TREES, BIRDS AND AGRICULTURE

Biodiversity in **U**ganda's **F**arming **S**ystems in **R**elation to **A**gricultural **I**ntensification

A Preliminary Study

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A Contribution to the Strategic Criteria for Rural Investments in Productivity (SCRIP) Program of the USAID Uganda Mission

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Strategic Criteria for Rural Investments in Productivity (SCRIP) is a USAID-funded program in Uganda implemented by the International Food Policy Research Institute (IFPRI) in collaboration with Makerere University Faculty of Agriculture and Institute for Environment and Natural Resources. The key objective is to provide spatially-explicit strategic assessments of sustainable rural livelihood and land use options for Uganda, taking account of geographical and household factors such as asset endowments, human capacity, institutions, infrastructure, technology, markets & trade, and natural resources (ecosystem goods and services). It is the hope that this information will help improve the quality of policies and investment programs for the sustainable development of rural areas in Uganda. SCRIP builds in part on the IFPRI project *Policies for Improved Land Management in Uganda (1999-2002)*. SCRIP started in March 2001 and is scheduled to run until 2006.

The origin of SCRIP lies in a challenge that the USAID Uganda Mission set itself in designing a new strategic objective (SO) targeted at increasing rural incomes. The *Expanded Sustainable Economic Opportunities for Rural Sector Growth* strategic objective will be implemented over the period 2002-2007. This new SO is a combination of previously separate strategies and country programs on enhancing agricultural productivity, market and trade development, and improved environmental management.

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ABSTRACT

Traditional agricultural practices, however inefficient in some respects when compared to modern agriculture, were nevertheless adequate for the populations of central and western Uganda until quite recently. Nowadays, with rising expectations, greater productivity is expected. Consequently, agricultural landscapes are changing, gradually in some places but rapidly in others, through the conversion of natural vegetation into fields and pastures, rendering the remaining natural habitats smaller, more fragmented, and less diverse, inevitably leading to the loss of biodiversity. Despite this we believe that the direction of biodiversity change can still be influenced by policies and public investment programs, for example through the provision of economic incentives and new knowledge that would encourage as well as enable specific land management practices. Yet better information is needed for such policies and programs to be effective. On this background this pilot study was carried out to improve the understanding of how agricultural intensification affects the abundance and species richness of woody vegetation and birds. Data were collected on land use, woody plants, and birds in 14 study sites situated within crop-based agricultural production systems in the western and central regions of Uganda.

A defining feature of the study is the use of data collection methods that have rarely been combined: survey of agricultural land use and land cover, survey of woody vegetation, and survey of birds. We adopted two methods for agricultural land cover/use survey: transect walks and boundary mapping. Transect walks, guided by the route followed by a bird surveyor were used to collect data in smallholder agroecosystems while boundary mapping was done in large-scale systems. Agricultural land use was characterized principally through different measures of cultivation intensity and secondarily through crop diversity and cropping patterns. Biodiversity was assessed by the occurrence of different bird and trees species. Data of all tree species were captured from 20m radius plots, placed 50m apart along the transect, while occurrence of the birds and their relative abundance were surveyed by Timed Species Counts (TSCs). Predictive modeling and regression analyses were used to examine the relationships between land use and biodiversity variables.

With due reservations given the preliminary nature and low number of study sites of the study, we found little evidence for a decline in birds, at least over the last 8 - 15 years, in the agroecosystems with highest biodiversity (less intensively cultivated smallholder farms). Yet

when comparing across study sites, we found strong evidence that species are progressively lost (with only a few gains) as agriculture is intensified. Losses are greatest amongst the more specialized species which are also those of greater conservation concern. Large-scale plantations had much lower levels of biodiversity than smallholder farms, but we were not able to measure changes in biodiversity over time for large-scale systems. The comparison of predicted (based on original natural vegetation) versus actually recorded bird species showed a significant negative effect of smallholder farming on birds, especially with regard to forest specialists species, and a much larger effect of large-scale agriculture. The effect was bigger for high intensity smallholder farms compared to farms with low cultivation intensity, except in the case of generalist species. Large, charismatic species such as the Long-crested Eagle, hornbills and parrots, were scarce or absent from high-intensity cultivations.

We we not able to examine the importance of different spatial patterns of woody vegetation, but we predict that higher degrees of patchiness – i.e. clumping – are likely to be beneficial. More trees, particularly native trees, support more birds and, in all probability, other biodiversity. A survey including a larger number of smallholder sites (at least 30) would be required to establish which land use characteristics (within the range presented by contemporary smallholder systems) are more favorable for birds and trees, and perhaps for other indicators of biodiversity richness. The present study provides a good model for designing such a larger study.

1. INTRODUCTION

1.1. Overview

Traditional agricultural practices, however inefficient in some respects when compared to modern agriculture, were nevertheless adequate for the populations of central and western Uganda until quite recently. Nowadays, with rising expectations, greater productivity is expected. Consequently, agricultural landscapes are changing, gradually in some places but rapidly in others, through the conversion of natural vegetation into fields and pastures, rendering the remaining natural habitats smaller, more fragmented, and less diverse, inevitably leading to the loss of biodiversity. With that background, this study asks what we can do to reduce this biodiversity loss in Uganda's agroecosystems while also ensuring an increasing supply of food to growing markets and local populations? Our rationale is that the direction of biodiversity change can still be influenced by policies and public investment programs, for example with incentives that would encourage specific land management practices such as agroforestry, riparian buffers and wildlife corridors, but that better information is needed for such policies and programs to be effective.

This pilot study was undertaken by the SCRIP programme of the International Food Policy Research Institute (IFPRI), together with Makerere Institute of Environment and Natural Resources (MUIENR). It provides information on patterns and trends in biodiversity (trees and other woody vegetation, and birds) as well as agricultural land use in a sample of smallholder and large-scale farming systems in the western and central regions of Uganda. From this, we assess how biodiversity is affected by agricultural intensification.

Given the preliminary nature of this research, we decided to base it largely upon nine smallholder farming areas for which data on birds have already been collected for a number of years. Five new sites, of contrasting land uses such as cotton fields and a tea plantation, were added for the purposes of this study.

1.2 Statement of the Problem

The basic premise of the research is that the surviving biodiversity in Uganda's agroecosystems (in this study biodiversity refers to woody plants and birds, unless otherwise stated) provides important economic, cultural and environmental benefits to society and that it therefore merits more attention. Conversion of natural ecosystems for agricultural production, followed by agricultural intensification, inevitably leads to the progressive loss of biodiversity. Agricultural intensification is here understood either as increased cropping frequency in small-scale systems characteristic of smallholders, with a corresponding reduction in the areas of fallow and of natural vegetation, or land use conversion to large-scale, monoculture characteristic of plantation agriculture.

The general effects of the conversion to agriculture of natural habitats in the tropics are well-understood (Donald 2004, Schalemann *et al*, in press). In broad terms, all large mammals and most specialist species of other groups (plants, birds, butterflies etc) disappear or at best survive in much reduced numbers. To some extent they are replaced by incoming, generalist species, such as feral cats and rats, weaverbirds and the kinds of butterflies that eat your cabbages. In his review of studies on tropical biodiversity related to coffee, rice, oil palm and soybean production, Donald (2004) found that production of all four commodities has greatly increased in recent years through area expansion and increased yields per unit area. As a rule, both types of land use change lead to loss of biodiversity, although conversion of natural habitats to low-intensity production may have less of an impact than intensification of the present low-intensity systems. Moreover, the impact of land use conversion on specialist species, i.e. those depending on a particular habitat type for survival, are usually much greater than on widespread generalists. This suggests a need to focus on specialists in research and conservation work. According to Donald (2004: 32), 'all 13 studies of bird populations [in shade coffee or cocoa] demonstrated decline in forest-specialist species' and habitat specialists of all taxa 'are clearly more susceptible to disturbance of natural habitats than generalists'.

Not only do agroecosystems have less biodiversity value than those that are natural or semi-natural (the latter being mainly pastoral), but they are losing biodiversity more quickly. Pomeroy and Mwima (2002) and Pomeroy and Tushabe (2004) have shown that whilst the annual rate of loss for Uganda as a whole is about 0.8%, it can reach nearly 2.5% in agroecosystems.

The oldest and most common strategy to combat these losses is to designate enough Protected Areas – such as national parks and forest reserves – to conserve at least some populations of as many species as possible. In Uganda, this has been the policy of governments since early colonial days and remains so today. Yet very significant amounts of wild (as opposed to domesticated) biodiversity is found outside Protected Areas on farms, pastureland, and even in urban areas. A striking example is that more than 200 different species of birds have been found at Makerere University (there are only about 800 in the whole of the US, which is about five million times larger!) (authors' observations).

A key hypothesis of our study is that agroecosystems vary significantly regarding the state of biodiversity found within them, and so in the bundle and value of biodiversity-derived ecosystem services provided (the benefits people derive from ecosystems). These differences are related to the intensity and spatial configuration of agricultural land use, which in turn are affected by factors such as natural resource conditions, farm sizes, population pressure and market demand, and current and past land use and management practices. Thus, while continued agricultural intensification will clearly lead to some destruction of biodiversity, our argument is that opportunities do exist for enhanced biodiversity conservation through better polices and targeted interventions in relatively biodiversity-rich agroecosystems (and through the restoration of natural flora and fauna in degraded systems, although this option is likely to be more costly).

According to Schalemann *et al* (in press), development policies have considerable potential to either ease or exacerbate the disproportionate impact of agriculture on areas of highest biodiversity value, such as much of Uganda. In this regard, the justification for doing this research is that the effectiveness of such policies and interventions in Uganda depends on better information on: a) the present state of biodiversity (and level of food production) in common types of agroecosystems of variable levels of intensification and biodiversity quality; b) long-term trends in biodiversity (and food production) in such systems; c) the factors determining spatial and temporal variations in biodiversity in agroecosystems.

In view of this, our overall research objectives were:

- To contribute to an improved understanding of how agricultural intensification affects the abundance and species richness of woody vegetation and birds (and associated ecosystem services), taking woody vegetation and birds as surrogates for biodiversity as a whole.
- To suggest 'best bet' policy and program interventions that may most effectively minimize the trade-offs between food production and biodiversity conservation in Uganda.

1.3 Agriculture-Biodiversity Linkages in Uganda

Birds and Trees in Uganda's Agroecosystems

Our study emphasizes the interaction between agricultural land use, woody vegetation, and birds, and especially how the first two affects the latter. Not all birds depend upon trees of course, but we chose these two taxa because they have been extensively surveyed in Uganda (see, for example, Tushabe *et al,* in press). They differ significantly in their life-forms and hence show only moderate levels of congruence (H Tushabe, in prep). The most specialized species of trees and birds are likely to be those most sensitive to change and hence the most critical indicators of the biodiversity impact of land use conversion.

<u>Trees and other woody plants</u>

Smallholder farms are typical of much of central and western Uganda. Trees are a conspicuous feature of many of these landscapes, creating a vegetation type which is intermediate between savanna and grassland. However, while tree savannas can occur naturally or as a result of edaphic features, they can also be derived from agricultural activities (Pullan, 1974). In agroecosystems, the woody vegetation is altered in composition and density in order to facilitate its use (Young, 1994). Plant cover and the diversity of woody plants are composed of both indigenous and exotic plants whose life forms include lianas, trees, shrubs and herbs.

Schroth *et al* (2004) describe various benefits to conservation in the tropics of landscapes with trees. The extent to which they apply to Uganda is not well-known, although there are some preliminary indications of the importance of trees to birds (Naidoo, 2004, Nalwanga, 2004, Pomeroy *et al,* 2003). Trees are an important feature of many agricultural landscapes in Uganda and they provide economic benefits such as fruits, medicines, fiber, timber, fuel wood, shade and wind-breaks for crops and livestock to local people, who often also assign them spiritual, recreational, and aesthetic values. Further, trees help to maintain life conditions through soil stabilization, nutrient cycling (from deeper soil layers), microclimate effects, carbon sequestration and habitat for birds and other species.

<u>Birds</u>

Uganda has a very rich bird fauna. Birds have aesthetic and cultural values and they provide (indirect) economic services through the pollination of crop plants, they eat insect pests (although birds can also be pests), and they attract tourists. In some parts of Uganda they are also eaten, but not often in the south. They also help to regulate ecosystem processes through seed dispersal, feeding, and pollination.

In Uganda, more than 180 species of birds are forest specialists (FF-species in Bennun *et al* 1996), being largely confined to forest and very rarely recorded from agricultural areas. There are another 130 forest generalist species (F-species) and 103 forest visitors (f-species). Many of the 233 F- and f-species also occur in woodlands and other landscapes where trees are plentiful. For example, about 25 F-species and 50 f-species have been recorded on Makerere hill, in Kampala (Pomeroy, 2002).

Linkages between agriculture and biodiversity

In Uganda, agricultural intensification may have a particularly high impact on national biodiversity resources. Relatively high human population densities and low agricultural productivity means that a very large share of the land area is already being utilized for crop or livestock production. This situation is accentuated by rapid population growth and increased market production, which induce farmers to clear new land for production and to intensify land use in existing agricultural areas. These processes inevitably degrade habitats for most types of natural flora and fauna through changes such as the reduction in space and food resources (e.g. wild fruits), loss of roosting and nesting places, and fragmentation of habitats restricting movement and seed dispersion. Conserving biodiversity in agricultural systems is therefore increasingly important for overall environmental conservation in the country.

Few studies have examined the specific effects on biodiversity of agricultural conversion in Uganda and most have had a small geographical coverage. They include Dranzoa (1990), who studied birds in small forests and compared them to nearby cultivations. Nalwanga (2004) compared birds and trees in agricultural landscapes near Kampala, whilst a small comparative study of birds in relation to land use and soils was made by Pomeroy *et al* (2003). The importance of tree plantations for birds was compared to that of natural forests by Pomeroy & Dranzoa (1998). An important study by Naidoo (2004) showed that forest interior (forest specialist in our terminology) birds are virtually absent from farmlands even within a few hundred meters of the forest edge, and that even best-practice agroforestry would change this very little. Yet conversion of natural habitats to agriculture can sometimes lead to an increase in species numbers, to which the so-called 'intermediate disturbance hypothesis' applies (Ricklefs & Miller, 1999; Mangnall & Crowe, 2003). But the extra species tend to be common generalists that are of little conservation concern (see, for example, Söderström *et al,* 2003). We cannot expect forest interior species to survive outside forests (whose own conservation is therefore of great importance), but there are many other categories of birds which use trees.

A few examples will serve to illustrate how and how much different species of birds depend on trees or crops, that is, the specific mechanisms linking birds with trees and agriculture. Birds such as the Red-eyed Dove and various raptors use trees mainly to roost and nest in, and for this the species of tree may not be important. The dove, and some raptors, feed on or near the ground, and so the number (and type) of crops might be important – indirectly for the raptors, whose prey are attracted (or not) by particular crops, and at particular stages of their growth cycles. Other birds, including many of the actual 'forest species' feed in the trees as well as nesting in them. They are more closely associated with native tree species. It may be appreciated that these interactions are often complex and species-dependent, implying a need for years of detailed study to reach a thorough understanding of them.

A Note on Ecosystem Goods and Services

Rapid biodiversity loss in Uganda and elsewhere is part of a general shift in the bundle of ecosystem services towards increasing supplies of food (and feed and fiber) at the expense of benefits derived from other services, such as the provision of nonfood goods (genetic resources, fresh water, fuel wood), regulation of ecosystem processes (climate, disease and flood control), cultural benefits, and life supporting services (soil formation, nutrient cycling, pollination) (Millennium Ecosystem Assessment 2002). How to minimize such trade-offs and at a reasonable cost is a key challenge for achieving sustainable development. From this perspective, this study examines the trade-offs between the provision of food (and fuel wood) through agricultural land use and ecosystem services derived from woody vegetation, especially as habitats for birds, through longitudinal analyses and comparisons of selected agroecosystems in Uganda. The study is limited in the sense that it does not quantify these trade-offs, e.g. by assigning monetary values to services, but considers only a few biophysical dimensions of agricultural land use.

One way of conceptualizing the trade-offs between the services supplied by a given ecosystem is by a production function, where "production" refers to all ecosystem services and not only farm products. The maximum total value of ecosystem services produced is given by the production frontier (total efficiency situation), which describes possible combinations of ecosystem services provided at given levels of natural resources (including genetic), capital, labor and technology. On a given point on the production frontier (a multidimensional 'surface'), an increase in the value of one service, say food, necessarily leads to the reduction in one or more services, say bird habitats, the value of which is given by the slope of the asymptote to the frontier curve at that point. Thus, depending on the initial bundle of services produced by the ecosystem (the shape of and initial position on the production frontier), more or less biodiversity must be sacrificed to produce one more unit of food. In this situation, minimizing trade-offs is by targeting systems where the biodiversity cost of increasing an extra unit of food is relatively small, i.e. systems that have a gently sloping production frontier. Policy interventions may also increase the level of capital or technology in a given system and so allow for the provision of more food (biodiversity) at less or no cost to the provision of biodiversity (food) – equal to an upward shift in the production frontier. Similarly, at constant technology, using existing production factors more efficiently will increase the provision of both food and biodiversity, if, as most often is the case, ecosystem provision is inefficient (within the production frontier). An example would be a consolidation of woody vegetation (e.g. woodlots) into more contiguous habitats, which would enhance wildlife conservation without reducing total crop area.

1.4. Study Design

We compare areas with different agricultural land use characteristics (particularly the intensity of cultivation) with respect to the occurrence of various categories of trees and birds, focusing especially on their degree of specialization to the forest habitat, which was the predominant original vegetation type in the study area. Habitat specialists are the most sensitive elements of biodiversity and so critical indicators of biodiversity change. By this approach we hope to gain insight into how agricultural intensity affects these forms of biodiversity and hence how these effects might be mitigated.

Selection of study sites

Data were collected on land use, woody plants, and birds in 14 study sites situated within crop-based agricultural production systems in Uganda (Table 1.1). Although few of the sites were selected for the purpose of this study (Section 1.1), they were nevertheless believed to exhibit sufficient variation in land use for us to examine the relationship between land use and biodiversity across agroecosystems. The key land use characteristics examined are the scale of production (small holding vs. large-scale), and cultivation intensity within the small holding type.

As eight of the nine smallholder sites belong to the national bird monitoring scheme, they can be used to examine trends in bird occurrence over periods of up to 15 years. The four large scale sites (mainly commercial plantations) and the pasture site were specifically added for the purpose of this study. Seven of the 14 sites are clustered around Kampala in Mpanga, Wakiso and Mukono districts. One smallholder site is situated near Lake Kyoga in Nakasongola District. The last cluster of six sites is situated in western Uganda in Mubende, Kabarole and Kasese districts.

The majority of sites are in areas which were formerly forest or moist savannas. Land at Katugo, Kanyawara and Kyegegwa has only been recently cleared – or is still being cleared – and some of their woody vegetation is remnants of the original habitat. These areas still practice shifting cultivation to some extent. The Ziika site is rather atypical, in that part of it is rocky grassland, and like Mukono and Mpanga it is within commuting distance of Kampala. Suburban-type houses with lawns are beginning to appear amidst the traditional bananas and other crops. The remaining small-scale sites are Bujagali, Kifu and Mubuku. Of the large-scale sites, the Lugazi tea and sugar estates each extend over several hundred hectares and have been established for several decades. Commercial horticulture is a new and rapidly-developing activity, mainly producing flowers for export. This activity is represented by the Nsimbe horticulture site, which is partly covered with hothouses, the remainder being open grassland with some trees. The cotton fields near Kasese are unusual in that an area of hundreds of hectares is almost entirely devoted to cotton, alternating seasonally with maize and beans, but is farmed by individuals who each own only a few hectares. Savannas in the south and west are increasingly being cleared to provide better grazing for livestock. In many cases, as with the Mubuku pasture site, some trees are left, partly to provide shade. Since most of the sites had been selected for reasons other than examining agriculture–biodiversity linkages, and neither randomly nor systematically, the project design does not meet standard statistical requirements for extrapolation.

Table 1. 1 Key features of the study sites

Scale of farming	Site name	District	Longitude [a] (Centre)	Latitude [a] (Centre)	Cultivation intensity [b]	Original natural vegetation [c]	Mean altitude[f]	Mean annual rainfall (mm) [d]	Approx. habitat extent (ha) [h]	Distance to nearest forest of >1 km² [g] (km)	Distance to nearest permanent swamp [g] (km)
Large scale	Lugazi Sugar	Mukono	32.93	0.36	1.00	Forest/Savanna Mosaic	1100	1400	>100	10	0
	Lugazi Tea	Mukono	32.89	0.37	1.00	Forest/Savanna Mosaic	1200	1400	>100	10	1
	Nsimbe Horticulture	Mpigi	32.41	0.27	1.00	Forest/Savanna Mosaic	1100	1300	50	5	0
	Kasese Cotton	Kasese	30.01	0.03	1.00	Grass Savanna	900	800	>100	15	3
Small scale [e]	Bujagali	Jinja	33.15	0.51	0.98	Forest	1200	1300	>100	3	10
	Mpanga	Mpigi	32.30	0.20	0.82	Forest/Savanna Mosaic	1100	1300	>100	0	2
	Kifu	Mukono	32.72	0.45	0.73	Medium Altitude Moist Evergreen Forest	1100	1300	>100	0	1
	Mubuku	Kasese	30.11	0.26	0.72	Dry *Acacia* Savanna	1100	1100	50	12	2
	Katugo	Nakasongola	32.46	1.17	0.63	Dry *Combretum* Savanna	1100	1100	50	>20	5
	Mukono	Mukono	32.77	0.41	0.61	Forest/Savanna Mosaic	1100	1300	>100	5	5
	Kanyawara	Kabarole	30.35	0.56	0.51	Medium Altitude Moist Evergreen Forest	1300	1400	>100	2	2
	Kyegegwa	Kyenjojo	31.00	0.50	0.26	Moist *Acacia* Savanna	1300	1000	>100	1	1
	Ziika	Wakiso	32.53	0.12	-	Post-cultivation Communities	1100	1400	20	>20	0
Pasture	Mubuku	Kasese	30.15	0.27	0.00	Dry *Acacia* Savanna	1100	1100	50	12	3

Notes:
a In decimal degrees. Source: the survey.
b See Section 3.1. Intensity was not determined for Ziika. Source: the survey.
c Source: Langdale-Brown *et al* (1964).
d Rainfall is bimodal at all sites. Source: Atlas of Uganda
e Small-scale sites are ordered in decreasing levels of agricultural land use intensity.
f Mean altitude computed from GPS readings taken during data collection for this study.
g Source: Lands and Survey maps 1:50,000.
h Source: the survey

Selection of Variables Describing Biodiversity and Land Use in Agroecosystems
Agricultural land use was characterized principally through different measures of cultivation intensity and secondarily through crop diversity and cropping patterns. Biodiversity was assessed by the occurrence of different bird and trees species. Here we summarize the variables selected to describe the three main components of the study; more detail is given in Chapter 2.

The agriculture-focused land use variables are: proportion of fallow, cultivated area, and natural (native) vegetation; fallow age; type of natural and fallow vegetation; cropping pattern (mono or mixed cropping); number of crops; dominant and secondary crops. The cultivation intensity, here defined as the share of cultivated land in total farmland (fallow plus cultivated), as well as the farming system types, were derived from these data. Other encountered land uses such as settlements or roads were also measured.

The key variables describing *bird biodiversity* were species richness (Jack 1 and Chao 2 estimates (Magurran, 2004) based on Timed Species Counts, Freeman *et al,* 2003) and abundance (lambda values by category of species). The major bird categories considered include tree birds, water birds, grassland specialists, aerial feeders, migrants, and threatened species (Red Data List), the most important for this study being tree birds.

The variables describing exotic and indigenous *woody vegetation*, respectively, are total number of stems (by species and diameter at breast height), species richness, canopy cover (proportion), density (number of trees per hectare), species found in fallows, and human use (medicine, timber, agroforestry, etc). The woody vegetation categories considered are palms, shrubs, trees, and woody lianas.

1.5. Specific Research Questions and Objectives

Although this was only a pilot study, it did attempt to address the question: how does agricultural intensification affect the abundance and species richness of woody vegetation and birds and how can we most effectively minimize the trade-offs between food production and biodiversity conservation? More specifically: what characterizes the woody vegetation and bird fauna found in crop-based agroecosystems of different levels of cultivation intensity in terms of the variables described in Section 1.4?[1] How do these agroecosystems differ with respect to other agricultural land use variables noted in Section 1.4? How have bird species richness and abundance changed over time in specific systems? Do any of the more specialized birds survive in agroecosystems? If so, how important is woody vegetation?

The specific study objectives were as follows.

1. To describe patterns (and trends in some cases) in biodiversity in selected crop-based agroecosystems (smallholder and large-scale) in central and western Uganda, in terms of the occurrence of woody vegetation and birds (including predicted bird occurrences based on spatial extrapolation).
2. Examine the effects on biodiversity of agricultural intensification, especially the loss of woody vegetation and of birds associated with this habitat type (i.e., the effects on birds of the decline in woody vegetation), but also possible gains in bird habitats, such as croplands and grasslands, associated with land use/cover change.
3. Identify, where possible, those agroecosystems, which have both high biodiversity values and high rates of loss, i.e., systems where interventions that reduce food production–biodiversity trade-offs would have the greatest impact on biodiversity.
4. Suggest specific methods of mitigating biodiversity losses during intensification of the types of agro-ecosystem under study.
5. Consider the relative importance to birds of native and exotic trees.

[1] The study focuses on crop-based systems, but includes one pasture (see Pomeroy *et al*, 2003 for birds in livestock systems).

2. METHODS

2.1 Overview

A defining feature of the present study is the use of data collection methods that have rarely been combined: survey of agricultural land use and land cover, survey of woody vegetation, and survey of birds. Below we describe these in turn as well as the methods of data analysis.

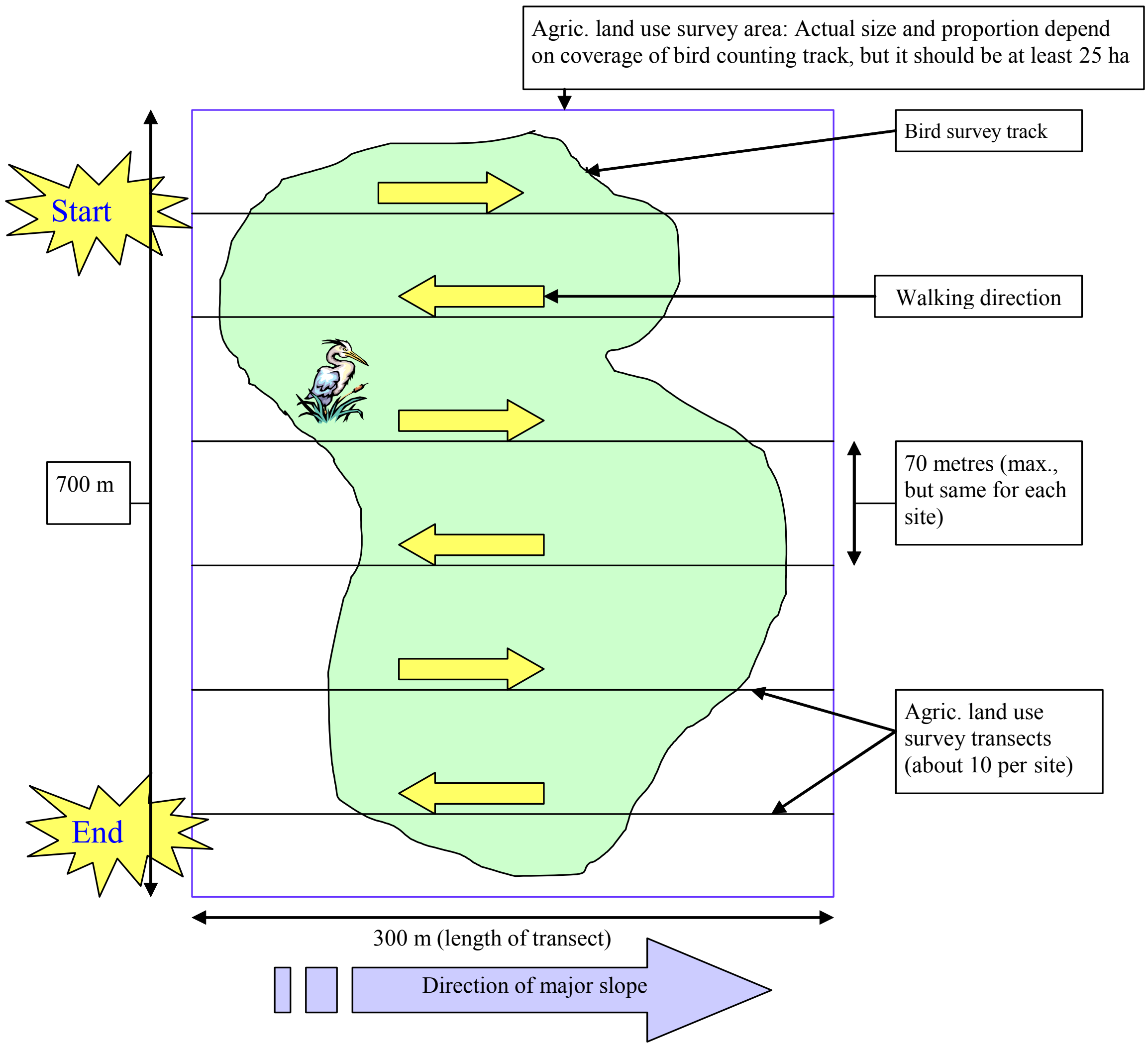
2.2 Agriculture-focused Land use Survey

The land use survey involves descriptions of the different types of land uses at the study sites and their relative extent, focusing on agricultural land use, as well detailed descriptions and survey of woody vegetation (see Section 2.3). We adopted two methods for agricultural land cover/use survey; transect walks and boundary mapping. Transect walks were used to collect data in smallholder agroecosystems while boundary mapping was done in large-scale systems. The sites were surveyed with respect to the following agriculture-focused land use variables: proportion of fallow, cultivated area, and natural (native) vegetation; fallow age; type of natural and fallow vegetation; cropping pattern (mono or mixed cropping); number of crops; dominant and secondary crops. The cultivation intensity, here defined as the share of cultivated land in total farmland (fallow plus cultivated), as well as the farming system types, were derived from these data. Other encountered land uses such as settlements or roads were also mapped.

Transect Walks

The route followed by the bird surveyor (see below) was the basis of establishing the area to lay transects for the survey of land use and woody vegetation in that particular site. The area for the land use survey was meant always to encompass the area covered by the bird survey and was to be around 500m x 500m or any rectangle of about 25 ha (see Figure1). It was delineated by 'boxing in' the area covered by the bird survey while allowing an outside margin of some 50-100m from where the birds were observed. This was achieved by first following and mapping the route of the bird surveyor on his/her first count, and later identifying the approximate area to conduct the land use and woody vegetation survey. The total transect length in each site was supposed to be at least 3000m to ensure a sufficient number of land use observations for statistical analysis (about 50-60 per site in smallholder sites). The transects were parallel spaced about 70m apart. The length of the transects was adjusted to accommodate the varying dimensions of the bird counting area but always added up to around 3000m. For example, if the length of the bird survey area was 600m, we laid out $600m/70m + 1 = 9.6$ or 10 transects, each with a length of $3000m/10m = 300m$

Figure 2. 1: Sketch of agricultural land use/cover survey transects



Land use information was recorded for each land use section on the Transect Survey Data Form (see Appendix 2 for Data Collection Form and accompanying notes) and a general description of the farming system and land use characteristics of the site done in relation to the main study variables.

Table 2.1 presents an overview of the land use survey. Eight out of the nine smallholder sites were surveyed as intended, while the Ziika site was too narrow to accommodate the use of transect walks and consequently a complete boundary mapping was used. In practice, the overall transect length was either slightly less or more than 3000m in some sites. This was mainly due to errors caused by obstructions when measuring the section length using a measuring tape. The average transect length was adjusted to allow for the varying terrain orientation in some sites but eventually would add up to around 3000m in each site. The area covered by transects in each site was almost the same, except in Mpanga where it was reduced because the last section of the site was too narrow to accommodate a transect of more than 60m to make enough and comparable observations.

The route followed by a bird surveyor in plantations would either make a complete loop or a single line. In the case of a complete loop, the total area was recorded. The Kasese Cotton site recorded a relatively big area due to the large extent of the cotton fields. We recorded a smaller area in Nsimbe Estate (horticultural) because flower tents that we could not access occupied most of the site. Other inaccuracies that were beyond our control were associated with GPS readings. In sites like Kyegegwa where the vegetation was too dense, the GPS tended to lose its reception thus affecting accuracy of the recorded coordinates. Also we had anticipated using a compass to keep the direction of transects but this later proved difficult and time consuming. We therefore adopted the use of a hand held GPS with pre-loaded transect information to keep the transect direction. This proved to be faster and reliable except that the GPS reception would be affected whenever we approached or got under dense vegetation cover.

Table 2. 1. Overview of land use survey; further details of sites are given in Table 1.1

Site	District	Land use survey method [a]	Total area covered (ha)	Overall transect length (m)	No of land use observations	Average transect [c] length (m)
Lugazi Tea	Mukono	BM[b]	12.7	-	-	-
Kasese Cotton	Kasese	BM	46.6	-	-	-
Lugazi Sugar	Mukono	BM	-	-	-	-
Hima pasture	Kasese	BM	15.0	-	-	-
Nsimbe estate	Mpigi	BM	3.4	-	-	-
Mpanga	Mpanga	TW	15.8	2257	81	266
Kifu	Mukono	TW	21.1	3006	85	301
Bujagali	Mukono	TW	20.7	2953	124	295
Kanyawara	Kabarole	TW	22.6	3230	105	323
Kyegegwa	Mubende	TW	20.7	2963	57	370
Mubuku	Kasese	TW	21.2	3026	66	432
Katugo	Nakasongola	TW	20.4	2910	59	291
Mukono	Mukono	TW	19.1	3067	79	375
Ziika	Wakiso	BM	9.0	-	-	-

Note: [a] TW and BM refer to Transect walk and Boundary mapping respectively
[b] Did boundary mapping instead of the planned transect walks
c Transects were placed 70 meters apart and along the slope in respect to terrain orientation

Boundary Mapping of 'Baseline Sites' With Natural Vegetation

We had planned to make a boundary mapping of large areas of natural vegetation that are adjacent to four of the study sites, for later comparison with the agricultural study sites. But due to limited time this was not achieved in this round of field work. These 'natural vegetation' sites are Kamulekyezi and Kasese Woodland (both next to Queen Elizabeth National Park), Ziika, and Kiwumulo.

2.3. Descriptive Analysis of Land Use Data

Descriptive analysis was done of the data collected from both the smallholder and large scale study sites. In case of smallholder sites, proportions, means and frequencies where calculated for all variables, while an assessment based on direct observation was done for the large scale sites. Some photographs taken during data collection were also used to enhance the description of study variables for some sites.

General Land Use Description

Various land use types were encountered in the smallholder study sites. To determine which of these land use types were dominant, we calculated the proportion of each type as the total length of a particular land use section divided by the overall transect length for the site. A Bray-Curtis cluster analysis (single link) was used to compare similarity in land use pattern across sites. This method classifies objects judged to be similar according to distance or similarity measures. Data can be continuous or binary. Bray-Curtis similarity using group-average clustering appears to give a useful hierarchy of clusters (Pielou, 1984). General description of land use was done for sites with large-scale plantations or pasture.

Farmland Description

Farmland is defined as composed of cropland (cultivated area), pastures, and fallows. *Cropland* was described with respect to cropping patterns, dominant and secondary crops, and crop diversity. The proportion of different cropping patterns was calculated by dividing the length of crop sections with mixed or mono cropping by the total length of the cultivated area in each site. Dominant and secondary crops were recorded for the cultivated land use sections and the proportion of each dominant crop in total length of cultivated land use calculated. Crop diversity was measured as the total number of dominant and secondary crop types encountered on each site.

Four indicators were used to describe the intensity of land use: the main one is cultivation intensity, and the others are fallow vegetation type, fallow age, and the proportion and type of natural vegetation. The three former are closely related in that the frequency of cultivation determines the age of fallows, which in turn affects the maturity of the vegetation in the fallows. *Cultivation intensity* is here defined as the share of cultivated areas in relation to the total farmland area and was calculated for each site as follows:

$$CI_i = \left(\frac{\sum_i LC}{\sum_i LC + \sum_i LF} \right) x100$$

where: CI = Cultivation intensity (%) for site *i*

LC = Sum of length (m) of cultivated sections in site *i*

LF = Sum of length (m) of fallow sections in site *i*

Fallow vegetation was categorized according to dominant vegetation types: grassy, bushy, woody, or bushy-woody. More specific vegetation descriptions were done by the survey of woody vegetation (see Section 2.3). The proportion of each vegetation type was calculated by dividing its total length by the overall length of fallow for every site. The mean *fallow age* was calculated for each site as the fallow age of each section with fallow weighted by the proportion of that section in the total length of transects with fallow. Fallow sections were also grouped in two-year age classes. The age of fallows was estimated by a local farmer assisting the field worker.

Natural Vegetation Description

Areas with natural vegetation were categorized according to dominant vegetation types: grassy, bushy, woody, or bushy-woody. More specific descriptions were done by the survey of woody vegetation (see Section 2.3). The proportion of each vegetation type was calculated by dividing its total length by the overall length of natural vegetation in the site.

2.4 Survey of Woody Vegetation

Sampling Design

The area and transects used for surveying the woody vegetation were the same as for the agriculture-focused land use survey described in the previous section. Inventories of demarcated plots have been widely used in floristic sampling and ecological studies in recent years (e.g., Poulsen, 1997). The results of species richness estimates depend on the size, shape and number of plots surveyed and on the choice of the parameter depend on the scope of the study (Thompson and Conkle, 1992). Circular plots of 20 m radius were used in this survey. They were measured by use of a string stretched from the centre. The plots were placed along the transects at intervals of 50 m where records of the species, geographical position, and land use type were taken.

Tree data of all the species were captured from the 20 m radius plot and recorded in diameter classes. All young plants identified as trees were recorded as saplings if their diameters where less than 2.5 cm at breast height (dbh). All woody plants above 2.5 cm dbh were recorded in classes of 2.5-9.9 cm, 10-19.9 cm, 20-39.9 cm and >40 cm. Along the transect, we also recorded the numbers of individuals encountered and the crown cover (in meters) for trees higher than 3 meters. These records of crown cover were used to estimate the canopy cover in each site. Lianas whose diameter was greater than 1 cm at 1 meter from the ground were recorded as present or absent whenever encountered in the plot. All climbing plants, woody or herbaceous, were recorded as lianas whenever they were seen to climb, entangle, or scramble on other plants within the plot.

Opportunistic Records

Plots can give fairly good data on distribution and abundance, but cannot give the total number of different species in an area, as there are plants that will only be encountered outside the plots. Opportunistic records were used to record any new species seen or encountered for the first time in a site. This method was also used to survey plants on large-scale farms, which had only a very limited amount of woody vegetation.

Voucher Specimens

Plant identification, naming and classifying can only be complete after several stages which involve comparing new material with existing material. For this to be achieved, we collected voucher specimens for most of the species encountered in the study sites to allow for further confirmation at the Makerere University Herbarium.

Total species

The plant species lists (species richness) were compiled from the plot data and opportunistic encounters, which were used to indicate the number of indigenous and exotic species and their distribution.

Canopy cover

Canopy cover was calculated as a proportion for both exotic and indigenous tree species in each site. Canopy diameter (length in meters) was measured for trees encountered along each transect in the circular plots. This information was used to compute canopy cover per plot and in turn the percentage canopy cover per site as per the formula below.

$$\text{Percentage canopy cover } (C_i) = \frac{\sum P_i}{\sum A_i} \times 100$$

Where P_i = Canopy diameter (length in meters) per plot in site *i*

A_i = Total plot diameter (length in meters) along transect in site *i*

2.5 Bird Surveys

The occurrence of the birds and their relative abundance at all sites were surveyed by Timed Species Counts (TSCs: Pomeroy & Dranzoa, 1997; Freeman *et al,* 2003). Essentially, these consist of listing all the species seen or heard during a one-hour walk around the habitat being sampled. (A small proportion are not identified and hence cannot be included). Alongside the species list, the time is noted every 10 minutes and subsequently species are scored *six* if they were recorded in the first ten minutes, *five* for the second ten minutes, and so on to *one* if they were not found until the final ten minutes. The raw TSC scores for each species at each site were then transformed to what are termed lambda values (Freeman *et al,* 2003), which in effect are encounter rates per minute. These estimates of abundance can be summed across sites or by categories of birds.

A series of counts was made at each site (Table 2.2). For all of the smallholder sites, except Mukono, counts were made in various years going back at least to 1996, and in some cases to 1989 (Table 2.2), which allows us to look for trends over time. Data from the different sites were collected for a variety of reasons, hence the scatter of dates. The counts in 2004 were done as part of this study. Regression analyses of TSC scores against time were used to look for trends.

The total number of birds expected at any particular site can be estimated by various methods (Bibby *et al*, 2000); we used Jack 1 and Chao 2 (Magurran, 2004) which, like the lambda values, were calculated in a computer program customized for this purpose by the National Biodiversity Data Bank at MUEINR.

Trends for species were also determined by the above program, and were summed by pooling the values for groups of species. Grouping species under various categories increases sample sizes, as well as bringing together species with defined similarities. The procedure is widely used in bird studies (e.g. Naidoo, 2004). We used several categories (Table 2.3), based upon specialization (forest birds, water birds, grassland birds) feeding mode (aerial species), migratory patterns (whether within Africa or beyond) and conservation status (Red Data Listed). No globally-threatened species were recorded, but there were several of conservation concern in the region (Bennun & Njoroge, 1996): one regionally vulnerable, one regionally near-threatened and eight whose main breeding range is confined to East Africa (Appendix 9). Of course, not all species are specialists and only a minority is migrants, whilst others belong to two or even three categories. A complete species list of birds recorded, with membership of these categories, is given in Appendix 9.

Table 2. 2. Numbers of bird counts at each site, by years

Site	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total
Lugazi sugar																9	1	10
Lugazi tea																9	1	10
Nsimbe horticulture																9	1	10
Kasese cotton																1	6	7
Bujagali											5					2	2	9
Mpanga	6	3														9	1	19
Kifu	2	4														11	3	20
Mubuku									3							3	3	9
Katugo			1	2	2	2	1	1								2	2	13
Mukono																9	1	10
Kanyawara	4	4	4		1	1	1									3	2	20
Kyegegwa		5	2			1										2	2	12
Ziika	4	5														9	1	19
Hima pasture																	7	7

Notes: Data from the different sites were collected for a variety of reasons, hence the scatter of dates. The counts were made by Christine Dranzoa, Dianah Nalwanga, Derek Pomeroy and various helpers.

Table 2. 3. Categories of birds as used in this study

Main category	Sub-categories with codes		Descriptions
Tree birds[a]	FF	forest specialists	Characteristic of forest interior
	F	forest generalists	Normally breed in forests or forest patches; may occur outside
	f	non-forest tree birds [b]	
Water birds[c]	WW	water specialist	Normally restricted to wetlands or open water
	W	non-specialist	Often found near water
Grassland[d]	GG	grassland specialist	Species particularly characteristic of open grasslands
Aerial[d]	AA	aerial feeders	Species feeding on the wing
Migrants[c]	A	Afrotropical	Species migrating within Africa
	P	Palaeractic	Species breeding in Europe or Asia
	Ap		Species with both Afrotropical and Palearactic population
	p		Species with some Palearactic populations
Red Data List [e]	R-VU	Regionally vulnerable	Endangered in the region
	R-NT	Regionally near-threatened	Could become endangered in the region
	R-RR	Regionally restricted	Species with the greater part of its distribution in East Africa

Notes:
a Bennun *et al* (1996) (who refer to them as 'forest birds')
b Referred to as forest visitors by Bennun *et al*
c Wilson (ed) 1995 (where they are referred to as W and w respectively)
d NBDB (unpublished)
e Bennun & Njoroge (1996)

2.6 Multivariate Statistical Analyses

Ordination techniques were used to summarize relationships between different species and their locations as well as their responses towards certain environmental gradients resulting from cultivation intensity. Correspondence Analysis (CA), a powerful tool that is used to reveal block structures within species distribution data, was used. CA assigns scores to sites and species such that similarly-scored sites are more similar in species composition than sites located further apart in the CA coordinate space. The direct gradient analysis method of CA, Canonical Correspondence Analysis (CCA), takes this further by incorporating environmental data into the analyses, to reveal any responses towards such data as measured in the field. Two methods were used here: simple CA using presence-data to reveal any associations amongst sites, both for woody plants and bird species assemblages; and detrended CCA using a number of variables to reveal responses of birds, especially tree birds, to different parameters associated with agricultural activities.

Simple Correspondence Analysis

Binary data matrices were constructed for both woody plants and birds and fed into a multi-variate statistical analysis package, MVSP (Kovach, 1999). Hill's algorithm was used and the final scores adjusted by sample scaling, a technique useful to reveal samples configurations (Kovach, 1999). Because CA is particularly sensitive to species that occur in a few species-poor sites (Hill, 1979), the 'down-weighting rare' option was used.

Canonical Correspondence Analysis

To examine the effects of agriculture on bird distributions, a number of land use variables that were thought to be relevant were predetermined and measured in the field (see Section 2.1 and Appendix 4) (Note that two sites, Mubuku Pasture and Ziika Cultivations were omitted from these analyses, the former due to its unique nature, not being an agricultural site; and the latter due to missing values).

A species-site data matrix was constructed for birds. Encounter-rates data (Lambda scores, Section 2.4) were used for abundance values, and the values for land use variables (see Appendix 4) as environmental data.

All the variables were fed into the analysis for initial exploration of determinant variables. One problem of CCA is intercorrelation among the variables themselves, and it was therefore necessary to use variance inflation factors (VIF) and our best judgment to eliminate some variables from the analyses, while maintaining those that were thought to have significant and independent effects on the distribution of birds within agricultural systems. At each stage of the elimination process, CCA plots were examined for meaningful patterns.

We did the analyses from two angles: one with all the birds included, and one with only 'tree birds' since these might be particularly sensitive to agricultural intensification.

3. RESULTS FROM THE LAND USE SURVEY

3.1 Land use Intensity, Types and Patterns

In Table 3.1 we provide a summary of land use in the study sites. There was considerable variation in land use variables among smallholder sites, while the large-scale farming systems had very uniform land uses. High cultivation intensity (implying relatively small areas with fallow), short fallow period, low proportion of natural vegetation, and dominance of mono cropping are all indicators of high land use intensity. The large scale systems all exhibit high land use intensity by these measures. Land in smallholder sites in central Uganda is more intensively exploited than land in our western sites. This may be attributed to the differences in market access and population density between the two regions. Among all smallholder sites, Bujagali in central Uganda and Kyegegwa in western Uganda had the highest and lowest land use intensities, respectively.

Table 3. 1. Summary of Land Use Intensity in all study sites

Scale of farming	Land use type	Site name	Cultivation intensity[1] (%)	Mean fallow age (years)	Proportion in total land use			Proportion of monocrop in cultivated area	Total number of different crops
					Fallow vegeta tion	Culti-vated area	Natural vegeta-tion		
Large scale	Commercial plantations	Lugazi sugar	100	-	0.00	0.98	0.00	1.00	1
		Lugazi tea	100	-	0.00	0.90	0.00	1.00	1
		Nsimbe horticulture	100	-	0.00	0.90	0.00	1.00	1
	Individual plots	Kasese cotton	100	-	0.00	0.98	0.01	1.00	1
Small scale (small holder farms)	High cultivation intensity	Bujagali	98	1.63	0.02	0.86	0.01	21	16
		Mpanga	82	3.00	0.15	0.71	0.03	37	10
		Kifu	73	4.30	0.24	0.63	0.02	20	11
	Medium cultivation intensity	Mubuku	72	2.70	0.22	0.57	0.02	78	8
		Katugo	63	3.43	0.22	0.37	0.15	31	13
		Mukono	61	4.63	0.25	0.56	0.00	57	10
	Low cultivation intensity	Kanyawara	51	4.43	0.37	0.39	0.05	29	11
		Kyegegwa	26	7.82	0.41	0.15	0.44	31	7
	Farmland/ pasture	Ziika	NA	-	0.00	0.45	0.50	-	-
Pasture	Managed	Hima pasture	0	NA	0.00	0.00	0.00	NA	NA

Notes: [1]Cultivation intensity is defined in Chapter 2

Table 3.1 also shows that the cultivated area was the most dominant land use, with highest proportions in all the sites apart from Kyegegwa. Fallow land was the second dominant land use in Kanyawara (0.37), Mubuku (0.22), Kifu (0.24), and Mpanga (0.15). Natural vegetation was most dominant in Kyegegwa and much reduced in other sites. Settlements and access road networks were common in some sites but recorded relatively low proportions. Unique land use types such as market place and football pitches were encountered in Mubuku and Mpanga sites respectively while burial and land occupied by deserted factory were in Mukono. Planted woodlots were only seen in Mubuku and Kanyawara sites.

Although the cultivated area dominated in all sites, there was variation in cultivation intensity across sites. Results in Table 3.1 show that Bujagali and Mpanga had cultivation intensities of over 80%. Other land use types encountered in these sites were mainly settlements and road networks, while little natural vegetation remains there. Kifu and Mubuku had similar cultivation intensities of around 70%, while Mukono and Katugo had 63% and 61% respectively. As expected, the analysis also shows relatively low (26%) cultivation intensity value for Kyegegwa, which is also the impression we got from visual observations. In fact, few fields were encountered and these were poorly maintained and some abandoned. Local farmers said that many fields had been abandoned because of poor yields stemming from infertile soils. However, more in-depth interviews would be needed to reliably establish the reasons behind these and other land use patterns observed in the sites.

Generally the Kyegegwa site showed the least similarity in all land use aspects with other sites. The Katugo site had also a distinct land use pattern, with part of the study site being an 'unmanaged pasture land' (very stony with stunted scrub) and the other with cultivation and a few settlements. Kanyawara and Bujagali had relatively similar land use patterns, with the cultivated areas being associated with settlements. From field observations, the Kyegegwa and Mubuku sites showed a clear isolation of settlements from other land use types. In fact, only one settlement was encountered within the Kyegegwa site while others were scattered along the main Mubende to Fort Portal road.

3.2 Dominant Crops, Cropping Patterns and Crop Diversity on Cultivated Land

Cropping Pattern

All sites exhibited both mixed and mono cropping patterns. Table 3.1 also shows the relative proportions of the cropping patterns in each site. With the exception of Mubuku and Mukono, other sites show a similar cropping pattern, with low proportions of mono than mixed cropping which conforms to the expected characteristic of cropping patterns in smallholder sites. In sites like Kifu and Bujagali, it was common for mixed cropping patterns to include more than five crops, such as coffee, bananas, vanilla, beans and yams. Mono-cropping in Mubuku comprised of mainly cotton with small amounts of maize or banana.

Dominant Crops

Dominant crops (in terms of area covered) serve as an indicator of the farming system in a given area. Table 3.2 shows the dominant crops and their corresponding area proportions. Generally, land use was dominated by a few staple foods, notably bananas (no distinction was made between cooking and dessert bananas) and root crops (cassava and sweet potatoes), which together dominate between 25% and 83% of cropland, depending on site (the site average is 60%). Cereals (maize) were important in two sites. Coffee, Uganda's main export crop, in contrast, on average only covered a very small share (10%) of cropland and was absent in three sites, while cotton, Uganda's biggest export crop in the 1960s, was found in only one site. This confirms the common perception that Ugandan smallholders are overwhelmingly subsistence oriented, although it is quite possible that many of the observed food crops, especially bananas and maize, are sold for cash.

Bananas were the most dominant in Mpanga, Kanyawara, Kifu, Mukono and Kyegegwa sites. Bananas in Kifu were commonly mixed with vanilla, while in Mpanga and Kanyawara they were mixed mainly with beans. In Kyegegwa, many banana plantations were abandoned, probably about 3 – 4 years ago. Root crops (cassava and sweet potatoes) were the most dominant in Katugo and second dominant in Bujagali, Mpanga, Kanyawara, and Mukono. Coffee dominated only in Bujagali and was the second most important in Kifu, while it was not observed in Kanyawara, Kyegegwa and Mubuku sites. Maize was the second most dominant in Kyegegwa and Mubuku. Vanilla, which grows under shade and thus may encourage planting and conservation of trees, was only encountered in Kifu and Bujagali. Vanilla was grown in association with bananas or coffee, apart from in Kifu where there were more established vanilla gardens under planted trees. Cotton was only encountered in Mubuku among the smallholder sites, where it was the dominant crop. This is probably because the site is adjacent to the main cotton growing villages in the district. Beans were recorded in all the sites although they were relatively less dominant.

No clear relationship could be discerned between cultivation intensity and type of farming system. The high intensity sites in Bujagali and Mpanga are dominated by coffee, bananas and root crops, while bananas also dominate the low intensity sites.

Table 3.2. Dominant crops in smallholder sites

Dominant crop	Proportion of crop in total section length of cropland in site (*The two most common crops are marked in bold*)							
	Bujagali	Mpanga	Kifu	Katugo	Kyegegwa	Kanyawara	Mubuku	Mukono
Banana	0.02	**0.43**	**0.31**	0.14	**0.26**	**0.58**	0.20	**0.37**
Sweet potatoes	**0.16**	**0.26**	0.11	**0.32**	0.17	**0.20**	0.00	0.14
Cassava	0.13	0.07	0.13	**0.38**	0.14	0.05	0.05	**0.18**
Coffee	**0.37**	0.02	**0.23**	0.02	0.00	0.00	0.00	0.17
Maize	0.08	0.00	0.00	0.07	**0.23**	0.00	**0.22**	0.06
Beans	0.07	0.06	0.04	0.02	0.20	0.09	0.03	0.02
Cotton	0.00	0.00	0.00	0.00	0.00	0.00	**0.40**	0.00
Vanilla	0.08	0.00	0.15	0.00	0.00	0.00	0.00	0.01
Groundnuts	0.01	0.11	0.00	0.04	0.00	0.02	0.00	0.00
Tomatoes	0.02	0.05	0.00	0.00	0.00	0.00	0.04	0.00
Millet	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00
Egg plant	0.01	0.00	0.00	0.00	0.00	0.00	0.05	0.00
Moringa	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sugarcane	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Sorghum	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Secondary Crops

Other most important secondary crops encountered in the mixed cropping patterns include cassava that was the most common in all the sites except Mubuku. Maize was also common in Bujagali and Mubuku. Coffee was encountered in Bujagali, Mpanga and Katugo and was not observed in sites in western Uganda. Millet and sorghum were rare crops in the mixed cropping patterns, while vanilla was only encountered in Kifu and Bujagali.

Crop Diversity

Crop diversity, here measured as the number of different crops in a site, varied distinctly across sites (Table 3.3). Bujagali recorded the highest diversity, reflecting the complex mixed cropping patterns that were observed there, followed by Katugo, Kanyawara, Kifu, Mpanga, Mukono, Mubuku, and Kyegegwa.

Table 3.3. Frequency of different crops in each site

Crop	Number of times crop encountered along transects in smallholder sites							
	Bujagali	Kanyawara	Katugo	Kifu	Kyegegwa	Mpanga	Mubuku	Mukono
Cassava	66	15	17	27	9	23	6	17
Maize	30	8	5	4	6	3	12	6
Banana	19	29	7	24	5	24	8	21
Sweet potato	17	15	14	8	4	15	-	8
Beans	9	6	1	5	4	2	4	2
Yams	5	11	4	6	-	1	1	1
Sorghum	2	-	-	-	-	-	-	-
G. Nuts	1	1	3	1	-	5	-	-
Pumpkin	1	-	-	-	-	-	-	-
Millet		4	-	-	-	-	-	-
Coffee	47	-	5	17	-	10	-	13
Cotton		-	-	2	-	-	12	-
Sugarcane	4	-	-	3	1	-	-	-
Vanilla	15	-	-	9	-	1	-	5
Moringa	2	-	-	-	-	-	-	-
Mango	-	-	3	-	-	-	-	-
Jack fruit	1	-	1	-	-	-	-	-
Orange	-	-	1	-	-	-	-	-
Papaya	-	2	1	-	-	-	-	-
Pineapple	-	1	1	-	1	-	-	1
Avocado	-	1	-	-	-	-	-	-
Egg plant	4	-	-	-	-	-	2	-
Tomatoes	2	-	-	-	-	3	4	-

3.3 Fallow Land Description

The maturity of fallows was described with respect to dominant vegetation and estimated age. Four dominant vegetation categories were encountered: bushes, grasses, woody vegetation or similar proportions of bushy and woody vegetations. In general, immature vegetation – grasses and bushes – dominate fallows in the sites (Table 3.4), reflecting the high cultivation intensities in central and western Uganda (and the associated high population densities). Fallow vegetation in Mubuku, Kifu, Katugo and Mpanga was mainly grassy while it was mainly bushy in Kanyawara and Bujagali (Table 3.4). Fallow was mainly woody in Kyegegwa and to some extent in Katugo and Kifu. Equal proportions of bushy and woody fallow vegetation only existed in Mubuku, but the woody portion tended to be on land next to a cliff, which could probably not be put to agricultural use. However, total fallow length was much reduced in Bujagali and somewhat pronounced in the Kyegegwa and Kanyawara sites. Fallow in Kyegegwa is tending to natural vegetation status.

Table 3.4 Proportion of fallow according to vegetation type in smallholder sites

	Mubuku	Kanyawara	Kyegegwa	Kifu	Katugo	Mpanga	Bujagali	Mukono
Total fallow length (m)	675	1202	1216	707	649	355	54	768
Fallow type	Proportion of dominant vegetation							
Grassy	0.67	0.39	0.20	0.73	0.51	0.61	0.46	0.51
Bushy	0.15	0.61	0.37	0.20	0.45	0.39	0.54	0.49
Woody	0.00	0.00	0.44	0.07	0.03	0.00	0.00	0.00
Bushy-woody	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

The fallow period was categorized into age classes to show the maturity of fallow vegetation in each site, and it was assumed that fallow age in long land use sections weigh more than in short sections. Results in Table 3.5 generally show that a high proportion of the fallow in Bujagali was relatively young with an average age of 1.6 years. Fallow in Kanyawara was better distributed between age-classes, with the highest proportion between 0 – 1.9 years, and relatively 'old' with an average fallow age of 4.4 years. The Kyegegwa site had the oldest fallows with most fallows between six and eight years. Katugo, Kifu, Mpanga and Mubuku sites had most fallow area between 2.0 – 3.9 years but with varying average fallow ages.

Some local people attributed the long fallow periods in Kyegegwa to absentee land ownership (by "wealthier" government officials), while others viewed the land as unsuitable for cultivation (poor soils), which forced farmers (owners) to shift crop cultivation to more fertile areas.

Table 3.5. Proportion of fallow according to age class

	Bujagali	Kanyawara	Katugo	Kifu	Kyegegwa	Mpanga	Mubuku	Mukono
Average fallow age (years)	1.63	4.43	3.43	4.30	7.82	3.00	2.70	4.63
Age class (years)	Proportion of fallow in site (highest value in bold)							
0 - 1.9	**0.69**	**0.26**	0.12	0.17	-	0.20	0.24	0.16
2.0 - 3.9	0.31	0.22	**0.61**	**0.59**	0.05	**0.64**	**0.51**	**0.23**
4.0 - 5.9	-	0.17	0.19	-	0.10	-	0.25	0.09
6.0 - 7.9	-	0.18	-	0.14	**0.38**	0.16	-	0.00
8.0 - 9.9	-	-	-	-	0.28	-	-	0.30
10.0 - 11.9	-	0.17	0.07	0.05	0.12	-	-	0.12
12.0 - 13.9	-	-	-	-	-	-	-	0.10
14.0 - 15.9	-	-	-	0.10	-	-	-	-
16.0 - 17.9	-	-	-	-	0.06	-	-	-
Grand Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: Average fallow age is weighted by proportion of land use section in total length of sections with fallow.

3.4 Natural Vegetation Description

Table 3.6 shows the calculated proportions of natural vegetation types in the study sites. The vegetation was grassy, bushy, woody or with similar proportions of bushy and woody (bushy-woody) vegetation. Natural vegetation is all vegetation that is not crops, planted woodlots or planted pastures and so includes fallow vegetation. Overall section length of natural vegetation was highest in Kyegegwa and somewhat pronounced in Kanyawara and Katugo. In other sites, natural vegetation occurred in small pockets that were barely more than ten meters in length. The woody natural vegetation recorded the highest proportion in Kyegegwa, Katugo and Kifu but was more mature in Kyegegwa. In Kanyawara, the vegetation was either bushy or woody. Least proportions were recorded for the grassy type of natural vegetation in some sites.

Table 3. 6. Type and proportion of natural vegetation in each site

Site	Cultivation intensity (%)	Overall length of fallow sections (m)	Proportion of vegetation type			
			Grassy	Bushy	Woody	Bushy-woody
Bujagali	98	18	0.00	0.67	0.33	0.00
Mpanga	82	67	0.25	0.50	0.25	0.00
Kifu	73	64	0.00	0.25	0.75	0.00
Mubuku	72	59	0.00	0.67	0.33	0.00
Katugo	63	449	0.33	0.17	0.50	0.00
Mukono	61	768	0.51	0.49	0.00	0.00
Kanyawara	51	216	0.00	0.50	0.00	0.50
Kyegegwa	26	1295	0.10	0.29	0.62	0.00

3.5 Land Use in the Ziika site

Due to the narrowness of the Ziika site, boundary mapping was preferred to transect walks. The land use data thus obtained do not allow for comparisons with the other smallholder sites, however. A relatively small area was mapped and we were able to categorize land use into two sections: the section with grassland next to Ziika forest, and the one neighboring the main highway to Entebbe that is occupied by homesteads and scattered gardens. The observed dominant crops in the site were mainly cassava and sweet potatoes. The characteristics of the site were quite unusual in that the soils are very shallow (almost bare rock), and in places where crops are grown, soil has been added from the excess soil, that was dumped when the Entebbe road was constructed.

3.6 Land Use Description in Plantation sites

Five out of fourteen sites had a homogenous land use but with varying characteristics. These were the Kasese cotton and Hima pasture in western Uganda, the Lugazi sugar and tea estates in Mukono district, and Nsimbe horticultural estate in Wakiso district. Information on the key variables collected in these sites is summarized in Table 3.7.

Table 3. 7. Summary of data collected from large-scale /plantation sites

Site	Lugazi Tea	Lugazi Sugar	Kasese Cotton	Hima pasture	Nsimbe horticulture
District	Mukono	Mukono	Kasese	Kasese	Mpigi
Total area covered (ha)	12.7	NA	46.6	15	3.4
Estimated share of cultivated land (%)	90	98	98	-	90
Dominant crop	Tea	Sugarcane	Cotton	Pasture	Horticulture
Presence of fallow patches	No	-	-	-	-
Presence of natural vegetation pockets	-	-	Yes	-	-
Woodlot /trees presence	Yes	-	-	Yes	-
Other land use/cover features	-	Stream	-	-	-

Kasese Cotton

From Table 3.7 it may be seen that Kasese cotton recorded the biggest area but was divided into many small plots under individual ownership. The share of cultivated land was estimated at 98%, with the remaining percentage being the two clustered groups of homesteads, natural vegetation pockets and wasteland. The dominant crop was cotton at the time of the survey, though local farmers said they rotated it with mainly groundnuts and maize. Few pockets of natural vegetation existed in small water gullies and no trees were observed in the plantation save for those planted around the homesteads and the natural vegetation in the neighboring national park. According to the local people, trees tend to attract birds that cause pre-harvest losses of cotton. There were no fallow patches and other land use features recorded for this site.

Hima Pasture

Hima pasture had the second biggest mapped area and was the only site with intensively-managed pasture. The bushes were cleared in the recent past to make a paddock but several trees were left standing (see Figure 3.1). But according to the farm owner, this was intended to provide shade to the cattle rather than for biodiversity conservation purposes. However, when viewed from a distance, the trees form relatively good vegetation cover that supports part of the bird community. The paddock has neighboring natural vegetation (government forest reserve), which has an implication on the bird counts that were made, as explained elsewhere in the report.

Figure 3. 1. A view of Hima pasture with a degraded forest reserve in the background

Lugazi Tea Estate

As the name suggests, tea was the dominant crop in the site (see Table 3.7). The bird monitoring section of the tea estate is located between the valley and hilltop. The share of cultivated land was estimated at 98% with the remaining portion being patches of woodlot, access road networks and wasteland (very stony). The woodlot patch (see figure 3.2) was of mainly eucalyptus, but most trees were seen beyond the tea plantation. There were no patches of fallow or natural vegetation encountered around the site.

Figure 3. 2. A view of Lugazi tea estate showing the woodlot patches in the background

Lugazi Sugar Estate

Like the tea estate, there were no fallows or pockets of natural vegetation in Lugazi sugar estate. The crop was dominantly sugarcane in a mosaic of mature and young sugarcane. The area we mapped was relatively small due to the method and route followed by the bird surveyor (see Section 2.4). Other features observed were a stream that cut across the study site and woodlot patches along the boundary of the estate outside our study site.

Nsimbe Horticulture Estate

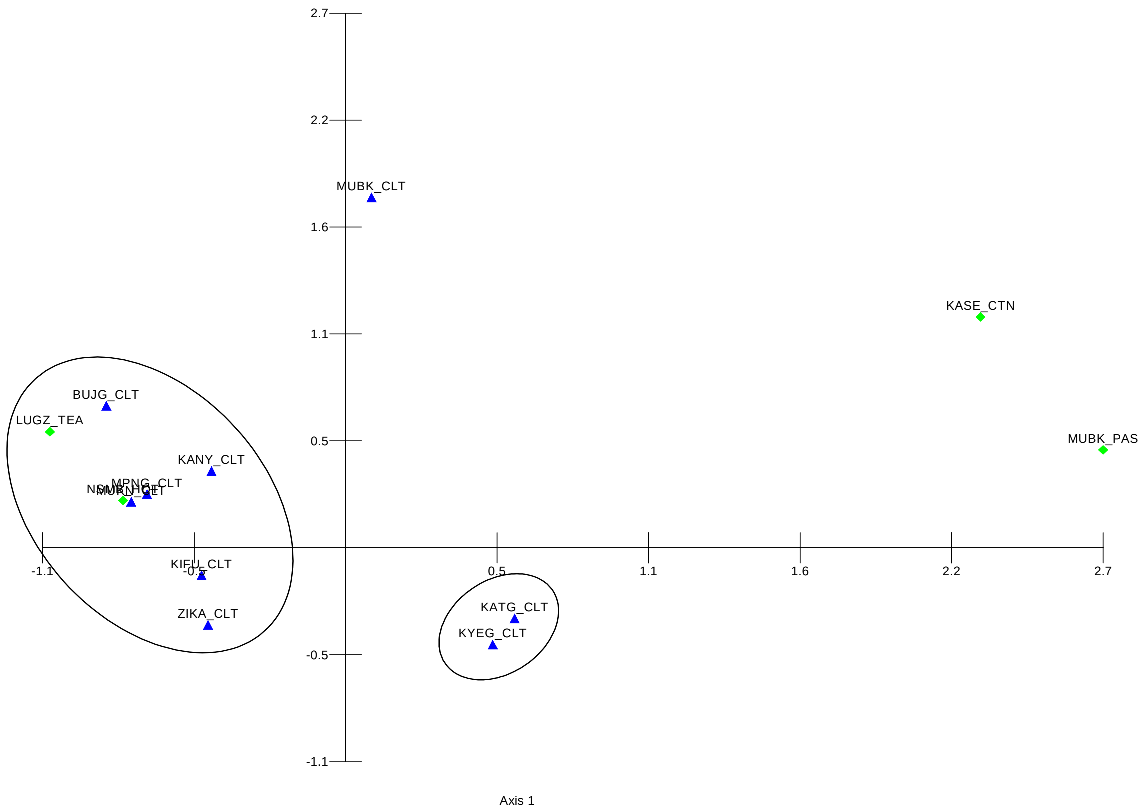
Nsimbe estate had an uncommon land use, consisting mainly of hothouses, compared to the other study sites. Consequently, we mapped a relatively small area due to access problems. The farming activity is mainly horticulture, in particular flower-growing. There were no fallow areas or natural vegetation observed on the site. Some trees were scattered in compounds of the estate housing section.

4. RESULTS FROM THE SURVEY OF WOODY PLANTS

4.1 Woody Plant Species Associations by Site

We undertook a correspondence analysis (a form of cluster analysis, see Section 2.5) on the woody plants data matrix to examine woody plant species associations by site (Figure 4.1). This revealed two main clusters of sites, and three scattered sites (Hima Pasture, Kasese Cotton, and Mubuku). Among the latter, it is interesting to note that Mubuku and Hima Pasture are near to each other and both are Dry *Acacia* Savannas, but nevertheless they have very different assemblages. This may be due to the distinct difference in land use modification – cultivation and pasture – the latter maintaining the site almost in its original state as far as woody plants are concerned. The two other savanna sites, Katugo (Dry *Combretum* Savanna) and Kyegegwa (Moist *Acacia* Savanna), form a small distinct cluster. The largest cluster comprises the remaining smallholder sites and, surprisingly, two large-scale sites, Lugazi Tea and Nsimbe Horticultural. This pattern may be explained by the fact that the original vegetation on all these sites was the same kind of forest, i.e. moist forest/savanna mosaic, according to the vegetation study by Langdale-Brown (1964) (Table 4.1).

Figure 4. 1. Correspondence analysis results for woody plants.



▲ = Small Scale Farms; ◆ = Large Scale Farms

LUGZ_TEA= Lugazi Tea; NSMB_HOT = Nsimbe Horticulture; KASE_CTN = Kasese Cotton; BUJG_CLT = Bujagali Cultivations; MPNG_CLT = Mpanga; KIFU_CLT = Kifu; MUKN_CLT= Mukono; MUBK_CLT = Mubuku; KTG_CLT = Katugo; KANY_CLT = Kanyawara; KYEG_CLT = Kyegegwa; ZIKA_CLT = Ziika; MUBK_CLT = Mubuku; MUBK_PAS = Hima Pasture. Note that Lugazi Sugar was excluded because of the small number of woody plants recorded, which was distorting the results.

4.2 Species Richness

Overall, we recorded a total of 270 woody plant species in all the 14 sites (Table 4.1). Indigenous species were the most dominant (about 70% of the total); and by vegetation establishment trees and shrubs recorded the highest numbers for both indigenous and exotic species.

Table 4. 1. Total number of plant species recorded from study sites

By vegetation establishment	By Origin		Total
	Exotic	Indigenous	
Palms	2	3	5
Shrub	29	87	116
Tree	37	100	137
Woody lianas	0	12	12
Total	68	202	270

Table 4.2 (and Figure 4.2) show the number of woody plant species by site and by the scale of farming and land use type. Clearly, and as expected, large-scale agriculture leads to a considerable loss of woody plant species richness compared to smallholder farming. The Lugazi and Nsimbe sites in addition have a relatively high share of exotics (45% compared to 30% on average for all sites), which is likely to have a negative influence on other forms of biodiversity (e.g. the avifauna). Interestingly, we encountered many more indigenous species in Kasese Cotton than in the other large-scale sites. This could be related to the fact that this site consists of a large block of individual plots managed by smallholders, who are more likely to conserve trees for household uses than are plantation managers. There are also more shrubs there, related to boundary vegetation between plots. The above suggests that woody biodiversity is not only affected by the scale of farming (large versus small scale) but also by farm ownership or management (small farmers versus large companies).

Regarding the eight smallholder sites, a visual interpretation of scatter plots (see appendix 5) revealed no clear associations between cultivation intensity and any of the species richness indicators used here – total number of woody plants or number of shrubs, trees, indigenous plants, or exotic plants (Table 4.2). Only at the extreme ends of the cultivation intensity gradient could an effect be observed. Kyegegwa with a cultivation intensity of only 26% also had the highest number of all woody plants as well as shrubs and indigenous species. Surprisingly, Kyegegwa had less tree species than many much more intensely cultivated sites. This is mainly due to its lack of exotic tree species, while it has a high presence of large indigenous trees (see Table 4.3). At the other extreme, Bujagali recorded very low numbers of total plants, indigenous plants, and shrubs, although Mubuku with an intensity of 72% scored equally low or lower on these variables, and had a much lower number of trees and total plants. It is interesting to note the high species diversity of exotic trees in most smallholder sites, which may reflect that these species are planted and managed by farmers for multiple household uses (see below).

In the absence of extreme cultivation pressures (as in Bujagali and the large-scale sites), high species richness seems to be related to the proximity to natural forests (see Table 1); and the most species rich sites are those that in addition have a good presence of exotics. That said, this proposition is based on a very small number of variables and observations and cannot be tested statistically with the available data. Kifu, a high-intensity smallholder site, had the highest number species (95) of all the sites. The site neighbors a forest, which seems to result in a high presence of indigenous species, and it hosts a good number of exotics. Kyegegwa with 90 species is within 1 kilometer of a moist *Acacia* savanna with forest patches. Mpanga (71 species in total) likewise neighbors a large forest (Mpanga Forest Reserve) and has in addition a high presence of exotic species (29), most of which are conserved for their usefulness. Katugo, a medium-intensity site, recorded the third highest species richness (85) due to the presence of many indigenous species of shrubs and trees common to dry woodlands. Apart from grazing, the woodland section of Katugo remains undisturbed by cultivation, which explains the abundance of indigenous species.

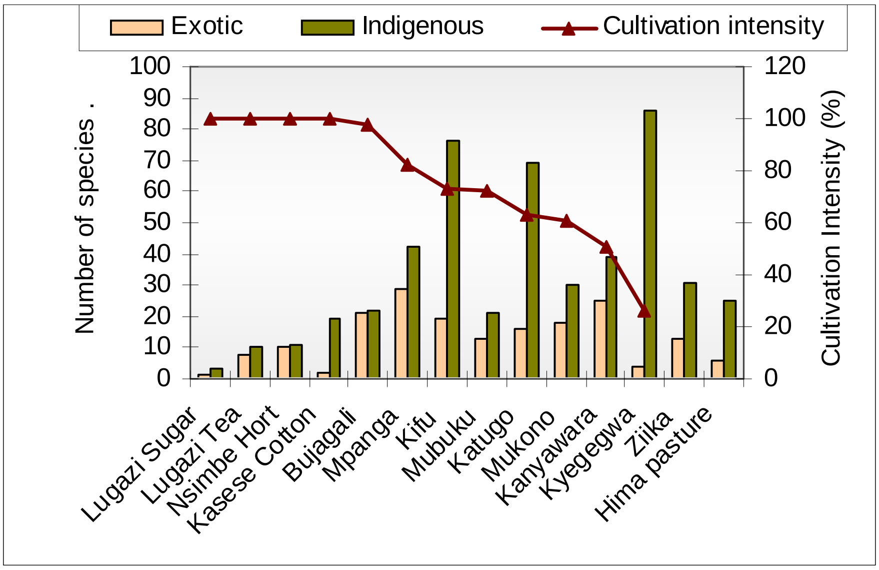
The Hima pasture site had a relatively high number of both indigenous and exotic species for this kind of land use. The pasture appeared to have been cleared quite recently and most of the remaining trees were left to provide shade to the animals.

Table 4. 2. Number of species of woody plants recorded at each site

Scale of farming	Land use type	Site name	Cultivation intensity [1] (%)	By Origin		By Growth Form				Total
				Exotic	Indigenous	Palms	Shrub	Tree	Woody Liana	
Large scale	Commercial plantations	Lugazi Sugar	100	1	3	0	2	2	0	4
		Lugazi Tea	100	8	10	0	4	14	0	18
		Nsimbe Hortic.	100	10	11	3	4	14	0	21
	Individual plots	Kasese Cotton	100	2	19	0	15	6	0	21
Small scale (small holder farms)	High cultivation intensity	Bujagali	98	21	22	0	14	29	0	43
		Mpanga	82	29	42	1	21	49	0	71
		Kifu	73	19	76	0	35	58	2	95
	Medium cultivation intensity	Mubuku	72	13	21	0	18	16	0	34
		Katugo	63	16	69	0	42	42	1	85
		Mukono	61	18	30	1	16	31	0	48
	Low cultivation intensity	Kanyawara	51	25	39	1	18	44	1	64
		Kyegegwa	26	4	86	0	43	39	8	90
	Farmland /pasture	Ziika	NA	13	31	1	16	26	1	44
Pasture	Managed	Hima pasture	0	6	25	0	17	14	0	31

Notes: [1] Cultivation intensity is defined in Section 2 (methods).

Figure 4. 2. Number of exotics and indigenous woody species at each site



4.3 Tree Density and Canopy Cover

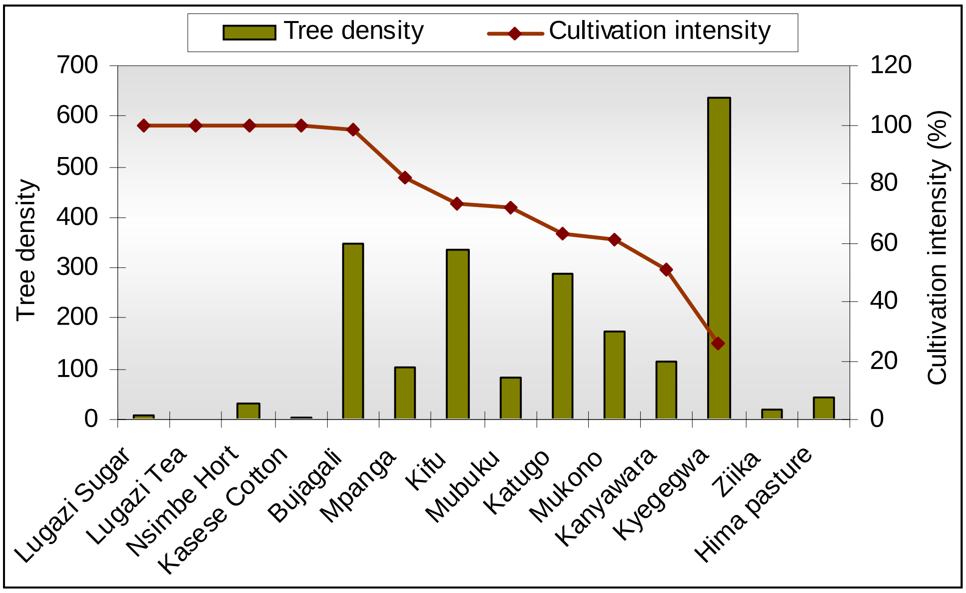
We used tree density (stems per hectare) and percentage canopy cover as measures of the abundance of woody vegetation in the study sites (Table 4.3 and Figure 4.3). Not surprisingly, large-scale farming is associated with very low tree densities and very low canopy covers (<1%) of both the exotic and indigenous species, i.e. the same pattern as for species richness. The smallholder-managed Kasese Cotton was the only large-scale site with a significant number of indigenous plants, while all exotic plants were shrubs, backing up the above argument about the importance for biodiversity of farm management vis-à-vis scale. The higher tree density for Nsimbe is partly due to the sampling procedure we followed at this site. As explained in section 4.2, it was rather difficult to sample the entire site and we ended up in a section that had a higher concentration of trees; but the larger section was occupied by hothouses and had trees.

A visual interpretation of scatter plots for the eight smallholder sites revealed no clear effect of cultivation intensity on tree density or canopy cover (Table 4.3 and Appendix 5). Only at the extreme ends of the cultivation intensity gradient could an effect be observed. As expected, Kyegegwa with only 12.8% cultivation intensity had by far the biggest canopy coverage and tree density, due mainly to its high proportion of natural vegetation.
Canopy cover and tree density in the highest intensity site, Bujagali, were unexpectedly high, and tree abundance in some of the other high or medium intensely cultivated sites – Kifu, Katugo and Mukono – was also high compared to the lower intensity sites. This is mainly due to the relatively high incidence of exotic tree species in those sites; in fact, there seems to be a weak inverse relationship between cultivation intensity and the abundance of exotic trees. The higher importance and abundance of exotic woody plants found in high-intensity sites supports the notion that as farmland as well as natural vegetation gets scarcer, farmers put more effort into planting and maintaining trees on their farms to obtain valuable products such as fruits, building poles and local medicines. Enhanced tree management is in fact part of the intensification process. For example, in Kifu, Mpanga and Bujagali most of the exotic species were fruit trees like *Mangifera indica, Persia americana, Artocarpus heterophyllus,* and *Psidium guajava* that are used as a source of income. Other observed trees were those that are used for agro-forestry purposes such as nurse trees (like *Albizia chinense* and *Jatropha caurcus)* that are planted together with crops like bananas and vanilla.

Table 4. 3. Tree density (stems/ha) and canopy cover (%) per site

Scale of farming	Land use type	Site name	Cultivation intensity (%)	Tree density (stems/ha)	Species canopy cover (%)		
					Exotic	Indigenous	Overall
Large scale	Commercial plantations	Lugazi Sugar	100	6.1	0.06	0.06	0.12
		Lugazi Tea	100	1.2	0.22	0.25	0.47
		Nsimbe Hortic.	100	32.6	0.29	0.35	0.64
	Individual plots	Kasese Cotton	100	4.4	0.00	0.04	0.04
Small scale (small holder farms)	High cultivation intensity	Bujagali	98	346.2	2.93	5.12	8.05
		Mpanga	82	103.3	3.13	2.67	5.80
		Kifu	73	334.8	2.46	4.58	7.05
	Medium cultivation intensity	Mubuku	72	83.5	1.81	0.94	2.75
		Katugo	63	286.8	0.88	3.14	4.03
		Mukono	61	174.7	2.44	6.29	8.74
	Low cultivation intensity	Kanyawara	51	116.3	1.86	1.02	2.88
		Kyegegwa	26	635.2	0.20	12.59	12.79
	Farmland/pasture	Ziika	NA	19.9	0.46	0.95	1.41
Pasture	Managed	Hima pasture	0	44.3	0.10	0.99	1.10

Figure 4. 3. Tree density in relation to cultivation intensity in the study sites



Tables 4.4 and 4.5 show the number of stems by diameter class for exotic and indigenous species respectively. Saplings, shrubs and small trees (2.5 – 19.9 cm) dominate the woody plants in all sites, and there is a distinct decline in the number of stems from these classes to the next one up (20 – 29 cm), especially for indigenous species. This reflects the general immaturity of the vegetation (except at Kyegegwa) related to the generally short fallow

cycles that do not allow for the development of larger shrubs and trees (see Table 4.7). It also suggests that farmers remove field trees when they reach a size where they start to attract bird pests and compete for light and water with crops.

Very few large trees are found on the large-scale sites, the Kasese cotton site being a noticeable exception, as discussed above. Expectedly, among the smallholder sites Kyegegwa had by far the highest incidence of large indigenous trees and hardly any exotics, and in some places the vegetation resembled that of a mature forest. However, in the high-intensity sites of Bujagali and Kifu we also found a relatively high number of medium sized (30 – 39 cm) and large (>40 cm) trees, half of which were exotics. As earlier discussed, this may reflect the trend towards enhanced tree planting and conservation as land scarcity becomes more extreme. For example, we observed that farmers in these sites had planted species like *Markhamia lutea* in the fields for use as poles and firewood. Such strategies may be adopted in lieu of planting woodlots, which requires more space.

Table 4. 4. Count of stems of *exotic* species, by stem diameter

Scale of farming	Land use type	Site name	Cultivation intensity (%)	Sapling	Stem diameter (cm)					
					2.5-9.9	10-19.9	20-29.9	30-39.9	≥40	Total
Large scale	Commercial plantations	Lugazi Sugar	100	0	0	2	4	0	0	6
		Lugazi Tea	100	0	26	17	3	3	1	50
		Nsimbe Hortic.	100	0	17	12	9	2	19	59
	Individual plots	Kasese Cotton	100	0	21	0	0	0	0	21
Small scale (small holder farms)	High cultivation intensity	Bujagali	98	27	115	86	30	17	16	264
		Mpanga	82	12	33	39	18	5	8	103
		Kifu	73	6	67	39	24	11	4	145
	Medium cultivation intensity	Mubuku	72	1	18	48	9	3	18	96
		Katugo	63	27	58	47	9	10	2	126
		Mukono	61	6	9	43	25	9	4	90
	Low cultivation intensity	Kanyawara	51	23	13	33	29	9	19	103
		Kyegegwa	26	0	4	6	0	0	0	10
	Farmland /pasture	Ziika	NA	14	16	7	11	16	0	50
Pasture	Managed	Hima pasture	0	4	11	0	0	0	0	11
Total				120	408	379	171	85	91	

Table 4. 5. Count of stems of *indigenous* species, by stem diameter

Scale of farming	Land use type	Site name	Cultivation intensity (%)	Sapling	Stem diameter (cm)					
					2.5-9.9	10-19.9	20-29.9	30-39.9	≥40	Total
Large scale	Commercial plantations	Lugazi Sugar	100	0	0	0	0	0	0	0
		Lugazi Tea	100	7	1	6	2	0	3	12
		Nsimbe Hortic.	100	0	0	1	9	2	2	14
	Individual plots	Kasese Cotton	100	0	41	19	17	13	0	90
Small scale (small holder farms)	High cultivation intensity	Bujagali	98	64	259	220	54	15	15	563
		Mpanga	82	29	52	9	4	6	8	79
		Kifu	73	169	394	101	19	12	7	533
	Medium cultivation intensity	Mubuku	72	25	22	18	1	1	0	42
		Katugo	63	132	233	81	30	7	11	362
		Mukono	61	10	101	72	23	8	9	213
	Low cultivation intensity	Kanyawara	51	39	90	27	3	2	6	128
		Kyegegwa	26	167	296	202	100	78	92	768
	Farmland /pasture	Ziika	NA	11	13	19	18	12	9	71
Pasture	Managed	Hima pasture	0	2	18	28	14	6	10	76
Total				**655**	**1520**	**803**	**294**	**162**	**172**	

4.4 Woody Plants for Human Use

The common uses of the recorded woody plant species in each site were categorized according to type of use by the forester on the research team (Table 4.6). The number of uses is greater than the number of recorded species because many species have more than one use, for example many timber species also provide shade, firewood, poles and medicine. The large number of useful species at each site (except perhaps Mubuku) is striking and draws attention to the economic importance of woody plants (see, e.g. Baldascini 2002). Most species are used for either firewood or poles. About half as many are suitable for ornamental, medicinal and timber purposes, while only a few species provide shade and fruits.

A significant number of agro-forestry species were found in all sites. Interestingly, the most intensely cultivated sites had the highest number species suitable for agro-forestry, which supports the hypothesis on the positive relationship between land scarcity and enhanced tree management discussed above.

As expected, the large-scale sites include very few woody plant species for human use compared to the smallholder sites (Table 4.6). Among the latter, no relationship was found between cultivation intensity and total number of uses of woody plants in a visual interpretation of scatter plots (Table 4.6 and Appendix 5). The number of uses is obviously closely related to species diversity, which we discussed in Section 4.2. Kifu, a high-intensity site, had the highest number of uses (235), corresponding to a high number of indigenous species (76) associated with the proximity to a forest, coupled with a fair number of exotic species, which are commonly conserved for their usefulness. Katugo, a medium-intensity site, recorded the next highest score (205) due to the presence of relatively many small-sized trees and shrubs that have multiple purposes such as firewood and poles. Mpanga (185 uses) likewise neighbors a large forest (Mpanga Forest Reserve) and has in addition a high presence of exotic species (29). As expected, Kyegegwa records many uses (180) due to the dominance of natural vegetation with mainly indigenous species (86).

Table 4. 6. Number of uses of woody plant species in each site, by type of use

Scale of farming	Site name	Type of use							
		Medi-cines	Timber	Fruits	Poles/ firewood	Orna-mental	Shade	Agro forestry	Total uses
Large scale	Lugazi Sugar	3	1	2	4	4	1	1	16
	Lugazi Tea	10	8	6	16	15	7	4	66
	Nsimbe Hortic.	8	9	5	17	16	6	6	67
	Kasese Cotton	5	2	0	16	6	4	2	35
Small scale (small holder farms)	Bujagali	20	17	8	30	28	8	15	126
	Mpanga	20	33	12	53	41	10	16	185
	Kifu	28	37	10	81	44	16	19	235
	Mubuku	17	9	5	26	20	7	9	93
	Katugo	30	24	14	68	38	21	10	205
	Mukono	21	14	8	30	22	11	11	117
	Kanyawara	26	27	6	50	38	15	9	171
	Kyegegwa	23	22	6	82	22	16	9	180
	Ziika	17	17	7	31	25	6	6	109
Pasture	Hima Pasture	9	6	3	26	11	13	3	71

4.5 Woody Plants in Fallows

We used the woody vegetation data to characterize the quality of fallows in smallholder farms in terms of the maturity of the vegetation. As shown in Table 4.7, in all sites but Kyegegwa most fallow shrubs and trees were very small (2.5 – 10 cm in diameter) and hardly any were larger than 20 cm. This is consistent with the observed short fallows (Chapter 3) that do not allow for mature vegetation to develop before they are cleared for cultivation. The exception is Kyegegwa, which had fallow patches with a considerable number of medium-sized and large trees, although the 2.5–10 cm class still dominated. A list of the most common tree species in fallows is provided in Appendix 6.

Table 4. 7. Number of woody plants on fallow land in smallholder sites, by stem diameter

Smallholder site name	Cultivation intensity (%)	Average fallow age	Stem diameter (cm)					Total
			2.5-9.9	10 – 19.9	20 – 29.9	30 - 39.9	>40.1	
Bujagali	98	1.63	2	4	1	0	0	7
Mpanga	82	3.00	26	7	6	3	2	44
Kifu	73	4.30	23	9	1	3	1	37
Mubuku	72	2.70	0	0	0	0	0	0
Katugo	63	3.43	54	20	0	0	2	76
Mukono	61	4.63	23	8	3	1	0	35
Kanyawara	26	4.43	0	0	0	1	0	1
Kyegegwa	51	7.82	70	56	21	14	6	167

5. RESULTS FROM THE BIRD SURVEYS

5.1 Introduction

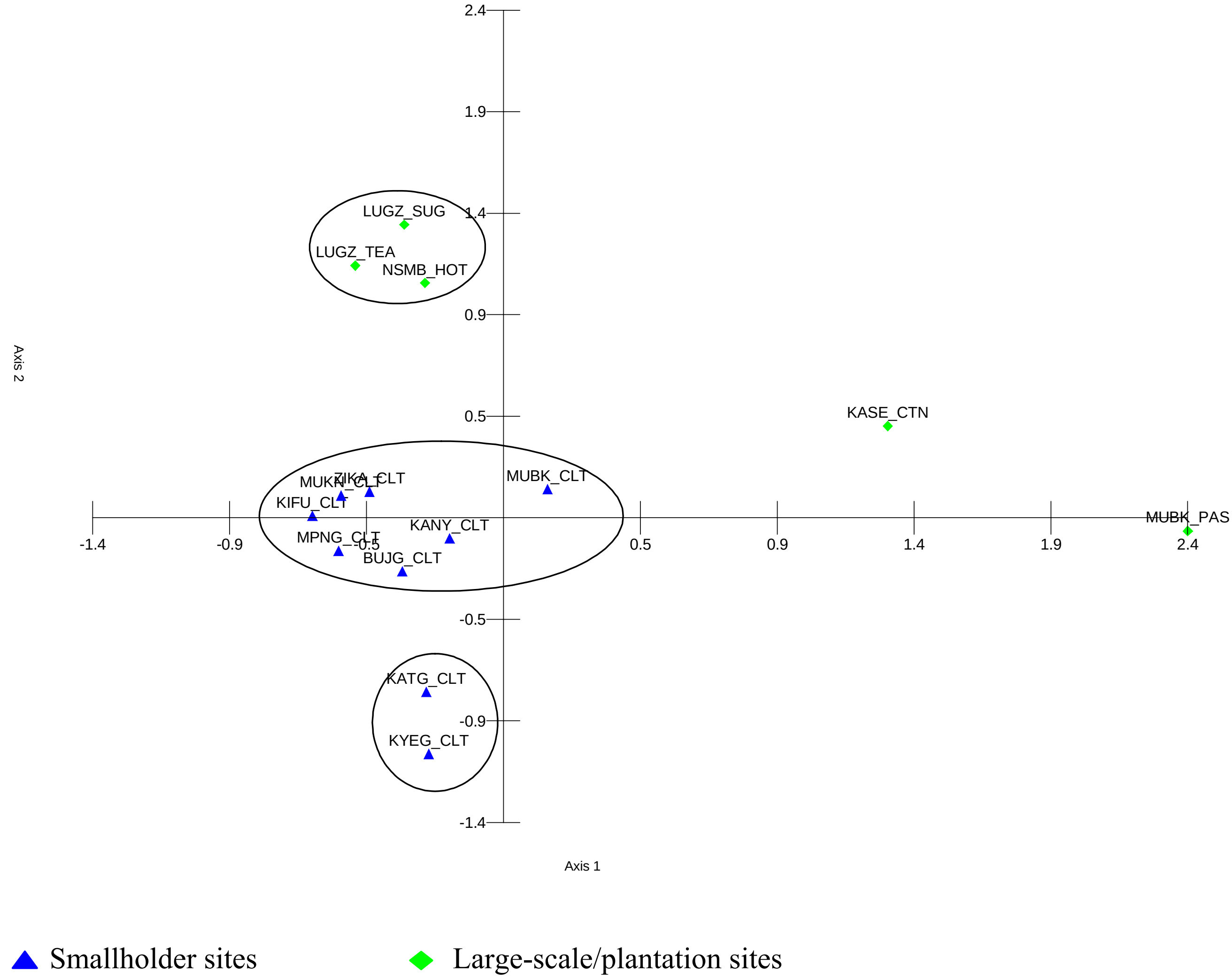
As we described in Chapter 1, eight of our sites were selected because we already have bird data for them from previous years – up to 16 years for some sites – thus allowing us to look for trends over that period of time. Altogether, we recorded a total of 241 bird species, representing almost a quarter of the total for Uganda. Unlike the plants – both crops and trees – all of the bird species are indigenous. The Angola Swallow, Common Bulbul, African Thrush, Grey-backed Camaroptera, and Bronze Mannikin were found at every site, and the Tawny-flanked Prinia missed only one (Appendix 9), where scientific names are given). On the other hand, 69 species were recorded from only a single site.

A total of 1014 bird species have been recorded in Uganda (Carswell *et al*, in press), but many would not be expected at our sites. For instance the list includes 189 forest interior birds and 232 waterbirds (Wilson 1995), as well as a good number that are largely restricted to the drier north and north-east. Hence our total of 241 represents a good proportion of the remaining 593. But the presence of so few (only ten, or 5%) of the forest specialist species, mostly in very small numbers, confirms Naidoo's (2004) observations that these species are, as expected, very largely confined to forest, a point to which we shall return in the next section.

5.2 An Overview of the Bird Communities

Seven of the smallholder sites had very similar sets of bird species, despite a geographic spread of more than 400 km, as shown by the correspondence analysis (in effect, a form of cluster analysis) in Figure 5.1. (Our analyses are described in Section 2.5). The other two smallholder sites (Katugo and Kyegegwa) are both in areas of 'bush' with relatively recent clearings for growing crops, and their separation resembles that for woody plants (Figure 4.1). The five remaining large-scale sites were clearly very different from the smallholdings; among the former the three plantations in particular resembled each other. The three main clusters correspond to three levels of intensification, and clearly demonstrate that it changes bird communities, and shows the cotton and pasture sites to be quite different from any of the others.

Figure 5. 1. Correspondence analysis results: birds and sites.



LUGZ_TEA= Lugazi Tea; LUGZ_SUG = Lugazi Sugar; NSMB_HOT = Nsimbe Horticulture; KASE_CTN = Kasese Cotton; BUJG_CLT = Bujagali; MPNG_CLT = Mpanga; KIFU_CLT = Kifu; MUKN_CLT= Mukono; MUBK_CLT = Mubuku; KTG_CLT = Katugo; KANY_CLT = Kanyawara; KYEG_CLT = Kyegegwa; ZIKA_CLT = Ziika; MUBK_CLT = Mubuku; MUBK_PAS = Hiima Pasture.

5.3 Species Richness

The numbers of species actually recorded at individual sites varied considerably (Table 5.1), partly because of different numbers of counts. As described in Section 2.4, we used two methods to estimate total species richness – that is, the numbers of bird species that might be recorded from an indefinite number of counts. As agriculture intensifies, estimates from both methods show a steep decline in the numbers of species (Table 5.1). Amongst the smallholder sites, the less intensively cultivated have about 40% more species than the more intensive ones, whilst the commercial monocultures have only a third of the species of low intensity small farms. But although the difference between the sites in the 'High' and 'Medium' intensity groups is small, overall it is clear that agricultural intensification is associated with species loss. This suggests that many species are unable to adapt to changing land use.

Table 5. 1. Observed and estimated species richness of birds for each site, based upon one-hour Times Species Counts (TSCs, Section 2.4)

Scale of farming	**Land use type**	**Site name**	**Total TSCs**	**Total species observed**	**Jack 1 estimate**	**Chao 2 estimate**	**Estimates for groups [a]**	
							Jack 1	Chao 2
Large scale	Commercial plantations	Lugazi sugar	9	36	43	39	43	55
		Lugazi tea	10	26	33	32		
		Nsimbe horticulture	10	43	52	93		
	Individual plots	Kasese cotton[b]	7	57	77	77	77	77
Small scale (smallholder farms)	Higher cultivation intensity	Bujagali	9	82	113	133	104[c]	111[c]
		Mpanga	19	81	100	103		
		Kifu	18	79	98	96		
	Medium cultivation intensity	Mubuku	9	85	116	123	102[c]	103[c]
		Katugo	13	101	134	130		
		Mukono	10	55	57	56		
	Lower cultivation intensity	Kanyawara	20	98	125	131	143[c]	148[c]
		Kyegegwa	12	133	180	192		
	Farmland/pasture	Ziika	18	96	124	121		
Pasture	Improved	Hima pasture	7	69	96	97	96	97

Notes: [a] Groups of sites, [b] Smallholders all growing cotton, [c] High, medium and low intensities

5.4 Distribution of Bird Categories by Site and Land use

As explained in Section 2.4, birds have frequently been separated into a number of categories, mainly based upon habitat characteristics (tree birds, water birds, grassland birds and aerial species) or importance (as in the case of Red Data species, and sunbirds). For each category and each type of land use, we have data on numbers of species and of individual birds (the latter reflected by lambda values) (Table 5.2). We have used averages in this table, because of the differing numbers of sites in each group, and of counts per site.

Table 5. 2. Average numbers of bird species and lambda scores for various categories of birds and of land use. The lambda values are a measure of the numbers of individual birds.

Bird species category[a]		Average number of species[b]				Average summed lambda values			
		Large scale		Small scale		Large scale		Small scale	
		Commercial plantations (n = 3)	Individual cotton plots (n = 1)	Smallholder farms (n = 9)	Pasture (n = 1)	Commercial plantations (n = 3)	Individual cotton plots (n = 1)	Smallholder farms (n = 9)	Pasture (n = 1)
'Tree birds'	FF	0	0	2	0	0.000	0.000	0.005	0.000
	F	4	3	15	1	0.026	0.005	0.113	0.003
	f	13	15	34	18	0.245	0.183	0.323	0.306
	All	*17*	*18*	*51*	*19*	*0.271*	*0.188*	*0.441*	*0.309*
Waterbirds	WW	0	1	2	2	0.000	0.003	0.013	0.008
	W	9	12	13	7	0.209	0.149	0.094	0.098
	All	*9*	*13*	*15*	*9*	*0.209*	*0.152*	*0.107*	*0.106*
Grassland birds	GG	4	13	6	11	0.042	0.109	0.017	0.150
Aerial species	AA	3	5	9	8	0.082	0.021	0.059	0.055
Migrants	A	1	6	5	5	0.023	0.047	0.020	0.084
	Ap	1	1	1	1	0.009	0.002	0.008	0.009
	P	3	8	5	6	0.021	0.062	0.019	0.049
	All	*5*	*15*	*11*	*12*	*0.053*	*0.111*	*0.047*	*0.136*
Red Data species		0.3	0.0	3.0	4.0	0.001	0.000	0.017	0.019
Sunbirds		2.0	0.0	7.2	1.0	0.019	0.000	0.060	0.034

Notes a the categories are fully explained in Table 2.3 c *n* is the number of sites in the group

b to the nearest whole number, except for Red Data species and sunbirds, which are few

The 241 bird species listed in Appendix 9 represent 24% of the Ugandan total, according to Carswell *et al* (in press). However, of the species that we observed, the proportions belonging to the various bird categories vary considerably (Table 5.3). In every case, the proportion recorded in the large-scale, high intensity farms is lower than that for smallholder farms, and particularly so for the more specialized species. This highly significant result (P<< 0.001, Sign Test) can only partly be explained by the higher number of counts on smallholder farms (9 sites, 127 counts, Table 5.1) compared to 36 counts on the four large-scale farms. This is because species accumulation curves fall away rapidly towards an asymptote.

Table 5. 3. Numbers of species of birds in various categories (as defined in Section 2.4) on intensive and smallholder farms, in relation to the total numbers recorded in Uganda.

Main category	Code	Total for Uganda	On large scale farms (n = 4)		On smallholder farms (n = 9)	
			No.	% of total	No.	% of total
'Tree birds'	FF	189	0	0	10	5
	F	127	10	8	43	34
	f	112	30	27	65	58
	All	*428*	*40*	*9*	*118*	*26*
Waterbirds	WW	160	1	1	6	4
	W	72	18	25	30	42
	All	*232*	*19*	*8*	*36*	*16*
Grassland birds	GG	71	15	21	16	23
Aerial species	AA	37	9	24	18	49
Migrants[a]	A	56	8	14	13	23
	P	134	8	6	15	11
	All	*190*	*16*	*8*	*28*	*15*
Red data species	R-CR	1	0	0	0	0
	R-EN	14	0	0	0	0
	R-VU	59	0	0	2	4
	R-NT	69	0	0	1	1
	R-RR	54	1	1	8	15
	All	*192*	*1*	*1*	*11*	*6*
Sunbirds		35	4	11	11	31

Notes: a only the main categories (there are very few *Ap* and *p* species)
b Mainly from Carswell *et al* (in press) and Appendix 9.

Regardless of the number of counts, or the type of farm, the proportions of specialized tree birds and waterbirds are far fewer than the less specialized ones – in the case of 'non-forest tree birds' (f) species, more than half of the Ugandan total occurred in our counts on smallholder farms, while 27% occurred on large scale farms. Whilst that suggests the favourable conservation value of smallholder farming compared to plantation agriculture, these less specialized species are mostly widespread, often common, and generally at no risk of extinction at present.

Amongst the specialist categories (Table 5.2 and 5.3), aerial-feeding birds are best represented, with nearly half of the Ugandan species on smallholders farms. This compares with 23% of the grassland species – which are characteristic of savannas – and 4 and 5% respectively for specialists water and forest birds.

Tree birds It is interesting to note the quite high number of forest birds (FF, F) observed on smallholders' farms, compared to the very few observed in large scale systems. Most were forest generalists (F): the few forest specialists (FF) were mostly recorded at sites close to forest (Table 1.1), and tended to be species with seasonally fluctuating food supplies, such as Grey Parrots, which commonly fly over Kampala on their way from one forest to another.

Waterbirds The presence of waterbirds at agricultural sites is at first surprising, but most are simply water-associates (W), such as Black-headed Heron and Barn Swallow (Table 5.2); the few specialists (WW) occur at low levels of abundance, as shown by their small lambda scores. Most of our sites were quite close to permanent water (Table 1.1).

Grassland birds Sugar, horticultural and cotton crops support quite large numbers of grassland species (GG), such as widowbirds. This is not altogether surprising, because sugar is a tall grass, the horticultural farm had large grassy areas around the hothouses, and the cotton fields adjoin the grasslands of Queen Elizabeth National Park.

Aerial species This category (AA) includes especially the various species of bee-eaters and swallows, which occurred at all sites, and were sometimes numerous over commercial farm land.

Migrant birds Farms of all sorts support few migrants of any species other than Barn Swallows (Table 5.2; note the low lambda values and (Table 5.3) the low proportions) and those that do occur are found particularly on smallholder farms and usually in small numbers.

Red Data species Almost by definition, these are highly-specialised birds. No globally-threatened species was recorded, and for the regionally-listed species, none was Critical or Endangered (Table 5.3). As one would expect, cultivated areas contribute little – compared to pastoral lands and Protected Areas – when it comes to species of high conservation concern.

Sunbirds Amongst the 'goods and services' provided by 'wild biodiversity' is pollination; and sunbirds are thought to be important pollinators of crop plants (Bob Cheke, pers. comm.). On average, there were far fewer of these species in intensively-cultivated crops (where, of course they may not be needed) compared to smallholder farms.

Summary

Although the total numbers of species drop markedly with increased intensity of agriculture (and that applies to most of the categories of species as well), we have only limited evidence for a decline in the total amount of birdlife, as represented by lambda scores. But the decline in all categories of 'tree birds' and most migrant categories suggests that a larger data set might well show statistically significant changes.

5.5 Predicted Versus Recorded Number of Bird Species

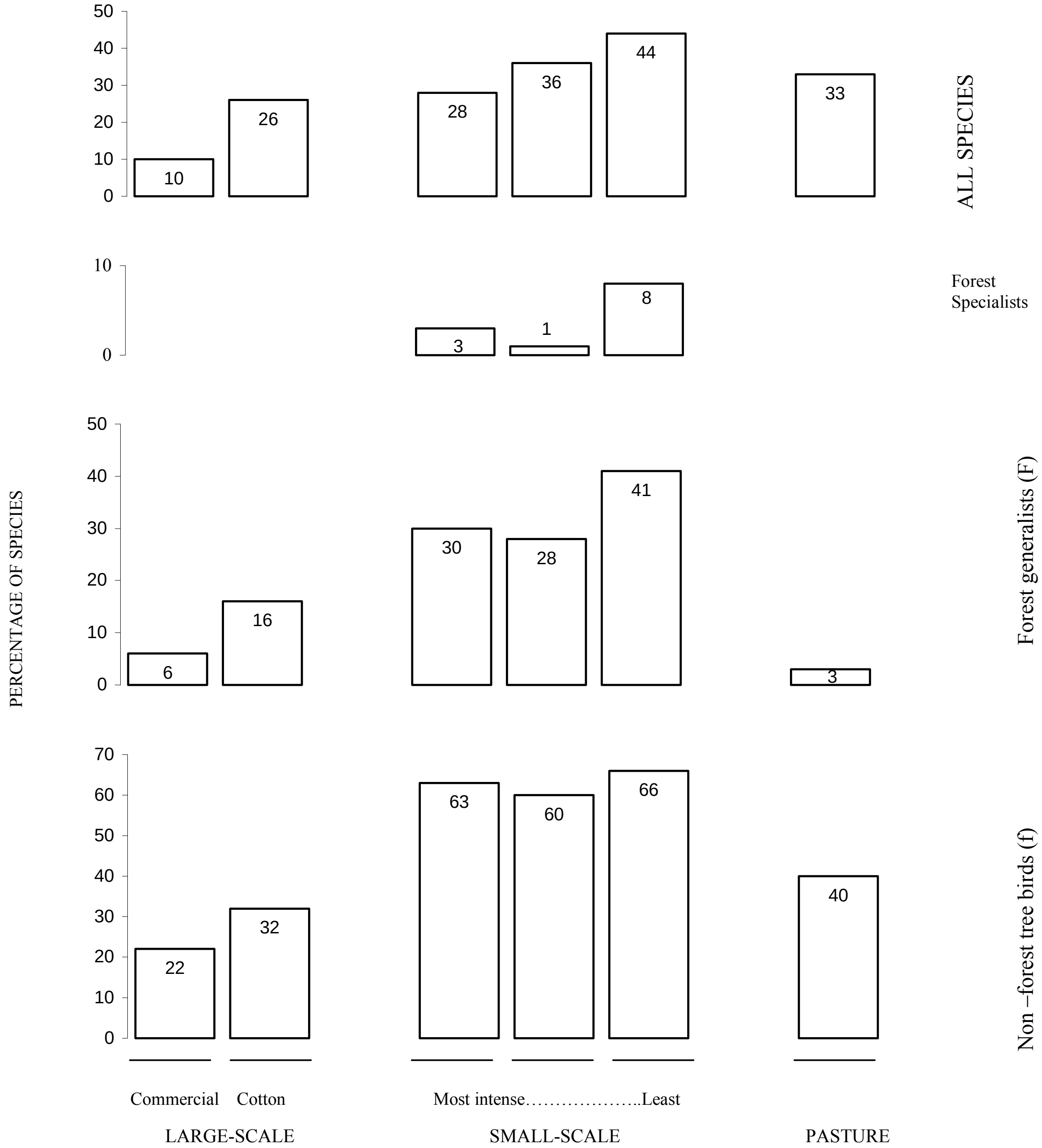
The National Biodiversity Data Bank (NBDB) at MUIENR developed a program (known as BDB – Biodiversity Data Bank) for predicting the places where a species is likely to occur in Uganda, based upon the actual rainfall and the vegetation map of Langdale-Brown *et al* (1964) for places where it actually does occur (see Tushabe *et al*, 2001, for a detailed description). This procedure can only be used for the approximately 500 common, non-waterbirds of the 1000-plus Ugandan species. Here, we have used it to predict, for each site, which species would be expected to occur there. (The Uganda bird atlas (Carswell *et al,* in press), shows the results of this procedure for these species). This allowed us to generate lists for each site, and to compare them with our own lists (counts) from the field as shown in Figure 5.2. These show similar trends to the data in Table 5.3, but bring out very clearly the kinds of birds – specialists – which are most poorly represented in agricultural areas.

There was only one site where more than half of the species predicted were actually recorded. This was Kyegegwa, the small-scale farming site with the highest proportion of natural vegetation. There are several reasons why so few predicted species were actually recorded, notably:

1. The predictions are based upon the original natural vegetation, much of which has now gone, although to varying degrees (least at Kyegegwa, of our sites).
2. As Table 5.1 shows, the estimated species richness today exceeds the recorded numbers because we had insufficient counts to capture all of the species, especially those that are rare or nocturnal.

3. The number of counts per site varied (Table 2.2).

Figure 5.2. The percentage of species actually recorded, compared to the numbers predicted, for large and small-scale agricultural sites, and pasture. The first two categories are subdivided; details of these two and other points are in the text.



Although the second and third of these reasons are important, and affect the results to a certain extent, the first is likely to predominate – so we have made the not unreasonable assumption that it explains most of the differences between the predicted and observed lists.

Whilst these points need to be born in mind, Figure 5.2 above shows some striking differences between land-use categories, notably:

1. Very few of the predicted species (only 10% of them) occur in large-scale commercial sites, compared to 44% in the least intensively cultivated small-scale farms.
2. No forest specialists (FF) and few forest generalists (6%) were found in the large-scale commercial sites, compared to 8 and 41% respectively in the least intensively cultivated small-scale farms.
3. Even the non-forest tree birds (f) which require some trees but not forests, only reached 22% of those predicted in commercial estates, but over 60% in the small-scale farms.

Hence there is strong corroborating evidence for progressive loss of species with increasing agricultural intensity, particularly in combination with large-scale plantation agriculture, and, most importantly, virtual absence of forest specialist species even from the least intensively-cultivated areas. The essential importance of conserving large areas of natural forest could not be more clear. However, it is only for the non-forest tree birds (f) that the trend is significant, confirming the observation above from Table 5.4. Interestingly, it has recently been shown that tree cover on smallholder farms in central and eastern Uganda increased from 23 to 28% between 1960 and 1995 (Place and Otsuka, unpubl.). The area of that study overlaps ours, and the increase in tree cover by about a fifth, although lower than that for tree birds, is of a similar order and may partly explain our observations.

5.6 Changes in Bird Numbers over Time

For the nine smallholder sites, we can examine trends over a period of 8-16 years (the length of time varies between sites), using simple regressions. Table 5.4 shows the results, with species summed according to the categories explained in Table 2.3. Relatively few categories of birds showed significant trends (12 out of 76 possible, at $P \leq 0.05$), but considering the table as a whole, the number of categories/site showing an increase was fewer than the number decreasing, by 32 to 44, which is approaching a significantly greater number of declines. At Kifu, all trends were negative, which is significant ($P = 0.05$, Sign test), as is the fact that f-species increased at eight sites out of nine ($P = 0.05$).

Table 5. 4. Trends in bird numbers over the last 8-16 years in smallholder sites:[b] values of *t* for the main categories of birds[a]. A dash (-) indicates that there were none.

Relative cultivation intensity	Sites	Tree birds			Waterbirds				Migrants[a]	
		FF forest specialist	F forest generalists	f non-forest	WW Specialists	W Generalists	Grassland birds	Aerial species	A Afrotropical	P Palearactic
Higher	Bujagali	-	0.60	0.46	-0.43	-0.77	1.04	0.65	-1.47	2.02*
	Mpanga	0.98	-1.11	3.87***	3.17**	-0.67	-0.87	-0.18	0.84	-3.32**
	Kifu	-1.44	-0.22	-0.29	-1.42	-0.89	-0.38	-0.05	-0.99	-
Medium	Mukono	0.01	-1.27	0.23	-0.72	-0.93	1.60	0.00	-1.18	-
	Mubuku	-	-1.14	1.68*	-1.01	-0.78	-1.85*	-2.04**	-0.21	0.65
	Katugo	-	0.74	0.01	0.28	0.19	-1.05	-1.93*	-0.58	-0.43
Lower	Kanyawara	0.75	2.02*	0.06	-1.73	-1.30	1.71*	-2.66	-0.68	-2.49*
	Kyegegwa	-1.15	-0.34	0.97	1.74	0.53	-1.24	-0.32	-2.13*	-1.16
	Ziika	-0.73	0.15	3.13**	2.01*	2.92**	-0.31	4.00***	-0.96	0.02

Note a: Data for the few *Ap* and *p* species are given in Appendix 7.

b: A more detailed version of these results is given in Appendix 9.

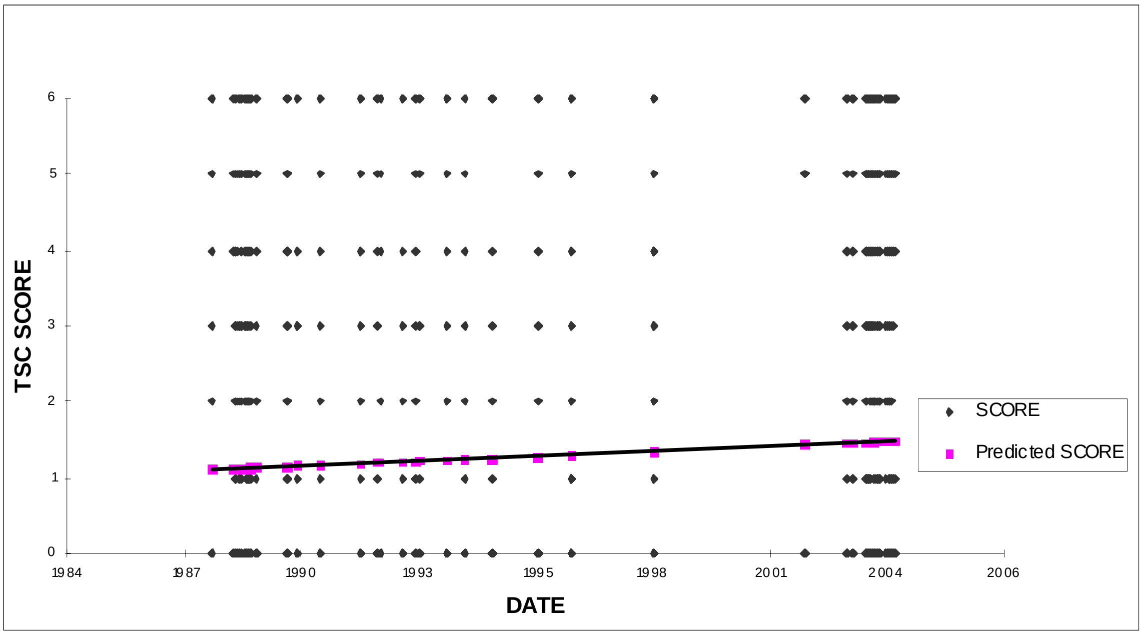
Overall, most categories of birds in smallholder sites seem merely to be showing the usual ups and downs of any bird population. This was confirmed when we explored the data for 'tree birds' in more detail, by combining the TSC scores (abundance) for all sites, thus creating a very large data set which suggests that each category is in fact increasing, albeit slowly (Table 5.5, Figure 5.3). However, it is only for the non-forest tree birds (f) that the trend is significant, confirming the observation above from Table 5.4. Interestingly, it has been shown that tree canopy cover on agricultural land in southern Uganda increased from 0.23 to 0.28 between 1960 and 1995 (Place and Otsuka, 2000). The increase in f-birds has been about 2% per year over approximately similar periods.

Table 5. 5. Regression analyses for tree birds with time, pooling data for all smallholder sites, showing F (analysis of variance) and P (probability) values. The predicted scores are the results of a regression analysis of the full data set.

		n	F	P
Specialists	FF	281	0.41	ns
Generalists	F	2038	0.69	ns
Non-forest	f	3970	21.75	<<0.001

Note: A more detailed version of these results is given in Appendix 8.

Figure 5.3. The abundance of non-forest tree birds, as measured by 3970 TSC scores, has shown an increase in smallholder sites. The predicted scores are the results of a regression analysis of the full data set.



5.7 Summary / Discussion

Observations from both low ad high-intensity farmlands (Section 5.4) largely confirm the relations between actual and observed species (Section 5.5) in showing that it is primarily the more specialized species that disappear with intensification. A likely cause is that the specialists are less adaptable.

The only major environmental change over time which has been documented in these areas is an increase in tree cover. Out observation that all three categories of 'tree birds' on smallholder farms showed a similar increase in time is strongly suggestive of a cause-and-effect relationship and provides strong support for agroforestry as a contributory factor in bird conservation in the countryside.

6. BIRDS, TREES AND AGRICULTURAL LAND USE

6.1 Introduction

We have seen in Chapter 5 how numbers of species are reduced by agricultural intensification, although numbers of individual birds may actually increase. In other words, a few species benefit from the process. However, these generalizations do not hold true equally for all categories of birds.

In this chapter, we look for relationships between the numbers of birds and some of the variables in their environments – these being agricultural and land use features, and the trees, and we consider which species are most involved. All birds require food and nest sites, and somewhere to roost at night (very few roost on their nests outside the breeding season). Some birds feed on crops, to the extent that they can become pests. Others feed on fruits of native trees, such as figs or cultivated ones like pawpaws. Many eat insects, and contribute to pest control. Each of the many species differs from each of the other in some respects.

Here of course we can only look at broad features of the birds' environments – the numbers of crops being grown, or the extent of the tree canopy, for example.

6.2 The Response of Birds to Land use Intensity

In this section, we look both at the different bird categories (and the numbers of species involved) and their abundance, and relate this first to the agricultural data before moving to the trees. Our underlying hypothesis is that increasing cultivation intensity reduces the diversity of birds (as measured by species richness) by reducing the extent and quality of natural vegetation, which represent important components of bird habitats. We also expect that there will be a link between crop diversity and that of birds, since many studies have shown that habitat heterogeneity increases diversity.

So firstly, we have correlated bird abundance (as represented by summed lambda values) with the measure of cultivation intensity described in Section 2.2. The lambda scores for each species at each site are taken from Appendix 9.

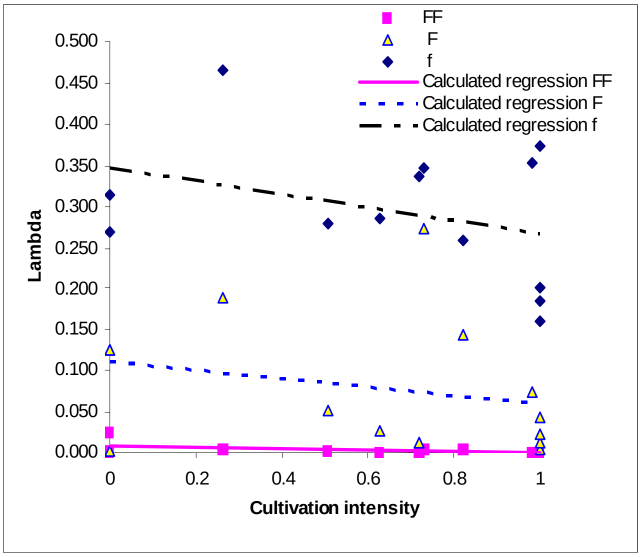
The results are shown in Figure 6.1 and Table 6.1 for the main categories of birds. Overall, there are few correlations, but some are worthy of comment. All sites are derived from an original vegetation of forest or savanna (Table 2.1), so they would not be expected to be of importance for wetland specialists. The positive trend with non-specialist (W) waterbirds (Figure 6.1B) results partly from the attraction of the open spaces in the intensively-cultivated sites to species such as Black-headed Heron, Hadada and Barn Swallow. Uganda receives relatively small numbers of migrants (although of many species, Carswell *et al*, in press). By far the most important group of birds are those using trees. Notice, in Figure 6.1A, that the lambda scores for non-forest tree species (f) are around 0.3, but much lower for all other groups – except generalist waterbirds (W) (Figure 6.1B) – on average, they are below 0.1 (Figure 6.1 A – E).

For all three categories of tree birds, where future options in land management might have their greatest impact, there is a negative trend with increasing agricultural intensification. At present, our results are not statistically significant (Table 6.1) except perhaps for the forest specialists (FF) (which in any case are already very rare), but this would be likely to become clearer with a larger data set.

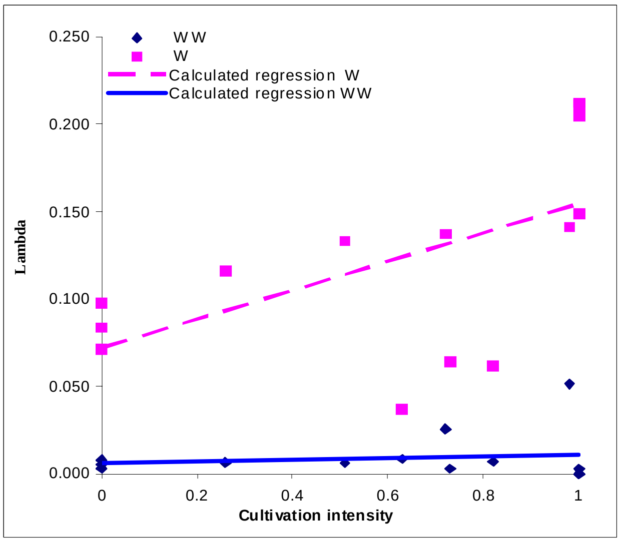
The more intensively-cultivated sites include a variety of grassy areas, and the sugar cane in particular attracts widowbirds and cisticolas.

Figure 6. 1. Scatter diagrams and fitted regressions showing summed lambda values for various categories of birds compared to intensity of cultivation. Details of the calculated regressions are given in Table 6.1, and the categories of birds are explained in Table 2.3. Note the ranging scales on the axis for lambda values.

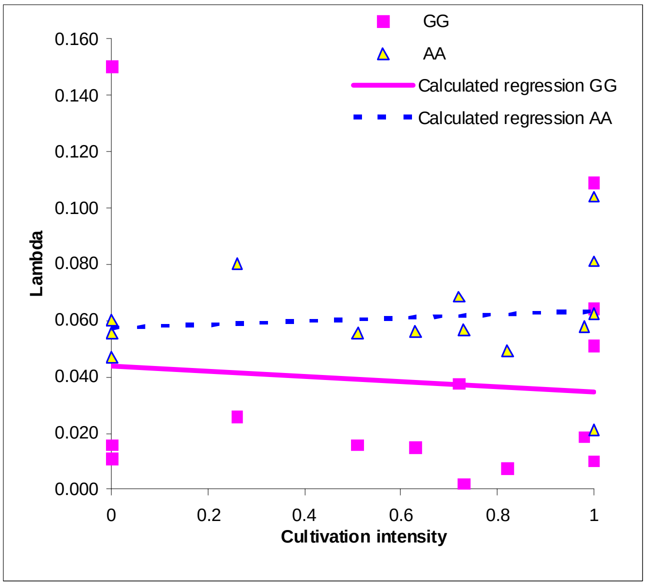
A Tree birds



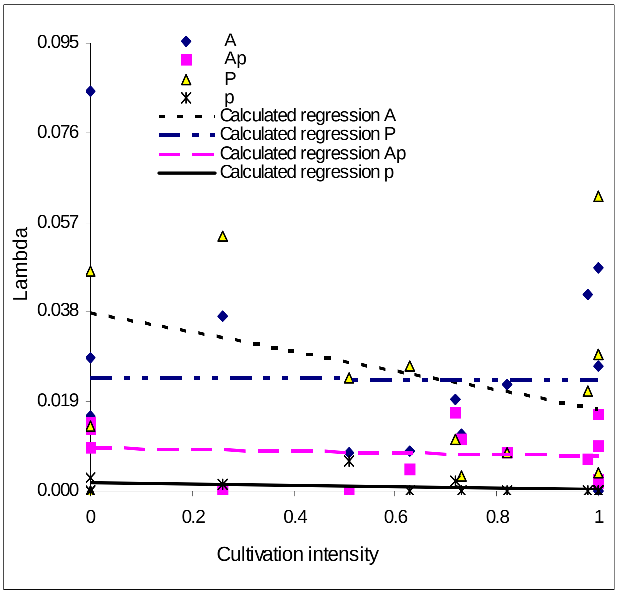
B Water birds



C Aerial feeders



D Migrants



E Red Data species

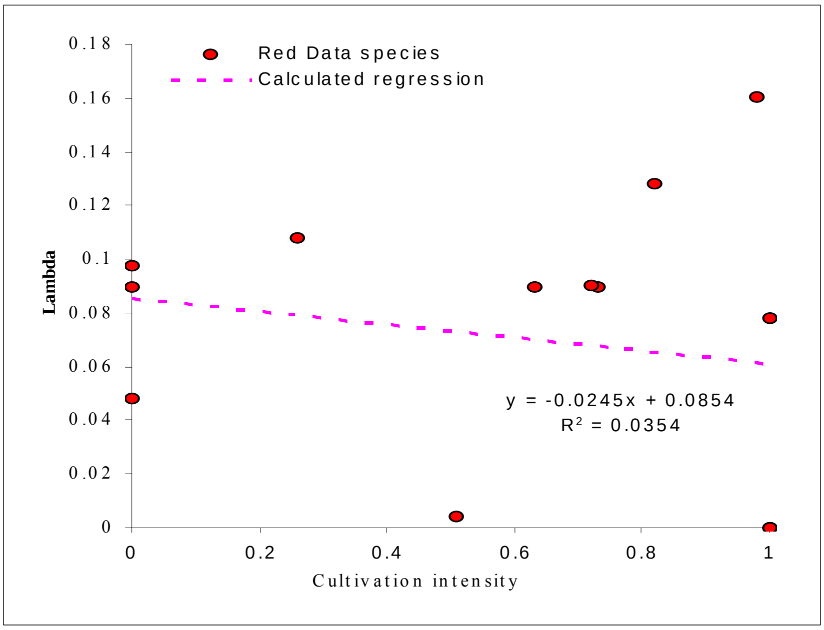


Table 6. 1. Correlation (R^2) and regression statistics (Y, P) of bird abundance compared to the intensity of cultivation (n = 14; Fig 6.1, A to E).

Bird categories and sub-categories		Category code	R^2	R	Y	P
Tree birds	Forest specialists	FF	0.2598	-0.510	-0.0085x + 0.0084	<0.1
	Forest generalists	F	0.0662	-0.257	-0.9524x + 0.111	ns
	Non-forest species	f	0.1094	-0.331	-0.673x + 0.3366	ns
		All	0.0139	-0.118	-0.0427x + 0.1521	ns
Waterbirds	Specialists	WW	0.0233	0.153	0.0053x + 0.0059	ns
	Generalists	W	0.3233	0.569	0.0823x + 0.072	<0.05
		All	0.0581	0.241	0.0438x + 0.0389	ns
Grassland birds		GG	0.0067	-0.082	-0.0089x + 0.0435	ns
Aerial species		AA	0.0159	0.126	0.006x + 0.0573	ns
Migrants		Ap	0.0183	-0.135	-0.0019x + 0.0573	ns
		A	0.1317	-0.363	-0.0204x + 0.0376	ns
		P	0.0014	-0.037	-0.0017x + 0.0265	ns
		p	0.2255	0.475	0.0021x - 0.004	ns
		All	0.0158	-0.126	-0.058x + 0.018	ns
Red Data species			0.0354	-0.188	-0.0245x +0.0854	ns

6.3 The Response of Birds to Crop Diversity

Cultivation intensity is only one of several land use variable. So we correlated the remaining agricultural land use/cover variables with cultivation intensity (Table 6.2), which demonstrates a string of mainly negative correlates. The lowest level of correlation (apart from exotic canopy cover, Section 6.3) is with the number of crops per site. We therefore expected this variable to provide the greatest contrast to cultivation intensity. So we repeated the analyses with this as the independent variable – the results are shown in Table 6.3.

Table 6. 2. Other agricultural land use variables (as described in Table 2.4 and Section 3.1) correlated to cultivation intensity across all sites (n = 12). *Figures are values of r and of probabilities.*

Variable	**Correlation coeff.**	**Probability level**
Proportion of mono cropping	0.6115	<0.05
Canopy cover – exotic	-0.1294	ns
Numbers of crops	-0.4326	ns
Proportion of grass fallow	-0.4578	ns
Proportion of two main crops	-0.6706	<0.03
Canopy – indigenous	-0.7228	<0.01
Proportion of natural vegetation	-0.7640	<0.01
Average fallow age	-0.9591	<0.001

Overall, the abundance of birds increases with the number of different crops in a site, but rather weakly (P>0.1). But for individual bird categories there are, again, few significant correlations and no clear pattern (six are positive, including all tree species, and five are negative). We found in Chapter 5 that, although cultivation intensity has a clearly negative effect on the numbers of bird species, and particularly the more specialist species, it does not have any strong effect on the actual numbers of bird individuals. Apparently the commoner species become even more common. The results in Table 6.3 suggest that the same is broadly true of the numbers of crops. However, environmental variables interact with each other, as the high correlations in Table 6.2 show. So we felt that multivariate analyses might provide more insights.

Table 6. 3. Correlation (R^2) and regression statistics of bird abundance compared to the number of different crops found at each site.

Bird categories and sub-categories		Category	R^2	R	Y =	P
Tree birds	Forest specialists	FF	0.0534	0.23	0.0003x + 0.0011	ns
	Forest generalists	F	0.158	0.40	0.0063x + 0.034	ns
	Non-forest species	f	0.1812	0.43	0.007x + 0.2436	ns
		All	0.0268	0.16	0.0046x + 0.0929	ns
Waterbirds	Specialists	WW	0.3902	0.62	0.0017x - 0.0034	<0.05
	Generalists	W	0.5465	0.74	-0.0083x + 0.1918	<0.05
		All	0.0528	0.23	-0.0033x + 0.0942	ns
Grassland birds		GG	0.4188	0.65	-0.0038x + 0.0589	<0.05
Aerial species		AA	0.0584	0.24	0.0009x + 0.0696	ns
Migrants		Ap	0.0011	0.03	-0.00004x + 0.0079	ns
		A	0.007	0.08	-0.0002x + 0.018	ns
		P	0.113	0.34	-0.0012x + 0.0319	ns
		p	0.0424	0.21	0.00007x - 0.0003	ns
		All	0.0064	0.08	-0.0002x + 0.0145	ns
Red Data species			0.0354	-0.188	-0.0245x + 0.0854	ns

6.4 The Response of Birds to Sets of Variables

We expect every species of bird to respond to a different set of environmental variables from every other species. These differences are often in respect to specific resources and can vary with age of bird and season. For this analysis we have considered all the species, in other words the bird community as a whole. A canonical correspondence analysis (CCA) was carried out to compare the abundance of the individual bird species in this community with six selected agricultural land use and tree vegetation variables – tree canopy cover (both indigenous and exotic), cultivation intensity, numbers of crops, the proportion of grasses in total fallow land, the proportion of natural vegetation, and the proportion of mono cropping, all of which are described in Chapter 2. Figure 6.2 shows a CCA biplot of all birds using these six environmental variables.

The first eigenvalue on the first axis was 0.309, implying that this axis represents a fairly high gradient (or proportion) of the total species and environmental variances. The first two axes explain 44.6% of the variance. The sum of the eigenvalues on the six constrained axes was 0.529, while the total for all the axes was 0.721, implying that the explained inertia is 73%, a rough measure of how well species composition is explained by the variables.

From Figure 6.2, the proportion of natural vegetation and of grass fallow, as well as the canopy cover of trees, seem to have the strongest influence. Cultivation intensity does not seem to have much influence, probably because many of the passerine species will be attracted to cultivated lands.

However, the picture changes when we look only at the tree birds (FF, F and f, Table 2.3). A biplot of these is shown in Figure 6.3. In this analysis, the first eigenvalue is 0.318, and the first two axes explain 50% of the variation. The explained inertia makes 78.5% of the total and therefore the variables chosen explain the distribution of the data well. Here, number of crops, cultivation intensity and the canopy of indigenous trees seem to be underlying factors. Of particular interest is the fact that the canopy cover for exotic trees remains an influencing factor too, though to a lesser extent than of native trees.

Figure 6. 2. Canonical Correspondence Analysis joint plot for all birds.
The dots represent the orientation of the species in the 'All birds' dataset. The arrows represent variables related to agricultural land use/cover as in Table 2.4. The length of the arrows indicate the level of importance. CROPS = Number of crops; PROP_GFL = Proportion of area under grass fallow; PROP_NVG = Proportion of area under natural vegetation; PROP_MON = Proportion of area under monoculture; CANOPY = Total Canopy cover for all trees; CLT_INT = Cultivation intensity.

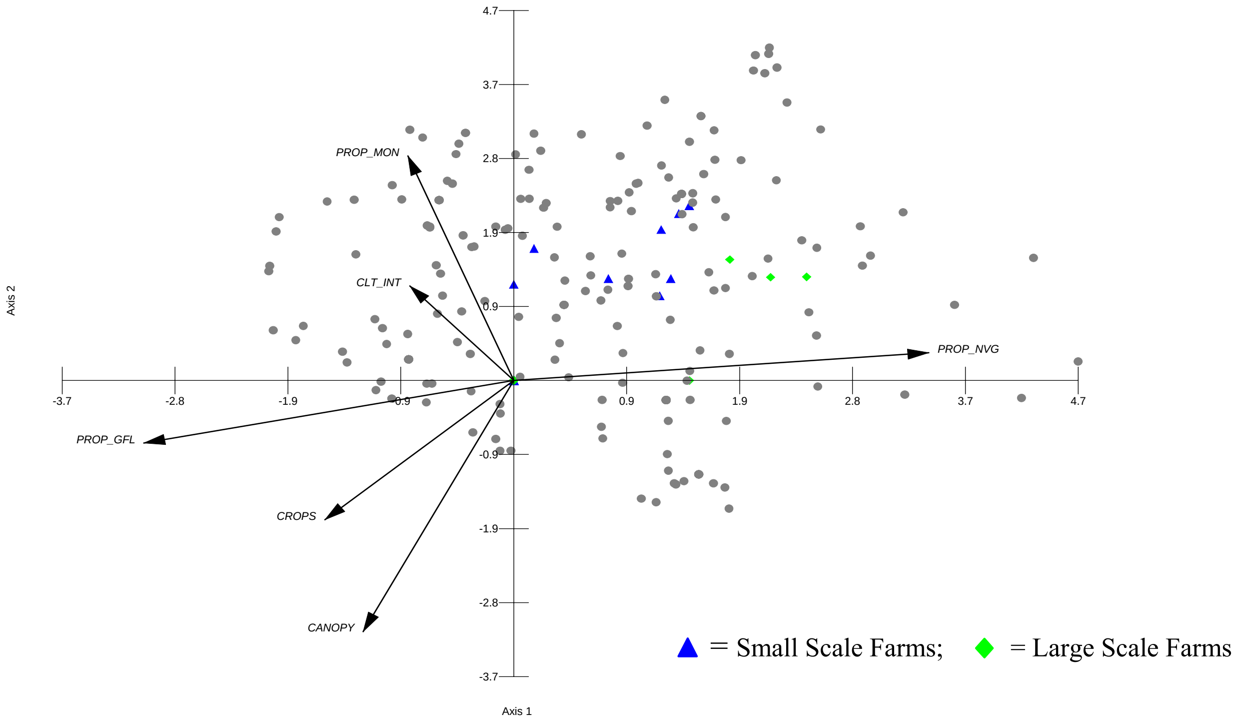
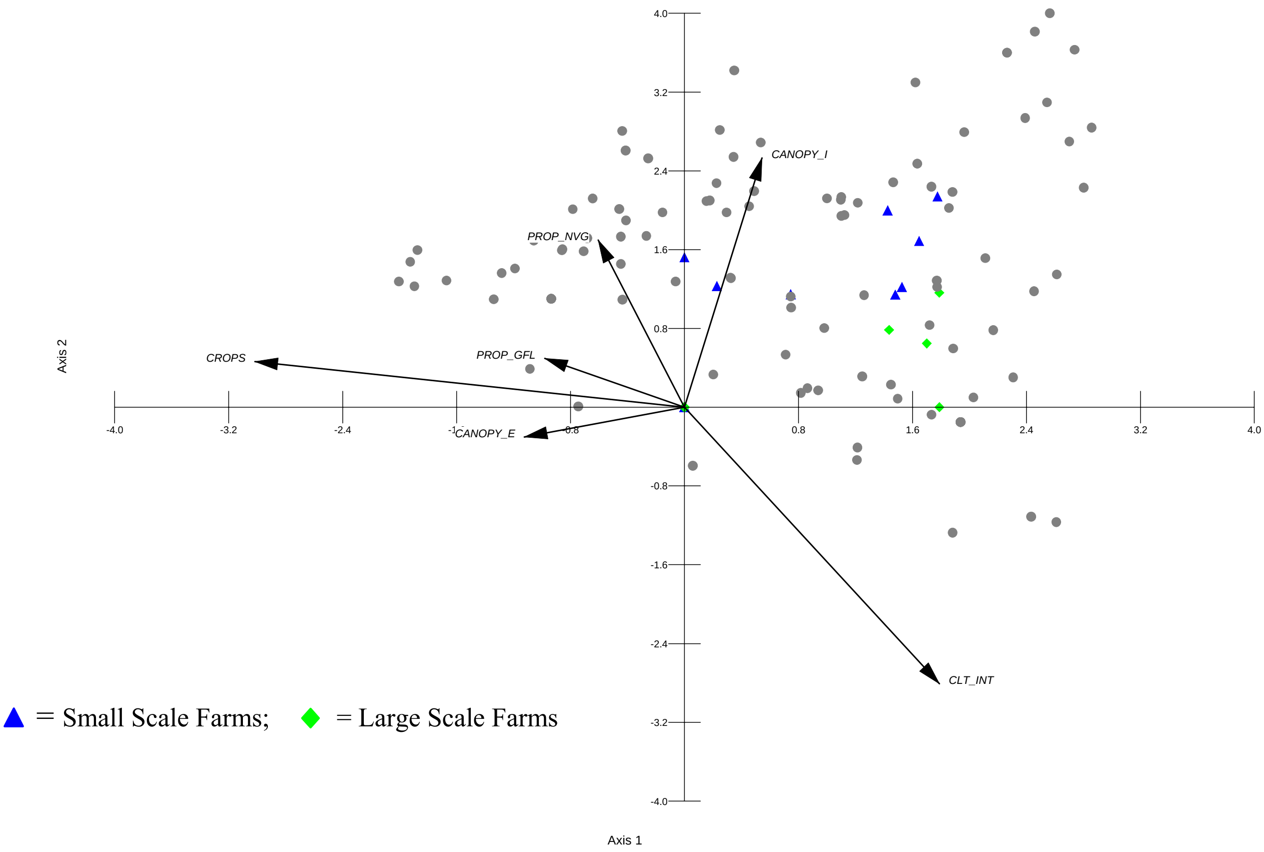


Figure 6. 3. Canonical Correspondence Analysis joint plot for 'tree birds'.

Key as for Figure 6.2, except Canopy Cover which is here split into 'indigenous (I)' and 'exotic (E)'



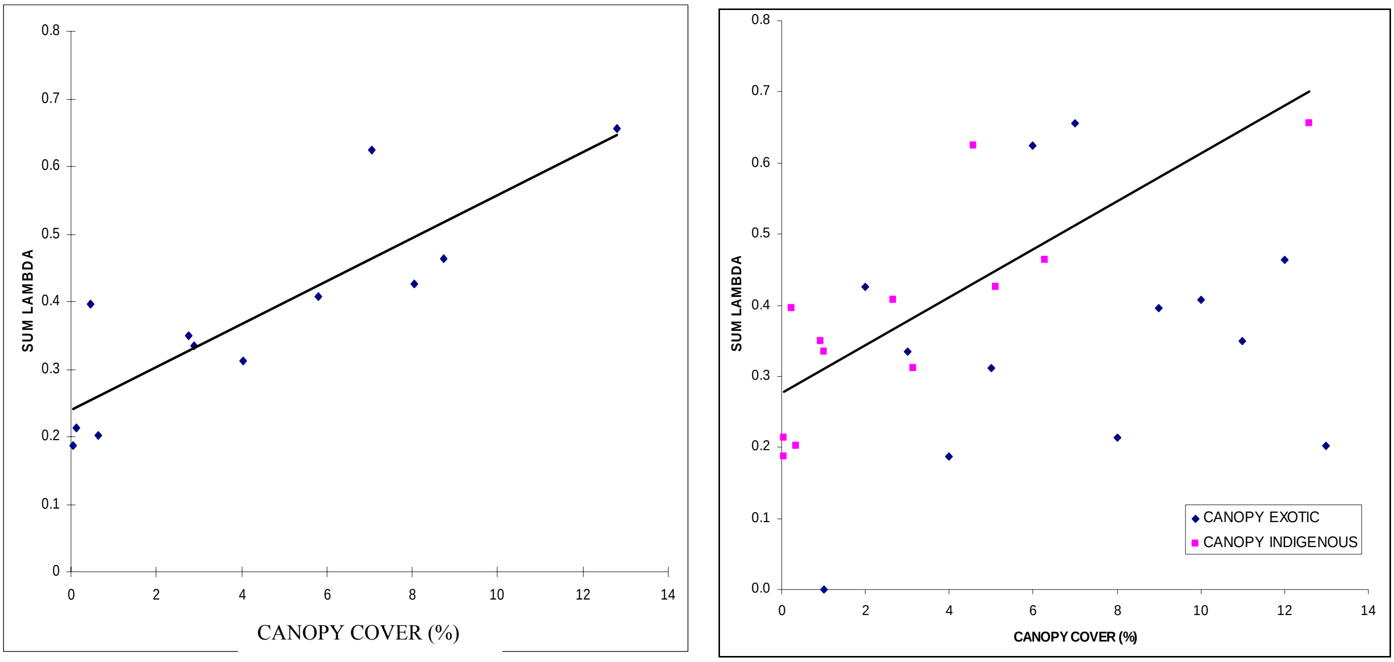
Only years of detailed study would reveal the web of interactions in these agroecosystems. As we pointed out in Section 6.1, the possible interactions between birds (or indeed butterflies or other biodiversity) are many and various. Trees, however, in all their great variety (there are well over a thousand species in Uganda) seem particularly important.

6.5 Which Trees?

The importance of trees for many bird species is not only reflected in their decline in numbers as agriculture becomes more intensive, as already seen, but of course by actual canopy cover (Figure 6.4A). Whilst all trees are important, Figure 6.4B provides strong evidence for native species supporting larger numbers of birds than exotics. At present, native trees are far more common than exotics (see, for example, Table 4.1); but if farmers continue to prefer planting exotics, we may well see a decline in many interesting and perhaps important bird species. It seems likely that native trees provide more food for birds, although exotics may be just as good for roosting, and possibly nesting.

Figure 6. 4. The number of 'tree birds' (FF, F and f), as represented by the sum of their lambda scores at each site, compared to total tree canopy cover (A). There is no correlation between 'tree birds' and exotic trees (B: R^2 = 0.162, r = 0.402, P > 0.05), in contrast to the relationship with native trees, where there is a strong correlation (R^2 = 0.674, r = 0.821, P > 0.01).

A B



7. REVIEW, FUTURE RESEARCH AND RECOMMENDATIONS

7.1 Review of Findings

Agricultural intensification clearly leads to a loss of species, both of woody plants and birds. But for birds, unlike trees, this does not apply to the total 'amount of bird' – as reflected by our assessment of numbers of individuals (lambda values), rather than of species. Thus, although conservation value is lost, through the disappearance of the more specialized species, the value of ecosystem services to local farmers may be affected much less. These may be of major significance. Just one example of the services mentioned in Section 1.3 is pollination. Globally, 'pollination services' have an estimated annual value of US$112 billion (de Marco & Coelho, 2004) but specific data for Africa are very sparse. Bees and a wide variety of other insects are likely to be important, but what of sunbirds? On average, seven sunbird species were recorded on smallholder farms, compared to only two on large-scale farms (Section 5.4); but nobody knows what they pollinate.

As pointed out in Section 1.4, each of the measured variables on agriculture and trees were expected to be important to birds as a whole, and Figure 6.2 shows that this is so. Crop diversity, the extent of fallow land and the amount of native vegetation were all important to birds in general. Of course, every one of the 241 bird species will have had its own particular requirements, as suggested by the scatter of observations in the figure.

Our findings on the importance to birds of trees, and especially native trees, are no surprise; previous studies in Uganda by Naidoo (2004) and Nalwanga (2004) found similar associations, but we have extended these over a larger area. Results elsewhere, for example Hirano *et al* (1985) in Japan, Söderström *et al* (2003) in West Africa and others suggest a global trend in the relationships of birds and trees, and in particular Hirano *et al* showed the particular importance of large trees of a variety of species to overall species richness in birds; and our results appear to confirm this for Uganda (Section 4.2).

The various benefits of agroforestry have been widely reviewed (see, for example Schroth *et al* 2004) and these include the benefits to birds that we have mentioned. However, we have also shown very clearly that the specialist bird species – such as the forest specialist (FF) and to some extent the forest generalist (F) species (Table 2.3) – are absent, or at least scarce, in even the least intensive cultivations, and there is no realistic prospect of their being conserved by current agroforestry practices (Naidoo 2004).

We found more evidence in the literature that specialists cannot tolerate extensive habitat change. Few such birds are found in banana plantation in Uganda (Seavy, submitted), or in areas of South Africa that were formerly fynbos (Magnall & Crowe, 2003); but an indication of the complexity of these situations – and the risk of making broad generalizations – comes from Seavy's finding that sunbirds were more abundant in bananas than in nearby forests, whereas Magnall & Crowe found them to be amongst the groups that were most negatively affected by agricultural development. Obviously we still have much to learn.

Of course, there are many kinds of specialist birds, not only those of forests; and we also recorded decreases in raptors, Red Data species, and probably migrants, as agricultural intensity increased. Other birds, such as aerial species and those of grasslands, were less affected, whilst some waterbird species were more common in commercial farms. However, the total numbers in these last three groups were generally low: agroecosystems, in other words, are not important places for them.

Interestingly, we found little evidence of decline in birds of smallholder farms during the past 10-16 years – and indeed an increase in tree birds that perhaps reflected an increase in trees (Section 5.4). This suggests that this farm type is benign so far as biodiversity is concerned, but it remains possible that further research will show more results that are statistically significant, and the indications from our study are that these are more likely to be declines than increases. In this regard, the significant difference between actual and predicted species richness in all smallholder sites (Figure 5.2) likely represents habitat destruction associated with agricultural expansion (i.e. the first clearings of the original vegetation) and early phases of intensification, while intensification appears to have a lower effect on species richness within the range of cultivation intensity that the smallholder study sites represent.

There is less information on taxa other than birds although, for example, Eilu *et al* (2003) found agroecosystems in south-western Uganda to be relatively rich in plant species. Elsewhere in the world, Sauberer *et al* (2004) showed moderate levels of congruence in Austrian agricultural landscapes between eight taxa (and relatively high levels for vascular plants and birds). If this pattern holds in Uganda (and Tushabe *et al* (in press) suggest that it does) then the virtual absence of specialist species in agroecosystems will apply to all taxa, not just birds. All of which goes to emphasize again the necessity of an extensive (and well-managed) Protected Area system.

7.2 Future Research

This small study will, we expect, lead to others of greater depth and scale. Obvious (and some less obvious) aspects should include –

- Carefully-planned selection of sites – this project was limited by the need to use data from existing sites, due to budget constraints and the advantages of using data from a longer time period.
- Collection of additional kinds of data, such as the spatial characteristics of sites and in particular the clumping of trees, and the particular importance of large trees.
- Both in north America (e.g. Beecher *et al* 2002) and Europe (e.g., Pain & Donald, 2002) there is evidence that there are more birds and other native species on organic farms than in others. Since Uganda already leads the region in organically-produced crops such as coffee and cotton (IFOAM, 2004), this is an aspect well-worth pursuing.
- Whilst 'win-win' situations are politically attractive, present evidence, including that of this study and, for example, Nkonya & Pender (2003), have found few strategies that would lead to higher household incomes without, at the same time, degrading natural resources. Some sorts of agroforestry may be exceptions, but much more needs to be known about which kinds, and what prospects they have for being widely adopted. Some agricultural practices, such as organic farming and minimum tillage, as well as crop diversity, may be beneficial both to farmers and to biodiversity.
- Nkonya & Pender (2003) also thought that some livestock farms were likely to retain more biodiversity than those which are cultivated. Our one pasture site does at least hint at support for this idea, and suggests that more such sites should be studied. We already have some data for a variety of rangelands.
- The next few years are likely to see greatly increased pressures on trees – for all sorts of purposes (National Biomass Study, 2003). The effects of this on biodiversity are being captured at MUIENR through the national bird monitoring programme – but it needs to be expanded beyond the existing 37 sites, of which only 10 are in agroecosystems.

- As yet, no analyses have been conducted on the survival of tree species of conservation concern (e.g., rare species) in agroecosystems. This is partly because no appropriate listings have yet been made for trees, but that could be done.
- We know next to nothing of the ways in which wild biodiversity affects agricultural production (except for some pest species). To what extent are the birds and bees beneficial to farmers, and how can these services be secured?

7.3 Recommendations

1. Agricultural intensification should follow a landscape approach. The importance of trees and other woody plants, and especially native plants, is clear. It may be practicable to incorporate trees in fields of intensive crops, but well-managed, local forest reserves, vegetation corridors along streams, small roads and boundaries, and especially growing more trees around buildings, should all be possible.
2. Nevertheless, although we believe the evidence behind Recommendation (1) to be sound, considerable more research is needed if the results are to be of greatest benefit to all. Many choices exist, and we are far from knowing which is best. Hence the urgent need for well-planned research.
3. Crop diversity and fallow land contribute quite strongly to bird species diversity – and very probably to biodiversity in general. Since mixed cropping systems have many other benefits too, they are to be strongly encouraged. Large-scale plantation agriculture, in contrast, is associated with very low biodiversity richness, whether of birds or trees. Much more could be done to make these farm types more environmentally friendly, without necessarily incurring large economic losses to the owners.
4. However well we manage agroecosystems, they can only complement an effective Protected Area system. The latter needs to be developed too.

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Appendix 1. Outputs Achieved Compared to those Proposed

Six outputs were bulleted on page 10 of the Research Agreement. Here we list them again and comment upon the actual output, as in the draft report of December 2004. Inevitably there have been a few changes, but more of emphasis than of significant content.

1. The location and characteristics of agroecosystems with high and rapidly declining biodiversity levels ('hot spot' situations).
   - We have in fact shown that, in the agroecosystems with highest biodiversity (less intensively cultivated smallholder farms) there is little evidence for a decline, at least in birds over the last 8 - 15 years.
   - But by comparisons across sites, we have found strong evidence that species are progressively lost (with only a few gains) as agriculture is intensified. Losses are greatest amongst the more specialized species which are also those of greater conservation concern.
   - The analysis of poverty and other socioeconomic characteristics (to be carried out by IFPRI) of the study sites were not done due mainly to the need to focus the limited time and resources on doing a proper job on the biophysical variables. We also wanted see what came out of this analysis before resources were invested in collecting socioeconomic data. Socioeconomic variables would be included in a possible follow-up study, now that the measurement and analysis of land use variables have been tested. The data underlying the poverty maps would then be available, as would probably the data from the 2002 population census and the 2002/03 UNHS.

2. The characteristics of agroecosystems that combine relatively high levels of food production and high biodiversity ('win-win' situations)
   - There is an inverse correlation between agricultural intensity and biodiversity, as measured by trees and birds. The level of food production was not assessed due to time constraints and the decision not to collect socioeconomic data until the results from the land use analyses were ready (see bullet 1.3 above)
   - Retaining or planting trees, crop diversity, areas of fallow land and patches of native vegetation all contribute to bird species diversity.
   - We suspect, but have not yet shown, that large, mature trees are especially important.

3. Rates of losses (and gains) of bird species in different agroecosystems
   - We were only able to test this for smallholder farms, but on these the rates of gains and losses over a 15-year period are generally insignificant, although a gradual increase in ‘tree birds’ correlated with an increase in trees in south and eastern Uganda. Large-scale plantations had much lower levels of biodiversity than smallholder farms, but we were not able to measure changes in biodiversity over time for large-scale systems.

4. Land cover/use patterns associated with, respectively, high and low biodiversity levels
   - The most conspicuous finding here was that large-scale plantations had much lower levels of biodiversity than smallholder farms. The comparison of predicted (based on original natural vegetation) versus actually recorded bird species (Figure 5.2) showed a significant negative effect of smallholder farming on birds, especially with regard to forest specialists species, and a much larger effect of large-scale agriculture. The effect here was bigger for high intensity smallholder farms compared to farms with low cultivation intensity, except in the case of generalist species.
   - The effect of smallholder cultivation intensity on biodiversity was less pronounced when comparing actually recorded birds across the nine smallholder sites, and not statistically significant.
   - A survey including a larger number of smallholder sites (at least 30) would be required to establish which land use characteristics (within the range presented by contemporary smallholder systems) are more favorable for birds and trees, and perhaps for other indicators of biodiversity richness. The present study provides a good model for designing such a larger study.

5. Types and spatial patterns of woody vegetation in agroecosystems associated with high forest bird species richness.
   - More trees, particularly native trees, support more birds and, in all probability, other biodiversity.
   - We have not been able to examine the importance of different spatial patterns of woody vegetation, but we predict that higher degrees of patchiness – i.e. clumping – are likely to be beneficial.

6. Estimated (predicted and actual) conservation values for different agroecosystem types using bird-based indicators (and maps) such as total species richness, global conservation value, regional conservation value, eco-tourism value, national significance, and ratio of generalist to (forest) specialist species
   - Figure 5.2 clearly demonstrates the disappearance of specialist species (effectively, those of high conservation value) from intensively-cultivated farms, compared to their estimated occurrence when the sites were covered by the original natural vegetation. To a lesser extent, this also applies to birds as a whole.
   - Of the ten recorded Red Data species (all of regional rather than global concern) only one, a swallow, occurred at any of the intensively-cultivated sites.
   - Large, charismatic species such as the Long-crested Eagle, hornbills and parrots, were scarce or absent from high-intensity cultivations.

Appendix 2. Land Use Transect Survey Data Form

Site name: ________________ Transect #:______ Compass direction (degrees):______
Total transect length: __________ GPS Unit #. _________ Date: ____________

Observ. point/ section[1]	**Length**[2]	**GPS way point #**[4]	**General land use**[3]	**Cropland**[5]					**Fallow land**		**Natural vegetation**[8]
				Pattern	Dominant crops				Vegetation[6]	Age[7]	
	metres	*UTM*			*1st*	*2nd*	*3rd*	*4th*			
Start											
1											
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GENERAL COMMENTS:

Notes to the Transect Survey Data Form

[1]The observation point is the boundary between two land uses. The observation section is the area in front of you up to the next boundary, when you face in the walking direction. Thus, observe the land use in front of you (the walking direction), and towards the right (facing forward) in case land use differs between your right and left.

[2] Length (in meters) of landuse section, i.e. from the current observation point to the next in the walking direction.

[3]Whether the section is cultivated (i.e. plots planted with crops this season) [*cult*], fallow [*fallow*] a permanently grazed and managed pasture (fenced paddock) [*pasture*], not presently occupied by crops or livestock but with natural vegetation [*forest, wetlands, bushland, grassland*], or another type of land use/cover such as a lake, stream, road, compound, village, etc [*specify*].

[4]The GPS waypoint # (also saved in the GPS unit). The first GPS waypoint/coordinate of a transect does not have a corresponding land use section.

[5]Note the crops found on the section, with the dominant crop first (and so forth), as well as the cropping pattern (single stands or mixed). Use this column also for paddocks.

[6]Grassy, bushy, woody, other (specify).

[7]Years passed since last harvested (as estimated by local farmer).

[8]Describe the vegetation as accurately as possible to allow for a subsequent detailed classification.

Appendix 3. Frequencies of Woody Vegetation Species in all Study Sites

Species	Bujagali	Kanyawara	Kasese Cotton	Katugo	Kifu	Kyegegwa	Lugazi Sugar	Lugazi Tea	Mpanga	Mubuku	Hima Pasture	Mukono	Nsimbe Hort.	Ziika
Abutilon mauritianum	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Acacia abyssinica	0	0	1	0	0	11	0	0	0	0	6	0	0	0
Acacia gerrardii	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Acacia hockii	0	0	1	14	0	19	0	0	0	0	5	0	0	0
Acacia polycantha	0	0	0	11	0	0	0	0	0	7	0	0	0	0
Acacia sieberiana	0	0	1	0	0	1	0	0	0	2	3	0	0	0
Acalypha neptunica	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Acalypha wilkesiana	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Acanthus pubescens	0	8	0	0	0	22	0	0	0	0	0	1	0	0
Alangium chinense	0	2	0	0	0	0	0	0	1	0	0	0	0	0
Albizia chinensis	4	0	0	0	8	0	0	0	0	0	0	1	0	0
Albizia coriaria	0	0	0	13	2	19	0	0	0	2	12	0	0	0
Albizia glaberrima	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Albizia grandbracteata	4	11	0	0	18	1	0	0	1	3	0	2	0	0
Albizia gummifera	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Albizia zygia	2	0	0	12	6	26	0	0	3	0	0	0	0	1
Alchonea cordifolia	0	0	0	0	2	4	0	0	0	0	0	1	1	1
Alchonea hitella	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Aleurites morucana	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Allophylus abyssinica	0	0	1	3	1	11	0	0	0	2	0	0	0	0
Allophylus dumerii	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Anacardium occidentale	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Annona mauricata	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Annona senegalensis	0	0	0	11	0	0	0	0	0	0	0	0	0	0
Antiaris toxicaria	2	0	0	0	17	5	0	0	7	0	0	4	0	0
Antidesma venosum	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Araucaria angustifolia	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Artocarpus heterophyllus	46	1	0	8	18	2	0	0	33	1	0	11	1	1
Azadirachta indica	2	0	0	1	0	0	0	0	0	0	0	0	0	0
Azima tetandra	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Species	Bujagali	Kanyawara	Kasese Cotton	Katugo	Kifu	Kyegegwa	Lugazi Sugar	Lugazi Tea	Mpanga	Mubuku	Hima Pasture	Mukono	Nsimbe Hort.	Ziika
Bauhinia maracablum	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Bauhinia thonningii	0	0	0	7	0	0	0	0	0	0	0	0	0	0
Bersama abyssinica	0	1	0	1	0	9	0	0	0	0	0	0	0	0
Blighia unijugata	0	2	0	0	2	39	0	0	0	0	0	0	0	1
Bridelia micrantha	1	2	0	0	11	4	0	1	4	0	0	1	0	1
Bridelia scleroneura	0	0	0	11	0	1	0	0	0	0	2	0	0	0
Broussonetia papyrifera	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Buddleja pulchella	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Calliandra calothyrsus	1	0	0	0	0	0	0	0	0	1	0	1	0	0
Callistemon citrinus	2	2	0	0	0	0	0	0	1	0	0	0	0	0
Canarium schweinfurthii	0	0	0	0	1	0	0	1	1	0	0	0	0	1
Capparis erythrocarpoides	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Carica papaya	12	6	0	5	9	0	0	1	4	1	0	8	1	0
Casuarina equisetifolia	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Catha edulis	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Celtis africana	2	0	0	0	3	0	0	0	1	0	0	0	0	0
Celtis durandii	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Celtis mildbraedii	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Chaetacme aristata	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Citrus reticulata	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Citrus sinensis	3	1	0	1	0	0	0	0	0	0	0	1	0	0
Clausena anisata	0	0	0	3	1	33	0	0	0	0	0	0	0	0
Clerodendrum myricoides	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Clutia abyssinica	0	0	0	0	0	6	0	0	0	0	0	0	0	0
Cocos nucifera	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Codiaeum variegatum	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Combretum collinum	0	0	0	21	0	0	0	0	0	0	0	0	0	0
Combretum molle	0	0	0	9	0	3	0	0	0	0	1	0	0	0
Cordia africana	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Cordia ovallis	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Croton macrostachyus	1	3	0	0	1	0	0	0	0	0	0	0	0	0
Croton sylivaticus	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Species	Bujagali	Kanyawa ra	Kasese Cotton	Katugo	Kifu	Kyegegwa	Lugazi Sugar	Lugazi Tea	Mpanga	Mubuku	Hima Pasture	Mukono	Nsimbe Hort.	Ziika
Cupressus lusitanica	1	0	0	0	0	0	0	1	0	0	0	1	0	1
Cyphomandra betacea	0	0	0	0	0	6	0	0	0	0	0	0	0	0
Dalbergia lactea	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Dichrostachys cinerea	0	0	1	5	0	1	0	0	0	0	0	0	0	0
Dombeya burgessiae	0	0	0	1	0	3	0	0	0	0	0	0	0	0
Dombeya mukole	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Dovyalis macrocalyx	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Dracaena fragrans	6	0	0	0	1	0	0	0	1	1	0	0	0	1
Dracaena steudneri	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Ekebergia carpensis	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Elaeis guineensis	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Embelia schimperi	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Entada abyssinica	0	0	0	3	0	28	0	0	0	0	0	0	0	0
Entandrophragma angolense	0	0	0	0	2	0	0	0	1	0	0	1	0	0
Entandrophragma utile	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Erlangea cordifolia	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Erythrina abyssinica	0	9	0	0	3	15	0	1	1	1	0	4	0	1
Erythrococca trichogyne	0	0	0	0	0	8	0	0	0	0	0	0	0	0
Eucalyptus citridiola	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus grandis	0	8	0	0	0	0	0	1	0	6	0	2	1	1
Eucalyptus saligna	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Euclea latidens	0	0	1	2	0	1	0	0	0	0	0	0	0	0
Eugenia capensis	0	0	0	0	0	7	0	0	0	0	0	0	0	0
Euphorbia candelabrum	0	0	1	0	0	1	0	0	0	0	4	0	0	0
Euphorbia catinifolia	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Euphorbia tirucalli	0	1	1	0	0	0	0	0	0	3	0	0	0	0
Fagaropsis angolensis	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Ficus asperifolia	1	0	0	0	6	18	0	0	0	0	0	1	0	0
Ficus barteri	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Ficus brachypoda	6	2	0	2	7	2	0	0	2	0	0	7	1	1
Ficus cyathistipula	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Ficus exasperata	13	0	0	0	11	0	0	0	1	0	0	0	0	0

Species	Bujagali	Kanyawa ra	Kasese Cotton	Katugo	Kifu	Kyegegwa	Lugazi Sugar	Lugazi Tea	Mpanga	Mubuku	Hima Pasture	Mukono	Nsimbe Hort.	Ziika
Ficus glumosa	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Ficus mucuso	2	0	0	0	3	0	0	0	0	0	0	0	0	0
Ficus natalensis	7	1	0	3	11	1	0	0	8	5	0	17	1	1
Ficus ottoniifolia	0	0	0	0	3	2	0	0	0	0	0	1	0	0
Ficus polita	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Ficus pseudomangifera	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Ficus saussureana	0	1	0	0	0	0	0	0	0	0	0	0	1	0
Ficus sur	0	1	0	0	6	7	0	0	0	0	0	2	0	0
Ficus sycomorus	0	0	0	0	0	0	0	0	0	0	7	0	0	0
Ficus thonningii	0	0	0	9	0	3	0	0	0	0	1	0	0	0
Ficus valifolia	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ficus vallis-choudae	0	0	0	0	0	1	0	0	0	0	0	0	1	0
Ficus vasta	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Funtumia elastica	0	1	0	0	2	4	0	0	0	0	0	0	0	0
Gardenia ternifolia	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Gliricidia sepium	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Grevillea robusta	0	4	1	0	0	0	0	0	0	2	0	0	0	0
Grewia bicolor	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Grewia mollis	0	0	0	5	0	0	0	0	0	0	12	0	0	0
Grewia trichocarpa	0	0	1	13	0	1	0	0	0	0	4	0	0	0
Harrisonia occidentalis	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Harungana madagascariensis	0	0	0	0	5	1	0	0	0	0	0	1	0	1
Hevea brazilensis	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Hymenocardia acida	0	0	0	8	0	0	0	0	0	0	0	0	0	0
Jacaranda mimosifolia	0	3	0	0	0	0	0	0	0	0	0	1	0	0
Jatropha curcas	30	0	0	1	12	0	0	0	2	2	0	8	0	0
Keetia guienzii	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Kigelia africana	0	2	0	2	0	0	0	0	0	0	0	0	0	0
Lannea barteri	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Lannea sp	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Lannea welwitschii	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Lantana camara	0	0	0	7	2	0	0	1	0	0	0	0	0	0

Species	Bujagali	Kanyawara	Kasese Cotton	Katugo	Kifu	Kyegegwa	Lugazi Sugar	Lugazi Tea	Mpanga	Mubuku	Hima Pasture	Mukono	Nsimbe Hort.	Ziika
Lantana trifolia	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Leucaena leucocephala	4	0	0	0	0	0	0	0	0	0	0	0	1	0
Lonchocarpus trichocarpus	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Maerua bussei	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Maesa lanceolata	0	14	0	0	20	24	0	0	6	0	0	3	0	0
Maesopsis eminii	15	1	0	3	8	0	0	0	10	0	0	4	0	1
Mangifera indica	9	1	0	11	7	0	1	1	11	8	0	11	1	1
Margaritaria discoidea	0	0	0	1	2	4	0	0	1	0	0	0	0	1
Markhamia lutea	65	2	0	1	28	24	0	1	4	2	0	18	0	0
Maytenus heterophylla	0	0	0	0	0	7	0	0	0	0	7	0	0	0
Maytenus senegalensis	0	0	0	2	0	5	0	0	0	0	2	0	0	0
Melia azedaratch	0	0	0	0	0	0	0	0	0	2	5	0	0	0
Michelia champaca	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Microglossa sp	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Milicia excelsa	19	0	0	0	3	0	0	1	0	0	0	4	0	0
Milletia dura	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Mimusops bagshawei	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Monodora myristica	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Morinda lucida	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Moringa oleifera	7	0	0	0	0	0	0	0	1	0	0	1	0	0
Myrianthus holstii	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Neoboutonia melleri	0	1	0	0	0	0	0	0	0	0	0	1	0	0
Newtonia buchananii	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Olea africana	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Oxyitnenthera abyssinica	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pachystela brevipes	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Paulinia pinnata	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Pavetta crassipes	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Pavetta oliverana	0	0	0	0	0	7	0	0	0	0	0	0	0	0
Peddiea fischeri	0	0	0	0	1	35	0	0	0	0	0	0	0	0
Persea americana	12	16	0	2	6	2	0	1	6	0	0	12	1	0
Phoenix reclinata	0	0	0	0	0	53	1	0	0	0	0	1	0	0

Species	Bujagali	Kanyawara	Kasese Cotton	Katugo	Kifu	Kyegegwa	Lugazi Sugar	Lugazi Tea	Mpanga	Mubuku	Hima Pasture	Mukono	Nsimbe Hort.	Ziika
Phyllanthus capillaris	0	0	0	2	0	1	0	0	0	0	0	0	0	0
Phyllanthus ovalifolius	0	0	0	2	4	6	0	0	1	0	0	0	0	0
Pinus carribaea	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Pinus patula	0	7	0	0	0	0	0	0	0	0	0	0	0	0
Piptadeniastrum africana	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pittosporum spathicalyx	0	0	0	0	2	0	0	0	0	0	0	0	0	1
Plumeria rubra	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Polyscias fulva	0	0	0	0	1	0	0	0	2	0	0	0	0	1
Popowia lucida	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Premna angolensis	0	0	0	0	0	17	0	0	0	0	0	0	0	0
Prunus africana	0	1	0	0	1	0	0	0	1	0	0	0	0	0
Pseudospondias microcarpa	0	0	0	0	2	0	0	1	0	0	0	5	0	0
Psidium guajava	5	1	0	0	5	0	0	0	0	0	0	7	0	1
Psorospermum febrifegum	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Psychotria kirkii	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Psydrax faulknerae	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Pycnanthus angolensis	0	0	0	0	0	0	0	0	0	0	0	2	0	1
Raphia farinifera	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Raurea thomsoniana	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Rauvolfia vomitoria	0	0	0	0	2	0	0	0	0	0	0	1	0	1
Rhaphia sp	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Rhus natalensis	0	0	1	19	0	7	0	0	0	0	3	0	0	1
Rhus vulgaris	0	0	1	5	0	2	0	0	0	0	1	0	0	1
Ricinus communis	1	0	0	0	0	0	0	0	0	5	0	0	0	0
Roystenea regia	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Rutidea orientalis	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Rytigynia beniensis	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Sapium ellipticum	4	2	0	0	13	37	0	0	10	0	0	14	1	1
Schefflera barterii	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Scolopia rhamnophylla	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Scutia myritna	0	0	0	7	0	0	0	0	0	0	0	0	0	0
Securinega virosa	6	0	1	2	4	8	0	0	5	0	1	8	0	0

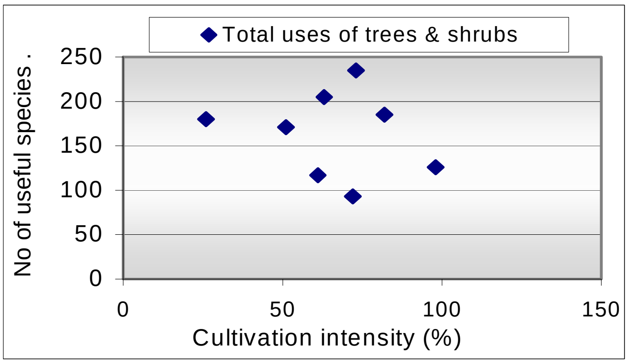
Species	Bujagali	Kanyawa ra	Kasese Cotton	Katugo	Kifu	Kyegegwa	Lugazi Sugar	Lugazi Tea	Mpanga	Mubuku	Hima Pasture	Mukono	Nsimbe Hort.	Ziika
Senna didymobotrya	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Senna floribunda	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Senna occidentalis	0	0	0	0	2	0	0	1	0	0	0	0	0	0
Senna siamea	1	0	0	0	0	0	0	1	2	1	0	0	0	0
Senna spectabilis	3	0	0	6	5	1	0	0	2	5	4	2	0	1
Sesbania sesban	0	0	0	0	4	0	1	0	0	1	0	0	0	0
Solanecio mannii	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Solanum mauritianum	0	1	0	2	8	9	0	1	5	0	0	2	1	1
Solanum pandriforme	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Spathodea campanulata	10	1	0	0	15	1	0	0	0	0	0	1	1	1
Steganotaenia araliacea	0	0	0	3	0	0	0	0	0	0	0	0	0	1
Sterculia dawei	2	0	0	0	5	0	0	0	0	0	0	0	0	0
Stereospermum kunthianum	0	0	0	6	0	0	0	0	0	0	0	0	0	0
Strychnos innocua	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Strychnos phaetrica	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Syzygium cuminii	0	0	0	1	5	0	0	1	3	0	0	1	0	0
Tabernaemontana holstii	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Teclea nobilis	0	0	0	2	1	11	0	0	0	0	0	0	0	1
Terminalia catapa	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Terminalia dawei	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Terminalia glauscesens	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Terminalia mantaly	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Terminalia sperba	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Theobroma cacao	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Thevetia peruviana	0	1	1	0	1	0	0	0	1	1	1	1	0	0
Toddalia asiatica	0	0	0	0	0	2	0	0	0	0	0	0	0	2
Toona serrata	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Trema orientalis	0	0	0	0	2	6	0	0	0	0	0	0	0	0
Tricalysia bridsoniaria	0	0	0	8	0	1	0	0	0	0	0	0	0	0
Trichilia dregeana	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Trichilia prieureana	0	0	0	1	2	0	0	0	0	0	0	0	0	0
Trichilia rubescens	0	0	0	1	0	0	0	0	0	0	0	0	0	0

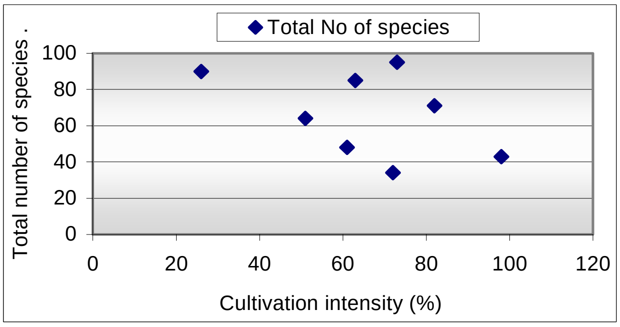
Species	Bujagali	Kanyawara	Kasese Cotton	Katugo	Kifu	Kyegegwa	Lugazi Sugar	Lugazi Tea	Mpanga	Mubuku	Hima Pasture	Mukono	Nsimbe Hort.	Ziika
Trilepisium madagascariense	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Trimeria grandiflora	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Triumfetta cordifolia	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Turrea vogeli	0	0	1	0	0	0	0	0	0	0	1	0	0	0
Uvaria welwitschii	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Vangueria apiculata	0	0	0	1	0	2	0	0	1	0	0	2	0	0
Vernonia amygdalina	17	8	0	7	14	6	1	1	6	9	0	9	1	1
Vernonia auriculifera	0	9	0	0	14	22	0	0	11	0	0	0	0	0
Vernonia campanea	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Vernonia purpurea	0	1	0	0	1	1	0	0	0	0	0	0	0	0
Vitex doniana	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Vitex ferruginea	0	0	0	13	0	0	0	0	0	0	0	0	0	0
Warburgia ugandensis	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Xymalos monospora	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Zanha golugensis	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Zanthoxylum giretii	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Zyziphus mucronata	0	0	0	3	0	0	0	0	0	0	0	0	0	0

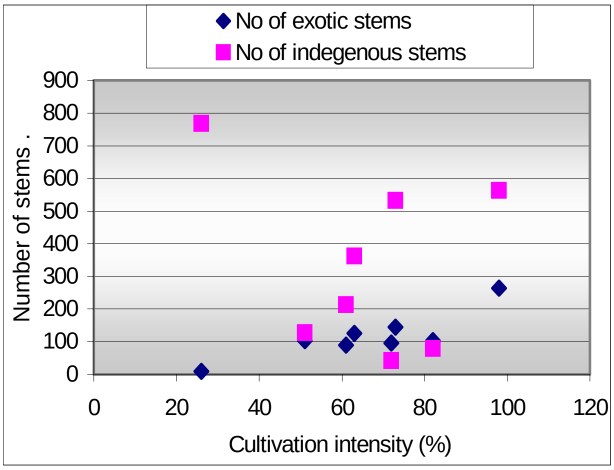
Appendix 4. Variables Used in Multivariate Statistical Analyses

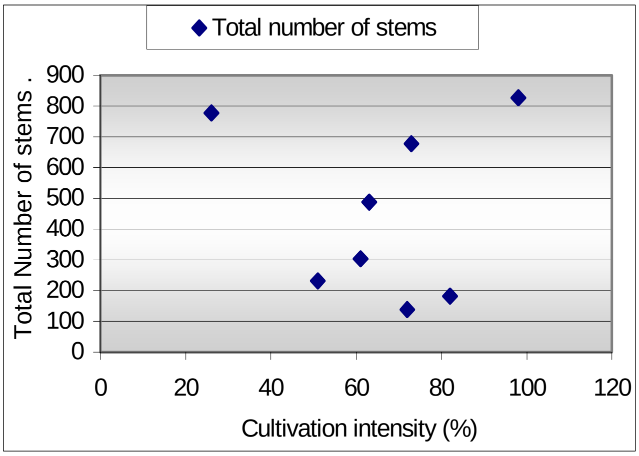
Site	Site code	Proportion of cultivated area	Proportion of natural vegetation	Proportion of fallow vegetation	Cultivation intensity (propn)	Average fallow age (years)	Proportion of grassy fallow	Proportion of mono cropping	Sum of proportion of two most dominant crops	Number of different crops	Canopy Cover for Indigenous and Exotic Species	
Variable Code:		*PROP_CLT*	*PROP_NVG*	*PROP_FAL*	*CLT_INT*	*AVG_FAL*	*PROP_GFL*	*PROP_MON*	*PROP_TWO*	*CROPS*	*CANOPY_I*	*CANOPY_E*
Lugazi Sugar	Lugz_sug	0.98	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1	0.02	0.02
Lugazi Tea	Lugz_tea	0.90	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1	0.08	0.14
Kasese Cotton	Kase_ctn	0.98	0.01	0.00	1.00	0.00	0.00	1.00	1.00	1	0.14	0.01
Nsimbe Horticulture	Nsmb_hot	0.90	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1	0.37	0.78
Bujagali	Bujg_clt	0.86	0.01	0.02	0.98	1.63	0.61	0.21	0.53	16	3.00	2.01
Mpanga	Mpng_clt	0.71	0.03	0.15	0.82	3.00	0.46	0.37	0.69	10	1.85	1.15
Kifu	Kifu_clt	0.63	0.02	0.24	0.73	4.30	0.51	0.20	0.54	11	2.98	0.89
Mubuku	Mubk_clt	0.57	0.02	0.22	0.72	2.70	0.67	0.78	0.62	8	0.87	0.67
Katugo	Katg_clt	0.37	0.15	0.22	0.63	3.43	0.73	0.31	0.70	13	2.85	0.51
Mukono	Mukn_clt	0.49	0.00	0.32	0.61	4.63	0.51	0.57	0.55	10	3.94	1.93
Kanyawara	Kany_clt	0.39	0.05	0.37	0.51	4.43	0.20	0.29	0.78	11	1.26	0.48
Kyegegwa	Kyeg_clt	0.15	0.44	0.41	0.26	7.82	0.39	0.31	0.49	7	12.18	0.11

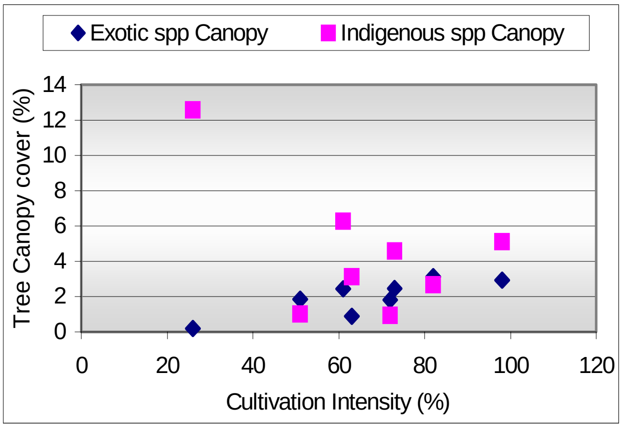
Appendix 5. Scatter Plots of Cultivation Intensity against Woody Plants Variables for 8 Smallholder sites

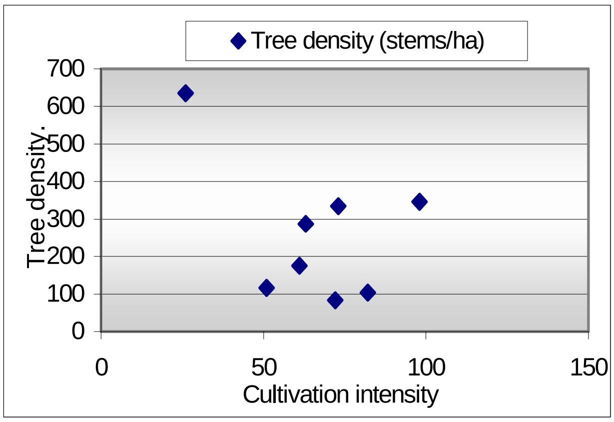


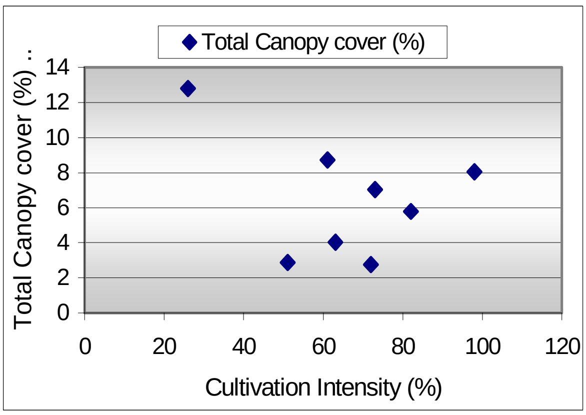












Appendix 6. Some of the Common Tree Species in the Fallows. Numbers of individuals recorded.

Species	Bujagali	Kanyawara	Katugo	Kifu	Kyegegwa	Mpanga	Mukono
Sapium ellipticum				3	10	3	4
Phoenix reclinata					13		
Vernonia auriculifera				3	5	5	
Markhamia lutea				3	5		4
Maesa lanceolata					6	4	
Blighia unijugata					9		
Entada abyssinica					8		
Vernonia amygdalina						4	4
Artocarpus heterophyllus						7	
Rhus natalensis			7				
Acacia polycantha			6				
Bridelia micrantha				3		3	
Albizia coriaria			5				
Combretum collinum			5				
Grewia trichocarpa			5				
Vitex ferruginea			5				
Albizia grandbracteata				4			
Ficus asperifolia					4		
Maesopsis eminii	1					3	
Mangifera indica						4	
Peddiea fischeri					4		
Persea americana							4
Solanum mauritianum						4	
Milicia excelsa				3			
Psidium guajava							3
Calliandra calothyrsus	1						
Ficus brachypoda	1						
Ficus natalensis	1						
Jatropha curcas	1						
Spathodea campanulata	1						
Zanthoxylum giretii		1					

Note: Sites not included in table had no trees in their fallows

Appendix 7. Summary of Bird Data (number of species (upper line for each site) and total lambda scores (lower line) for each category and site).

SITE	Total Species	Species with xter[a]	FF	F	f	All forest species	WW	W	All wetland species	GG	Ae	A	Ap	p	P	All migrants	Red Data Species
Lugazi Sugar	36	34	0	3	14	17	0	11	11.000	5	4	0	1	0	1	2	1
				0.013	0.201	0.214		0.212	0.212	0.051	0.062		0.0161		0.029	0.045	0.0041
Lugazi Tea	26	23	0	2	10	12	0	8	8.000	2	1	0	1	0	1	2	0
				0.023	0.373	0.396		0.205	0.205	0.010	0.081		0.0021		0.004	0.0006	
Nsimbe Horticulture	43	42	0	6	15	21	0	9	9.000	6	4	3	1	0	1	5	0
				0.043	0.160	0.202		0.211	0.211	0.064	0.104	0.027	0.010		0.029	0.066	
Kasese Cotton	57	57	0	3	15	18	1	12	13	13	5	6	1	0	8	15	0
				0.005	0.183	0.188	0.003	0.149	0.151	0.109	0.021	0.047	0.002		0.062	0.112	
Bujagali Cultivations	82	82	0	11	31	42	4	14	18	5	9	7	1	0	5	13	6
				0.074	0.352	0.426	0.051	0.141	0.193	0.019	0.058	0.041	0.007		0.021	0.069	0.0546
Mpanga Cultivations	81	72	3	18	28	49	1	12	13	4	7	3	1	0	3	7	3
			0.005	0.143	0.259	0.407	0.007	0.062	0.069	0.008	0.049	0.022	0.008		0.008	0.039	0.012
Kifu Cultivations	79	69	3	23	29	55	1	8	9	2	5	3	1	0	1	5	2
			0.005	0.273	0.347	0.625	0.003	0.064	0.067	0.002	0.057	0.012	0.011		0.003	0.026	0.033
Mukono Cultivations	55	44	2	9	20	31	1	8	9	3	5	2	1	0		3	2
			0.025	0.124	0.315	0.464	0.005	0.084	0.089	0.011	0.060	0.016	0.014			0.030	0.014
Mubuku Cultivations	85	73	0	5	33	38	3	17	20	8	12	5	1	1	3	10	2
				0.012	0.337	0.349	0.026	0.137	0.163	0.037	0.068	0.019	0.016	0.002	0.011	0.049	0.006
Katugo Cultivations	101	74	0	12	36	48	1	10	11	3	10	4	1		7	12	3
				0.026	0.285	0.312	0.009	0.037	0.046	0.015	0.056	0.008	0.005	0	0.026	0.039	0.007
Kanyawara Cultivations	98	84	4	20	34	58	2	13	15	4	8	3		1	4	8	4
			0.002	0.052	0.280	0.334	0.006	0.133	0.139	0.016	0.056	0.008		0.006	0.024	0.039	0.004
Kyegegwa Cultivations	133	111	3	23	44	70	1	17	18	8	9	6		1	8	15	3
			0.004	0.187	0.465	0.656	0.006	0.116	0.122	0.026	0.080	0.037		0.001	0.054	0.092	0.010
Ziika Cultivations	96	86	3	17	35	55	1	15	16	6	6	5	1		5	11	3
			0.003	0.125	0.268	0.396	0.003	0.071	0.075	0.016	0.047	0.028	0.013		0.014	0.0544	0.013
Mubuku Pasture	69	56	0	1	18	19	2	7	9	11	8	5	1	1	5	12	4
				0.003	0.306	0.308	0.008	0.098	0.106	0.150	0.055	0.084	0.009	0.003	0.047	0.143	0.019

Notes: a Species with characteristics, such as F or P.

Appendix 8. Regression Analyses of Bird Numbers (as represented by lambda values) with Time, for the various categories[a] The first eight sites are ordered in decreasing levels of agricultural intensification (section 2…); Ziika included an area of grassland. For each site, the following regression statistics are given: Student's *t*, the number of observations, *n* and the proportion of the variance explained, r^2. Negative values of *t* indicate decreasing numbers of birds.

SITE	Total counts	Previous counts[b]	This study	Regression analysis	FF	F	f	WW	W		AA	A	Ap	PP	p
Bujagali Cultivations	9	5	4	**t**		0.600	0.464	-0.428	-0.770	1.042	0.645	-1.470	2.260^{x}	2.016^{x}	
				n		99	288	36	126	45	81	63	9	45	
				r^2		0.088	0.088	0.005	0.088	0.005	0.024	0.024	0.421	0.086	
Mpanga Cultivations	19	9	10	**t**	0.979	-1.108	3.870***	3.173**	-0.670	-0.874	-0.183	0.837	-0.058	-3.316**	
				n	57	342	532	19	228	76	133	57	19	57	
				r^2	0.017	0.004	0.027	0.372	0.002	0.0102	0.025	0.012	0.025	0.166	
Kifu Cultivations	18	7	11	**t**	-1.442	-0.218	-0.290	-1.420	-0.890	-0.385	-0.005	-0.998	-1.065		
				n	13	116	184	11	46	10	44	11	8		
				r^2	0.159	0	0.001	0.183	0.025	0.018	0	0.100	0.025		
Mukono Cultivations	10	0	10	**t**	0.006	-1.270	0.229	-0.718	-0.930	1.599	0	-1.180	2.108		
				n	20	90	200	10	80	30	50	20	10		
				r^2	0	0.018	0	0.061	0.011	0.084	0.025	0.072	0.025		
Mubuku Cultivations	8	3	5	**t**		-1.142	1.675^{x}	-1.011	-0.78	-1.845*	-2.035**	-0.206	2.427*	0.647	0.822
				n		45	297	27	153	72	108	45	9	27	9
				r^2		0.025	0.009	0.025	0.025	0.025	0.025	0.001	0.457	0.016	0.088
Katugo Cultivations	13	9	4	**t**		0.743	0.001	0.284	0.194	-1.047	-1.931*	-0.579	0.285	-0.425	
				n		156	481	13	130	39	130	52	13	91	
				r^2		0.004	0.007	0.025	0.025	0.025	0.025	0.007	0.007	0.002	
Kanyawara Cultivations	20	15	5	**t**	0.752	2.022*	0.058	-1.725	-1.3	-1.711^{x}	-2.655	-0.679		-2.486	0.287
				n	80	399	677	40	259	80	158	60		80	19
				r^2	0.025	0.001	0.025	0.073	0.007	0.036	0.025	0.025		0.025	0.005
Kyegegwa Cultivations	12	7	5	**t**	-1.153	-0.343	0.967	1.739	0.534	-1.238	-0.316	-2.128*		-1.160	-0.790
				n	36	276	540	12	204	96	108	72		96	12
				r^2	0.025	0	0.025	0.025	0.001	0.016	0.001	0.025		0.014	0.059
Ziika Cultivations	18	9	9	**t**	-0.732	0.149	3.131**	2.012^{x}	2.917**	-0.314	4.001***	-0.962	0.307	0.0181	
				n	54	306	630	18	270	108	108	90	18	90	
				r^2	0.001	0.025	0.015	0.025	0.025	0.025	0.131	0.001	0.006	0	

Notes a The categories are defined in Section 2.4 a dash (-) indicates that birds in this category were absent

b Numbers of counts from 1996 to 2003, inclusive. All counts were included in the regressions

c Probability values: x $P<0.1$ * $P<0.05$ ** $P<0.01$ *** $P<0.001$

Appendix 9. Lambda Values per Site (x 10^{-3})

				Large-scale Sites				Small-scale Sites									Pasture
AT_NO	Species Name	Species	Species Categories	Kasese Cotton	Lugazi Sugar	Lugazi Tea	Nsimbe Horti.	Bujagali	Mpanga	Kifu	Mukono	Mubuku	Katugo	Kanyawara	Kyegegwa	Ziika	Hima
17	Cattle Egret	*Bubulcus ibis*	GG				5.41	9.1			5.61	2.06					
26	Black-headed Heron	*Ardea melanocephala*	W	10.9	14.95		8.17	1.9	0.9	0.96	5.61	15.4		3.85	1.46	0.96	
28	Hamerkop	*Scopus umbretta*	W		4.65							4.08	2.74		1.5	3.17	
30	Open-billed Stork	*Anastomus lamelligerus*	W, GG, A					3.77									
32	Abdim's Stork	*Ciconia abdimii*	GG, A					1.87									
34	White Stork	*Ciconia ciconia*	P,	2.74													
36	Marabou Stork	*Leptoptilos crumeniferus*	W		24.69							6.06	1.32			5.41	
39	Hadada	*Bostrychia hagedash*	W		2.06		1.8	2.06			10.1	11.4		0.86	1.42	1.9	
73	Black-shouldered Kite	Elanus caeruleus	GG		2.06											0.98	2.41
75	Black Kite	*Milvus migrans*	Ap	2.41	16.25	1.83	9.53	6.6	8.1	11	14.3	16.4	4.51			12.8	9.24
77	Palm-nut Vulture	*Gypohierax angolensis*											1.34			0.96	
80	Hooded Vulture	*Neophron monachus*	f		6.6		5.41	1.87		0.94						0.98	
86	Brown Snake Eagle	*Circaetus cinereus*						2.02				1.87					5.72
87	Banded Snake Eagle	*Circaetus cinerascens*	F					1.98					1.29				
90	Harrier Hawk	*Polyboroides typus*	f	2.67		3.92		1.98		4.26			2.78			0.97	2.67
93	African Marsh Harrier	*Circus ranivorus*	WW							3.08	5.41					3.24	
98	African Goshawk	*Accipiter tachiro*	F					1.9									
100	Shikra	*Accipiter badius*	f					4.35				1.94	1.38		1.46	1.9	
103	Little Sparrowhawk	*Accipiter minullus*	f											0.84	1.48		
106	Great Sparrowhawk	*Accipiter melanoleucus*	F											1.77			
109	Lizard Buzzard	*Kaupifalco monogrammicus*	f					7.41	0.9	2.99	3.64	1.98	4.58	1.75	1.5	0.94	
116	Tawny/Steppe Eagle	*Aquila rapax*	GG, P												1.48		2.67

Appendix 9 continued... Lambda Values per Site (x 10^{-3})

AT_NO	SPE_NAME	Species	Species categories	Kasese Cotton	Lugazi Sugar	Lugazi Tea	Nsimbe Horti.	Bujagali	Mpanga	Kifu	Mukono	Mubuku	Katugo	Kanyawara	Kyegegwa	Ziika	Hima Pasture
117	Wahlberg's Eagle	*Aquila wahlbergi*	f, A					1.94					2.74		6.45		
119	African Hawk Eagle	*Hieraaetus spilogaster*		2.74									2.78	0.87	1.50		
122	Long-crested Eagle	*Lophaetus occipitalis*	f		8.34		6.74		4.17			3.85		5.03		1.94	2.41
129	Kestrel	*Falco tinnunculus*	P	5.26													
132	Grey Kestrel	*Falco ardosiaceus*								0.97							2.53
142	Helmeted Guinefowl	*Numida meleagris*	GG							0.97			4.32			0.93	9.84
154	Crested Francolin	*Francolinus sephaena*											2.67				
155	Scaly Francolin	*Francolinus squamatus*	F							0.96				0.85			
157	Heuglin's Francolin	*Francolinus icterorhynchus*	GG	2.53									6.16				
161	Red-necked Spurfowl	*Francolinus afer*															5.41
164	Button Quail	*Turnix sylvatica*	GG	2.47													
226	Crowned Plover	*Vanellus coronatus*	GG														2.60
268	Green Pigeon	*Treron calva*	F					1.94		0.96			1.32	0.84	9.18		
270	Tambourine Dove	*Turtur tympanistria*	F	2.41				1.98	2.90	20.88	6.45	2.06		1.77	5.04	3.08	
271	Blue-spotted Wood Dove	*Turtur afer*	f	6.06	12.14		0.01	40.55	9.31	6.74	14.66	7.06	45.68	10.54	65.06	4.26	
283	Red-eyed Dove	*Streptopelia semitorquata*	f				16.71	34.48	1.85	14.52	19.24	24.69	4.45	10.29	122.38	8.92	9.24
286	Ring-necked Dove	*Streptopelia capicola*	f	43.53								4.35	4.65	0.84	4.73	0.97	120.40
289	Laughing Dove	*Streptopelia senegalensis*		11.78				2.02				17.19		1.80	2.99	0.98	2.47
290	Grey Parrot	*Psittacus erithacus*	FF											0.87			
292	Brown Parrot	*Poicephalus meyeri*					3.77	2.02			8.17	4.17	2.78		0.01	0.98	2.47
293	Red-headed Lovebird	*Agapornis pullaria*	f											0.01			
296	Great Blue Turaco	*Corythaeola cristala*	F						1.98	17.44	34.29					13.76	
298	White-crested Turaco	*Tauraco leucolophus*	f										7.30				
302	Ross' Turaco	*Musophaga rossae*	F				1.80	6.74	0.92	3.14			1.34		21.13	7.32	
303	Bare-faced Go-away Bird	*Corythaixoides personata*															5.72
305	Eastern Grey Plantain Eater	*Crinifer zonurus*					17.69	10.82	6.45	34.03	59.78		27.19	0.87	55.00	12.60	

Appendix 9 continued... Lambda Values per Site (x 10^{-3})

AT_NO	SPE_NAME	Species	Species categories	Kasese Cotton	Lugazi Sugar	Lugazi Tea	Nsimbe Horti.	Bujagali	Mpanga	Kifu	Mukono	Mubuku	Katugo	Kanyawara	Kyegegwa	Ziika	Hima Pasture
309	Red-chested Cuckoo	*Cuculus solitarius*	F, A						5.18	4.17		1.90		2.69	19.11	0.95	
311	Eurasian Cuckoo	*Cuculus canorus*	P												1.42	0.94	
317	Emerald Cuckoo	*Chrysococcyx cupreus*	F											0.85	4.45		
319	Klaas' Cuckoo	*Chrysococcyx klaas*	f						0.92	1.89			1.34	1.80	9.18		2.60
320	Didric Cuckoo	*Chrysococcyx caprius*		12.14				2.02		1.94				0.84	12.52	2.06	
321	Yellowbill	*Ceuthmochares aereus*	F	0.01									1.32		1.42		
323	White-browed Coucal	*Centropus superciliosus*		5.00				1.94	0.89	1.96		4.26	6.06	0.86	9.18	3.02	
329	Scops Owl	*Otus scops*	p												1.48		
349	Freckled Nightjar	*Caprimulgus tristigma*													1.44		
357	Scarce Swift	*Schoutedenapus myoptilus*	F, AA											0.85			
358	Palm Swift	*Cypsiurus parvus*	AA					7.23	5.08		5.94		20.76			7.23	2.74
362	Eurasian Swift	*Apus apus*	P, AA					1.94					1.29			2.02	
363	White-rumped Swift	*Apus caffer*	AA		1.87						5.94	4.65					
365	Little Swift	*Apus affinis*	AA									15.91					
367	Alpine Swift	*Tachymarptis melba*	P, AA									1.98		6.25			2.74
368	Blue-naped Mousebird	*Urocolius macrourus*															13.35
369	Speckled Mousebird	*Colius striatus*			4.17		8.00	10.54	15.42	14.73	18.23	36.77	34.63	13.35	91.63	8.19	13.35
371	Narina's Trogon	*Apaloderma narina*	F												3.23		
373	Chestnut-bellied Kingfisher	*Halcyon leucocephala*	f, W, A	8.70								2.02					
374	Blue-breasted Kingfisher	*Halcyon malimbica*	FF, W						0.90							0.94	
375	Woodland Kingfisher	*Halcyon senegalensis*	A				15.82	4.45			6.06	4.17				8.70	
376	Striped Kingfisher	*Halcyon chelicuti*							1.85				1.36			6.67	
378	Pygmy Kingfisher	*Ceyx picta*	f, W					1.90				2.06					

Appendix 9 continued... Lambda Values per Site (x 10^{-3})

AT_NO	SPE_NAME	Species	Species categories	Kasese Cotton	Lugazi Sugar	Lugazi Tea	Nsimbe Horti.	Bujagali	Mpanga	Kifu	Mukono	Mubuku	Katugo	Kanyawara	Kyegegwa	Ziika	Hima Pasture
385	Little Bee-eater	*Merops pusillus*	GG									2.06		0.84	3.13	2.02	
387	Cinnamon-chested Bee-eater	*Merops oreobates*	F											1.77			
390	White-throated Bee-eater	*Merops albicollis*	f, A, AA	2.41			1.80	20.76	15.42	6.74		9.31	1.29	3.64	3.13	16.43	18.92
393	Madagascar Bee-eater	*Merops superciliosus*	A, AA	2.53				1.90	1.82				2.94		1.44		2.41
394	Eurasian Bee-eater	*Merops apiaster*	f, P, AA	5.41				1.87					4.26		1.50		
401	Broad-billed Roller	*Eurystomus glaucurus*	F, W, A	2.53			8.89	6.74		0.94	9.91		1.36		5.31	0.94	2.60
418	Pied Hornbill	*Tockus fasciatus*	F						2.74	2.00						3.08	
419	Crowned Hornbill	*Tockus alboterminatus*	f	2.41				2.06	4.00	7.23				0.87	1.42	4.50	
420	Grey Hornbill	*Tockus nasutus*		2.67									2.63				
422	Black and White Casqued Hornbill	*Ceratogymna subcylindricus*	F			13.35	5.94		57.25	138.63	22.96			7.57		63.91	
425	Grey-throated Barbet	*Gymnobucco bonapartei*	F							0.98							
426	Speckled Tinkerbird	*Pogoniulus scolopaceus*	F		4.35				5.13	10.01	11.51				1.50		
429	Red-rumped Tinkerbird	*Pogoniulus atroflavus*	FF								16.71						
430	Yellow-throated Tinkerbird	*Pogoniulus subsulphureus*	FF						2.93	3.14	8.52					0.95	
431	Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*	F			9.31		4.65	41.62	40.55	12.06		1.38	2.74	65.39	11.28	
433	Yellow-fronted Tinkerbird	*Pogoniulus chrysoconus*	f		4.26			4.45	4.12	2.00		1.87	22.88		4.96	6.74	
435	Hairy-breasted Barbet	*Tricholaema hirsutus*	F												2.99		
437	Spotted-flanked Barbet	*Tricholaema lacrymosus*											1.34				5.26
439	White-headed Barbet	*Lybius leucocephalus*											4.65		1.40		2.41
443	Double-toothed Barbet	*Lybius bidentatus*	f				8.17		2.90		10.54		9.02		4.73	8.10	
445	Yellow-billed Barbet	*Trachylaemus purpuratus*	FF												1.50		
450	Wahlberg's Honeybird	*Prodotiscus regulus*	f											0.85			
455	Black-throated Honeyguide	*Indicator indicator*	F												2.90		
456	Lesser Honeyguide	*Indicator minor*	f									2.02					

Appendix 9 continued... Lambda Values per Site (x 10^{-3})

AT_NO	SPE_NAME	Species	Species categories	Kasese Cotton	Lugazi Sugar	Lugazi Tea	Nsimbe Horti	Bujagali	Mpanga	Kifu	Mukono	Mubuku	Katugo	Kanyawara	Kyegegwa	Ziika	Hima Pasture
465	Nubian Woodpecker	*Campethera nubica*													4.45		
473	Cardinal Woodpecker	*Dendropicos fuscescens*												1.79			5.00
477	Grey Woodpecker	*Dendropicos goertae*	f					1.87		2.00					1.40		
489	Flappet Lark	*Mirafra rufocinnamomea*	GG	2.53													2.47
498	White-headed Roughwing	*Psalidoprocne albiceps*	f, AA		4.26			4.26	1.85	29.42	8.70	4.35	4.45		5.80	7.32	
499	African Sand Martin	*Riparia paludicola*	W, AA									2.06					
500	Sand Martin	*Riparia riparia*	WW, P, AA					6.90				2.06	8.70	5.29			5.41
503	Rufous-chested Swallow	*Hirundo semirufa*	AA									2.06			1.48		
504	Mosque Swallow	*Hirundo senegalensis*	AA				14.11					1.90		8.34	4.80		5.72
505	Striped Swallow	*Hirundo abyssinica*	AA		27.44		13.35		5.47	7.23	23.05	2.06		17.49	11.78		
512	Angola Swallow	*Hirundo angolensis*	W, AA	5.56	28.77	81.09	74.72	4.55	14.11	10.27	16.71	17.69	2.90	0.87	9.72	11.78	11.33
513	Eurasian Swallow	*Hirundo rustica*	W, P, AA	5.13				8.52	5.41	3.08		4.35	8.00	12.84	40.55	2.02	6.06
514	House Martin	*Delichon urbica*	P, AA										1.38				
525	Plain-backed Pipit	*Anthus leucophrys*	GG												1.44		12.92
527	Tree Pipit	*Anthus trivialis*	f, P										1.38		4.45		
529	Yellow-throated Longclaw	*Macronyx croceus*	GG	14.31			1.80		0.90			4.26		0.84	2.99	2.00	33.65
530	Red-shouldered Cuckoo Shrike	*Campephaga phoenicea*							0.88				2.90		1.40	0.95	
538	Little Greenbul	*Andropadus virens*	F						4.17	4.45		1.94			11.78	5.41	
542	Yellow-whiskered Greenbul	*Andropadus latirostris*	F												1.48		
545	Joyful Greenbul	*Chlorocichla laetissima*	FF											0.87			
547	Yellow-throated Leaflove	*Chlorocichla flavicollis*	f									2.06			1.48		
562	Common Bulbul	*Pycononotus barbatus*	f	27.44	54.65	55.96	25.59		38.57	102.96	98.08	117.87		81.83		82.67	49.25
563	Nicator	*Nicator chloris*	F							0.98							
576	White-browed Robin Chat	*Cossypha heuglini*	f	2.74		1.77		2.02				7.23	1.29			1.96	2.53

Appendix 9 continued... Lambda Values per Site (x 10^{-3})

AT_NO	SPE_NAME	Species	Species categories	Kasese Cotton	Lugazi Sugar	Lugazi Tea	Nsimbe Horti.	Bujagali	Mpanga	Kifu	Mukono	Mubuku	Katugo	Kanyawara	Kyegegwa	Ziika	Hima Pasture
578	Snowy-headed Robin Chat	*Cossypha niveicapilla*	F, W									4.26			3.03		
588	Brown-backed Scrub Robin	*Cercotrichas hartlaubi*	f	2.41								2.06			1.44		2.60
589	White-browed Scrub Robin	*Cercotrichas leucophrys*				1.71							6.25	0.01	1.46		
592	Stonechat	*Saxicola torquata*												11.00			
612	African Thrush	*Turdus pelios*	f	5.88	1.94	1.77	1.77	9.31	6.39	10.01	13.98	21.51	4.32	8.34	12.78	6.52	5.56
621	Moustached Warbler	*Melocichla mentalis*		2.74								1.87	2.86		1.42		
635	Olivaceous Warbler	*Hippolais pallida*	P												1.40		
638	Red-faced Cisticola	*Cisticola erythrops*	W	16.03		1.80		42.74	8.00			27.63	1.36	54.86	18.23	7.32	
640	Whistling Cisticola	*Cisticola lateralis*											1.38				
641	Trilling Cisticola	*Cisticola woosnami*											2.70		3.13		25.78
642	Chubb's Cisticola	*Cisticola chubbi*	F, W											2.82			
647	Winding Cisticola	*Cisticola galactotes*	W	6.45	15.82	5.61						7.23			0.01		
650	Croaking Cisticola	*Cisticola natalensis*	GG	5.56	2.06		5.61					1.94			1.44		
652	Siffling Cisticola	*Cisticola brachyptera*											2.78	3.88	3.17		2.47
655	Zitting Cisticola	*Cisticola juncidis*	W, GG	25.78													
658	Tawny-flanked Prinia	*Prinia subflava*	f, W	31.37	47.96	88.73	53.90	47.00	16.58	39.53	28.77	11.51	9.24	25.13	4.58	20.07	
662	White-chinned Prinia	*Schistolais leucopogon*	F					1.94	0.90					1.69	1.48		
664	Buff-bellied Warbler	*Phyllolais pulchella*	f												1.46		
667	Yellow-breasted Apalis	*Apalis flavida*	f							0.93							
673	Buff-throated Apalis	*Apalis rufogularis*	FF												1.48		
677	Grey-backed Camaroptera	*Camaroptera brachyura*	f	22.31	10.82	179.18	15.82	75.38	26.83	39.59	13.01	23.05	54.36	5.13	33.14	20.07	2.41
691	Red-faced Crombec	*Sylvietta whytii*	f					2.02									
695	Willow Warbler	*Phylloscopus trochilus*	f, P	2.74					1.92				1.31	4.93	1.46	2.96	

Appendix 9 continued... Lambda Values per Site (x 10^{-3})

AT_NO	SPE_NAME	Species	Species categories	Kasese Cotton	Lugazi Sugar	Lugazi Tea	Nsimbe Horti..	Bujagali	Mpanga	Kifu	Mukono	Mubuku	Katugo	Kanyawara	Kyegegwa	Ziika	Hima Pasture
701	Grey-capped Warbler	*Eminia lepida*	f, W					1.94							3.13		
713	Black Flycatcher	*Melaenornis edoliodes*						10.54	2.77	0.94		4.17	2.86	0.84	2.94		2.53
717	Spotted Flycatcher	*Muscicapa striata*	P	2.53										0.85			
719	Ashy Flycatcher	*Muscicapa caerulescens*	F													1.96	
720	Swamp Flycatcher	*Muscicapa aquatica*	WW					1.94									
723	Dusky Flycatcher	*Muscicapa adusta*	F		4.35		8.89			2.02	5.41			5.83		1.96	
728	Lead-coloured Flycatcher	*Myioparus plumbeus*	f										1.32		3.17		
732	Blue Flycatcher	*Elminia longicausa*	f					10.01		3.17	8.00	2.06		8.80			
739	Paradise Flycatcher	*Terpisiphone viridis*	f					8.70		3.08	7.70	1.87	4.65	0.87	4.58		
740	Red-bellied Paradise Flycatcher	*Terpisiphone rufiventer*	FF											0.01			
742	Black and White Flycatcher	*Bias musicus*	f									7.23		0.01	9.18	0.98	
746	Wattle-eye	*Platysteira cyanea*	f		4.35	3.92		13.35	10.92	6.98	15.82	2.06	8.41	1.75	4.96	4.17	
749	Chin-spot Batis	*Batis molitor*	f												1.46		5.26
751	Black-headed Batis	*Batis minor*	f										1.32				
761	Brown Babbler	*Turdoides plebejus*													9.18		
764	Black-lored Babbler	*Turdoides sharpei*													1.50		5.56
771	Black Tit	*Parus leucomelas*	f						2.84				1.34			0.96	
781	Green-headed Sunbird	*Cyanomitra verticalis*	F						2.96	4.55		1.87	1.32	10.06	7.41	3.08	
784	Olive Sunbird	*Cyanomitra obscura*	FF						0.92	0.98				0.01			
785	Green-throated Sunbird	*Chalcomitra rubescens*	F						1.89	2.04				0.86			
787	Scarlet-chested Sunbird	*Chalcomitra senegalensis*				1.74		16.99	16.71	21.57	13.98	8.70	13.61	39.69	6.25	13.91	33.65
790	Bronze Sunbird	*Nectarinia kilimensis*	f									6.45		7.49	4.88		
794	Collared Sunbird	*Hedydipna collaris*	F						1.83	2.00			5.80	2.77	4.65	1.98	
796	Olive-bellied Sunbird	*Cinnyris chloropygia*	F		4.35			26.57	3.88	8.19			4.20	0.01	5.13	2.00	
802	Mariqua Sunbird	*Cinnyris mariquensis*						4.26	9.31	8.49	7.85	6.90	44.80	0.86	6.56	0.95	

Appendix 9 continued... Lambda Values per Site (x 10^{-3})

AT_NO	SPE_NAME	Species	Species categories	Kasese Cotton	Lugazi Sugar	Lugazi Tea	Nsimbe Horti	Bujagali	Mpanga	Kifu	Mukono	Mubuku	Katugo	Kanyawara	Kyegegwa	Ziika	Hima Pasture
803	Red-chested Sunbird	*Cinnyris erythroceria*	WW					40.55	6.98								
808	Variable Sunbird	*Cinnyris venusta*	f		20.07			4.26	13.91	16.09	14.66		10.18	8.89	5.04	17.69	
810	Copper Sunbird	*Cinnyris cuprea*	f, W		18.81	11.51	1.74	4.17	4.04	5.08	3.51		4.38	4.93	1.50	7.32	
811	Yellow White-eye	*Zosterops senegalensis*	f					10.27	23.73	4.08	20.76		6.35	6.77	5.31	5.59	
812	Fiscal	*Lanius collaris*	GG	6.06					2.90		1.71	16.71			6.56		62.86
814	Mackinnon's Shrike	*Lanius mackinnoni*	f					1.90	0.90						2.90		
815	Grey-backed Fiscal	*Lanius excubitorius*	f, W, A	16.71								2.06				0.95	57.54
824	Grey-headed Bush Shrike	*Malaconotus blanchoti*													1.50		
827	Grey-green Bush Shrike	*Malaconotus bocagei*	F												1.48		
828	Sulphur-breasted Bush Shrike	*Malaconotus sulfureopectus*	f										4.73		3.13		
830	Marsh Tchagra	*Antichromus minuta*	W												1.48		
831	Brown-headed Tchagra	*Tchagra australis*						1.90				1.98	4.20	4.53	3.08		5.56
850	Black-headed Oriole	*Oriolus larvatus*	f				12.06						2.99				
833	Black-headed Tchagra	*Tchagra senegala*		10.54									1.31				
836	Northern Puffback	*Dryoscopus gambensis*	F					9.10	0.90	0.93			2.86			0.94	
841	Tropical Boubou	*Laniarius aethiopicus*	f				6.45		0.90	1.89	8.34	2.06	29.63	0.87	48.55	2.04	5.26
843	Black-headed Gonolek	*Laniarius erythrogaster*	f								1.71	2.06	11.03			6.52	
848	Western Black-headed Oriole	*Oriolus brachyrhrhynchus*					1.74										
853	Drongo	*Dicrurus adsimilis*	F							1.96					1.50		
855	Pied Crow	*Corvus albus*			2.02		6.45	2.06		0.94	5.94	23.84	1.38			0.93	2.67
858	Piapiac	*Ptilostomus afer*											1.29				
866	Purple-headed Glossy Starling	*Lamprotornis purpureiceps*	F											0.85			
869	Blue-eared Glossy Starling	*Lamprotornis chalybaeus*													3.08		

Appendix 9 continued... Lambda Values per Site (x 10^{-3})

AT_NO	ENGLISH NAME	SPECIES NAME	Species categories	Kasese Cotton	Lugazi	Lugazi Tea	Nsimbe Horti	Bujagali	Mpanga	Kifu	Mukono	Mubuku	Katugo	Kanyawara	Kyegegwa	Ziika	Hima Pasture
870	Lesser Blue-eared Glossy Starling	*Lamprotornis chloropterus*											2.74				
871	Splendid Glossy Starling	*Lamprotornis splendidus*	F				15.42	10.27	1.92	1.98	12.52		2.86	3.77	4.80	1.98	
872	Ruppell's Long-tailed Glossy Starling	*Lamprotornis purpuropterus*		9.24		4.08	15.82		0.90	0.96	10.54	13.35	2.67		2.82	2.96	5.72
876	Violet-backed Starling	*Cinnyricinclus leucogaster*	f, A														2.74
881	Grey-headed Sparrow	*Passer griseus*		2.74		3.39		4.65	47.45	39.53	20.59	10.27	1.29	33.31	1.40	8.00	8.70
893	Baglafecht Weaver	*Ploceus baglafecht*	f							0.98		21.62	1.29	10.92	12.86	0.94	8.70
894	Slender-billed Weaver	*Ploceus pelzelni*	F, W					10.01							1.50		
895	Little Weaver	*Ploceus luteolus*										1.90					
896	Black-necked Weaver	*Ploceus nigricollis*	f			1.80			3.02	5.24		1.98		2.64	8.27	4.21	
897	Spectacled Weaver	*Ploceus ocularis*	f						0.90	0.95			1.31		1.44	0.97	5.26
900	Holub's Golden Weaver	*Ploceus xanthops*	W											3.96	12.41	0.94	
902	Northern Brown-throated Weaver	*Ploceus castanops*	f, W											0.87			
907	Vieillot's Black Weaver	*Ploceus nigerrimus*	f				1.83	1.94	38.68	19.11	3.64			29.33	25.13	1.92	
908	Black-headed Weaver	*Ploceus cucullatus*		6.25		17.77	20.76	30.01	21.96	16.09		3.92	1.36	4.65	13.35	14.95	5.56
909	Weyns' Weaver	*Ploceus weynsi*	F						2.87								
910	Yellow-backed Weaver	*Ploceus melanocephalus*	WW	2.74				2.02				21.51			6.45		2.60
911	Golden-backed Weaver	*Ploceus jacksoni*	W					3.85								1.98	2.41
920	Red-headed Malimbe	*Malimbus rubricollis*	FF							0.95					1.40	0.98	
922	Red-headed Weaver	*Anaplectes rubriceps*											2.78				
923	Cardinal Quelea	*Quelea cardinalis*	A											1.82			
925	Red-billed Quelea	*Quelea quelea*	A	14.31											1.42		
927	Black Bishop	*Euplectes gierowii*	W						0.90				1.34				
928	Black-winged Red Bishop	*Euplectes hordeaceus*											2.86		1.46		

Appendix 9 continued... Lambda Values per Site (x 10^{-3})

AT_NO	ENGLISH NAME	SPECIES NAME	Species categories	Kasese Cotton	Lugazi	Lugazi Tea	Nsimbe Horti.	Bujagali	Mpanga	Kifu	Mukono	Mubuku	Katugo	Kanyawara	Kyegegwa	Ziika	Hima Pasture
929	Southern Red Bishop	*Euplectes orix*	GG	2.47													2.74
932	Fan-tailed Widowbird	*Euplectes axillaris*	W		12.36	5.94			0.88					4.65			
934	White-winged Widowbird	*Euplectes albonotatus*	GG	16.03													
935	Red-naped Widowbird	*Euplectes ardens*										1.90			4.80		
937	Grosbeak Weaver	*Amblyospiza albifrons*	f, WW									2.06		0.87			
939	Grey-headed Negrofinch	*Nigrita canicapilla*	F						4.04	3.11	8.89			1.68	2.99	0.97	
945	Green-winged Pytilia	*Pytilia melba*											1.36				
959	Red-billed Firefinch	*Lagonosticta senegala*		5.56			1.74	16.71	5.88	6.25	8.17	9.76	7.52	15.42	1.40	8.10	5.88
963	African Firefinch	*Lagonosticta rubricata*							0.91				1.34	0.01		0.97	2.53
965	Yellow-bellied Waxbill	*Estrilda melanotis*	f											0.84			
966	Fawn-breasted Waxbill	*Estrilda paludicola*												5.77			
969	Waxbill	*Estrilda astrild*	W, GG	2.53	13.35	6.32	5.83		2.96	0.95	3.70	2.02	4.45	8.43	7.28		
970	Black-crowned Waxbill	*Estrilda nonnula*	f		1.98	24.78	1.80	13.01	7.91	3.11	7.15	18.23		14.40	5.04	0.96	
972	Black-faced Waxbill	*Estrilda erythronotus*	F										1.31				
974	Red-cheeked Cordon Bleu	*Uraeginthus bengalus*						1.94					8.41				
980	Bronze Mannikin	*Lonchura cucullata*		10.54	14.52	5.22	25.59	18.23	25.34	30.01	53.90	23.18	21.26	24.92	2.99	33.27	2.53
981	Black and White Mannikin	*Lonchura bicolor*	f		4.35				14.79	5.85	13.06	4.08	2.90	5.94	11.78	14.11	
984	Red-billed Firefinch Indigobird	*Vidua chalybeata*						1.90					1.31				
985	Pin-tailed Whydah	*Vidua macroura*	GG	8.96				1.90				4.08		5.66	1.50		2.41
991	African Citril	*Serinus citrinelloides*	f					7.41	0.90			12.06	4.65	12.06	4.88	0.95	2.41
995	Yellow-fronted Canary	*Serinus mozambicus*			1.94			8.00	9.95	0.95	7.85	6.19	11.33	16.25	4.88	10.54	2.74
997	Brimstone Canary	*Serinus sulphuratus*		5.26										1.79	1.40		2.60
1005	Golden-breasted Bunting	*Emberiza flaviventris*													1.48		5.13