strong environmental and supportive policies and legislation (e.g. The National Environment Statute of 1995; and The Land Act of 1998), the present land-use pattern in the area is quite haphazard and results in poor management and degradation of the environment. The lack of a buffer zone between the forest reserve and sugarcane plantations has already resulted in direct conflicts between the local farmers and important wild forest animals, particularly the endangered chimpanzees (Hill, 2000; Tweheyo *et al*., 2005). One of the habituated chimpanzees was killed in 2003 as it strayed into an adjoining sugarcane plantation in search of food, and a number of others have been injured by snares set by local hunters and farmers (F. Babweteera, 2003, pers comm). It is, therefore, necessary to establish and maintain a buffer zone—an area around or adjacent to the protected area, where a harmonious relationship between the natural environment and people is promoted (Brown, 1992). Buffer zones have had positive impacts in some parts of the world where they have been implemented. For example, land degradation around forest patches in Maribios, Nicaragua was halted when locally formed co-operatives integrated trees into the land-use system in various ways (Sayer, 1991).

The encroachment into BFR by migrants and illegal timber harvesting is happening with some encouragement by corrupt authorities in the local administrative councils. Similarly, Banana *et al.* (2007) attributed the decline in forest conditions in the Mpigi District of Uganda between 1994 and 2000, among other factors, to corruption by local government officials, as they allowed powerful individuals from within and outside the community to illegally harvest timber. The mapping of frontier forest according to 'risk of mismanagement' from corrupt behaviour, places Uganda in the High Corruption Level category (Bryant *et al*., 1997; Transparency International, 2002). The correlation between corruption and forest crime is believed to be remarkably high in many countries (Contreras-Hermosilla, 2001), and in most parts of Africa, corruption whether petty or grand, is a major force undermining environmental equity and in degrading and destroying ecosystems (Mock, 2003). For Uganda, corruption in the forest sector seems to have been aided by the central government's retrenchment policy of the 1990's that greatly reduced the Forest Department's (presently NFA) manpower (i.e. forest rangers, forest guards, patrol persons, etc.) on the ground to monitor and guard the forest (Muhereza, 2003). Furthermore, in Uganda at present, the need to access resources to alleviate poverty out-weighs the desire to conserve natural resources, while political interests out-weigh the need to follow the approved laws and regulations. This has been a serious impediment to management, particularly where the demand for natural resources to sustain livelihoods is acute, since voting decisions are based on the perceived ability of the aspiring politicians to help local people (voters) access resources to increase their income (Bazaara, 2003). There is also a misconception among Uganda's politicians that since the Country needs 'development', then it cannot afford the luxury of protecting nature's ecological processes. They tend to identify development merely with sectoral growth, ignoring the underdevelopment introduced in related sectors through negative externalities and the related undermining of the productivity of the ecosystem (Shiva, 1991). As a consequence, a number of reserves (e.g. Butamira, Namanve and Kalangala Islands Forests), which were public land, have been degazzetted on the directives of the President for agricultural expansion by the so-called investors. Thus, in 2001, Butamira Forest Reserve was allocated to Kakira Sugar Works Ltd to grow sugarcane, while in 2002 some of the Kalangala Islands forests were also degazzetted and allocated to BIDCO, an edible oil processing company to plant palm oil trees. In 2006, there was a push by the Mehta Group and government to degazzette about 7100 ha of Mabira Forest Reserve so that the Mehta Group can grow sugarcane. Such moves are more likely to be a disincentive to local communities and NGO's to actively participate in the sustainable management of Uganda's forests and woodlands, particularly those on public land.

Whereas there have been attempts to decentralize the management of forests/woodlands in various parts of the country, it would not be advisable for BFR with its high biodiversity value. Completely decentralising management of such a forest reserve runs the risk of degradation as local councils are more interested in short-term revenues than biodiversity issues, and are often reluctant to reinvest revenues into forest resource management. For example, significant loss of forest/woodland cover has occurred in local forest reserves that were returned to the Bunyoro-Kitara Kingdom within Uganda, who were more interested in monetary income rather than sustainable harvesting (Muhereza, 2003). In addition, with over 70 of the local communities around BFR coming from elsewhere in the country (mainly Nebbi, Arua and Lira districts) and the Democratic Republic of Congo (DRC), few consider themselves residents, and many plan to return to their original homes in the future. Hence, they are not

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interested in the long-term planning and management of the forests/woodlands. In this case the involvement of the NFA, a central government department, to resolve conflicts between forest users who have differing objectives and temporal needs is necessary. In his analysis of forest policies and legislation in Uganda, Banana (2005) revealed that neither the top–down protectionists nor the decentralised co-management approaches have been uniformly effective in averting threats to forest resources. Similarly, case studies on forests in Kenya and Tanzania have reported both success and failure in halting resource degradation under decentralised management. Ongugo and Njuguna (2004), in decentralised forests in Kenya, showed that despite the efforts and good intentions of decentralization in the Forest Department, the conditions within many forests continued to be poor. In contrast, Kajembe *et al.* (2005) revealed that community forest-based management (CBFM) in Duru-Haitemba, Tanzania, had a positive impact on the resource base, while joint forest management (JFM) at Kwaizu Forest Reserve did not as illegal activities were still rampant and deforestation was increasing. They suggested that the success at one site and relative failure at the other was probably linked to the type of ownership of the resource and the law enforcement mechanism.

CONCLUSIONS

This study provides comparative estimates of changes in land-use and cover types within and in areas adjoining BFR. Land-use and cover was found to have changed significantly, from 1988–2002, in particular the areas of forests/woodlands outside the BFR decreased (8·2 per cent loss), while areas under sugarcane plantations and subsistence agriculture increased substantially (over 17-fold). A number of socio-economic factors, including human population increases, insecure land tenure, inappropriate economic policies, conflicts of interest, lack of alternative sources of income and weaknesses in the legal and policy framework were the causes/drivers of land-use and cover changes in the area. Furthermore, the sandy clay-loam soils that are suitable for arable agriculture and predominately in the southern side of BFR have to some extent facilitated the agricultural expansion in that area.

As commercialization of sugarcane and tobacco growing increases in importance, the value of productive land and incentives to increase yields will continue to escalate resulting in further loss of natural vegetation, and reduction of land available for food crop cultivation. This might also have crucial consequences for food security and nutrition for the local population. The continued loss of tree cover on private/communal lands leaves the managed BFR and neighbouring forest reserves as the only places for the conservation of wild plants and animals in the region. However, their conservation is threatened as they are viewed as the only major source of building materials, commercial timber and non-timber forest products by both inhabitants of surrounding and more distant villages. Poverty and political interference are major challenges to the management of forests/woodlands in the area. Therefore, strong institutions that can withstand conflicts of interest and a political will to sustainably manage the forests/woodlands in the area for both development and conservation are required. Since Uganda's forests/woodlands continue to be converted to other land-uses (e.g. agriculture and charcoal production), while socio-economic disparities keep increasing, there is a need for continuous monitoring of BFR and the surrounding areas. Future studies should consider more recent changes and also attempt to assess the changes within the interior of the forest at a finer scale of resolution (given the expected improvements in remote sensing technology) as it faces increased selective timber and pole harvesting (Mwavu and Witkowski, 2008). Research is also required to aid in the integration of aspects of the livelihoods of local rural people with both conservation and landscape planning, particularly because BFR is of prime importance for the conservation of plants and primates, particularly the endangered chimpanzees.

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