An investigation of land cover change in Mafungabusi 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 Mafungabusi Forest Reserve in Zimbabwe. Land cover change was analysed using aerial photography from 1976-1996 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 is found that whilst forest cover within the forest reserve has remained stable, there has been a steady decline in forest cover outside the forest reserve's boundaries.

Keywords: land use, GIS, participatory mapping, Zimbabwe, resource sharing

INTRODUCTION

The recent devastating floods in Mozambique highlighted the importance of land cover change in the major river catchments of southern Africa. Forest degradation upstream in Zimbabwe was in part held responsible for widespread flooding in Mozambique, following the arrival of Cyclone Eline in November 2000. In this paper, land cover change is examined within Mafungabusi Forest Reserve that forms part of the upper reaches of the Zambezi River’s catchment area and houses the Kariba Dam.

This paper explores three aspects of land cover change in and around Mafungabusi. Firstly, changes in land cover between 1976 and 1996 are assessed using historical aerial photography. Secondly, land use is described using participatory interviews centred on recent aerial photographs. Finally, 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 two-fold. Firstly, 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 about land use and perceived land cover change.

Description of study area

The study area is in the Gokwe South District, which falls under the Midlands Province of Zimbabwe. Figure 1 below shows the location of Gokwe South District in Zimbabwe.

The natural vegetation in the Gokwe area is dry deciduous savanna woodland with grassland areas, known as *vleis*, covering lower slopes close to surface drainage lines. Outside the forest reserve, this vegetation has progressively been cleared to make way for agriculture, initially through shifting cultivation and latterly to make way for cotton production. Typically, tree cover remains along the banks of streams and rivers and fruit trees are often left standing even within fields. Topographically, the study area consists largely of the gently undulating Mafungabusi plateau, which is dissected in places by streams.

Mafungabusi Forest Reserve was gazetted in 1954 for ecological reasons, since it forms part of the watershed for rivers such as the Sengwa and Mbumbusi. These rivers flow into the Zambezi, which contains the Kariba Dam, an important generator of hydroelectric power for both Zimbabwe and Zambia. Most of Gokwe was originally sparsely populated, because of the threat of disease from the tsetse fly in the area. However, more people migrated into Gokwe after the elimination of the tsetse fly in the 1950s and 1960s. This resulted in an increase in population in Gokwe and greater demand for land within the gazetted forest area.

In terms of current livelihoods, Gokwe is well known for cotton production activities (Worby 1994). Agriculture therefore remains the main source of income, especially the cultivation of grains such as maize with cotton as the main cash crop. Other non-farm agricultural activities such as marketing of fruits such as bananas and non-timber forest products (honey, mushrooms, and wild fruit) are also an important source of income to some households. 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 both Ndebele and Shona-speaking peoples forming part of the population.

Management of Mafungabusi Forest Reserve

The Forestry Commission, which is a central government body, is responsible for the day to day management of the gazetted forest. Tree-cutting, hunting, and deliberate burning are all prohibited within the forest reserve. A Forest Protection Unit (FPU), which forms part of 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 surrounding rural communities. This is some form of partnership between the

Forestry Commission and the households surrounding Mafungabusi Forest for natural resource sharing. These households have formed Resource Management Committees (RMCs), which are the institutions that are to spearhead the co-management project. Separate RMCs have been formed for most of the Village Development Committees (VIDCO's) surrounding the forest reserve. VIDCO's are the lowest geographical unit of administration in Zimbabwe's smallholder farming areas and each VIDCO typically contains about 1,000 inhabitants. 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 Resource Management Committees, namely Chemwiro-Masawi and Batanai (see Figure 1), were selected for this study. Batanai RMC encompasses one VIDCO whereas Chemwiro-Masawi RMC is comprised of two VIDCOs. These two cases offer useful insights into vegetation cover changes since Batanai is a former forest area that was ceded to the neighbouring communities in 1972. Prior to 1972 vegetation cover was similar to the rest of the Mafungabusi Forest. Chemwiro-Masawi has a longer settlement history, which offers a good comparison with Batanai.

METHODS

Changes in land cover were examined through a combination of Participatory Rural Appraisal (PRA) (Chambers 1994, IIED 1995) and analysis of historical aerial photography. Interviews with selected groups of local inhabitants were conducted in late 2000 to identify current land use, perceived changes in vegetation, and their possible causes.

Participatory Rural Appraisal (PRA)

Gokwe area has some of the lowest literacy levels in Zimbabwe (Central Statistical Office (CSO), 1992), so participatory approaches had to be used. These participatory tools were also intended to obtain information and views from various sectors of the community. Initially, focused group discussions involving up to 10 people were used to discuss different uses of the forest and perception of change over time. Follow-up discussions were then conducted separately with groups of men, youths and women, thereby encouraging women and youths to express views independently of men.

Resource Mapping was also used to get the relative perception of vegetation cover by the local communities. This is a participatory research approach where the people sketch the resources in their area in map form (Chambers 1994, IIED 1995) The technique can also be 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. The PRA fieldwork was completed by follow-up key informant interviews with the elderly people who knew more about their village. They then gave accounts of changes that have taken place within their environment.

Participatory mapping using aerial photography

In addition to the PRA fieldwork, semi-structured interviews were conducted with selected groups of respondents within the study area. Semi-structured interviews involve the use of a pre-designed series of open-ended questions, but also allow unanticipated themes or responses to be explored by the interviewer (Miles and Huberman, 1994). Respondents were asked about land cover changes, current and historical use of local natural resources, and observed distribution of fires and wildlife. Respondents were also asked to describe the likely future pattern of land cover change. 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, areas affected by fire, areas where pole-poaching was common and cropland areas damaged by wildlife.

Black and white 1:50,000 aerial photography from 1996 was used for these interviews, which were subsequently enlarged to 1:25,000 scale to make interpretation easier. Separate photo mosaics were obtained for the two study areas of Batanai and Chemwiro-Masawi. Aerial photography was used in preference to large-scale topographic maps because previous studies suggested that they were easier to interpret among those with only basic education. Aerial photography has successfully been used in interviews with poorly educated farmers in Nepal (Mather, de Boer, Gurung, and Roche, 1998), Cote d'Ivoire (Bassett, 1993), and in educational studies of young children from South Africa, the United States, England, Mexico and Iran (Blades, Blaut, Darvizeh, Elguea, Sowden, Soni *et al.*, 1998).

Three interviews based around the aerial photographs were conducted. The first interview was conducted in Batanai RMC with a group of 7 local farmers. Although one of these farmers was an RMC committee member, the majority were not directly involved in natural resource sharing. A second interview was conducted with 12 farmers within the Chemwiro-Masawi RMC. In general, this group was more directly involved in resource sharing and community groups. This group included the secretary of the local RMC, the ward councillor, and several RMC members. Both groups were comprised almost exclusively of men. Finally, an interview was conducted with a member of the Forest Protection Unit based within Mafungabusi Forest Reserve, who was familiar with the study areas. A synopsis of the discussions was written by one of the principal researchers the evening after each interview. In addition, a research assistant took notes during the exercise, thus providing two written accounts of each interview.

The aerial photo mosaics were subsequently scanned onto computer, imported into a GIS and geo-referenced, as described above. Land use zones and other observations recorded during all three interviews were then digitised on top of the geo-referenced scanned images by reference to the original acetates.

Historical aerial photography analysis

Aerial photo mosaics of the Batanai area of Mafungabusi and surrounding farmland were obtained for three years - 1976, 1984, and 1996. Black and white aerial photographs (scale 1:50,000) were scanned onto computer as three images for each year and geo-referenced to Universal Transverse Mercator co-ordinates. This was achieved by taking control points from two sources, a 1996 panchromatic Spot satellite image and 1:50,000 scale topographic maps and applying a linear transformation to these points. The satellite image was not used as a basis for identifying vegetation because of its resolution and to ensure that remote sensing data sources were consistent across the years studied. Root Mean Square (RMS) errors were calculated for each scanned image based on the formula (Johnston, 1998):

$$RMS = \sqrt{\{\Sigma\ [(x_i - X_i)^2 + (y_i - Y_i)^2] / n\}}$$

(Where x_i y_i are the true co-ordinates of the control points, X_i Y_i are the control point co-ordinates given by the transformation, and n is the number of control points used).

The RMS error statistics for each image are shown in Table 1. An allowable RMS error for 1:50,000 scale cartography was estimated from the United States National Map Accuracy standard (USGS, 1999) using the formula (Clark Labs, 2001):

Allowable RMS = (Error on the map * scale conversion * units conversion/ z score probability of occurrence) = 0.02 * 50,000 * 0.0254 / 1.64 = 15.48 metres

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 digitised by the authors over these photographs to delineate one of four main types of land cover: agricultural land, woodland/scrub, *vlei*, and forest. In addition, percentage tree cover was estimated for each polygon, being lowest for *vlei* and highest for the forest category. An attempt was made to identify eucalyptus woodlots that had been planted within the smallholder farming areas. However, replanting tends to be piecemeal and small-scale and these dispersed patches of eucalyptus proved too difficult to identify on the available photography.

Other data sources

Several routinely collected government data sets were used to crosscheck the findings from the interviews. This included 1981-1993 crop yield data for Gokwe communal area as collected by agricultural extension services (Agritex/USAID FEWS, 2001), precipitation records for the meteorological station at Gokwe, and the number of poaching arrests in Mafungabusi made by the Forest Protection Unit.

To identify declining soil fertility, annual reported crop yields for the Gokwe communal area were regressed against annual rainfall in the 12 months prior to harvest. The residual

variation in yields was then plotted over time to identify trends in yields, taking into account variability of rainfall.

RESULTS

Changes in Land Cover and Wildlife

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 Forest Protection Unit and communal farmers and through analysis of aerial photography. This table also compares perceived changes in land use and its drivers according to these interviews and governmental data.

Land Cover Changes within Mafungabusi:

The FPU guard interviewed felt that tree cover within Mafungabusi had remained largely unchanged in the last 10 years, although tree cover had declined in several areas on the edge of the forest reserve through pole poaching. At Batanai, the farmers' group felt strongly that tree cover had increased within Mafungabusi 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 Mafungabusi forest reserve, tree cover declined from 68% in 1976/7

to 66% in 1984, but then rose again to 71% by 1996. Figure 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 enforcement of the park's boundaries. The land cleared by these squatters can be seen on both the 1976 and 1984 aerial photographs in Figure 2. By 1996, the northern area of encroachment in Batanai had largely reverted to forest, whilst the southern area of encroachment 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 wood for fuel. The situation was being exacerbated further as diminishing crop yields forced some farmers to cultivate streambeds. 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 the local residents. Elsewhere, piecemeal felling of trees for timber and land clearance was taking place, although this was being counteracted to some extent by the planting of eucalyptus. 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 relatively unfamiliar with the situation within the communal areas, he did feel that there had been some localised loss of tree cover. In common with many other communal areas (Campbell, du Toit, and Attwell, 1989), indigenous fruit trees were not felled and no respondents envisaged a situation where fruit trees would be at risk.

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. As shown in Figure 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.

Changes in Wildlife Numbers and Distribution:

Perspectives on wildlife numbers differed between the various respondents. Reported sightings of larger wildlife in the park were restricted to zebra, wild pig and a pair of buffalo, though smaller animals such as wild hare and monkeys were also seen frequently. The forest guard felt that wildlife numbers had steadily declined over the past 10 years, whilst the Batanai group of villagers felt that wildlife numbers had remained more or less constant. In Chemwiro-Masawi, opinion was divided as to changes in wildlife numbers. Both the group of farmers at Batanai and the forest guard reported that wildlife, especially wild pigs, were increasingly concentrating in the area immediately surrounding Lutope camp because of the threat of hunting. This acted as a refuge, since most villagers were unwilling to risk hunting so close to the Forest Protection Unit Camp.

Crop damage by wildlife was reported as being rare. In Chemwiro-Masawi, relatively few large animals ventured outside the park and so the group of villagers there had not noticed any crop damage occurring. However, in Batanai, one stretch of farmland was very prone to crop damage by zebra and wild pigs, largely because the fields bordering the forest reserve were some distance from any homesteads (see Figure 3). The Forest Protection Unit and villagers at Batanai both described this area as the main focus of human-wildlife conflict.

Patterns of Land Use

Whilst many of the aspects of land use and land cover change presented below had been identified prior to group interviews and PRA, several themes only became apparent during the semi-structured interviews. These themes included the importance of declining soil fertility and crop yields as a driver of land clearance in the communal areas and the effect of land cover changes on climate and hydrology.

Fire

The group of farmers from the Chemwiro-Masawi interview held that the frequency of fires within the forest reserve had declined with the introduction of resource sharing, principally because of community enforcement and the imposition of steep fines for offenders. This contrasted with the views of the FPU, who felt that the burning regime had remained unchanged over the previous 10 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. Burning 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 thought to be a useful tactic for distracting forest guards for those wishing to enter the forest reserve illegally and considered a means of settling scores with the forest protection unit. Whereas the Chemwiro-Masawi group suggested that most communal farmers realised that persistent burning eventually reduced thatch and broom grass quality, the Batanai group considered burning to be a useful way of improving the quality of grazing 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.

Cattle-grazing

All respondent groups agreed that livestock numbers had not changed substantially in the last ten years. It was felt that there was a natural limit to the number of cattle that could graze

within Mafungabusi and this had limited the cattle population. All respondents reported that cattle graze unsupervised within Mafungabusi, but concentrate largely in the vleis and grassy areas once occupied by squatters. About 20 000 head of 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 that had been afforestated with gum trees and were deeply suspicious of planting schemes. In Chemwiro-Masawi, it was felt that uptake of planting locally was high because of free seedlings and pockets provided by Forestry Commission. However, some people expressed concern about the limited amount of land available for tree planting.

Thatch and Broom Collection

All respondent groups showed a 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 (Figure 3). Again, there were clear differences between Batanai and Chemwiro-Masawi. In Batanai, very little thatch and broom was available in the communal areas, and this led to some illegal collection of inferior quality *ndabula* grass for thatch from the forest margins, in addition to grass collection from permit areas. In Chemwiro-Masawi, thatch and broom grass grew within the communal area and so local residents had no need to visit Mafungabusi 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, thus guaranteeing an income stream to 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 became increasingly depleted.

Timber and Firewood Collection

In general, pole poaching was considered to be at its most intense along the boundary with the Bulawayo road (Figure 3), in the forest areas closest to communal settlement. A similar decrease in pole cutting with distance from settlement has been observed in a previous study of basal area plots within Mafungabusi (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. The Batanai group of farmers strongly expressed the view that tree cover had increased within the reserve, and the Chemwiro-Masawi group expressed the same view, albeit less strongly.

All respondents felt that firewood collection was restricted to the areas close to the forest margin. 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 (*Upaka Kirkiana* spp.).

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 one of the major causes 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 Mafungabusi. 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 their home temporarily would be at risk of losing both 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 the eradication of tsetse, the original *Shangwe* people inhabiting the area surrounding Mafungabusi were joined by migrants from elsewhere in Zimbabwe, attracted by its potential for growing cotton. On discovering that this area was

not very productive and was now densely crowded, some of these migrants moved further south to areas with less sandy soils known as *Chidhaka,* such as Madzivazvido or Chireya. Although cotton income attracted immigrants to the area, some incomers were forcibly moved by the colonial government as a result of the Native Husbandry Act. This act 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 population 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 pressure on available land (Mehlo 1970, Nyambara 1999). Many immigrants to Gokwe tend to be people with better resources than the original *Shangwe* people and some are former civil servants, mainly teachers. This meant that they had enough capital to buy most of the inputs required for successful cotton farming.

Declining soil fertility and crop yields:

Declining soil fertility was cited as a major cause of land hunger in both study areas. This is mainly due to the local Kalahari sandy soils, which are productive during initial cultivation but quickly lose their fertility with time. 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 also increased pressure on the forest reserve since it reduced the amount of land available for planting eucalyptus within the communal areas. In Batanai, some farmers were now cultivating streambeds in an attempt to overcome declining yields. In Chemwiro-Masawi, most farmers held that the use of fertilisers had no effect on yields in the sandy soils that predominate there and so even greater input availability would not counteract declining soil fertility there.

Estimates of yields made by the government extension services were significantly associated with precipitation in the preceding 12 months for all three crops examined. Changes in annual precipitation were most strongly associated with maize yields (adjusted R^2 = 0.68, N = 10), then with cotton (adjusted R^2 = 0.58, N = 10), and least strongly associated with groundnuts (adjusted R^2 = 0.44, N = 10). As shown in Figure 4, after accounting for precipitation, the residual variation in maize yields showed a significant downwards trend over time.

Climate and Hydrology

The group of farmers at Batanai felt that the changes in vegetation had affected local micro-climate. Rainfall was now concentrated more in the forest reserve than previously, with storm-clouds passing over the communal areas without shedding any rainfall until they reached the forest area. One consequence of this was that river beds were now dry for a longer part of the year in Batanai, although the farmers group at Chemwiro-Masawi felt that the springs in their area continued to function much as before.

Regulation and enforcement

Aside from the independence war, when the lack of enforcement enabled squatters to settle in Mafungabusi, enforcement changes have also had a profound influence on land cover, according to those interviewed. The group at Batanai felt strongly that the number of people arrested entering Mafungabusi had increased sharply in the last ten years. Not only were perimeter patrols more frequent, but the chances of an offender being let off with a caution were now much lower than in the past and fines had become more expensive. This stricter enforcement was the principal reason why the group considered tree cover within

Mafungabusi reserve to be increasing, yet simultaneously decreasing in the surrounding communal areas. 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. The Chemwiro-Masawi group felt that fencing could be used to further strengthen enforcement. The FPU felt that community involvement in enforcement was sporadic. In terms of fire-fighting, communal farmers helped the FPU during the thatch and broom collection season in May-June, but at other times of year their contribution was negligible.

Figure 5 shows police figures for the number of arrests brought to court for infringement of Mafungabusi forest reserve. There seems to be an increasing trend in the number of arrests and convictions. One, however, needs to be careful not to read too much into these figures as they may not be a reflection of changes in the actual poaching levels in Mafungabusi.

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 have been used to assess the impact of farming techniques on vegetation change (Potter, Barr, and Lobley, 1996), whilst in Ethiopia an interview technique known as ecological time-lines has been used to reconstruct histories of land cover change (Reid, Kruska, Muthui, Taye, Wotton, Wilson *et al*, 2000). In Kenya, interviews focussing on land use were conducted whilst walking along vegetation transects with respondents (Mahiri, 1997), whilst in Cote d'Ivoire group discussions with

herders were used to identify the drivers of changes in savannah landscapes (Bassett and 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 interview. It thus represents a promising addition to the range of interview techniques available for exploring land use and land cover change.

Undertaking a participatory mapping exercise in addition to the aerial photo analysis revealed greater detail about both the timing of land cover changes and their causes. It has previously been noted that there is substantial variation in both socio-economic characteristics and vegetation in many of Zimbabwe's communal areas (Jackson and Collier, 1988; Campbell, du Toit, and Attwell, 1989). Whilst this local variability was apparent in PRA and group interview data, this variability is not discernible from routinely collected 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 VIDCO 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. Furthermore, certain influences on vegetation change (notably fire and wildlife distribution) would be difficult to assess using conventional data sources.

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 VIDCO's 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, standardising group composition across different sites is in practice difficult to achieve.

Land Cover Change at Mafungabusi

The Forest Protection Unit had a somewhat different perception of land cover change relative to the smallholder farmers leaving 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 localised 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) pointed out how the technical officers may interpret developments on the ground so as to justify their own interventionist policies. The fact that perceptions of land cover change differed between the Batanai farmers and the FPU could be due to the latter's need to maintain their own 'official' position. The FPU might have suggested that forest cover in the reserve was unchanged as a means of justifying their presence as a barrier against degradation of the forest. Similarly, in a Jamaican reserve in the Hellshire Hills, forest guards suggested that tree cover was actually increasing under their protection, despite remotely sensed evidence to the contrary (Tole, *pers. Comm.*). In the Gokwe study sites, women tended to be 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 more scarce. Men on the other hand, are not the key players in terms of firewood collection.

Given the observations made both during interviews and from governmental data and aerial photographs, it seems likely that the communal areas surrounding Mafungabusi will experience ever-declining tree cover, unless radical 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 composition of the remaining communal woodland is likely to shift towards fruit trees and eucalypts as a result of incentive schemes for tree-planting. Within Mafungabusi, increased pole-poaching seems likely without either greater enforcement or economic incentives for local communities to police the reserve's boundaries. Gazetting Mafungabusi resulted in the local communities seeing it as a state property and this resulted in the ‘withdrwal’ of traditional forestry conservation practices within the gazetted area.

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 perceptions of change differed between respondents. 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, and Roche, 1998).

This study has highlighted the importance of integrating the technical Geographical information Systems (GIS) and participatory approaches to explain vegetation covers in two RMC areas in Gokwe. However, these two case study areas may not be typical of the whole

of Mafungabusi Forest Reserve and its environs. This meant that only localised changes were captured and NOT the whole picture. 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, covering as many RMCs as possible. Future work could also examine vegetation change over a longer period of time, since aerial photographs are available for earlier years. Researches in West Africa (Fairhead and Leach, 1996) have shown that there may be cycles of expansion and contraction of vegetation cover and this cannot be deduced by analysing a short time span.

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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Figure 1: Location of Gokwe South district, Mafungabusi reserve and the case study communities of Batanai and Chemwiro-Masawi

Figure 2: tree cover in the Batanai area of Mafungabusi and Gokwe communal area in (a) 1976/7; (b) 1984; and (c) 1996 (based on aerial photography)

Figure 3: patterns of land uses in the Batanai area of Mafungabusi reserve as described: (a) by smallholder farmers; (b) by the Forest Protection Unit

Figure 4: change in annual yield of three major crops in Gokwe communal area, 1981-1992, after accounting for variation in annual precipitation (Source: Agritex/USAID FEWS, 2001).

Figure 5: Number of forest poaching convictions per year at Mafungabusi forest reserve (source: Gokwe Zimbabwe Republic Police records)

year	Image no.	RMS error	No. control points
1976	1	22.7	16
1976	2	19.4	14
1976	3	15.4	15
1984	1	12.0	13
1984	2	25.4	15
1984	3	25.3	15
1996	1	23.9	12
1996	2	28.7	12
1996	3	23.0	11

Table 1: Root Mean Square error statistics for geo-referencing of aerial photography for Batanai, Gokwe South district

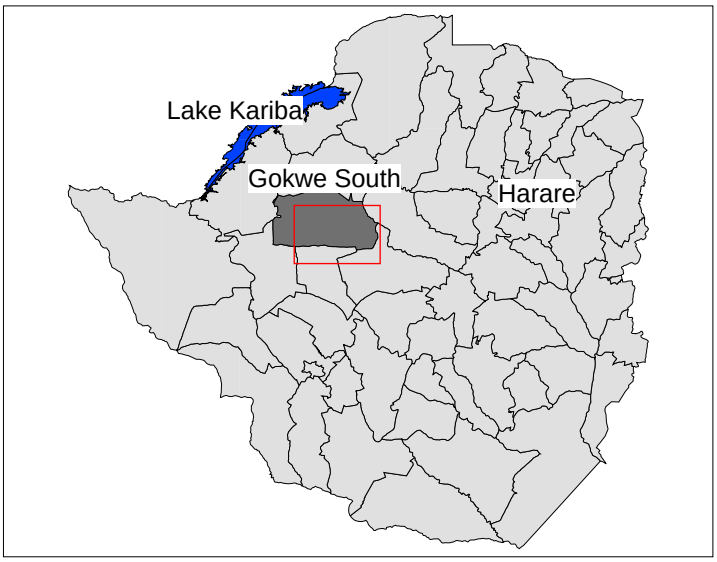
	FOREST PROTECTION UNIT	BATANAI	CHEMWIRO-MASAWI	SECONDARY DATA
LAND COVER & WILDLIFE CHANGES				
VEGETATION CHANGE in Mafungabusi	No change except for the 5-6km belt along Bulawayo road.	Tree cover had increased in Mafungabusi	Increased tree cover implied	Increase in tree cover on aerial photographs as former cultivation reverts to forest
VEGETATION CHANGE IN COMMUNAL AREA	Localised loss of tree cover	Severe loss of tree cover, increased stream bank cultivation in the river beds	Decrease due to commercial logging, Indigenous tree decreasing, gum trees are increasing-more gum trees than indigenous trees in	Decrease in tree cover visible on aerial photographs, especially in de-gazetted area

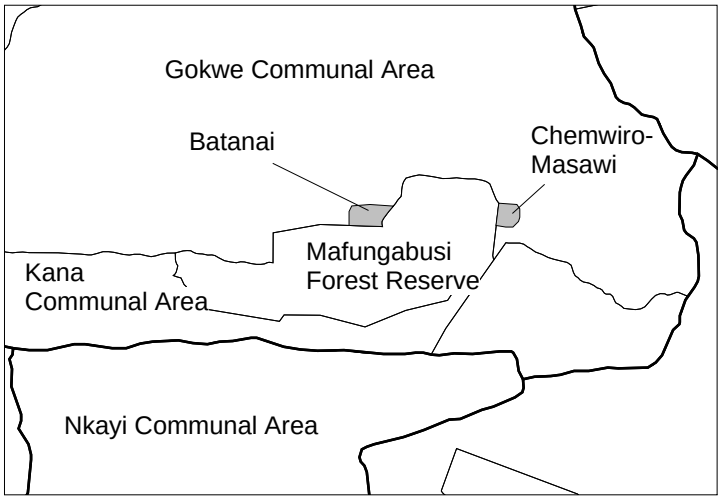
			future	
WILDLIFE CHANGE	Reduced wildlife numbers, more concentration around FPU camp at Lutope	Wildlife concentrated around the camp, but no change in numbers	Some felt that there was an increase whilst other felt that there was a decrease	Not available
LAND USE CHANGE				
CATTLE NUMBERS AND GRAZING	no change	no change	no change	Dip Tank figures
TREE PLANTINGS	Not aware of planting within communal areas	Some planting and some are not for fear of losing rights over trees and problems of slow growth.	Active planting taking place because of free seed and pockets, but shortage of land is a major problem	Eucalyptus not distinguishable from other forest cover types on aerial photographs
CHANGE IN FIRE	No change-fires annually	No comment	Fires had decreased	Not available
EFFECTS OF FIRE	Makes easier to kill game	People are starting fires, Easier to kill	Reduces thatch and Broom grass	

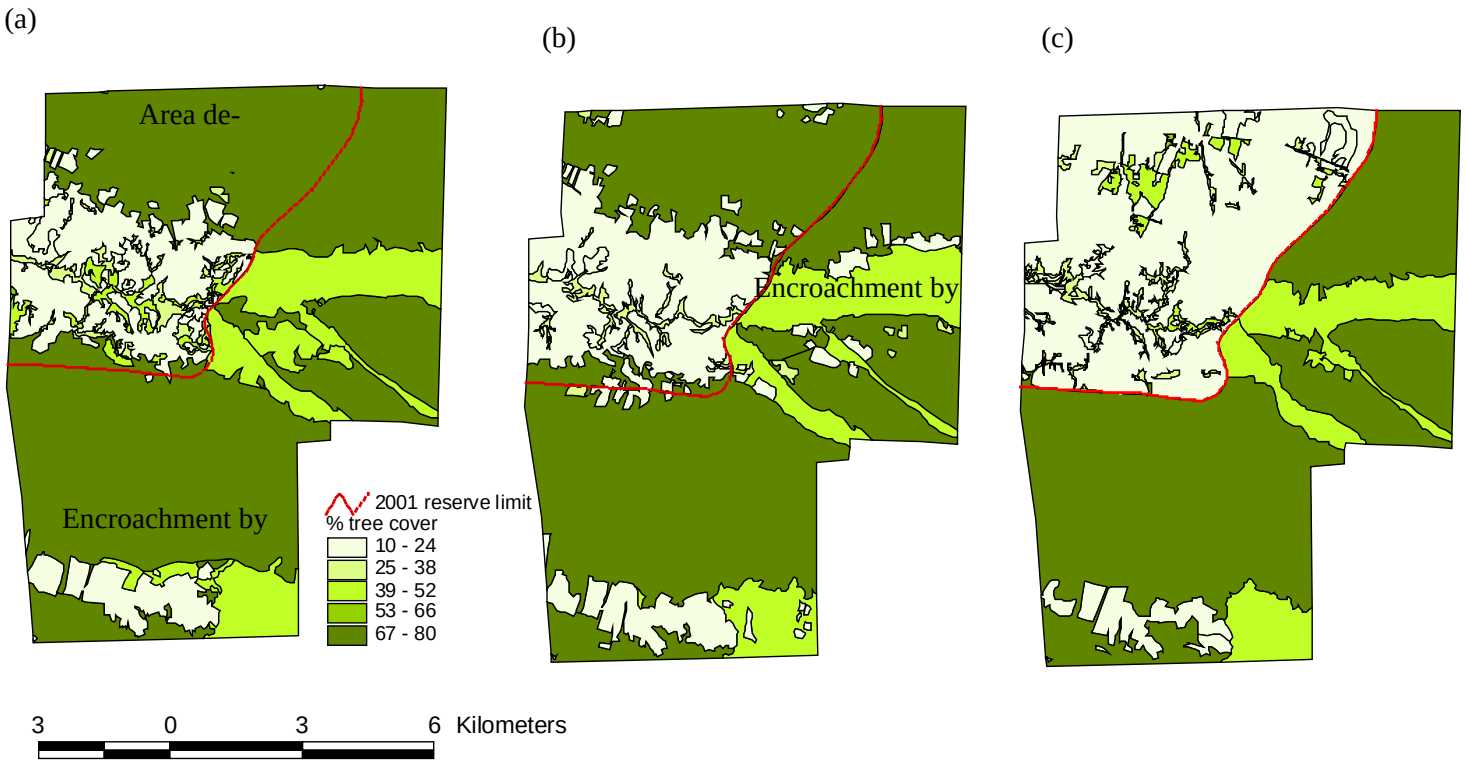
		game, reduce ticks, Distract FPU, Improve pasture quality, Revenge on FPU, enjoyment		
OBSERVED CHANGES IN LAND USE DRIVERS				
STRICTNESS OF ENFORCEMENT	Not specified	Fines and patrol had increased	Enforcement had increased because of the RMCs and resource sharing	Increase in number of poaching prosecutions from 1991-98
CLIMATE & HYDROLOGY	No comment	Definite reduced stream flow and rainfall in communal area	No change	Not available
POPULATION CHANGES	House-building by immigrants increases pole	Increased population has resulted in	Natural increase in population but	Historical figures only available no at district level

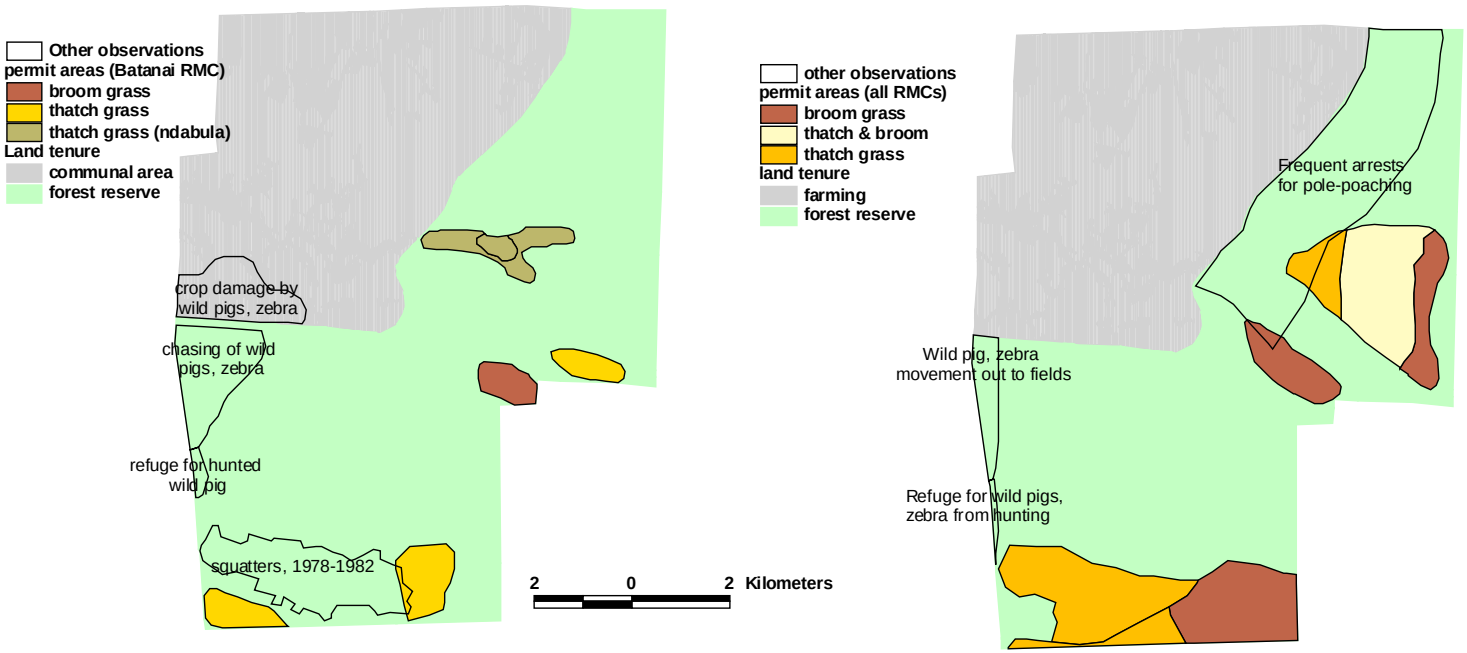
	demand	increased land demand and conflicts	immigration was going on	
SOIL FERTILITY CHANGE	No comment	Soil fertility is going down that's why stream bed cultivation is happening	Soil fertility has always been low but its deteriorating	Maize yields adjusted for rainfall from 1981-93, but cotton and groundnut yields do not.

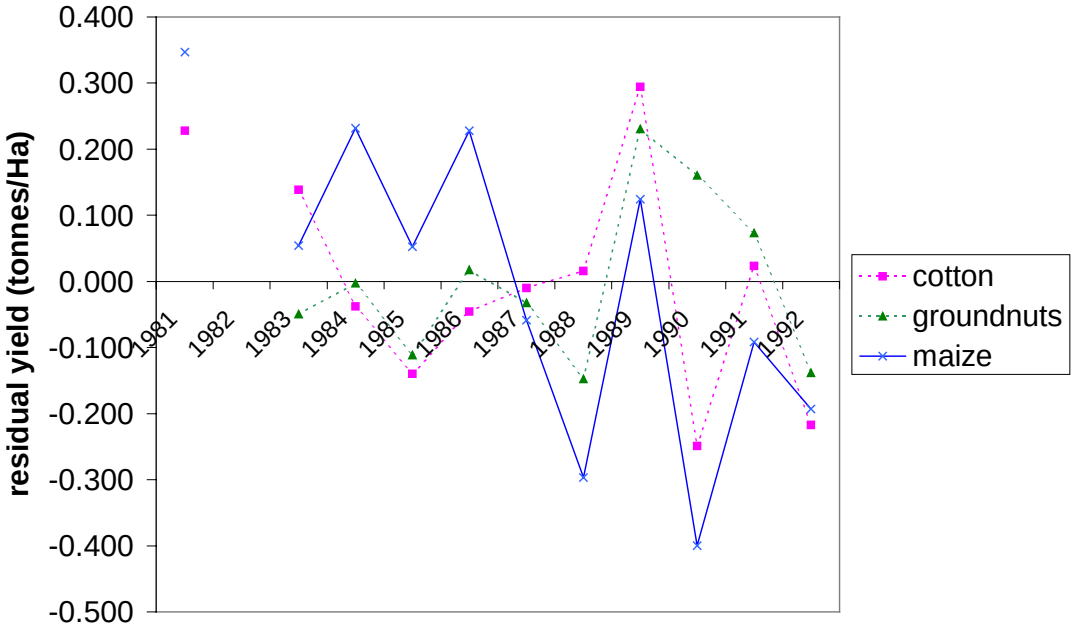
Table 2: changes in land cover, land use and land use drivers around Mafungabusi, as identified through governmental data and interviews with communal farmers and the Forest Protection Unit.

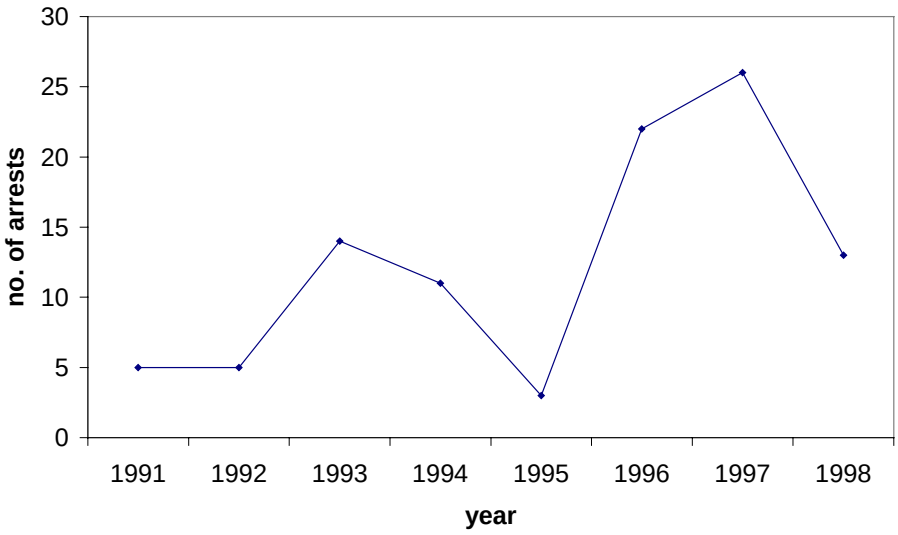

Lake Kariba
Gokwe South
Harare


Gokwe Communal Area
Batanai
Chemwiro-
Masawi
Mafungabusi
Forest Reserve
Kana
Communal Area
Nkayi Communal Area


(a)
(b)
(c)
Area de-
Encroachment by
Encroachment by
2001 reserve limit
% tree cover
10 - 24
25 - 38
39 - 52
53 - 66
67 - 80
3 0 3 6 Kilometers


Other observations
permit areas (Batanai RMC)
broom grass
thatch grass
thatch grass (ndabula)
Land tenure
communal area
forest reserve
crop damage by wild pigs, zebra
chasing of wild pigs, zebra
refuge for hunted wild pig
squatters, 1978-1982
2 0 2 Kilometers
other observations
permit areas (all RMCs)
broom grass
thatch & broom
thatch grass
land tenure
farming
forest reserve
Frequent arrests for pole-poaching
Wild pig, zebra movement out to fields
Refuge for wild pigs, zebra from hunting


residual yield (tonnes/Ha)
0.400
0.300
0.200
0.100
0.000
-0.100
-0.200
-0.300
-0.400
-0.500
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
cotton
groundnuts
maize


30
25
20
15
10
5
0
no. of arrests
1991
1992
1993
1994
1995
1996
1997
1998
year