LUCID's Land Use Change Analysis as an Approach
for Investigating Biodiversity Loss and Land Degradation Project

Linkages Between Changes in Land Use, Land Degradation and Biodiversity in S.W. Uganda

LUCID Working Paper Series Number: 12

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A. ABSTRACT

Like much of the rest of the world, Uganda is losing biodiversity fast – at about 10% per decade according to one estimate. The driving forces are generally agreed to be the increasing human population and the resulting changes in land use. However, the details of these processes are not well-documented.

In this preliminary study, we report on three study areas in south-western Uganda, all of which were originally savannas but which are now heavily used for the keeping of livestock or for agriculture. Land use changes were documented from remotely-sensed data and from interviews with local people. Signs of land degradation were recorded and soil analysed from a series of sites.

Biodiversity changes were investigated by using flowering plants and birds. Much of the native flora and most of the birds native to the area persist in pastoral areas (although large mammals are eliminated). However, native plants are greatly reduced in cultivated areas, where signs of land degradation are also most obvious. Comparing birds in areas of different land use, and over a period of years (using other data sources) shows that species requiring trees are prone to declines everywhere, but especially in cultivated areas.

Since pastoral lands are also beginning to change, well-managed Protected Areas are the key to survival of the native flora and fauna. Sympathetic land use practices, such as agroforestry, and corridors along roads and streams will be useful too. We suggest ideas to be tested along these lines.

B. INTRODUCTION

It has always been obvious that major changes in land use produce changes in the plants and animals that inhabit the land. However, the nature of these changes in biodiversity, and their extent, have not been well-documented in the African tropics. Such data as there are come principally from forests. For non-forest areas in Uganda, Nachuha *et al* (in prep) show that pastoral areas support almost as many birds as natural habitats, but for species of conservation concern, cultivated land is relatively poor.

These, together with a number of other studies, have shown that the rate of overall biodiversity loss in Uganda has reached about 10% per decade (Arinaitwe *et* al. 2000, Pomeroy & Mwima 2002). Rates of loss are particularly high in savanna areas, where they have reached more than 20% per decade, particularly because of the loss of large mammals; and in agroecosystems, where the limited data suggest a rate of about 50% (Pomeroy & Mwima 2002).

The major objective of this component of the LUCID programme in Uganda was to make some preliminary observations on changes in the flora and fauna, and to relate them to information on land cover-use, and soils, and also to people's perceptions of environmental change. However, to keep the study within manageable limits, all sites were in savanna areas of south-western Uganda.
Detailed findings on land cover-use, soils, and people's perceptions are given elsewhere – in the reports by Sam Mugisha, Joy Tukahirwa and Robinah Nanyuja, referred to as SR, JR and RR respectively. Current data on plants, represented by flowering plants, were reported on by Mary Namaganda (MR). Birds acted as surrogates for animals and were studied in detail by Nathan Chelimo (NR) with additional data by DEP.

Ideally, the effects of change require long-term studies. This was possible for land cover-use and people's perceptions of the availability of medicinal plants and some wildlife. In addition, some bird data drew on previous studies. For soils, plants and most bird data, the effects of change are deduced from comparisons of pairs of sites which are believed to be similar in respect of topography and original ('natural') vegetation, but one of which is now cultivated whilst the other serves as a control.

The main study areas in south-western Uganda were in the Sango Bay Area of Rakai District, in and around Lake Mburo National Park (Mbarara District) and at Rubaale near the border of Ntungamo and Kabale Districts. We refer to these here as SBA, LMNP and Rubaale, respectively. Additional areas

referred to in this article were at Kiwumulo in Mubende District and at three sites in the Queen Elizabeth National Park (Kasese District). All of these sites have in common that the original natural vegetation was savanna, although ranging from open grasslands of various types to quite dense woodlands (Table 1).

C. METHODS

One village was chosen as representative of each study area. These were Minziro in the SBA, Kiribwa near LMNP and Rubaale itself. Information was obtained directly from the villagers through focussed group discussions, interviews with key informants and structured questionnaires. People were asked about the environment as they see it today, as well as how it was 10, 20, 30 …. years ago, as far back as they thought that they could remember.

Data on soils, plants and birds were obtained from sites in the vicinity of these villages. In the case of the LMNP and SB areas, both grassland and woodland sites were included, but although there are grasslands near Rubaale, there are no woodlands. Apart from LMNP itself, woodlands and grasslands are extensively grazed by domestic livestock; we refer to them collectively as pastoral areas. Typical cultivated gardens were sampled in each of the three areas: bananas, cassava and beans being major crops in all of them. Within each of these areas, a series of sampling sites was selected to represent the principal land use types. These comprised – about 60 sites for soils (most with both top- and sub-soil data), 95 plant quadrats (MR) and 17 sites for birds (Timed Species Counts or TSCs: NR) (Table 1). Plant and soil data were collected from all of the main plant communities in each study area. In the LMNP area, data from within the park are only for birds. However, since a plant list for the park already exists (MUIENR 2002). Sampling sites for birds need to be large, preferably about 1 km^2 and hence are simply described as 'grasslands', for example, which might embrace two or more grassland plant communities.

Plant data are analysed in a separate report (MR); here, some further analyses are made, comparing their distributions to those of birds.

The bird data derived from the TSCs allow sites to be compared with respect to a number of variables, thus –

1. **Species diversity** (as reflected by the numbers of species, usually called species richness). It is commonly assumed that more species equals more biodiversity; however, one could argue that a site with a few rare species would be of more conservation value than one with many species, all of which are common. Total bird species richness at all sites was estimated by a simple Jack-knife method (Jack 1, Krebs 1989).
2. **Species of conservation concern.** For birds in East Africa, these fall into two categories, namely those of Regional Concern (Bennun and Njoroge, 1996) and those of Global Concern (BirdLife International, 2000). Collectively, these are sometimes called 'Red Data species', from the classic Red Data Books of IUCN.
3. **Specialists.** Various studies in Uganda have defined species that are specialised forest or water birds (Wilson 1995); more recently, grassland specialists have been recognised as well (MUIENR, unpublished). By their nature, specialists are most at risk from environmental change. Birds dependent upon trees were classified by Bennun *et al* (1996) as forest specialists (designated FF), forest generalists (F) and those other birds which are only found in well-wooded areas or forest edges (f-species).

Data from the 1980s at four additional bird sites were compared to these from 2001-02, the period of the main field studies reported here. These additional sites included three in Queen Elizabeth National Park (Table 1), which were grasslands with thickets and are considered as controls, since they have been within the National Park throughout, with negligible human impact. (However, two of the sites were sampled by a different method in the 1980s, limiting the comparisons which can be made). The fourth 'old' site, a woodland at Kiwumulo, is nominally a Forest Reserve but in fact is extensively

Table 1. Principal features of the study areas, and sampling efforts by land use type. Twelve TSCs (see text) were conducted at each bird sampling site, totalling 204.

Study area	Approximate values for - Altitude (m)	Annual rainfall (mm)[a]	Natural vegetation[b]	Number of plant quadrats and bird sampling sites by current land use: Protected Area		Pastoral		Cultivated	
				Plants	Birds	Plants	Birds	Plants	Birds
Sango Bay Area (SBA)	1160	1200	Grass savannas	0	0	17	3	12	2
Lake Mburo National Park (LMNP) and surroundings	1250	850	Dry *Acacia* savanna	0[d]	3	24	2	6	1
Rubaale	1500	900	Grass savannas	0	0	20	3	16	3
Queen Elizabeth[c] National Park (QENP)	920	800	Grass savannas	0	3	0	0	0	0
Kiwumulo[c]	1280	1100	Moist *Acacia* savanna	0	0	0	1	0	0

Notes a Atlas of Uganda (1967)
b From Langdale-Brown *et al* (1964)
c Sites included for having previous data
d Data from the vegetation study of MUIENR (2002) are used

used by pastoralists and, increasingly, has small plots of cultivation. There are also data from the early 1990s for one of the sites in LMNP, Rwonyo North.

Further details of the methods of study for each of these aspects are given in the appropriate reports.

Comparisons in the SBA between agricultural and pastoral areas only allow general comments as the cultivated areas were on low hills whilst the pastoral sites were low-lying, and seasonally flooded from the Kagera River.

D. RESULTS

D.1. Land Cover/Use

Changes in land cover/use between 1955 and 2000 were considerable in the areas surrounding those in which our studies were made (SR). However, the actual places within these areas from which field data were collected were much smaller (SR, Appendix Figures 1 (c), 2(c) and 3 (b)). Within these field study areas, the changes were small. Grazing and cultivation may be different in type or greater in intensity, but the areas being cultivated in 2000 were essentially the same as in 1955.

D.2. People's Perceptions

People in all three areas expressed concern about a wide range of environmental issues, with poverty being considered the major contributory factor, together (in Rubaale and Kiribwa) with land shortage (JR, RR). More than 80% of the people in each area cited signs of degradation as an environmental problem. Surprisingly though, soil factors were rated quite low as environmental problems: 5th in the SBA and 9th at LMNP and Rubaale. Soil erosion and declining crop yields were stated by many to be indicators of lower soil fertility (RR), but people were also troubled by pests and diseases of both livestock and crops, and these were sometimes considered more serious than soil factors.

D.2.a. Soil Degradation

Actual soil data show that, in all three areas, the organic content of topsoils was highest in woodlands and lowest, or nearly so, in cultivated areas (Table 2), as one would expect, since it reflects their respective amounts of vegetation and intensity of use. Further, cultivation itself reduces soil fertility (JR). Woodlands also have much higher levels of phosphorus than grasslands - but there were sometimes even higher levels in the cultivated areas. At the same time, as suggested by the high SD values, soil phosphorus contents varied greatly between nearby cultivated fields (values from the seven Rubaale samples, for example, ranged from 2.1 to 117.5 mg kg^{-1}). A likely explanation is that some farmers apply ash or fertiliser, whilst others do not (JR suggests 'deposition from external sources' (page 9)).

The 'bare hills of Mbarara' – including those of our Lake Mburo sites – are widely believed to have resulted from many years of over-grazing on soils that were already poor to start with. The same is probably true at Rubaale, and grasslands at both sites have only small amounts of both organic matter and phosphorus. At the Sango Bay and Lake Mburo sites these values were far lower than in the adjacent woodlands, which are typically valley-floor habitats.

Interestingly, people in the LMNP area agreed with general ecological thinking that unpalatable species of pasture plants, and the invasion of alien weeds, resulted from soil degradation which in turn was due to over-grazing (RR). They failed to mention the effects of fire, however.

Between 1955 and 2000, the reported levels of cultivation increased considerably in the areas to the north of LMNP, but much less so in the SBA and at Rubaale, which were already densely-settled in the 1990s (SR). It is likely, however, that agriculture has intensified in these areas with the proportion of land need for small-scale agriculture increasing by about 3.5% between 1955 and the 1990s (SR). In the LMNP area, the expansion of cultivation was almost entirely at the expense of savanna ecosystems.

Table 2. Values of two key soil variables from topsoils[a] in the three main study areas, arranged by main land use category. Phosphorus has long been considered a limiting factor to crop growth in many parts of Uganda (Langdale-Brown *et al*, 1964).

	Sango Bay area			Lake Mburo NP area			Rubaale	
	Woodland	Grassland	Cultivation	Woodland	Grassland	Cultivation	Grassland	Cultivation
n[b]	4	10	10	11	8	8	5	7
Total organic matter (%) - mean	3.97	2.67	1.90	6.65	1.62	1.64	2.18	1.60
- SD	0.77	0.30	0.32	1.43	0.21	0.21	0.23	0.49
Phosphorus ($mg\ kg^{-1}$) - mean	27.6	10.0	163.1	52.7	7.4	11.5	11.1	33.7
- SD	20.9	5.0	27.3	27.8	1.8	11.4	7.3	44.8

Notes a: there are also data (but less complete) for subsoils (JR).
b: *n* is the number of samples, and *SD* is the standard deviation of the mean

It is possible to compare aspects of soil fertility in pastoral sites with that of nearby cultivated areas, in both the Lake Mburo and Rubaale areas. Soil organic content, available calcium, magnesium and potassium all had higher values in pastoral than the nearby cultivated sites (JR). It is likely that they will have been similar within LMNP (for which there are no data) as in nearby pastoral areas although grazing pressure is generally lower in the park. Few cultivators use fertilisers, whereas the livestock on pastoral lands fertilise them naturally. Further, although some livestock owners admit to over-stocking (RR), soil erosion was less serious on grazed land than on comparable slopes that were cultivated. People reported that fertility was not affected by the position of their land on the slope, nor did it vary greatly with soil type, although black soils were said to be more fertile than those which are brown or grey (JR). Despite these observations, Bolwing (2002) cautions that there is 'scientific uncertainty regarding soil erosion and soil fertility … [in the Kigezi highlands]' so that 'we should be cautious when drawing conclusions about land use ….' (p. 18).

Aware of declining soil fertility and increasing soil erosion, people undertake various compensatory measures (JR). Those at Rubaale, where plots are small (averaging only a hectare) made greater efforts than in the SBA and outside LMNP, where family plots were typically twice as extensive. Curiously though, better educated people made no greater effort than the less educated..

D.2.b. Biodiversity values

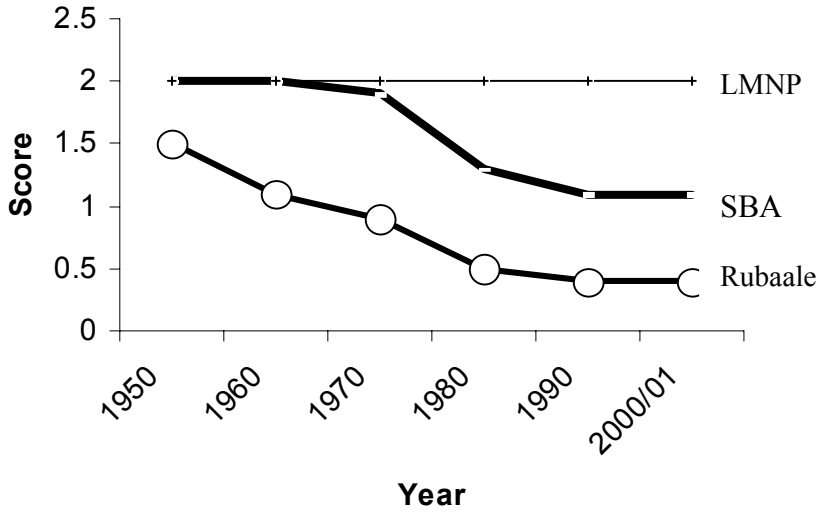
Turning to the biodiversity of these areas, some interesting results, spanning the past 50 years or so, come from interviewing long-term residents. Thus medicinal plants were perceived to have declined in all areas, but least in the SBA (RR). Some species disappeared completely from the Rubaale area, whilst in both the SB and Rubaale areas, several of the ***wild food plants*** considered important by people, together with honey, had also declined, but much less so in the SBA (RR).

Six species of ***wildlife***, all large mammals, were included in discussions with local people (Table 3). Whilst their abundance is perceived as not having changed in the LMNP area over the past 50 years, the majority of them have disappeared from the Rubaale area (Figure 1: RR).

Table 3. Species of large mammal included in the assessment of changes as perceived by local people.

	SBA	LMNP	Rubaale
Leopard	✓	✓	✓
Vervet Monkey	✓	✓	✓
Elephant	✓	-	-
Buffalo	✓	✓	✓
Bushpig	-	✓	
Sitatunga	✓	-	-

Figure 1. Trends in the relative abundance of the wildlife species indicated in Table 3. A score of 2.0 indicates that a species is common, 0.0 that it was not found in the area at the time in question. Data for each area are averages for all species (RR).)



D.3. Results of Transect Survey

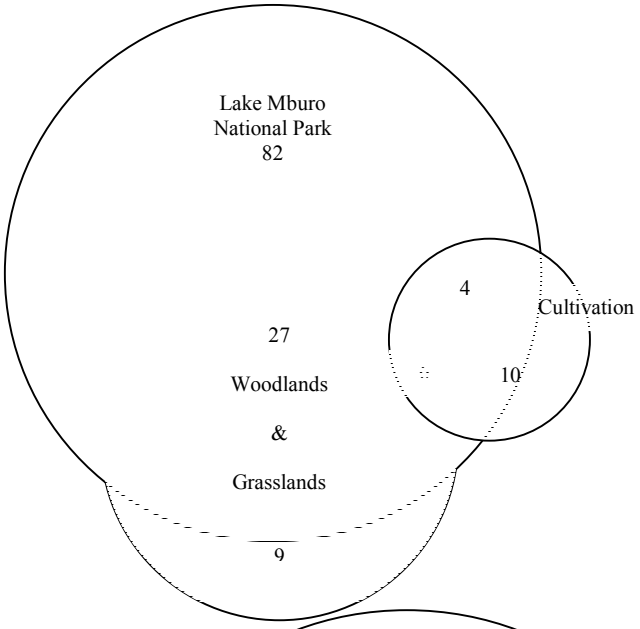
D.3.a. Flowering Plants

Combining data from all sites, including LMNP itself, some 408 species were recorded, about 8% of Uganda's total (Appendix 1). We have taken LMNP, with its detailed list of plants (comprising 322 species) and birds (about 350 species), as a basis for various analyses of the data. Although Lake Mburo is the driest of the three study area (Table 1), it has a wide range of habitats including seasonally-flooded valleys and rocky hillsides, as well as small riverine and gully forests. Thus it is reasonable to suppose that its various savannas would support most of the plants originally native to the whole area. To a large extent, this proved to be the case. Excluding cultivated plant species, and those weeds not native to the area, all but about 50 of the 240 species recorded in the plant survey were on the LMNP list (Figure 2).

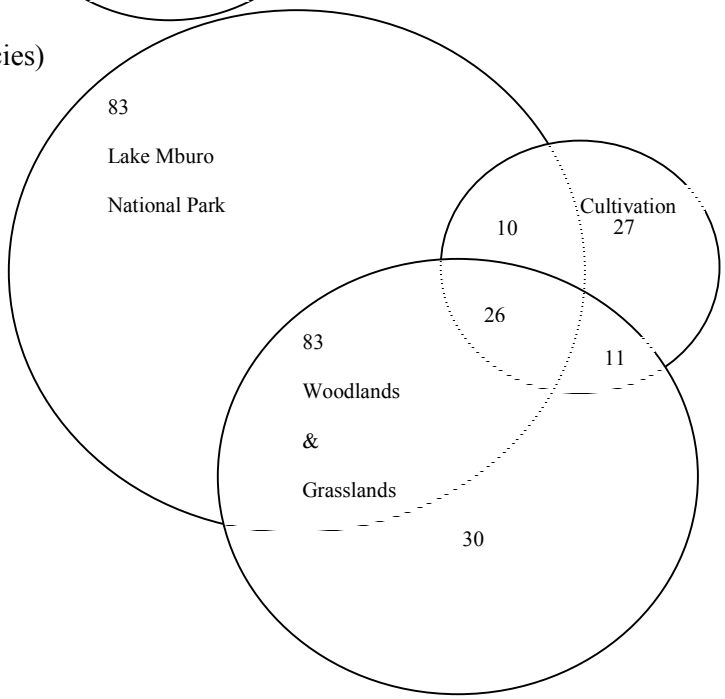
The natural savannas in southern Uganda support a large number of woody plant species – trees and shrubs. There are about 120 on the LMNP list, and a few more were found in our survey (Figure 2). More than 200 herbaceous plants have been recorded from the park, but here the proportion of additional species from outside is higher (Figure 2): whereas for woody plants only 31% of the LMNP list were shared with other habitats, for herbaceous species this was nearly double (59%). Put the other way around; if we again exclude cultivated and weed species, 92% of all the woody species in Appendix 1, and 82% of the herbaceous species have been recorded from within LMNP. It is likely that woody species are more readily exterminated outside the park, and hence the importance of the park in conserving than is evident. Further, as will be seen, the numbers of bird species also increase with the canopy cover of trees

Figure 2. Venn diagrams of the numbers for the numbers of (A) woody and (B) herbaceous plant species recorded in the two woodland, three grassland and three cultivated areas surveyed during this study, in relation to numbers in Lake Mburo National Park. Eight of the ten woody species found only in the cultivations were crop species, e.g. coffee, avocado; and all but four of the herbaceous species confined to cultivations are crops (such as beans) or weeds (such as *Oxalis*). Data are from Appendix 1.

A: Woody plants (138 species)



B: Herbaceous plants (270 species)



To see the effects of changing land use on biodiversity we can use both LMNP itself and the grasslands and woodlands as controls; collectively, we term the last two *pastoral areas*. All of these habitats have been affected by man, although less so in the National Park than elsewhere. But even the park has sometimes had large herds of cattle in recent years, particularly the 1980s and early 1990s. Our grassland and woodland areas are all grazed by domestic animals, but none has improved pastures and almost all the plants and all of the bird species are native to the area. All the savannas, including those within the park, are subject to frequent burning, which itself affects – even determines – the vegetation.

Changing land use through cultivation has a profound effect on the occurrence of flowering plants (MR; Table 4). Cultivations can support quite large numbers of plant species: for example, of 115 species recorded at the LMNP sites, 28 also occurred in the cultivated areas, which included banana plantations, areas of cassava, and fallow land (MR). But only 15 of these can be considered as native to the area, in the sense that they also occurred in the nearby natural vegetation. Of those 15, only four were woody species, all shrubs. Results from the LMNP and Rubaale areas were similar (Table 4). One of the woody species at LMNP that was found in both natural and cultivated areas was *Solanum incanum*! As would be expected, the majority of plants in cultivated areas are either planted by people, usually for food, or they are weeds. In either case their contribution to the conservation of biodiversity is negligible, since almost all of these species are widespread in tropical Africa and sometimes throughout the tropics.

Table 4. Numbers of plant species in major vegetation categories. For cultivated areas this table includes only those species which also occurred in at least one area of semi-natural vegetation. The figures are not additive, since any species can occur in more than one area.

Study area	Total species[a]	Broad vegetation type	Numbers of species in pastoral areas (i.e., semi-natural vegetation)[b]		- of which, species also found in cultivated areas	
			Woody	Herbs	Woody	Herbs
Sango Bay	104	Grassland	0 (0)	33 (16)	3	16
		Woodland	17 (11)	21 (7)		
Lake Mburo National Park	115	Grassland	2 (0)	38 (5)	4	24
		Woodland	26 (20)	59 (13)		
Rubaale	105	Grassland	1 (0)	64 (20)	1	13

a as recorded in this study, for all vegetation types including cultivation

b total numbers (unique species): *unique* here meaning species found in only one of the five vegetation categories (rows) of this table.

Considering the pastoral sites of the three study areas together, a large proportion of the native species are also found in Lake Mburo National Park (see Figure 2). The proportions of native species reported in this study and which are also known from a detailed survey of LMNP are 91, 87 and 88% for the LMNP area, SBA and Rubaale respectively (Appendix 1). Unsurprisingly, a fairly high proportion of the cultivated plants from the various areas are absent from LMNP. However, many of the species of cultivation are the same in all three areas (Appendix 1), confirming their tendency to be widespread.

D.3.b. Birds

The principal results for birds (NR) are summarised in Tables 5 and 6 together with comparable plant data. Both tables are based upon the 17 study sites in the three main areas. The sites are listed in the heading to Appendix 1: detailed descriptions appear in NR.

We can use the data in Table 5 to compare cultivated and non-cultivated areas. Mean numbers of species of both plants and birds are higher in pastoral than cultivated areas, and within pastoral area they are higher in woodlands than in grasslands. Bird species richness in pastoral areas as a whole (mean values 73 (93)) are higher than for LMNP. Well-wooded sites hold more species than do open grasslands. For example, the estimated species richness of the three pastoral sites in the SBA (S3, S1, S2 in decreasing order of woody vegetation cover) is 112, 102 and 66 respectively. A similar trend is apparent for the natural sties in LMNP, and for overall means of wooded and grassland sites in the pastoral areas.

D.3.b.i. Specialists

This dependence on ***trees*** of many bird species is further examined in Table 6. The two sites with the most woody plant species – the woodlands in the SBA and LMNP areas – also had the largest numbers of birds dependent upon trees. Figure 3A confirms this trend. However, mean species numbers per count are not correlated (Figure 3B), perhaps because trees reduce visibility, so that in any one count, less species are recorded in well-wooded areas.

Table 7 shows the numbers of plant and bird species which were recorded from only one site (excluding LMNP itself). As one would expect, numbers of these 'unique' species were low in cultivated areas. But the plant sites outside LMNP contained many such species, particularly woody ones, although few unique birds (nor were there many within the park). For birds, the SBA had the greatest numbers of these species.

Grasslands are threatened habitats in East Africa, being increasingly ploughed and cultivated, whilst pastoral areas that are not managed and improved are often heavily over-grazed. MUIENR (unpublished) has developed a list of 71 bird species that are most typical of open grassland in Uganda. Not surprisingly, the open areas in this study had the highest numbers of grassland (G) specialists, with a mean of 7.7 species for the seven sites. The average numbers in the six cultivated sites (some of which include open areas, especially when fallow) were 5.8. The four woodland sites had records of only 4.8 G species, on average.

Long-distance *migrants* found in Uganda belong to one of two categories –

- Afrotropical, meaning that they move within this biogeographical region; some of them breed in Uganda; and
- Palearctic species, breeding mainly in northern Asia and Europe, and visiting Uganda during the northern winter.

Many other savanna species undertake more local movements – the Red-billed Quelea is a well-known example.

Table 5. The effects of land use-cover on the numbers of plant species recorded from quadrats in various sites: upper boxes labelled PC, PG, PW (Note b); and numbers of bird species at 17 sites (data from Appendices 1 and 2, respectively). The latter comprise species actually recorded (and estimated by Jack 1 – see text). Bird sites are prefixed S, L and R – see Appendix 1 for key. Where there is more than one site in a particular area, they are arranged in order of decreasing woody vegetation cover from left to right: e.g., S3 > S1 > S2 in terms of trees and shrubs**.**

	SANGO BAY AREA Woody veg[a] : Most → Least					LMNP AREA Most → Least			RUBAALE Most → Least			MEANS
CULTIVATIONS (including fallow)	PC[b] 47						PC 30		PC 53			PC 43
	S4 58 (68)	S5 44 (55)					L6 59 (70)		R2 53 (63)	R3 40 (50)	R6 49 (59)	B 51 (61)
PASTORAL (woodlands and grasslands			PW 36	PG 39		PW 89		PG 40	PG 71			PW 63 PG 50
			S3 82 (112)	S1 75 (102)	S2 51 (66)	L4 77 (94)		L2 60 (89)	R1 39 (46)	R4 49 (66)	R5 43 (54)	BW 80 (103) BG 54 (71)
NATURAL						P all[c] (322)						P (322)
						L5 70 (92)	L3 70 (89)	L1 43 (60)				B 61 (80)

NOTES a woody vegetation is the sum of the estimated % cover in height bonds 3-8 and >8 m
b PC, PG, PW = Plants of cultivation, grasslands, woodlands
c the LMNP list (MUIENR 2002)

Table 6. The effects of land use-cover on the numbers of plant species, as in Table 4 and numbers of those which are woody (trees and shrubs, in parentheses) compared to numbers of birds species associated with trees (FF, F and f-species, see text). Data from Appendix 2.

	SANGO BAY AREA Woody veg: Most → Least					LMNP AREA Most → Least			RUBAALE Most → Least			MEANS
CULTIVATIONS (including fallow)	PC 47 (9)						PC 30 (6)		PC 53 (8)			PC 43 (8)
	S4 29	S5 26					L6 20		R2 22	R3 17	R6 17	B 22
PASTORAL (woodlands and grasslands			PW 36 (16)	PG 39 (9)		PW 89 (25)		PG 40 (1)	PG 71 (0)			PW 63 (21) PG 50 (3)
			S3 49	S1 29	S2 14	L4 31		L2 25	R1 12	R4 11	R5 7	BW 40 BG 16
NATURAL						P all (NP list) (322)						P (322)
						L5 30	L3 28	L1 14				B 24

PC, PG, PW = Plants of cultivation, grasslands, woodlands

Figure 3(A). Total bird species richness (from Jack-knife estimates) increases with the amount of woody vegetation, as represented by % cover: values for the height bands 3-8 and >8 metres were summed (r = 0.724, P<0.01). (B) Mean species numbers per one-hour TSC is less dependent upon trees (r = 0.137, NS).

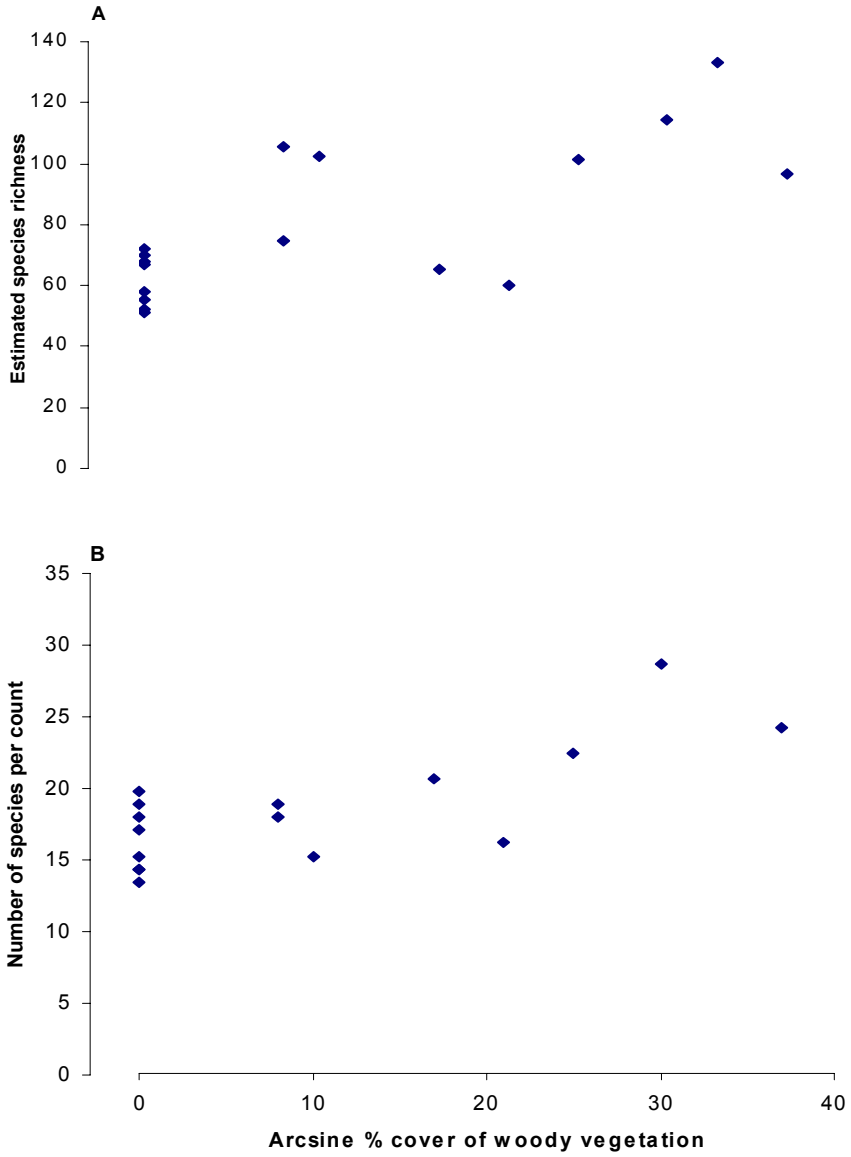


Table 7. Numbers of species of birds and plants recorded from only a single non-cultivated site outside LMNP; and the numbers recorded only from LMNP. For plants, figures in parentheses are woody species.

SANGO BAY AREA Woody veg : Most → Least						LMNP AREA Most → Least			RUBAALE Most → Least			MEANS
CULTIVATIONS (including fallow)	PC 7 (2)						PC 2 (1)		PC 4 (0)			PC 4.3 (1.0)
	S4 3	S5 2					L6 0		R2 0	R3 0	R6 1	B 1.0
PASTORAL (woodlands and grasslands			PW 16 (11)	PG 17 (0)		PW 34 (20)		PG 6 (0)	PG 22 (0)			PW 25 (16) PG 15 (0)
			S3 11	S1 7	S2 6	L4 1		L2 2	R1 0	R4 1	R5 0	BW 6.0 BG 2.7
NATURAL						P all (NP list) N/A						P N/A
						L5 2	L3 2	L1 3				B 2.7

PC, PG, PW = Plants of cultivation, grasslands, woodlands: similarly B for birds
N/A = Not applicable

On average, 6-7 migrant species were recorded from each site, with Afrotropical species outnumbering the Palearctics (Table 8). Woodlands supported the most migrants, especially within Lake Mburo National Park, where the average was 9.3 species per site. The lowest numbers, averaging 3.5 per site, were in the cultivated areas.

Table 8. Mean numbers of migrant species per site, as recorded from each of the main habitat types. Data are from Appendix 2, and have been combined for all three areas. The number of sites per category = n.

	n	Afrotropical	Palearctic
Woodlands – within LMNP	3	6.3	3.0
– unprotected	2	5.7	2.0
Grasslands	6	3.2	2.8
Cultivated areas	6	2.0	1.5

Six species from the regional *Red Data List* (Bennun & Njoroge 1996) were reported. The Harrier Hawk and Weyns' Weaver are considered to be regionally Vulnerable, whilst there are four species of Regional Responsibility. The two R-VU species occurred at only two and one sites respectively, but three of the R-RR species – Bare-faced Go-away-bird, Spotted-flanked Barbet and Black-lored Babbler – were found at five or more sites. The only one of these species to be found in a cultivated area was the Black-lored Babbler, and that was at only one site.

D.3.b.ii. Change in biodiversity with time

Table 9 summarises data collected from various areas over periods of from 8 to 18 years previous to the present study. Earlier data from two of the QENP sites (Mweya and Channel Track) came from transect counts (TCs) and are not directly comparable to the TSC data from all later dates. However, many of the same species were present in the TCs of the 1980s as in 2001-02 (Figure 4), and the two data sets show a significant value for the coefficient of correlation ($r = 0.326$, $n = 104$, $P<0.001$). The numbers of species recorded in transects are considerably fewer than from TSCs (a key reason for preferring the latter in this type of study). Thus there are far more cases in Figure 4 of TC = 0.0 (52) compared to TSC = 0.0 (16), from the combined list of 104 species. This is largely because transects cover only a small area (1.0 ha in this case) whereas birds seen or heard at any distance are included in TSCs, provided that they have been positively identified and are within the habitat being studied. Raptors, for example, are rarely recorded in TCs.

The smaller numbers of species recorded in TCs in QENP tends to mask the fact that there is, apparently, a high *turnover rate* (Table 10). Whilst many more species were noted in TSCs that TCs (75 compared to 52 on the Mweya peninsular, for example), a good number of those recorded in the earlier TCs (19) were not found in the TSCs some 15 years later. Some of these were probably present but undetected in the small number of counts made. Thus, of the 16 Channel track species recorded in TCs but not the TSCs of 2001-02, ten were recorded in other nearby sites at the later date. The difference between numbers of species observed and predicted ($\hat{S}$) is likely to be a reflection of the fact that many savanna birds are wanderers, occurring with varying frequency and at different times, but not resident in the area.

Table 9. Changes in bird biodiversity with time. Forest-related species are as detailed in Bennun *et al* (1996): the F and FF categories contain species which are forest-dependent to a lesser or greater extent; f-species also require trees but usually outside forests. Red Data (RD) species are as listed by Bennun & Njoroge (1996).

		Years of previous counts	Number of counts		Estimates of species richness				Numbers of forest-related species				Number of grassland specialists		Numbers of RD-species			
					Total		Mean per count		F/FF		f		G		GLOBAL		REGIONAL	
			Previous	01-02	Previous	01-02	Previous (SE)	01-02 (SE)	Previous	01-02	Previous	01-02	Previous	01-02	Previous	01-02	Previous	01-02
Woodlands	PA LMNP - Rwonyo	1991-96	12	12	122	110	26.8	31.9	8	5	27	25	10	3	1	0	8	3
	Kiwumulo	1988-93	15	7	168	132	39.8 (5.7)	39.1 (3.0)	23	17	51	40	11	5	0	0	3	3
	SBA woodlands[a]	1994	36	31	128	113	31.5	27.1	17.8	14.8	31.3	28.0	7	5	0.0	0.0	4.5	4.8
Grasslands	PA QENP - Mweya	1984-87	19	8	(78)	119	-		(1)	0	(16)	22	11	12	0	0	4	5
	PA Channel Track	1984-87	19	7	(76)	134	-		(0)	3	(15)	24	13	15	0	1	2	8
	PA Kamulikwezi	1989-95	12	6	110	85	23.2 (4.0)	25.5 (2.7)	1	2	28	14	11	12	0	0	5	9
	SBA grasslands[b]	1994	17	17	63	78	17.4	21.8	1.7	1.0	7.3	11.7	10	12	0.0	1.3	3.0	6.0
	Mean: PA	-	Σ = 62	Σ = 88	116	98	25.0	28.7	4.5	3.5	29.9	19.5	11.3	10.5	0.0	0.3	4.8	6.2
	Mean: non-PA	-	Σ = 67	Σ = 55	120	108	29.6	29.3	14.2	10.9	29.9	26.6	9.8	8.5	0.0	0.4	3.5	4.6

[a] AC, KS, MI, BA [b] ML, PS, NG – all are means of means, hence no SE [c] PA = Protected Area
[d] see text: previous counts were TCs and are excluded from means for species richness and forest-related species

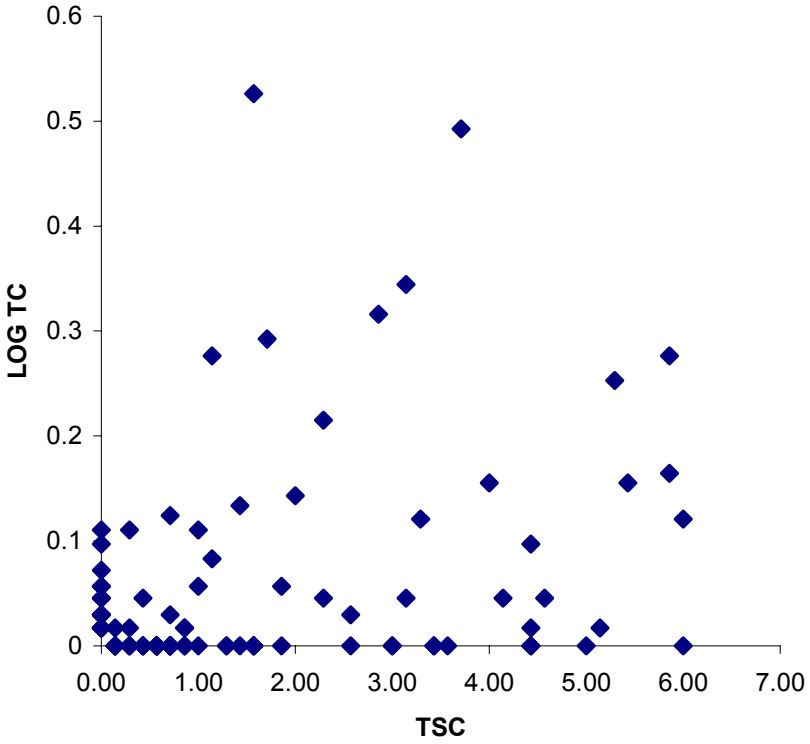


Figure 4. Transect Count (TC) data compared to Timed Species Count (TSC) data for the Channel Track site in QENP. Each point represents one species. Because of their highly-skewed distributions, TC data are shown as log (x + 1) values.

Table 10. An indication of species turnover between 1984/87 (TCs) and 2001/02 (TSCs) at two sites in Queen Elizabeth National Park.

	Species recorded -				
	- only in TCs	- only in TSCs	- in both	Total species recorded	Ŝ*
Mweya peninsular	19	33	42	94	119
Channel track	16	52	36	104	134

** see Table 7; the Channel track area has more tree species, as well as more birds, than the Mweya peninsular.*

The more detailed data for Kiwumulo and Kamulikwezi allow us to examine turnover rates in more detail (Table 11). These show that over a period of some 10-12 years, a relatively high rate of about 46% of the species at Kiwumulo and 47% of those at Kamulikwezi had changed. There was also a net loss of species: the number found only in the more recent period was rather less than in the earlier one, and estimates of total species richness declined too (Table 7), although mean numbers per count changed little and the relative abundance of birds as a whole actually increased. The net losses of species in both sites involved mainly the f-species (forest visitors) and 'others', which are predominantly generalist savanna birds such as the Village (or Black-headed) Weaver (which, of course, was not itself one of the species lost). The numbers of grassland specialists, of which there were nearly 20 species at Kamulikwezi in QENP, remained about the same.

The net loss of forest-related species is a cause of some concern; it amounted to ten species in Kiwumulo, and 13 at Kamulikwezi. The latter, although within the park, adjoins an area outside where almost all trees have gone; and Kiwumulo is in an area of active charcoal-burning.

At the same time, total bird species, assessed both by a Jack-knife estimate ($\hat{S}$) and its surrogate, mean species per one-hour count (Pomeroy & Dranzoa, 1997), declined in five of the six woodland estimates, but increased in three of the four grassland estimates. In fact at woodland sites numbers of both forest-related and grassland species declined, whereas in the grasslands, the grassland species increased whilst the trend in forest-related bird numbers (of which there were few) is not clear.

Numbers of *Red Data species* in Table 11 were few, and some of those were vagrants. However, there were big increases in both PA and non-PA sites between the two periods. It's nice to have some good news! Interestingly, of the seven variables in Table 11, three showed increases in the PAs but only two in the non-PAs. However, little can be deduced from this since, apart from the fact that the data are preliminary, they also show high variability. Repeats at, for example, 5-year intervals night reveal more significant trends.

Table 11. Species turnover in two savanna sites. Increases (gains) and decreases (losses) in numbers of species and their relative abundance are shown for the various specialist classes over a 10-12 year period. Although there was a net loss of species, there were gains in abundance in most categories.

	GAINS				NO CHANGE				LOSSES				
	F/FF	f	G	Others	F/FF	f	G	Others	F/FF	f	G	Others	Σ
KIWUMULO													
Nos of species[a]	4 (2.6)	3 (2.0)	2 (1.3)	8 (5.2)	0	38 (24.8)	3 (2.0)	41 (26.8)	3 (2.0)	14 (9.2)	8 (5.2)	29 (19.0)	153
Change in abund[b]	1 (1.2)	16 (19.5)	1 (1.2)	26 (31.7)	0	0	0	0	1 (1.2)	20 (24.4)	2 (2.4)	15 (18.3)	82
KAMULIKWEZI													
Nos of species[a]	1 (0.9)	1(0.9)	4 (3.7)	10 (9.3)	1 (0.9)	13 (12.1)	14 (13.1)	19 (17.8)	0	15 (14.0)	4 (3.7)	25 (23.4)	107
Change in abund[b]	1 (1.9)	8 (15.4)	8 (15.4)	14 (26.9)	0	1 (1.9)	1 (1.9)	1 (1.9)	0	4 (7.7)	5	10 (19.2)	47

NOTES a figures in parentheses are % of total
b estimates of relative abundance (TSC scores) of those which were present in both sets – the 'no change' group

D.6. Discussion

The limited evidence that we have suggests that biodiversity values of unimproved pastoral areas compare well with those in Protected Areas, although numbers of both woody plants and large mammal species are reduced, most of the latter to the point of extinction. However, cultivation produces catastrophic results for native plants. This of course is expected: any farmer will want the plants on his land to be crops, not weeds, and almost all crop species are exotic. Numbers of species alone are a poor guide to biodiversity values: traditional farming with mixed crops, or fallow land and areas that are simply neglected, can be quite diverse. Consequently farms can have fairly large numbers of species, but many of the non-crop plants are also exotic and the remainder are usually common, invasive species of little conservation significance.

Unlike plants, almost all birds in cultivated areas are native species but, as with plants, the common and widespread species predominate. Bird numbers may remain relatively high in areas of small-scale farming, as also noted by Wilson *et al* (1997) in Ethiopia, although as Table 5 shows, they were less than at other sites. Further, species of conservation concern (such as those listed as FF, F or f, all depending in some way upon trees) decline, usually steeply. As we have shown, and as Naidoo (in press) also found in and around Mabira Forest to the east of Kampala, bird species numbers are strongly correlated with woody canopy cover, trees being particularly important. But forest-related species seem to be declining in pastoral areas too, as found both here and in another study from the Sango Bay Area (Pomeroy 2001).

Red Data bird species, some of which occur outside as well as within PAs, are rarely found in cultivated landscapes and even when they do occur their numbers are usually low (Appendix 2). Changing land-use affects all taxa, and probably in similar ways all over the tropics (see, for example, moths in south-east Asia (Holloway 1989)). These changes in biodiversity are not directly caused by changes in soils, but they occur in parallel. People are well aware of these changes and especially of losses that occur in those parts of the biodiversity of most immediate concern to them – medicinal plants, for example. There is, however, little evidence of people's concerns leading to any very useful action: for example, they rarely attempt to grow species of medicinal plants near their homes. An important exception to this generalisation is the creation of woodlots, mainly of species of *Eucalyptus* and particularly in the south-west, such as the Rubaale area.

Plant conservation in these areas can be served quite well by LMNP, at least in the short term, provided that it continues to be well-managed. In particular, almost all of the woody species recorded in this study are also found within the park. However, the grasslands of the SBA and around Rubaale contain a wide variety of herbaceous plants, some of which are fairly local (Table 7) and these are less well represented in LMNP (Figure 2). Any suggestions for reserves in these areas should be encouraged.

The situation for birds is less clear. Less than half of the 280 or so non-waterbird species known from LMNP were recorded in this study. The various measures of bird biodiversity suggest changes in 'control' areas over time are of a similar order to those in pastoral areas (Table 8). Using contemporary data to compare the major habitat types, both pastoral and PA sites support roughly half as many species again, in total, as cultivated areas (Table 5). Of the more specialised species, there are too few data to demonstrate that cultivated areas support few grassland birds (as would be expected). Woodlands, however, hold twice as many of the species associated with trees as grasslands (all of which have some scattered trees), whilst both pastoral and PA sites have roughly half as many again as cultivated areas (Table 8). The decline in species associated with trees, which in this study were mainly f-species (Table 8, 10) appear to be part of a wider trend for which, as yet, not adequate explanation exists.

Analyses in this article are largely based upon numbers of species. Considerable amounts of additional data exist on species abundance (MR, NR, DEP) and would repay further analyses.

E. LINKAGES: SOME PRELIMINARY CONCLUSIONS

The data presented in this article confirm a number of well-known facts, including:

1. Land degradation is widespread and closely linked to poverty, lack of fertilisers, soil erosion and over-grazing.
2. In the areas which we studied, most of the cultivable land was already in use in 1955: the proportion of land being used for subsistence farming has increased by less than 5% in half a century.
3. There is a strong link between the conversion of land to cultivation and biodiversity loss. Although many species of plants and birds occur in cultivated areas, they are fewer than in pastoral and natural habitats, and most are of low conservation concern. For birds at least, cultivations with agroforestry have a higher species richness than those without, but this is only of significance if the tree density exceeds about 200 ha^{-1} (Naidoo, in press), which is unusual in the cultivated areas of south-western Uganda. For any useful conservation purpose, the proportions of these trees which need to belong to native species is likely to be significant, although it has been little studied.
4. The arrangement of trees in the landscape is likely to be crucial too. Although (to our knowledge) this too has not been studied, we predict that much more natural biodiversity will be conserved by, for example, tree lines and hedges along streams and roads than where the trees and bushes are simply scattered.
5. Our data support, in considerably greater detail, the perceptions of local people concerning biodiversity loss - it occurs in both time and space, and is greatest in agroecosystems. Current practice of pasture use – essentially depending entirely upon grazing the unimproved landscape – serves to retain a high proportion of the native flora and fauna, with the conspicuous exception of large mammals. Again, there are clear links between land use and biodiversity.
6. Consequently, the need for well-managed PAs is obvious, since pastoralism will surely begin to change too and agroecosystems are only of low value for the conservation of Uganda's native biodiversity.

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