An investigation of land cover change in Mafungautsi Forest, Zimbabwe, using GIS and participatory mapping

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Abstract

This paper investigates the processes governing land cover change in and around the Mafungautsi Forest Reserve in Zimbabwe. This study site lies at the interface between the state and communal property regimes. Land cover change was analysed using aerial photography for 1976, 1984 and 1996 within a Geographic Information System (GIS). Perceived change and its causes were investigated through governmental data sources, participatory mapping and interviews with the local community and forest guards. It was found that whilst forest cover within the reserve has remained constant, it has been steadily declining outside its boundaries. This decline, a result of agricultural expansion and demand for building materials and firewood, was perceived as more pronounced by local farmers than by the forest authorities.

Keywords: Land use; GIS; Participatory mapping; Resource sharing; Tree cover; Zimbabwe

Introduction

In the last decade, the established view of land cover change in Africa has been reappraised. For much of the last century, environmental degradation (loss of forest cover and soil erosion) were held to increase linearly with population density and
measures were put in place to combat such changes (Bassett & Bi Zueli, 2000). In Zimbabwe, for example, forest reserves were gazetted to protect river catchment areas through the removal of the human population. More recent work in Guinea, however, has shown that the relationship between population density and land cover change is more complex (Fairhead & Leach, 1996). In the longer term, cyclical expansion and contraction of forests may take place as agricultural land is abandoned and then recolonized. ‘Crisis narratives’ of environmental history have also been challenged by further work in Cote d’Ivoire (Bassett & Bi Zueli, 2000) and Kenya (Tiffen, Mortimore & Gichuki, 1994).

Previous research (Elliot & Campbell, 2001) has also questioned the simplistic assumption that a reduction in percentage tree cover necessarily leads to greater scarcity of woodland resources. Within Zimbabwe, Scoones and Wilson (1988) have shown that biomass production per hectare may actually increase as tree cover diminishes when remaining woodlots are managed by pollarding or coppicing. Similarly, Wilson (1990) showed that the abundance of fruit trees did not decline after deforestation, because fruit trees were selectively conserved and their value recognized by smallholders.

Specific responses to resource shortages in miombo woodlands are often complex and may vary between locales. Privatization of resources has been documented as one response to scarcity in Zimbabwe’s smallholder areas (Scoones & Wilson, 1988; Mukamuri, 1995), but elsewhere communal arrangements have been re-instigated in the face of natural resource shortages (van den Brink & Bromley, 1992). Campbell, Grundy and Matose (1993) found that the choice of tree species for construction and firewood became less selective as resources became scarcer. As firewood availability declines, harvesting arrangements change and men often become more involved in its collection (Campbell, Grundy & Matose, 1993). These findings imply that responses to perceived scarcity of natural resources may be complex and unpredictable.

Many of these more recent studies have relied on participatory methods to explore local understanding of environmental history. However, findings from participatory rural appraisal (PRA) can be affected by the composition of participant groups and group discussions influenced by one or two dominant individuals. To overcome these inherent weaknesses, Goebel (1996) has suggested that techniques such as PRA should best be deployed in conjunction with other methods, so that findings from technical and social research methods may subsequently be triangulated. One such complementary technology is GIS, which has previously been used with participatory methods to explore land cover change in Ghana and Zimbabwe (Elliot & Campbell, 2001). A second complementary technique is participatory mapping, in which maps or aerial photographs form the basis for group discussion of environmental change or land ownership. Aerial photography has successfully been used in interviews with illiterate farmers in Nepal (Mather, de Boer, Gurung, & Roche, 1998), Cote d’Ivoire (Bassett, 1993), and in educational studies of young children from several countries (Blades et al., 1998).

This paper explores land cover change in and around Mafungautsi Forest Reserve, part of the Zambezi River catchment area in central Zimbabwe. Changes in land
cover between 1976 and 1996 are assessed using historical aerial photography and land use is described using participatory interviews centred on the 1996 aerial photographs. Comments from these interviews about underlying drivers of land use change (population, soil fertility, and enforcement within the park) are compared, both between respondents and with other data sources. The reasons for the adoption of this strategy were twofold. First, whilst remote sensing studies can identify changes in land cover, the changes in land use that lead to vegetation change are very difficult to determine without follow-up fieldwork on the ground. Secondly, vegetation change as perceived by land users may differ from actual vegetation change and be an important determinant of behaviour among those using local natural resources. Participatory mapping techniques were therefore used to elicit information from residents regarding land use and perceived land cover change.

The study area

The study area lies in Gokwe South District in the Midlands Province of Zimbabwe (see Fig. 1). The natural vegetation in Gokwe is miombo woodland, dominated by *Brachystegia spiciformis* in association with *Julbernardia globiflora* (Gokwe South Rural District Council, 1994; Campbell, Frost, & Byron, 1996). There are also some areas of teak woodland dominated by *Baikiaea plurijuga* in association with *Pterocarpus angolensis* and *Guibourtia coleosperma*. Grassland areas, known as *vleis*, cover lower slopes near surface drainage lines. Outside the forest reserve, this vegetation has progressively been cleared for agriculture, initially through shifting cultivation and latterly as cotton production expanded. Typically, tree cover remains along stream and river banks and fruit trees are often left standing. Topographically, the study area largely consists of the gently undulating Mafungautsi plateau, which is dissected in places by streams.

Mafungautsi Forest Reserve was gazetted in 1954 for ecological reasons, since it forms part of the watershed for the Sengwa–Mbumbusi river system. These rivers flow into the Zambezi, which contains the Kariba Dam, an important generator of hydroelectric power for both Zimbabwe and Zambia. Before 1940, most of Gokwe was sparsely populated, because of the threat of disease from tsetse fly. However, some people migrated into Gokwe after the elimination of the tsetse fly whilst a significant number were forcibly moved from areas designated for European settlement in the 1950s and 1960s (Ndanga, 1987; Matose, 1994; Nyambara, 1999). This resulted in increased population density in Gokwe and greater demand for land within the gazetted forest area.

In terms of current livelihoods, Gokwe is known for cotton production activities (Worby, 1992). Agriculture is the main source of income, with cotton as the primary cash crop and maize cultivation also commercially important. Other income-generating activities include marketing of fruits (bananas) and non-timber forest products (honey, mushrooms and wild fruit). Local grasses are also sold to provide thatch for housing and for making brooms. The area is ethnically mixed as a result of continued immigration, with Ndebele and Shona-speaking peoples forming the majority of the population.
Fig. 1. Location of Gokwe South district, Mafungautsi reserve and the case study communities of Batanai and Chemwiro–Masawi.

**Management of Mafungautsi Forest Reserve**

The Forestry Commission, a central government body, is legally responsible for managing the gazetted forest. Tree-cutting, hunting and deliberate burning are all prohibited within the forest reserve. A Forest Protection Unit (FPU) within the Forestry Commission is responsible for enforcing these regulations and has the power to make arrests. In 1995, the Forestry Commission introduced co-management arrangements with the rural communities near Mafungautsi Forest. These arrangements make provision for natural-resource sharing within the gazetted forest but not
surrounding agricultural land. The communities have formed resource management committees (RMCs), which are new institutions intended to spearhead the co-management project. Separate RMCs have been formed for most of the village development committees (VIDCOs) surrounding the forest reserve. VIDCOs are the lowest geographical unit of administration in Zimbabwe’s smallholder farming areas and each VIDCO typically contains approximately 1000 inhabitants. Some RMCs have also been formed at levels above or below the VIDCO (Mapedza & Mandondo, forthcoming). The RMCs have the power to grant permits for collecting thatch and broom grass in selected areas of the forest reserve, as well as encouraging tree-planting in the smallholder areas and fighting fires within the forest reserve. Funds from these permits are controlled by the RMC and can be spent on community projects within the VIDCO.

Two RMCs, namely Chemwiro–Masawi and Batanai (see Fig. 1), were selected for this study. Batanai RMC encompasses one VIDCO whereas Chemwiro–Masawi RMC comprises two. Batanai was selected as a former forest area that was ceded to the neighbouring communities in 1972. Aerial photographs from the 1960s suggest that before being de-gazetted in 1972, vegetation cover in Batanai was similar to the rest of Mafungautsi Forest. By way of contrast, Chemwiro-Masawi has a longer settlement history.

**Methods**

Changes in land cover were examined through a combination of:

- participatory rural appraisal (PRA) (Chambers, 1994; International Institute for Environment & Development, 1995; Goebel, 1996);
- semi-structured interviews using aerial photographs;
- analysis of historical aerial photography within a GIS;
- analysis of secondary data relating to rainfall, crop yields and arrests, and
- follow-up interviews with Forestry Commission staff and groups of youths, women, and the elderly.

This approach was adopted following Goebel’s (1996) suggestion that PRA should be complemented by other techniques to overcome its inherent weaknesses. Interviews with local residents were conducted in late 2000 to identify current land use, perceived changes in vegetation, and their possible causes. People were invited to attend meetings in both study RMCs via community leaders. Attendees were then split into groups in a participatory manner so that people chose a group they wanted to join. Groups participated in PRA and semi-structured interviews as described below. The evening after each interview, one of the authors wrote a synopsis of the day’s discussions. In addition, a research assistant took notes during the exercise, thus providing two written accounts of each interview. Subsequently, follow-up interviews were conducted separately with groups of youths, the elderly, and women.
Participatory rural appraisal (PRA)

Gokwe South District has one of the lowest literacy levels in Zimbabwe, with only 39% of its people having received formal education (Central Statistical Office, 1992), so participatory approaches had to be used. The participatory approach was also chosen as a means of exploring perceptions of land cover change through a dialogue between ‘outsiders’ and ‘insiders’ (Chambers, 1983; Goebel, 1996). Focused group discussions involving up to ten people explored different forest uses and perceived change over time. Resource mapping was used to obtain the relative perception of vegetation cover by the local communities. In this participatory research approach, people sketch local natural resources in map form (Chambers, 1994; International Institute for Environment & Development, 1995). The technique was also used with time-lines, where events are placed in relation to significant events with known dates, such as a year of drought, independence, or when a new school was built.

Semi-structured interviews using aerial photography

Simultaneously with the PRA fieldwork, semi-structured interviews were conducted with groups of local respondents. Semi-structured interviews involve the use of a pre-designed series of open-ended questions, but also allow unanticipated themes to be explored by the interviewer (Miles & Huberman, 1994). Respondents were asked about land cover changes, use of local natural resources (current, likely future and historical) and fire frequency. Mosaics of aerial photographs were obtained for these interviews and acetates were fixed over the photo-mosaics. When describing the areas used for a particular purpose, respondents could therefore draw the boundaries of the zones used onto the acetate in marker pen. Such zones included areas for thatch and broom grass collection and areas affected by fire. Black-and-white 1:50 000 aerial photography from 1996 was used for these interviews and enlarged to 1:25 000-scale to make interpretation easier. Aerial photography was used instead of topographic maps because those with only basic education find aerial photographs easier to interpret (Bassett, 1993; Mather, de Boer, Gurung & Roche, 1998).

Three workshops were conducted using the aerial photographs. The first was conducted in Batanai with a group of seven local farmers. Apart from one RMC committee member, the majority were not directly involved in resource-sharing. A second interview was conducted with 12 farmers in Chemblo-Masawi. This group was more directly involved in resource-sharing and community groups and included the local RMC secretary, the ward councillor and several RMC members. Both groups consisted almost exclusively of men, with only one woman present. Finally, a similar interview was conducted with a member of the FPU at Mafungautsi to determine his perception of vegetation change.

The aerial photo mosaics were subsequently scanned onto computer, imported into a geographical information system (GIS) and geo-referenced, as described below. Land use zones and other observations recorded during all three interviews were then digitized on top of the geo-referenced scanned images by reference to the original acetates.
Historical aerial photography analysis

Black-and-white aerial photo-mosaics (scale 1:50 000) of the Batanai area of the reserve and surrounding farmland were obtained for 1976, 1984 and 1996 and scanned onto computer as three A3-size images for each year. These images were then geo-referenced to Universal Transverse Mercator (UTM) co-ordinates by applying a linear transformation to control points from a 1996 panchromatic Spot satellite image and 1:50 000-scale topographic maps. Root mean square (RMS) errors, which measure the positional accuracy of the UTM transformation (Johnston, 1998), were calculated for each scanned image and are shown in Table 1. Allowable RMS error was estimated as 15.5 m, based on a 1:50 000-scale cartographic standard (Clark Labs, 1999; US Geological Survey, 1999). Although most of the RMS statistics for the images failed to meet this standard, the map layers produced were used solely for the calculation of areas and not for map overlay, thus mitigating such positional inaccuracy.

Polygons were then digitized over these photographs to delineate four land cover types: agricultural land, woodland/scrub, vlei, and forest. Percentage tree cover was estimated for each polygon, being lowest for vlei and highest for the forest category. These percentages were derived from field observations of each land cover class made during 2000. An attempt was made to identify eucalypt woodlots planted within the smallholder farming areas. However, field observations in Batanai suggest replanting is piecemeal and small-scale and so these dispersed eucalypt patches proved too difficult to identify on the available photography. As significant land cover changes had taken place between 1996 (the latest available photography) and 2000/2001 (the period of fieldwork), formal ‘ground-truthing’ of these maps was not undertaken.

Secondary data analysis and follow-up interviews

Several government datasets were used to cross-check interview findings, including 1981–93 crop yield data for Gokwe communal area (Agritex/USAID FEWS,

<table>
<thead>
<tr>
<th>Year</th>
<th>Image no.</th>
<th>RMS error</th>
<th>No. of control points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976</td>
<td>1</td>
<td>22.7</td>
<td>16</td>
</tr>
<tr>
<td>1976</td>
<td>2</td>
<td>19.4</td>
<td>14</td>
</tr>
<tr>
<td>1976</td>
<td>3</td>
<td>15.4</td>
<td>15</td>
</tr>
<tr>
<td>1984</td>
<td>1</td>
<td>12.0</td>
<td>13</td>
</tr>
<tr>
<td>1984</td>
<td>2</td>
<td>25.4</td>
<td>15</td>
</tr>
<tr>
<td>1984</td>
<td>3</td>
<td>25.3</td>
<td>15</td>
</tr>
<tr>
<td>1996</td>
<td>1</td>
<td>23.9</td>
<td>12</td>
</tr>
<tr>
<td>1996</td>
<td>2</td>
<td>28.7</td>
<td>12</td>
</tr>
<tr>
<td>1996</td>
<td>3</td>
<td>23.0</td>
<td>11</td>
</tr>
</tbody>
</table>
2001), precipitation records for the district meteorological station, and the number of poaching arrests in Mafungautsi made by the FPU. Follow-up interviews were conducted separately with the elderly, women and young people to further investigate issues that emerged during the workshops. This enabled women and young people to express views independently of men, whilst the elderly gave accounts of changes that have taken place within their environment since the 1940s. Follow-up interviews were also conducted at various levels within the Forestry Commission.

Results

Changes in land cover

A clear-cut perceptual division between the forest reserve and the communal land pervaded all the interview sessions and is therefore reflected in the presentation of results here. Table 2 shows the pattern of land cover change in both areas as recorded through interviews with the FPU and communal farmers and through aerial photography analysis. This table also compares perceived changes in land use and its drivers according to these interviews and governmental data.

Land cover changes within Mafungautsi

The FPU guard interviewed felt that tree cover within Mafungautsi had remained largely unchanged in the last ten years, although pole-poaching had reduced tree cover in some peripheral areas of the forest reserve. At Batanai, the farmers’ group felt strongly that tree cover had increased within Mafungautsi over the past ten years, whilst opinions at Chemwiro-Masawi were divided, some perceiving increased tree cover and others a decrease. The PRA interview with the women’s group at Batanai suggested that they were even more aware of the reduction in tree cover than the male farmers’ group.

Analysis of aerial photography for the Batanai area supported the observations of farmers within this RMC. Within Mafungautsi Forest Reserve, tree cover declined from 68% in 1976–7 to 66% in 1984, but then rose again to 71% by 1996. Some 1.5% of this change may be due to positional inaccuracy in delineating the reserve boundary, as estimated from the RMS errors in Table 1. Fig. 2 illustrates the changes in land cover within Batanai. During and immediately after the independence war, several communal farmers encroached into the forest reserve as political insecurity led to the suspension of boundary enforcement. The land cleared by these ‘settlers’ can be seen on both the 1976 and 1984 aerial photographs in Fig. 2. By 1996, the northern area of encroachment had largely reverted to forest, whilst the southern encroachment area remained as grassland.

Land cover changes in communal areas

The Batanai group felt strongly that tree cover was diminishing rapidly within their village, because of pressure for agricultural land, building materials and fuel-wood. The situation was further exacerbated as diminishing crop yields forced some
Fig. 2. Tree cover in the Batanai area of Mafungautsi and Gokwe communal area in (a) 1976/7, (b) 1984; and (c) 1996 (based on aerial photography).
Table 2
Changes in land cover, land use and land use drivers around Mafungautsi, as identified through governmental data and interviews with communal farmers and the Forest Protection Unit

<table>
<thead>
<tr>
<th>Type of change</th>
<th>Forest Protection Unit</th>
<th>Batanai</th>
<th>Chemwiro–Masawi</th>
<th>Secondary data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Land cover and wildlife changes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation change in Mafungautsi</td>
<td>No change except for the 5–6-km belt along Bulawayo road</td>
<td>Tree cover had increased in Mafungautsi</td>
<td>Increased tree cover implied</td>
<td>Increase in tree cover on aerial photographs as former cultivation reverts to forest</td>
</tr>
<tr>
<td>Vegetation change in communal area</td>
<td>Localized loss of tree cover</td>
<td>Severe loss of tree cover, increased stream bank cultivation in the river beds</td>
<td>Decrease due to commercial logging, Indigenous trees decreasing, gum trees are increasing – more gum trees than indigenous trees in future</td>
<td>Decrease in tree cover visible on aerial photographs, especially in de-gazetted area</td>
</tr>
<tr>
<td>Wildlife change</td>
<td>Reduced wildlife numbers, more concentration around FPU camp at Lutope</td>
<td>Wildlife concentrated around the camp, but no change in numbers</td>
<td>Some felt that there was an increase whilst others felt that there was a decrease</td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Land use change</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle numbers and grazing</td>
<td>No change</td>
<td>No change</td>
<td>No change</td>
<td>Dip tank figures</td>
</tr>
<tr>
<td>Tree plantings</td>
<td>Not aware of planting within communal areas</td>
<td>Some planting and some not, for fear of losing rights over trees and problems of slow growth</td>
<td>Active planting taking place because of free seed and pockets, but shortage of land is a major problem</td>
<td>Eucalyptus not distinguishable from other forest cover types on aerial photographs</td>
</tr>
</tbody>
</table>

(continued on next page)
<table>
<thead>
<tr>
<th>Type of change</th>
<th>Forest Protection Unit</th>
<th>Batanai</th>
<th>Chemwiroy–Masawi</th>
<th>Secondary data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in fire</td>
<td>No change – fires annually</td>
<td>No comment</td>
<td>Fires had decreased</td>
<td>Not available</td>
</tr>
<tr>
<td>Effects of fire</td>
<td>Makes it easier to kill game</td>
<td>Used to kill game, reduce ticks, distract FPU, improve pasture quality, for revenge on FPU and enjoyment</td>
<td>Reduces thatch and broom grass</td>
<td></td>
</tr>
<tr>
<td>Observed changes in land use drivers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strictness of enforcement</td>
<td>Not specified</td>
<td>Fines and patrols had increased</td>
<td>Enforcement had increased because of the RMCs and resource sharing</td>
<td>Increase in number of poaching prosecutions from 1991 to 1998</td>
</tr>
<tr>
<td>Climate and hydrology</td>
<td>No comment</td>
<td>Definite reduced stream flow and rainfall in communal area</td>
<td>No change</td>
<td>Not available</td>
</tr>
<tr>
<td>Population changes</td>
<td>House-building by immigrants increases pole demand</td>
<td>Increased population has resulted in increased land demand and conflicts</td>
<td>Natural increase in population but no immigration was occurring</td>
<td>Historical figures only available at district level</td>
</tr>
<tr>
<td>Soil fertility change</td>
<td>No comment</td>
<td>Soil fertility is declining – hence stream-bed cultivation is happening</td>
<td>Soil fertility has always been low but is deteriorating</td>
<td>Maize yields adjusted for rainfall decline from 1981 to 1993, but cotton and groundnut yields are not.</td>
</tr>
</tbody>
</table>
farmers to cultivate stream-beds. In Chemwiro-Masawi, the situation was somewhat more complex. In one part of the communal area, trees had been felled commercially by permission of the district council, but against the wishes of local residents. Elsewhere, piecemeal tree-felling for timber and land clearance was taking place, although this was counteracted somewhat by eucalyptus planting. In the future, Chemwiro-Masawi residents felt that the composition of tree species on their land would shift towards eucalypts and away from indigenous species. Although the forest guard felt unfamiliar with the situation within the communal areas, he did feel that there had been some localized loss of tree cover. This was confirmed in a subsequent interview with another Forestry Commission representative, although there was no systematic monitoring of forest composition and biodiversity. In common with many other communal areas (Campbell, du Toit & Attwell, 1989), indigenous fruit trees were not felled and no respondents envisaged a situation where fruit trees would be at risk. In addition, some remaining patches of vegetation cover were associated with rain-making ceremonies (mutoro).

The observations of the Batanai community are again supported by the aerial photography. Percentage tree cover was estimated to have declined from 51% in 1976–7 to 47% in 1984 and then to 14% by 1996. This large decrease was mainly due to the de-gazetting of Batanai and subsequent clearing of land for cultivation and homesteads by immigrants. As shown in Fig. 2, in 1972 a section of forest was de-gazetted and legal occupation by smallholders began. By 1996, virtually all of this forest had been felled, whilst elsewhere in the communal area, further losses of tree cover took place, albeit on a smaller scale.

Patterns of land use

Whilst many land use drivers had been identified prior to fieldwork, several themes only became apparent during the semi-structured interviews. These themes included the importance of declining soil fertility and crop yields in driving land clearance in the communal areas and the perceived effect of land cover changes on rainfall patterns and streamflow.

Fire

The group of farmers at Chemwiro-Masawi held that the frequency of fires within the forest reserve had declined following co-management, principally because of community enforcement and the imposition of steep fines for offenders. In contrast, the FPU felt that the burning regime had remained unchanged over the previous ten years. In Batanai, fire was regarded as a useful means of managing vegetation. Not only did regular burning of vleis make hunting of game easier, but it also reduced tick populations. It therefore combated cattle disease and encouraged grass regrowth, thus improving grazing potential. Fires were occasionally started as a means of collecting honey. Fire was also considered a means of settling scores with the FPU and a useful tactic for distracting forest guards for those wishing to enter the forest reserve illegally. The Chemwiro-Masawi group felt that farmers there realized that persistent burning reduced thatch and broom grass quality, whilst the Batanai group
considered burning a means of improving grazing quality for cattle. The FPU regarded *vlei*-burning as more frequent in the Batanai area, with *vleis* closest to the communal areas being most at risk. In contrast, an earlier study at Mafungautsi (Matose, 1994) found that people starting fires were reprimanded, because fires were often followed by invasion of a noxious weed known as *mukauzani*, which is poisonous to cattle.

*Cattle-grazing*

All respondent groups agreed that livestock numbers had not changed substantially in the previous ten years. It was felt that there was a natural limit to the number of cattle that could graze within Mafungautsi. All respondents reported that cattle graze unsupervised, but concentrate largely in the *vleis* and grassy areas once occupied by ‘settlers’. Approximately 20,000 cattle are estimated to enter the forest every year (Matzke, 1993).

*Tree planting*

Views about tree planting within communal areas differed between the three interviews. In Batanai, farmers believed that there was little benefit to be derived from planting trees, partly because of the long delay before any wood could be harvested. Some also believed that the Forestry Commission might repossess communal land afforested with eucalypts and were suspicious of planting schemes. By contrast, in Chemwiro-Masawi, it was felt that uptake of planting was high because of free seedlings and pockets provided by Forestry Commission. However, some people expressed concern about limited land availability for tree planting. Subsequent field visits suggested that some individuals had planted eucalypts extensively.

*Thatch and broom collection*

All respondent groups showed clear awareness of their designated permit areas for thatch and broom collection, and there was a broad correspondence between the areas identified by the forest guard and those identified by villagers (Fig. 3). In Batanai, very little thatch and broom was available in the communal areas, and this led to some illegal collecting of inferior quality *ndabula* grass for thatch from the forest margins, in addition to the grass collection from permit areas. In Chemwiro-Masawi, however, thatch and broom grass grew within the communal area and so local residents had no need to visit Mafungautsi to collect grass for their own houses. This meant that the local RMC could grant permits to outsiders from neighbouring communal areas such as Nkayi, thereby guaranteeing income for the RMC. It was anticipated that local residents would continue to use thatch and broom from within the VIDCO in the future, but that demand for thatch and broom from other areas—and with it the value of permits—would increase as natural resources elsewhere became depleted.

*Timber and firewood collection*

Pole-poaching was considered to be most intense near the Bulawayo road (Fig. 3), in the forest areas closest to communal settlement. A similar decrease in pole-
Fig. 3. Patterns of land uses in the Batanai area of Mafungautsi reserve as described: (a) by smallholder farmers; (b) by the Forest Protection Unit (FPU).
cutting with distance from settlement was observed in a previous study of basal area plots within Mafungautsi (Vermeulen, 1996). Those interviewed felt that this area was especially prone to pole-poaching both because homesteads were located close to the reserve boundary and because pole trees within the communal area had been exhausted. All respondents felt that firewood collection was restricted to the forest margins. The Chemwiro-Masawi group suggested that collection was well controlled by the RMC, with dead wood only being gathered on designated days. In Batanai, respondents suggested that firewood collection was less well controlled and that those with Scotch carts could forage further for wood than those without transport.

Other non-timber forest products

All those interviewed believed that collection of wild fruits and mushrooms was restricted to the edges of the forest reserve. The Batanai group of farmers considered both fruit trees and mushrooms to be evenly distributed throughout the forest, whilst the Chemwiro-Masawi group felt that there were slightly more fruit trees along the edges of vleis. Only one respondent, the FPU guard, identified an area with a high density of mazhanje fruit trees (*Uapaca kirkiana*).

Honey collection was not permitted within the reserve. However, both groups of communal farmers expressed a desire to develop bee-keeping operations within the forest reserve, but despite investment in hives and fencing in one location, no such schemes were currently operating.

Underlying drivers of land cover change

Population

All groups agreed that increasing population was a major cause of vegetation change. The FPU noted that pole-poaching often increased following the arrival of new immigrants to an area, as the new arrivals sought materials for housing within Mafungautsi. In Chemwiro-Masawi, those interviewed felt confident that future population gains were likely to come from natural increases in population rather than immigration. In Batanai, it was felt that natural population increase was slowing because of HIV/AIDS, but immigration was continuing. One respondent suggested that anyone leaving his or her home temporarily would risk losing their land and housing to a newcomer, implying that immigration was perceived as ongoing.

The PRA and resource-mapping exercises revealed details of migrant characteristics and the timing of migration episodes. Following tsetse eradication, the original Shangwe people inhabiting the area surrounding Mafungautsi were joined by migrants from elsewhere in Zimbabwe, attracted by its cotton-growing potential. On discovering that this area was not very productive and now densely crowded, some of these migrants moved further north to areas with less sandy soils known as Chidhaka, such as Madzivazvido or Chireya. Although cotton income attracted immigrants to the area, some were forcibly moved by the colonial government as a result of the Native Husbandry Act of 1951. This allocated certain areas to white settlers and many of the current Batanai and Chemwiro-Masawi residents were forcibly evicted from Rhodesdale. After Rhodesdale was designated ‘Crown Land’, its popu-
lation was evicted in stages during the 1940s and 1950s (Ndanga, 1987; Nyambara, 1999). Others migrated from densely settled rural areas such as Zimuto, Chivhu, Chirimuhanzu, Gutu, Bikita, Gweru and Nkayi as a result of land shortages (Mehlo, 1970; Nyambara, 1999). Many immigrants to Gokwe tend to be wealthier than the original Shangwe people and some are former civil servants (mainly teachers). This meant that they had enough capital to buy inputs for cotton farming.

Declining soil fertility and crop yields
Declining soil fertility was cited as a major cause of land hunger in both RMCs. This is mainly due to the local Kalahari sandy soils, which are productive during initial cultivation but quickly lose their fertility over time (Manyame, personal communication). Most communal farmers historically countered this problem by cultivating extensively, but this is increasingly difficult due to the shortage of virgin land. Indirectly, declining soil fertility increased pressure on the forest reserve by reducing the land available for planting eucalyptus within the communal areas. In Batanai, some farmers cultivated stream-beds to overcome declining yields. In Chemwiro-Masawi, most farmers held that fertilizers did not improve yields in the predominantly sandy soils there and so even greater input availability would not counteract declining soil fertility. Such scepticism about fertilizer effectiveness was also found in an earlier study of Mafungautsi (Matose, 1994).

Regulation and enforcement
Aside from the independence war, when lack of enforcement enabled migrants to settle in Mafungautsi, enforcement changes have also profoundly influenced land cover at other times. The group at Batanai felt strongly that the number of people arrested when entering Mafungautsi had increased sharply in the previous ten years. Not only were perimeter patrols more frequent, but offenders were now more likely to be prosecuted and fines had become more expensive. This stricter enforcement was the principal reason why the group considered tree cover within Mafungautsi reserve to be increasing, while it was simultaneously decreasing in the surrounding communal areas. This observation is supported by quantitative data on the number of arrests within the reserve, which rose from an average of eight per year in 1991–4 to 16 per year in 1995–8. However, such prosecution figures are only a crude indicator of enforcement and may also reflect changes in poaching levels. The Chemwiro-Masawi group also felt that enforcement had become stricter, both because fines were more expensive and because the RMC were now involved in enforcement.

Discussion
Participatory mapping
Previous studies have examined land use and land cover change by combining remote sensing with a variety of interview techniques. In the UK, questionnaires were used to assess the impact of farming on vegetation change (Potter, Barr, &
Lobley, 1996), whilst in Ethiopia ecological time-lines were used to reconstruct histories of land cover change (Reid et al., 2000). In Kenya, interviews focusing on land use were conducted while walking along vegetation transects with respondents (Mahiri, 1997), and in Cote d’Ivoire group discussions with herders were used to identify the drivers of changes in savannah landscapes (Bassett & Bi Zueli, 2000). In this study, semi-structured interviews were combined with participatory mapping using photo-mosaics. The advantages of this technique were that it yielded land use maps that could be easily geo-referenced and related to remote-sensing data, whilst being sufficiently flexible to explore unanticipated themes that arose during interviews. It thus represents a promising addition to the range of interview techniques available for exploring land use and land cover change.

Participatory mapping revealed greater detail about the timing and causes of land cover change than aerial photo analysis alone. Previous studies have identified substantial variation in both socioeconomic characteristics and vegetation in many of Zimbabwe’s communal areas (Jackson & Collier, 1988; Campbell, du Toit & Attwell, 1989). Whilst this local variability was apparent in PRA and group interview data, it is not discernible from government data sources. For example, the interview data here suggested that in eastern Batanai, settlements were close to the forest margin, thus leading to greater crop damage by wildlife and pole-poaching. Such local variations in settlement patterns are not apparent in census population counts, which are available for the whole of Batanai RMC only. Specific events that affected land cover and its drivers—such as the evictions that took place under the Native Husbandry Act—could only be identified through interviews on the ground. This lends weight to the need to marry technical methods with participatory approaches (cf. Elliot & Campbell, 2001).

However, one difficulty with the participatory mapping technique in a developing-country context lies in distinguishing the relative impact of discussion group composition versus geographical location on interview results. In this study, the different results in the Chemwiro-Masawi and Batanai interviews were in part due to geographical differences between the two RMCs and partly due to differences in group composition (i.e. the presence of senior community representatives and RMC members in one group, but not in the other). In a rural developing-country setting, where respondents may be travelling some distance to attend interviews on an allocated day, standardizing group composition across different sites is in practice difficult to achieve (Goebel, 1996).

Land cover change at Mafungautsi

The FPU perceived land cover change somewhat differently to the smallholder farmers living on the forest reserve margins. Whilst many of the farmers felt that tree cover within the reserve had increased, the FPU felt that tree cover was stable with localized losses due to pole-poaching. The farmers were also more acutely aware of the loss of tree cover in the communal areas than the FPU. Such differences in perception of land cover change have also been found in other studies that combined interviews with remote sensing in West Africa. Fairhead and Leach (1996)
described how technical officers may interpret local developments so as to justify their own interventionist policies. The differing perceptions of land cover change between the Batanai farmers and the FPU could be due to the latter’s need to maintain their status. By suggesting that forest cover in the reserve was unchanged, the FPU could justify their presence as a barrier against forest degradation. In the Gokwe study sites, women were more aware of a reduction in vegetation cover, probably due to their key role in firewood collection and the need to walk further as fuel wood became scarcer. This awareness of forest cover among women concurs with previous work (Clarke, Cavendish, & Coote, 1996), which found that women knew of uses for a greater number of tree species than men.

Underlying tensions between many of the key actors at Mafungautsi became apparent during the course of the study. Some neighbouring communal farmers had cultivated land within the reserve during the period of weak enforcement from 1978 to 1983 and subsequently been expelled. This group still felt entitled to the gazetted land within the reserve and resented the presence of the FPU in enforcing the reserve’s boundaries. When co-management was introduced, it was seen as a mechanism for resolving this conflict (Matzke, 1993; Nhira, Baker, Gondo, Mangono, & Marunda, 1998). However, the FPU clearly felt that the new RMCs contributed little to enforcing regulations within the reserve, whilst one RMC was criticized for not distributing income generated through co-management more widely within the community.

Given the evidence presented here, it seems likely that the communal areas surrounding Mafungautsi will experience ever-declining tree cover, unless participatory action is taken. Even without any local population increases, this trend seems likely to continue because of soil fertility decline and because of felling by remote actors. If current land use drivers continue to operate, the remaining communal woodland is likely to shift in composition towards fruit trees and eucalypts as felling continues and some farmers take up incentive schemes for tree-planting. Within Mafungautsi, increased pole-poaching seems likely without greater economic incentives for local communities to respect the reserve’s boundaries. The gazetting of Mafungautsi resulted in local communities perceiving it as state property and the ‘withdrawal’ of traditional forestry conservation practices within the gazetted area. Imposed solutions, such as the rural afforestation programme (Whitlow, 1988; Elliot, 1991; McGregor, 1995), appear unsustainable in the long term and there is a need for local solutions adapted to the particular social, economic and political circumstances in Mafungautsi.

Future research

In this study, interviews based around aerial photographs were used to analyse historical patterns of land cover change. All respondents were able to interpret the photographs, but it was apparent that their perceptions of change varied. One way of resolving such differences may be to use discussion based around aerial photographs as a tool for planning future natural resource use. For example, permit zones for thatch and broom collection could be delineated through a discussion process.
between the Forestry Commission and the RMCs, referring to relevant aerial photographs as necessary. This approach has already proved successful in one study of forest resource conflicts in Nepal (Mather, de Boer, Gurung & Roche, 1998).

This study has highlighted the importance of integrating GIS and participatory approaches to explain vegetation covers in two RMC areas in Gokwe. This dialogue between technical and participatory research methods empowers local people to counter ‘technical wisdom’ using participatory technical tools. However, these two case study areas may not be typical of Mafungautsi Forest Reserve as a whole, since only localized changes were assessed and not the entire reserve area. Furthermore, there may be conflicts in natural resource use amongst the different RMCs, particularly as different communities may graze cattle or collect firewood in the same geographical areas. There is therefore a need to undertake similar research across a broader area and covering more RMCs. Future work could also examine vegetation change over a longer period of time, since aerial photographs are available for earlier years. Research in West Africa (Fairhead & Leach, 1996) has shown that there may be cycles of expansion and contraction of vegetation cover and this cannot be deduced by analysing a short time period.

In this study, participatory mapping using aerial photography and PRA were carried out in parallel by different groups of respondents. However, a more useful approach may be to undertake an initial PRA exercise, followed by photo-based interviews with several groups differentiated on the basis of the PRA. The initial PRA exercise with a large group could identify key sub-groups within the community on the basis of gender, age, wealth or length of residence. This group could then be separated into different sub-groups for the aerial-photo-based interviews. In this way, different perceptions of land cover change within the same community (e.g. between men and women) could be identified.

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