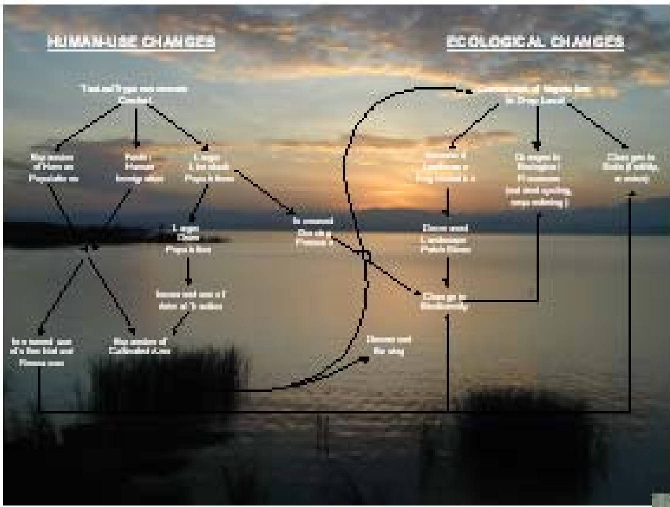
Environmental impact assessment of the elimination of the tsetse fly using SIT in the southern Rift Valley of Ethiopia

Final report *to the*

International Atomic Energy Agency (IAEA), Vienna, Austria

Submitted 12 March 2002

ILRI
INTERNATIONAL
LIVESTOCK RESEARCH
INSTITUTE



Cathleen J. Wilson, John McDermott and Robin S. Reid
International Livestock Research Institute (ILRI), Nairobi, Kenya

Zerihun Woldu, Sebsebe Demissew and Tesfaye Korme
Addis Ababa University
Addis Ababa, Ethiopia

Table of Contents

Executive summary

Between March 2001 and February 2002, scientists at the International Livestock Research Institute (ILRI) and the Addis Ababa University (AAU) completed an *ex ante* study of the impacts of controlling the tsetse fly on land use and the environment in the southern Rift Valley of Ethiopia, funded by the International Atomic Energy Agency (IAEA). This report explains that study with a technical report followed by an administrative report in Annex I.

In the southern Rift Valley, the Ethiopian Science and Technology Commission, supported by the IAEA, is controlling the tsetse fly first by using pyrethroid-based pour-ons and traps to suppress populations and then using the sterile insect technique (SIT). Previous research has shown that use of pyrethroid techniques has minor impacts on non-target terrestrial and aquatic insects and birds, and the few impacts that do exist are short lived. We do not expect to see any direct impacts of the sterile insect technique on non-target organisms. Rather, we expect that the indirect impacts of tsetse control and subsequent elimination, by encouraging expansion and intensification of land use, will have far greater impacts on the environment. Given this expectation, we designed this study to assess the impacts of tsetse control (by traps, pour-ons and SIT) on land-use and the environment.

The environmental impacts of tsetse control are often variable, differing from place to place. In addition, many different factors are likely to have had and will have major environmental impacts, independent of tsetse control and eventual elimination. Thus, assessing the environmental impact of tsetse control relative to other factors may be difficult. For these reasons, the key purpose of this report is to provide colleagues and decision makers in Ethiopia with some baseline data and monitoring tools/indicators to help them in assessing and acting on environmental changes. We also provide some 'educated' guesses on future potential scenarios, based on our experiences, to stimulate discussion and decisions on environmental monitoring and management in the southern Rift Valley control area.

While acknowledging that tsetse control may not be as important as other factors in influencing land use and land cover changes, as tsetse flies are restricted to areas below 2000 m in the study area, it is the lowland areas where we expect the environmental impacts of tsetse control will be the greatest. In the lowlands, grazing, cultivation and other forms of land use (e.g. wood collection) will expand. This is likely to put increased pressure and decrease (if not protected) riparian woodlands changing them to bushland. With even greater use bushland will change to wooded grassland. Smallholder cultivation, currently almost non-existent, will expand. There may also be 'knock-on' effects of the control in the lowlands on the agricultural practices in the nearby highlands. These 'knock-on' effects will largely depend on other factors such as increasing access to areas with improved tracks and roads and migration.

Beyond these general 'expected' impacts, field data collected during this study suggest that:

- Expansion of crops and livestock after tsetse control in the lowlands will likely strongly affect two fragile and species-rich areas: riparian woodlands and Nechisar National Park.
- Native species will lose abundance and possibly disappear entirely when agriculture expands after tsetse control in the lowlands.
- In the highlands, if cropland contracts as people move to the lowlands, some native biodiversity will be regained, but the original ecosystems will not be restored because the land has been so heavily used for both cropping and grazing for so long. If

cropland converts to grazing land, overall biodiversity will be lost but some unique grassland species may recover.

Future trends will depend on agricultural, environmental and socio-economic influences. These highlight the need to integrate socio-economic and environmental assessments.

Introduction

The tsetse fly has restricted human use of arable land in Africa and, as a consequence, has been both the major constraint to rural development (reference) and the 'protector of biodiversity' (Jordan 1986), depending on one's perspective. In the southern Rift Valley of Ethiopia, the highlands are tsetse-free and densely cultivated and grazed. Lowland areas, still infested with tsetse, support sparse cultivation and moderate grazing (FDRE 1997). With growing human populations and demand for increased food production, both highlands and lowlands are currently under pressure to be more intensely used for agriculture.

In March 2001, the International Livestock Research Institute (ILRI)[1] was contracted by the International Atomic Energy Agency (IAEA) to develop baseline data, monitoring tools/indicators and impact assessments to help Ethiopian decision makers with environmental monitoring and management. Of particular interest was to consider these in the light of the possible environmental impacts of eliminating the tsetse fly in the lowlands of the southern Rift Valley using the sterilised insect technique (SIT) as the final method of elimination (FDRE 1997, see Terms of Reference in Annex I). In addition to SIT, tsetse suppression began with the use of non-insecticidal traps and pour-on insecticide.

Previous studies have shown that tsetse control can have *direct impacts* on the environment by affecting non-target organisms and *indirect impacts* on the environment by affecting the way people use the land. The direct impacts of SIT, traps and pour-ons are expected to be small. Compared to other methods, the SIT method has the fewest direct impacts on non-target species (Muller and Nagel 1994; Leak 1999). Other methods use pesticides (e.g. DDT) that are often harmful to non-target organisms (Davies 1993; Nagel 1993; Douthwaite 1994; Leak 1999; Bourn et al. 2001; Vale 2002). The pour-on method uses pyrethrins which are low in toxicity to humans, other mammals and birds, but have been shown to have negative impacts on non-target insects (honey-bees), marine invertebrates and fish (Clark et al. 1989; Muller and Nagel 1994; Tomlin 1994). Pyrethrins also have a soil half-life of 12 days, an extremely low pesticide movement rating because they bind tightly to the soil, and are unstable in light and air and rapidly degrade in sunlight at the soil surface and in water (Ray 1991; Wauchope et al. 1992). The tsetse traps often catch non-target insect species as well (e.g. butterflies, bees; Muller and Nagel 1994; Wilson and warden Chemere Zewdie, personal observations). However, the effect of these suppression techniques on the environment and biodiversity is not completely understood and requires further research.

The indirect impacts of tsetse control (by SIT, traps or pour-ons) are expected to be larger than the direct impacts (Jordan 1986). While large, the environmental impacts of tsetse control often vary, depending on the environmental and socio-economic context. Beyond this, many different factors are impacting on the environment simultaneously, such as assessing and managing the environmental impacts of tsetse control/elimination, which, relative to other factors, may be difficult unless long-term experimental approaches are used.

A recent review of the evidence collected so far in Africa highlights the following points (Reid 1999):

- First, across Africa, the most crucial reservoirs of biological diversity are also areas where people and livestock concentrate their use: wet areas (gallery forests in Côte d'Ivoire, riparian forests in Ethiopia, alluvial woodlands in Zimbabwe, wetland thicket in Kenya, and wetland woodlands in Burkina Faso). Increased human and livestock use

1. ILRI sub-contracted scientists at the Addis Ababa University to collect data on the impacts of land use change on vegetation.

after tsetse/trypanosomosis control threatens the existence of these biologically rich areas and reduces their ability to sustain the flow of ecological goods and services to people over the long term.

- Second, upland or interfluve areas are less affected by intensified human use after tsetse/trypanosomosis control partly because the species in these habitats are better adapted to stress and partly because these areas are used less intensively than the wetter areas (Gardiner and Reid 1997a; Reid et al. 1997; Wilson et al. 1997; Kiema and Reid 1998). Thus, expansion of farming and grazing after tsetse/trypanosomosis control (or after human population growth more generally) is likely to affect some parts of the landscape more than others. There are therefore good opportunities to target better natural resource management efforts on crucial habitats.
- Third, in all systems studied, some species are lost and some are gained when low use areas are converted to cropped or heavily grazed areas after tsetse/trypanosomosis control (Gardiner and Reid 1997a; Reid et al. 1997; Wilson et al. 1997). The value of these lost and gained species to people and ecosystem function is unknown and needs to be assessed urgently.
- Furthermore, it is apparent that some taxonomic groups are more affected by the expansion of farming and habitat loss than others. For example, large mammals are more affected by human presence than any other taxonomic group (Reid, et al. 1996; Gardiner and Reid 1997b). On the other hand, birds and butterflies are less affected by conversion of wildland into farmland after tsetse/trypanosomosis control (Gardiner 1997; Gardiner and Reid 1997c; Wilson et al. 1997; Garden et al. 1998)

Given the varying and multiple factors influencing environmental change, the key purpose of this report is to provide colleagues and decision makers in Ethiopia with some baseline data and monitoring tools/indicators to help them in assessing and acting on environmental changes associated with the planned control and elimination of tsetse in the southern Rift Valley region of Ethiopia. We also provide some 'educated' guesses on future potential scenarios, based on our' experiences, to stimulate discussion and decisions on environmental monitoring and management in the southern Rift Valley control area.

Based on this broader objective, there were a number of specific sub-objectives in this study:

1) Co-ordinate and facilitate the management of the AAU–ILRI collaborative monitoring efforts,
2) Guide and assist in the assessment of existing environmental data and assist in the design and collection of additional data,
3) Guide and assist in the identification of representative areas for the collection of environmental data, preferably where veterinary and entomological data already exist;
4) Train staff and other individuals involved in the collection and evaluation of the data, as needed,
5) Assist in the establishment of baseline environmental data against which to assess the future impacts of SIT control,
6) Complete a quantitative assessment of the probable impacts of the evolution of agricultural systems after tsetse control on birds and plants (diversity and abundance) in the major vegetation types in the study area. This will be done by measuring bird diversity and abundance in areas with little human use (grazed but not cultivated) with areas already converted to agriculture,

7) Complete a qualitative assessment of the probable impacts of the evolution of agricultural systems after tsetse control on large mammals (presence/absence) in the study area,
8) Assist in integrating socio-economic, environmental (vegetation, bird and large mammals), veterinary and tsetse entomological data in preparation of a summary report on the situation, and
9) Complete a report on the potential impacts of SIT control on birds and mammals and compile a comprehensive summary report on environmental impacts.

In the following technical report, we describe the likely impacts of land-use change following tsetse control on birds, vegetation and large mammals in the highlands and lowlands of southern Ethiopia (objectives 6, 7 and 9 above). These data serve as a baseline against which future impacts of SIT can be assessed (objective 5). In addition, we suggest a future protocol for an environmental monitoring programme and recommend management interventions. The first four objectives were accomplished during the fieldwork. Objective 8 can be addressed once the socio-economic and disease data are available.

Description of the project area
General description
This study covers all of the land area that will be subjected to tsetse control in the first phase of the SIT project (Figure 1). This project area is situated about 300 km south of the capital of Addis Ababa and covers approximately 15,400 km^2 of highland and lowland landscapes. The project area includes Lake Abaya and a portion of Lake Chamo, as well as the towns of Arba Minch, Dila, Sodo and Chencha. Between the two lakes is the region's only protected area, Nechisar National Park. Elevation in the project area varies from 1100 to 3000 m. Rainfall in the highlands falls principally in one season, while in the lowlands rainfall is split into two seasons (FDRE 1997). Rainfall is high and sufficient for successful cropped agriculture (1200–2000 mm per year); in the lowlands, only some of the area has sufficient rainfall to support cultivation (400–1200 mm per year).

Soils
The project area is underlain by quarternary and tertiary volcanic rocks (EMA 1988). In the north and to the east the soils are largely eutric nitrosols (EMA 1988). This soil type has limited agricultural value as they are usually on rocky shallow slopes. Around Lake Abaya the predominant soils are calcaric eutric fluvic types. These alluvial soils are highly variable and often saline. They are generally good agricultural soils and often intensively used; however' the land-use should be adapted to high floods and groundwater potential nearest to the lake. Nechisar Park is mainly this soil type but in the western portion of the reserve and further west there are chromic and orthic luvisols (lithic phase) with good agricultural potential. This soil type in the stoney phase is also predominant south of Awassa.

The highlands surrounding the study area are Orthic acrisols-stoney phase soils that have few limitations although rooting may be limited by rock at shallow depths.

Vegetation
Vegetation in the project area varies from semi-arid scrubland to montane moorlands. There is little natural forest remaining in the entire area, other than in Nechisar and an occasional sacred forest in the highlands. Many areas in the lowlands and highlands show signs of overuse and erosion (see Annex VI — photo of eroded landscape). Other areas, often tsetse infested, were dense bushland. The shoreline habitat is also extensive around the perimeter of Lake Abaya and the northern end of Lake Chamo.

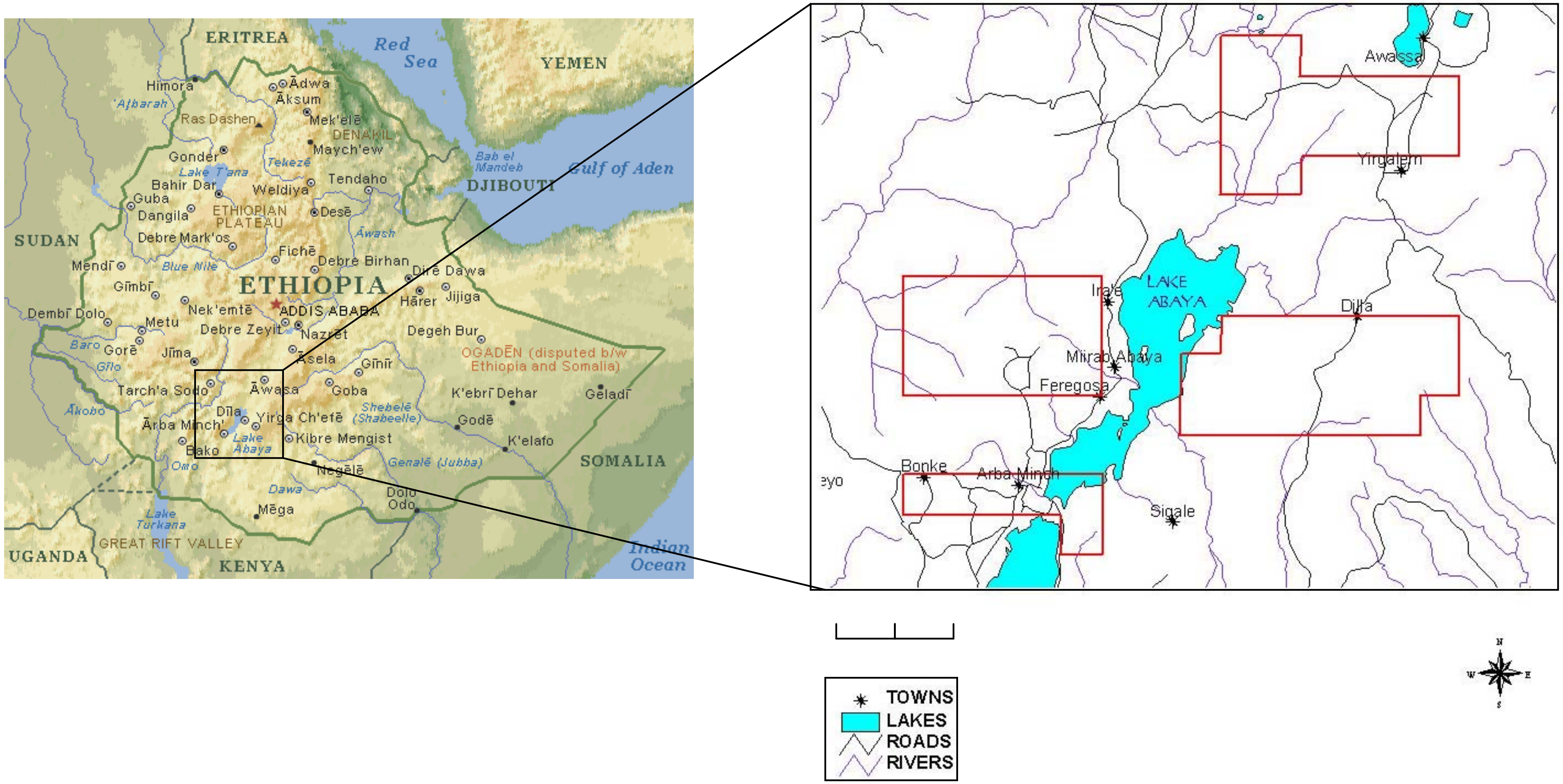
See ***Results and discussion — Vegetation*** section for detailed description of the predominant land-use/land cover types sampled in this study.

Land-use
A land-use/land cover map was classified and analysed by Dr. Tesfaye Korme at Addis Ababa University. He is currently comparing land-use by using remote sensing imagery for the project area from 1993–2001. These analyses will be valuable in assessing the rates of change in land use in the study area before and after tsetse control is successful.

Land-use in the project area varies from an area reserved for wildlife use (Nechisar Park) to intensified cultivation in the highlands (Chencha, Bule), to semi-arid lowland grazing (around lakeshores at lower elevations). There are a few state farms and plantations near to the larger rivers (e.g. Bilate).

Figure 1: *Map of the project area in the southern Rift Valley of Ethiopia.*

.



In the highlands near Dila, shade-grown coffee is grown and, therefore, farmers do not cut the very large trees, which are often native species. This system of agriculture in the highlands appears to be very sustainable. The large trees in these systems stabilise the soil and thus conserve soil nutrients.

Potential impacts of tsetse control on land use and the environment

It must be recognised that any impacts due to tsetse control will take place in landscapes already changing for a whole host of reasons. One important influence is that migration from other highland areas greatly hastened if accompanied by the development of roads. Significant changes in pre-tsetse control have already taken place, based on satellite image analysis and observations of land use and land cover changes by residents in the study area. Two important examples are the incursion of agricultural activities into the Nechisar Park and extensive tree clearing in the Deme River Valley.

Thus, the impacts we outline below on the potential impacts of tsetse control must consider that these changes may only serve to hasten current trends. If tsetse control is accompanied by a coordinated land use planning effort then some of the changes described below can be mitigated from the onset. However, land use planning efforts require considerable organisation and coordination and have rarely been part of tsetse operations in the past in other areas of Africa. Given the rapid changes in land use and land cover noted in past years and the strong pressures on land currently and in the future, there is an urgent need for land use policies and planning in the area.

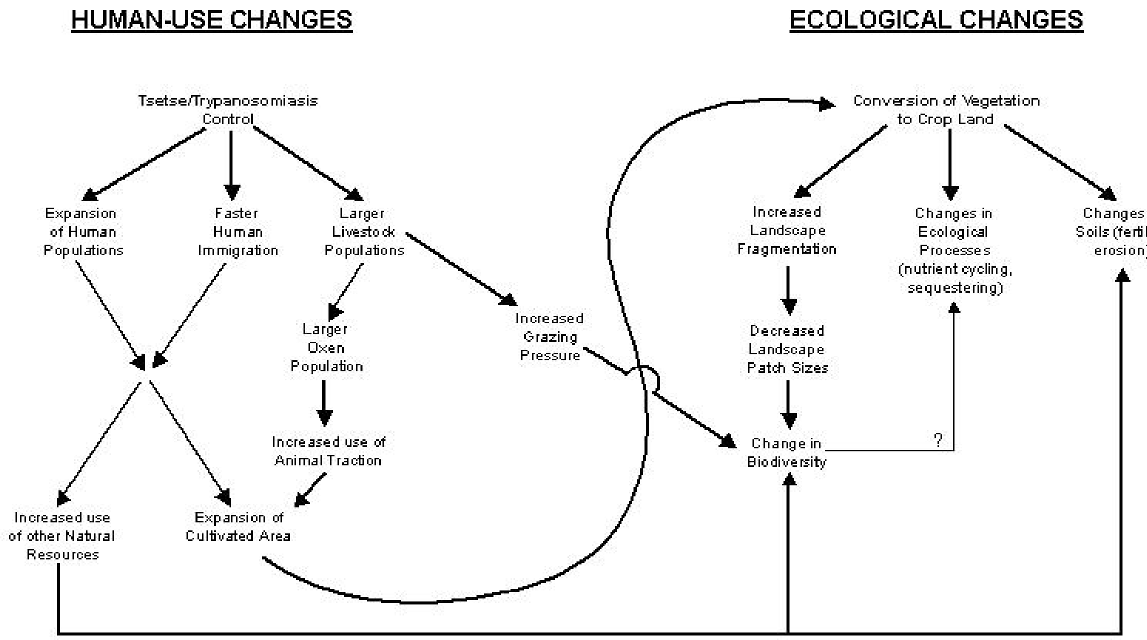
The most likely effects of tsetse control will be in its target zone, areas currently infested with the tsetse fly below 2000 m elevation (lowlands). Relieving the tsetse and trypanosomiasis constraint is expected to encourage an in-migration of people and their livestock and increased use of animal traction (see Figure 2). It is difficult to predict what the impacts of increased use of the lowlands will have on the highland. One possible trend is that people and their livestock move out of the highlands, relieving some of the land-use pressure there. However, it may be that these effects are relatively modest or that opening the lowlands only slows increasing population and utilisation pressure on the highlands. In summary, we expect that the impacts of tsetse control in the southern Rift Valley will have much greater impacts on the lowlands than on the highlands.

Clearly, the impacts of tsetse control on the highlands will depend on how strongly the disease constrains human populations, livestock populations and land use. Reduced livestock mortality will likely cause livestock populations to grow in the lowlands. Farmers with healthier oxen will be able to plow more land and areas freed from the disease may attract migrants, causing human populations to grow in the lowlands. Both the growth of human populations and livestock populations should indirectly expand the area of cropland or intensify production (yield/unit area cultivated). More people will also require more of other natural resources like fuelwood, wild foods (plants or wildlife), and water. More livestock will require more forage and water. As more people move to the lowlands, they will light more bushfires. Increased burning will remove critical nutrients from the system and release more greenhouse gases.

Depending on the magnitude of these changes, different effects on the environment can be expected. For example, increased grazing and browsing can either decrease woody vegetation by preventing regeneration of woody saplings (e.g. Belsky 1984) or can encourage woody regeneration by removing competition from grasses (e.g. Pratt and Gwynne 1977). Increased bushfire burning can either reduce woody vegetation strongly or have no effect, depending on burning frequency (Frost 1996). Farmers can either clear land for agriculture and remove woody vegetation or create forest islands from savannah (Fairhead and Leach 1996).

It is hypothesised here that the most important ecological impacts of tsetse control in the lowlands will revolve around impacts on vegetation, biodiversity, nutrient cycling, atmospheric emissions, and landscape pattern. In specific cases, disease control may have important impacts on water quality and erosion. This broad basket of effects implies that tsetse control could have potentially huge economic effects through the environment (Rapport et al. 1998), because it may affect many of the basic ecological goods and services that support human economic systems.

Figure 2. *Potential impacts of control in the lowlands.*



As already stated, tsetse control may not have a great impact on the highlands, depending on human migration patterns. This assumes that trypanosomiasis is the main constraint to greater utilisation of the lowlands, relative to malaria and other constraints. If most migration was local, highland areas may be vacated by farmers who move to tsetse-free areas in the lowlands. If others do not take up these lands, it is possible that some of the croplands in the highlands will be converted to fallow lands, woodlots and other land uses. In Latin America, farmers who take land out of production turn the most marginal lands into fallow first, thus taking the lands with the greatest erosion risk out of production first (Reid and Holmann unpublished interviews). Recovery of these marginal lands may increase biodiversity in the system, but not significantly because these areas are naturally poor in species. If this happens in the highlands in the study area, this would have strong environmental benefits in these steep lands. Return of highland areas to their original low use status is unlikely, as most highland habitats have already lost much of their ecological capacity through heavy use. Thus, highland habitats are unlikely to recover to their original state unless expensive ecosystem restoration is attempted.

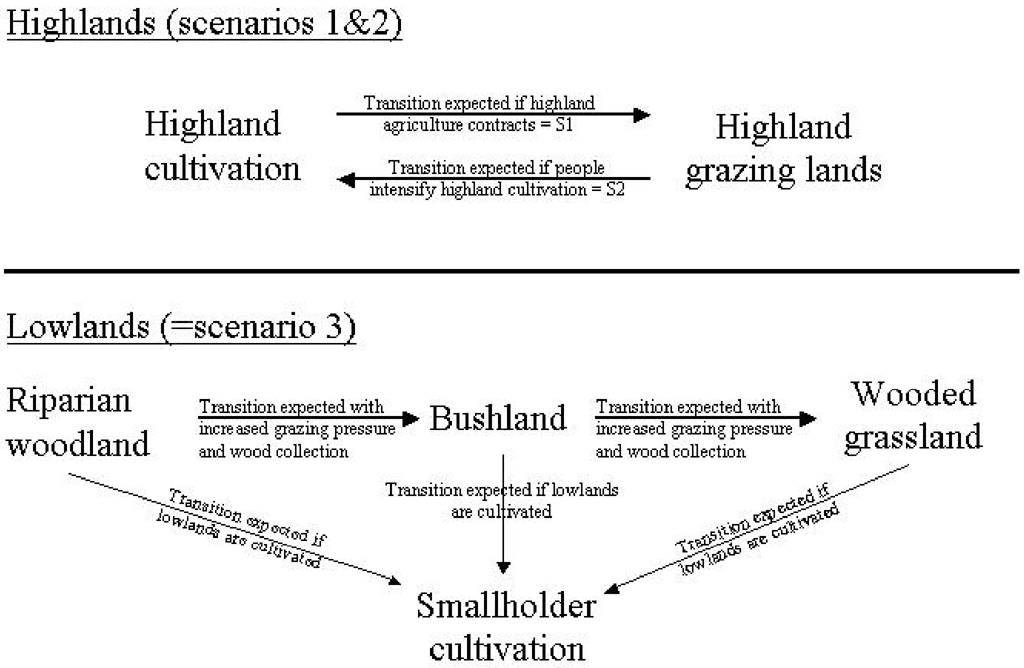
A more likely scenario is that cropland may not contract in the highlands for two reasons: 1) any land made open by out-migration will likely be used either by the growing populations left behind in the highlands or by in-migration of farmers from other areas, even more intensively used, or 2) the need for more land may be so great in the highlands that farmers left behind may use the vacated land to increase their cropland area.

Methods

Site selection and study design

This study tested some of the scenarios suggested above. It was designed to estimate the likely impacts of tsetse control, through selected changes in land-use, on biodiversity and vegetation. To do this, we selected sampling plots within different land-use/land-cover types (hereafter called LU/LC types) that represented the land-use changes that are likely to be driven by the control of the tsetse fly. Figure 3 shows the land-use types currently available in the study area and the likely transitions that tsetse control might cause between these types, given the three impact scenarios.

Figure 3. *Expected transitions between land-use types in the highlands and lowlands because of tsetse control that were measured in this study.*



Two land-use types were selected for study in the highlands (cultivated and grazing lands) and three were selected in the lowlands (riparian woodland, bushland, and wooded grassland). These lowland types are currently grazed by livestock at moderate to high levels. There were no cultivated areas large enough to sample in the lowlands. Two additional types (grassland and lakeshore) were sampled only in Nechisar National Park as a 'low-use' comparison to the lowland areas outside the park and to establish a baseline of information for this protected area (See Annex VI for photos of the LU/LC types sampled).

Replicated plots were established within each of these types on each of the four transects (running from highlands to lowlands) chosen for the socio-economic study conducted by the Southern Regional Government. Three plots (250 m × 250 m) were randomly located in each of the LU/LC types on each transect using an interpreted Landsat TM image of the project area (see Annex II for plot coordinates). These plots were selected through a sub-contract to Dr. Korme of AAU (see Annex I for his TOR's) using the following criteria:

1) The plots should fall within 2 km of a primary or secondary road, and
2) The plots should fall completely within a single LU/LC type.

The diversity of birds and plants were sampled in these plots. Two, 20 m × 20 m vegetation sub-plots (or releves) were selected within each of the larger 250 m × 250 m plots. In each LU/LC type, three plots were sampled; within each of these plots, two sub-plots were also sampled in the vegetation study. A total of 78 plots and 156 subplots were identified. The sample plot coordinates were captured by GPS in UTM format and then the GPS guided the researchers to each sample plot.

It was discovered that some of the plots were not the LU/LC type expected from the remote sensing classification. This is probably due to either a change in the land use since 1994 or an error in the classification of the image. These plots were re-located to the nearest location that fit the LU/LC type and the criteria above.

Not all LU/LC types were found in each transect. Additional plots were added to the study inside Nechisar National Park, for the purposes described above.

The data collected here were meant to be analysed jointly with the socio-economic data; however, at the time of the submission of this report these data were not available. We suggest that this be done by Ethiopian colleagues. Data from this study can be directly made available.

Sampling methods

Birds

C. Wilson collected bird and mammal data during the period of 6 November–4 December 2001. Plots as described above were sampled for bird diversity using a modification of the 'Timed Species Count' (TSC) method as described by Pomeroy (1986). This method allows a plot to be sampled thoroughly for approximately 30 minutes. All birds seen or heard within the plot during that time period are recorded. This results in a species list, which can be used to calculated species richness for each LU/LC type. Bird species abundance was not estimated as it is difficult to sample unless more intensive techniques (i.e. more time and resources) are used. Three plots in each LU/LC type in each transect were sampled once. Attempts were made to sample one plot in each of three time periods (0600–1030, 1031–1430, 1431–1800). The reason for sampling in each LU/LC types in various times of the day is to ensure that maximum number of species are seen. There were some areas (specifically in Transects 3 and 4) where this was not logistically possible as plots were scattered throughout the area.

A total of 66 plots were sampled in the project area. In addition, on 28 November 2001, C. Wilson accompanied the Nechisar Park warden Chemere Zewedie in the park boat for a survey of bird species along the Nechisar/Lake Chamo shoreline for a period of 6 hours.

Highland forest LU/LC types in the area consisted of plantations only. There are no native highland forests of measurable size that remain in the study area. The highland plantations were also often logistically difficult to reach and were therefore not sampled by C. Wilson. The vegetation crew did however sample these plots.

Vegetation
Zerihun Woldu and Sebsebe Demissew (together with their field assistants) collected plant species during the periods 25 April to 14 May 2001, 1 to 5 August and 14 to 18 January 2002.

The rainy season was ideal for the collection of vegetation data. This was accomplished during the field study in April–May 2001. A total of 53 out of 78 large plots and 106 out of 156 subplots (two subplots per large plot) were sampled. Because of the high intensity of the rain in May 2001, which made the road to Nechisar inaccessible, the plots in the transect (transect #5) were not sampled. The 13 plots (26 subplots) in Nechisar were sampled between 1–5 August 2001. Thus, the total number of vegetation plots was 66 (132 subplots).

A master plant species list including all species together with physical environmental data is shown in Annex IIIb. Because of the need to check the identity of some sterile and difficult (for naming) plant specimens, two additional field trips were conducted between November 20–27, 2001 and January 14–21, 2002.

Percent cover of plant species encountered was estimated following the modified Braun Blanquet approach (van der Mareel 1978). This method enables a visual estimation of the cover-abundance of plant species in a relevé. Except for the most common and well-known species, plants encountered were collected, identified and voucher specimens deposited at the National Herbarium, Addis Ababa University. Identifications were carried out using the Flora of Ethiopia and Eritrea (Edwards and Inga 1989; Edwards et al. 1995; Edwards et al. 1996; Philips 1997; Edwards et al. 2000). An Excel table was constructed listing all plant species collected by site, relevé, coordinates, altitudes, LU/LC, and percent cover.

Mammals
Surveys of mammals were conducted using key informant interviews in each transect (except 4 and Nechisar Park), see Annex IV. A total of 10 interviews were conducted (7 in the lowlands and 3 in the highlands). The same survey sheet was used for all samples. Interviewees were asked how old they were and how long they have lived in the area. It was preferred to have people over 20 years of age who had lived in the area all of their lives. Each interviewee was shown a picture of the animal from a textbook (Kingdon 1997; Stuart and Stuart 2000) and asked in which habitat type they usually saw the animal. In addition, any comments they had about the animals were recorded.

Asking key informants about wildlife has been found to be useful in other studies (Reid et al. 1996, 1997) and seemed to provide good general information about the local large mammals in the study area. There was not enough time or resources available to the project to conduct aerial surveys. The areas most likely to be impacted by tsetse control should be thoroughly surveyed. This includes Nechisar Park where impacts are expected and other bushlands near the lake.

Data analysis
Descriptive statistics on the number and uniqueness of species were calculated in a spreadsheet. For bird and vegetation data, species richness data were summarised by transect and overall transects by LU/LC type. Mammal data were analysed by transect only.

The greatest amount of information in our dataset lies within the data on the types and abundances of species in our plots. These data are highly complex and require the use of multivariate analysis techniques to highlight the information they contain. For bird species, we used canonical correlation analysis (see Jongman et al. 1995 for detailed information on this technique) to relate the patterns in the species data to environmental data we measured for each plot. The two-dimensional plots in the pages that follow show which different land-use/vegetation types support different bird faunas and how wide these differences are, and what species or plots are most closely associated with each land-use/vegetation type.

Results and discussion

(The authors of these sections are listed in parenthesis after each section title).

Birds (Wilson and Reid)

A total of 223 bird species were positively identified during the study (see Annex IIIa for Bird Species List). Six endemic bird species were found in the project area during this study (see Annex IIIa). These were Blue-winged Goose (*Cyanochen cyanoptera*), Rouget's Rail (*Rallus rougetii*), Wattled Ibis (*Bostrychia carunculata),* Thick-billed Raven (*Corvus crassirostris*), White-winged Cliff Chat (*Myrmecocichla semirufa),* and Abyssinian Black-headed Forest Oriole (*Oriolus monocha).*

The Cambridge survey found in Nechisar the Northern White-tailed bushlark *(Mirafra albicauda*) in grasslands of Nechisar Park, this is its only known locality in Ethiopia (Duckworth et al. 1993; Safford et al. 1993).

Bird species data by transect

There were no detectable patterns of bird species richness among transects (Table 1). Overall the riparian areas showed the highest number of species, while grasslands had by far the fewest. As will be mentioned in the following sections the number of unique species (species found only in specific habitat types) is very important. These numbers of unique species were summarised in Table 2.

Table 1. *Number of bird species (=richness) in each LU/LC type by transect.*

LU/LC Type	Average species richness/plot by transect				
	T1	**T2**	**T3**	**T4**	**T5**
Highlands:					
Cultivation	15.7	11.3	5.0	12.0	N/A
Grazing	11.7	11.0	6.3	N/A	N/A
Lowlands:					
Open Bushland	10.7	14.0	8.7	9.3	*
Wooded Grassland	11.3	10.7	10.7	9.0	6.0
Riparian	16.0	9.4	11.3	8.7	11.3
Grassland	N/A	N/A	N/A	N/A	2.3
Lakeshore	N/A	N/A	N/A	N/A	22.5

*Open bushland plots inside Nechisar fell within transect 4.

Bird species data by land-use/land cover types

Summing across all transects, Table 2 demonstrates how LU/LC types with high species richness may not necessarily have a very high number of species, which are specific to that habitat type.

Table 2. *Bird species richness and percent unique species in each LU/LC type in the study area.*

LU/LC type	Total number of species/plot	Number of unique species	Percent unique species (of total species)
Highlands			
Cultivation	132	8	6.0
Grazing	87	14	16.1
Lowlands:			
Open bushland	128	20	15.6
Riparian	155	19	12.3
Wooded grassland	143	16	11.2
Grassland*	7	2	*
Lakeshore**	45	17	37.8

*Only 3 plots were sampled from this land cover type. thus richness data may not be compatible across types.
**A different method was used for sampling the lakeshore.

Highland cultivation

The cultivated areas of the highlands appear to have a high number of bird species per plot. The complex vertical structure of the vegetation, availability of water and seed crops explains this richness. However if one looks more closely at the number of unique species found in this land-use type it can be seen that not very many of these species would be dependent solely on this habitat to survive. There were many ubiquitous ('weedy') species like the Common Bulbul (*Pycnonotus barbatus*), Red-eyed Dove (*Streptopelia semitorquata*), species of weavers (*Ploceus*) that can exist in and between multiple habitats. Taking this into consideration, we estimate that conversion of this land-use type to another would mean a loss of 6% of the species seen in this habitat.

Highland grazing
The grazing areas of the highlands were very low in the number of species found; yet many were dependent on this habitat type (16% of total species found there). These areas are very important to Rougets Rail (*Rallus rougetii*), and Blue-winged Goose (*Cyanochen cyanoptera*) both Ethiopian endemic species, as well as the Red-breasted Wheatear (*Oenanthe bottae frenata*) and several lark species.

This habitat is not likely to be affected by tsetse control in the lowlands directly. However, continued conversion of grassland to cultivation and more intensive grazing would put pressure on some species.

Open bushland
Open Bushlands of the lowlands have very high species richness. These areas are somewhat variable but in general provide good cover and foraging. The average number of species per plot for this LU/LC type was 128. Nearly 16% of these species were found only in this habitat type. This is the second highest percent unique species of all the LU/LC types sampled in this study. A variety of species are supported here including Quails, Falcons, Hornbills, Larks, Nightjars, Tchagras, Barbets, Parrots, Shrikes, Chats, Hoopoes, Grenadiers and Kingfishers.

The Cambridge survey of Nechisar also found a high number of species in this habitat type during their study there in 1990 (Duckworth 1992). They attributed this to the fact that there is a lot of bushland outside of the park and therefore some connectivity of this habitat and fauna flow. Having large unfragmented areas with diverse vegetation types often lends to very rich habitat types.

Many of these bushlands are infested with tsetse and therefore will most likely be converted to either cultivation or grazing land-use types in the future. As these habitats are fragmented we would expect the species numbers to decline.

Wooded grassland
The wooded grasslands had the second highest number of species per plot but the number of unique species was lower than both the lowland riparian areas and open bushlands. These habitat types were in general more used for grazing than the open bushland and therefore more open.

Some of the species that were seen only in wooded grasslands were: Red-headed Malimbe (*Anaplectes rubiceps*), White-headed buffalo weaver (*Dinemellia dinemelli),* Lesser kestrel *(Falco naumanni),* Upchers Warbler *(Hippolais languida),* Little Rock Thrush *(Monitcola rufocinerea),* Spotted Flycatcher (*Muscicapa striata),* Northern Brubru (*Nilaus afer*), Chestnut-crowned Sparrow-weaver (*Plocepasser supercilliosus),* Red-winged Pytillia (*Pytelia phoenicoptera), and* Chesnut-bellied Sandgrouse (*Pterocles exustus).*

It is likely that these areas could become more heavily used if tsetse is controlled and the populations of humans and livestock increase.

Riparian
The riparian areas were the most species rich and had a highest percentage of unique species as well. These habitats were difficult to find anywhere outside the Nechisar Park. The Deme River area is still fairly intact and some riparian woodlands to the west of Dila also remain

Some of the species found only in this habitat type were: Malachite Kingfisher (*Alcedo cristata*), Eastern Plantain-eater (*Corythaixoides zonurus*), Grey Woodpecker *(Dendropicos goertae),* White-winged Cliffchat (*Myrmecocichla semirufa)* an Ethiopian endemic*, Black Scimitarbill (Phoeniculus arterrimus),* Abyssinian Scirmitarbill *(Rhinopomastus mino*), and the Rufous Chatterer (Turdoides rubiginosus).

Riparian woodlands are also often tsetse infested and if control is successful then the degradation of these habitats will be accelerated by increased clearing for cultivation, wood collection and livestock grazing.

Grassland (in Nechisar only)
This land cover type was only found in Nechisar Park. The area of the park where the grasslands are found is somewhat of an island. There are no similar habitats remaining outside the park.

Only 3 plots were sampled in this habitat type and an average of 7 species seen. There were only 2 unique species found in this habitat type during this study the Saker (*Falco cherrug*) is worth mentioning here. The Cambridge survey had similar results in this grassland; however they found the Northern White-tailed bushlark *(Mirafra albicauda*) here. Nechisar Park is the only known locality in Ethiopia for this species (Duckworth et al. 1993; Safford et al. 1993).

Shoreline
The lakeshore was surveyed on only one day by boat. As this sampling technique differs from that used in the other LU/LC types, their data cannot be readily compared. However, looking at the number of species in general it can be seen that species richness here is very high. The number of unique species is also very high.

Some species found only along the lakeshore in this study were: Goliath Heron (*Ardea goliath),* Senegal Thicknee (*Burhinus senegalensis),* Great Egret *(Egretta alba),* Black Heron (*Egretta ardesiaca),* Little Egret (*Egretta garzetta),* Black-backed Gull (*Larus ridibundus),* Pelican (*Pelecanus onocrotalus),* Pink Pelican (*Pelecanus rufescens),* Long-tailed Comorant (*Phalacrocorax africanus),* Great Comorant (*Phalacrocorax carbo), and* African Darter (*Anhinga rufa).*

If cultivation or grazing use is increased near a lakeshore then these areas will be impacted and some species, especially those that nest near the shore and are sensitive to human disturbance will be lost (e.g. Pelicans).

Bird species composition

Figure 6a shows how the species composition of birds (names of birds are presented as the first three letters of the genus and species) of all the land-use/vegetation types, in both the highlands and lowlands, were related to each other. As one might expect, the biggest difference among the plots is not how they were used, but where they are in relation to elevation and the lakeshore. Thus, the birds in the two highland types, highland cultivation (HC) and grazing (HG) were more like each other and thus appeared near each other on the graph (they are in the same part of the ordination space). Compared to all other types, more unique species of birds were found in highland grazing areas than in the highland cultivated areas, because the highland grazing areas were farther removed from the centre point of the graph and in a different quadrant of the graphic from all the other types. The bird fauna in the 3 lowland types (OB, WG, RIP) were similar to each other in comparison to the highland types. The birds at the lakeshore (CST) were entirely different from those either in the highlands or the lowlands.

Figure 6a. *Bird species Canonical Correlation Analysis (CCA)–all LU/LC types (HC, HC, OB, WG, RIP, CST*).

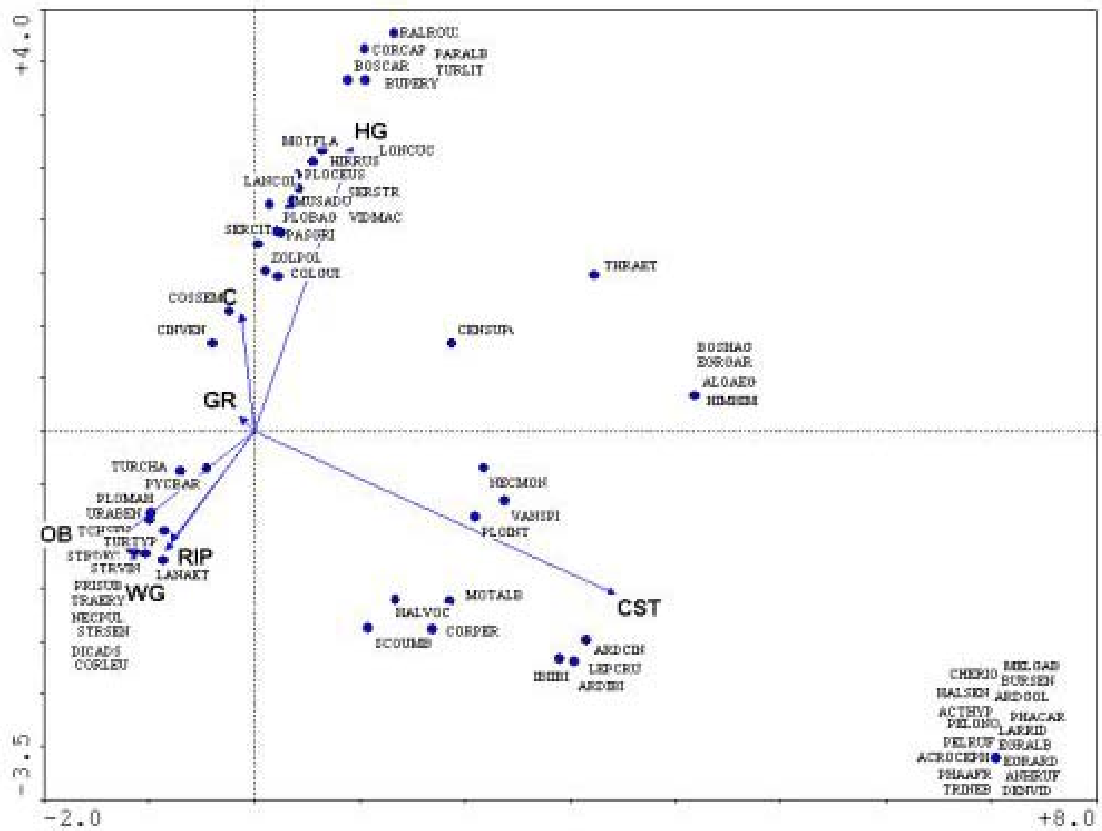


Figure 6b. *Bird species Canonical Correlation Analysis (CCA)–lowlands LU/LC types only (OB, WG, RIP)*

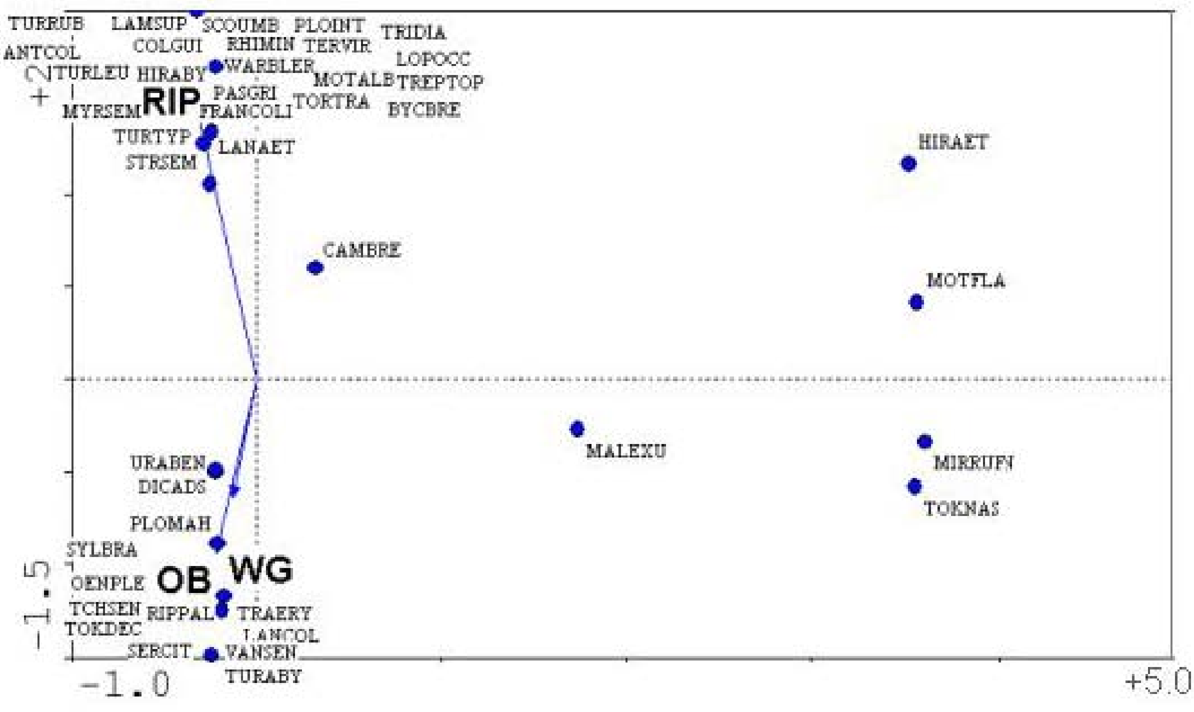
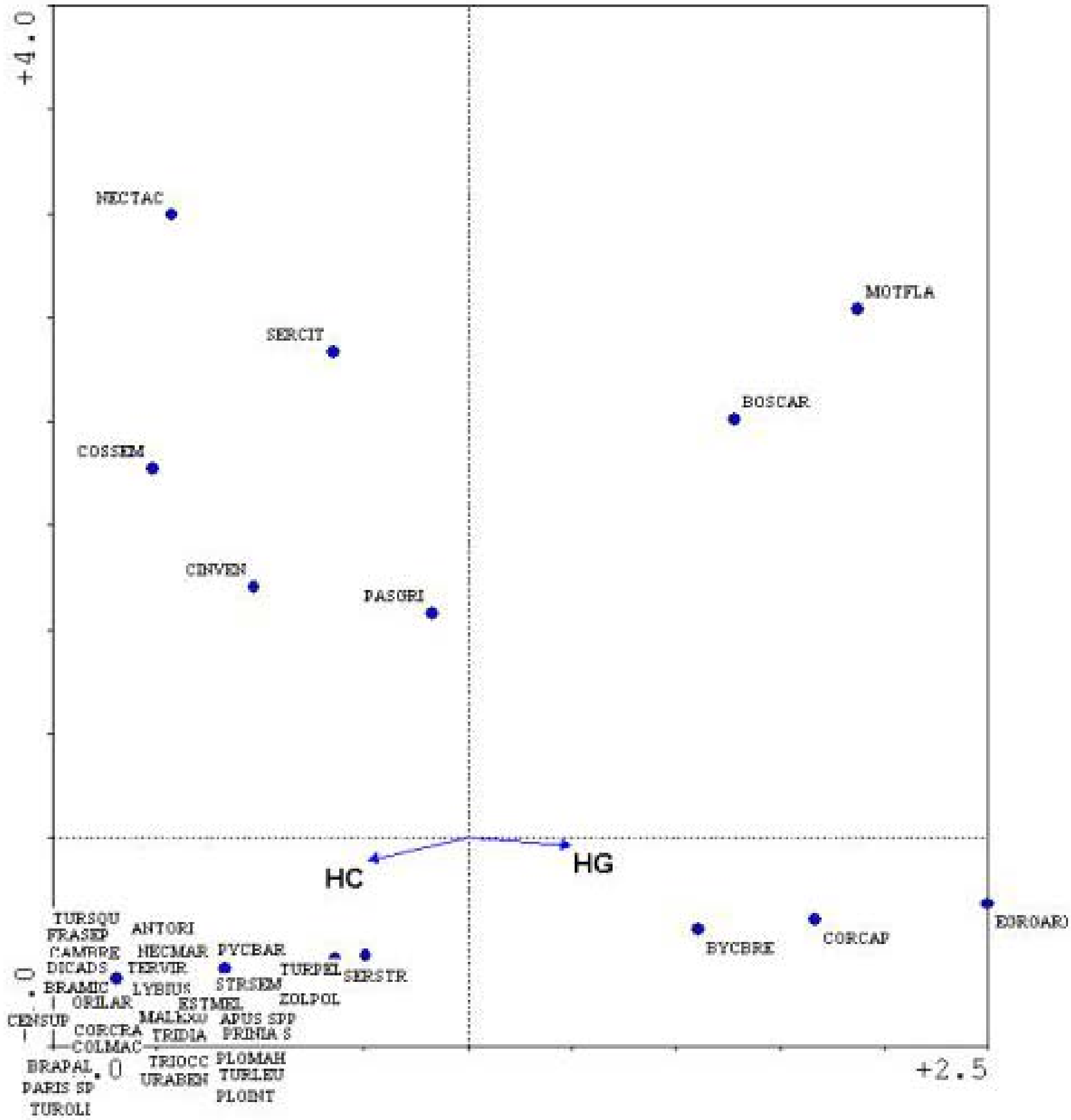


Figure 6c. *Bird species Canonical Correlation Analysis (CCA)–highland LU/LC types only (HC, HC).*



To tease apart the effects of land use, we created separate ordinations for the bird species in highland and lowland areas. As shown in the impact scenario for the lowlands (Figure 2), we expect that as farmers and their livestock move into the lowlands, grazing pressure and wood collection will rise. This will likely cause riparian woodlands and bushlands to become more open, converted into bushlands and wooded grasslands respectively. In Figure 6b, we see that the riparian woodlands support a unique bird fauna that will be lost if these areas are converted into less woody areas. The birds in the bushlands and grasslands are quite similar to each other, such that conversions between these two types will not have strong impacts on birds.

These effects are similar to what has been seen across Africa. Upland areas are less likely to be affected by intensified human use after tsetse/trypanosomosis control partly because the species in these habitats are better adapted to stress and partly because these areas will have less intensive changes in use (Gardiner and Reid 1997a; Reid et al. 1997; Wilson et al. 1997;

Kiema and Reid 1998). Thus, expansion of farming and grazing after tsetse/trypanosomosis control (or after human population growth more generally) is likely to affect lowland riparian areas and bushlands more than other parts of the landscape. There are therefore good opportunities to target better natural resource management efforts on these crucial habitats is important

If farmers move out of the highlands, we might expect cultivated areas to be left fallow and converted into grazing areas. In Figure 6c, we see that cultivated areas support more birds than grazing areas, although there are several unique bird species found in the grazing areas and nowhere else (as is clear in Figure 6a also). Thus, if farmers move out of the highlands and leave areas fallow, we expect that the bird fauna will become more diverse (because grasslands are more common), but the total number and abundance of birds may fall.

Vegetation (Sebsebe, Zerihun and Reid)

A total of 331 plant species were sampled in the study area. The list of the species found in each transect and LU/LC types are presented in Annex V, a list of the species found in each LU/LC type over the all transects is presented in Annex VI, and the master plant species list is found in Annex IIIb.

In order to make rigorous comparisons of plant species among land-use types, the data were transformed to account for the differences in sampling effort in each of the land use types. In the highlands, 9 plots or 18, 400 m^2 releves (0.72 ha) were sampled in each land-use type and in the lowlands, 15 plots or 30,400 m^2 releves (1.2 ha) were sampled in each type. The transformation was accomplished by dividing the raw data on the number of species (which appears in Table 4) by the total area sampled. The transformed data by land-use type appear in Table 3 and should be used for all comparisons between land-use types.

Table 3. *Number of species and number (%) of unique species per hectare.*

Land-use type	Number of species/hectare	Number (%) of unique species/hectare
Highland forest	119	24 (20.1%)
Highland cultivation	153	39 (25.5%)
Highland grazing	67	14 (20.8%)
Lowland open bushland	97	14 (14.4%)
Lowland riparian woodland	146	35 (24.0%)
Lowland wooded grassland	112	17 (15.0%)

Clearly, highland cultivation supports many more species than highland grazing or forest. Cultivated areas support twice as many species as grazing areas, and 20% more species than the forest from which the cultivation was derived. Similarly cultivation supports the greatest number of unique species in the highland habitats, with over a quarter of the flora unique to this type. Grazing areas and forests hold many unique species also, with a full 20% found in each of these types and nowhere else.

In the lowlands, plant species are concentrated near water in riparian woodlands. These woodlands support 50% more species than the open bushland and 30% more species than the wooded grasslands. A quarter of all the species in these unique riparian woodlands are found here and nowhere else on the landscape. The wooded grasslands are more diverse than the open bushlands.

Table 4. *Raw and untransformed data on species richness and number of rare species (*) in transects and LU/LC types.*

		Transect 1	Transect 2	Transect 3	Transect 4	Transect 5
LU/LC Types	Species richness	132	172	138	128	91
Highland cultivation	110	64 (10*)	63 (9*)	28 (3*)	38 (5*)	NS
Highland Forest	86	NS	35 (7*)	32 (5*)	30 (4*)	NS
Highland grazing	48	17 (4*)	21 (1*)	25 (5*)	NS	NS
Open bushland	117	31 (–)	59 (6*)	35 (2*)	35 (3*)	21 (5*)
Riparian	176	53 (7*)	58 (9*)	54 (13)	NS	70 (12*)
Wooded grassland	134	42 (2*)	49 (3*)	51 (1*)	63 (9*)	24 (3*)

(Note that the number of species in each transect does not correspond to the total number of species in the LU/LC type, this is due to common occurrence of some of the species in the LU/LC types concerned). NS = not sampled.

The control of the tsetse fly population mainly in the lowlands (open bushland, wooded grassland and riparian LU/LC types) will undoubtedly create favorable conditions for an increase in livestock population. This will have a direct and an indirect effect on agriculture, vegetation and land use both in the lowlands and in the highlands (highland cultivation, highland forest and highland grazing LU/LC types).

Highland cultivation

Within this LU/LC type, Transect 1 shows the highest number of species, while Transect 3 shows the least. The number of rare species also shows a similar trend.

This LU/LC type has the commonly cultivated species of crops such as *Ensete ventricosum* (Enset), an edible root crop and *Catha edulis* (Chat), a cash crop.

The presence of *Prunus africana* in Transect 2, sites 23 and 24 needs to be mentioned, as this is one of the species that is being threatened elsewhere in Africa for its medicinal properties. Also to be noted is the presence of *Sauromatum venosum*, one of the two species of the genus occurring in the highlands, both in the cultivated and forest LU/LC types.

As with birds, what happens to livestock and human populations as a result of tsetse control in the lowlands needs to be monitored as any of the different scenarios proposed above may occur. Decreasing livestock and human populations are likely to result in only a small change in species. If the number of livestock increases in the highlands, due to natural increase or greater livestock availability from the lowlands, this would likely lead to expansion of cultivation. The effect of this would be a decrease in species richness and/or cover/abundance, and a disappearance of rare species.

Highland forest
Within this LU/LC type, Transect 2 shows the highest number of species, while Transect 4 shows the least. The number of rare species also shows a similar trend.

The scattered presence of common highland species in this LU/LC type such as *Hagenia abyssinica, Olea europaea* subsp. *cuspidata* is cause for concern, as these species appear to be on the decline. The common tree species, *Juniperus procera* was also not encountered in the sampled sites, showing the decline in density of this species as well. The presence of endemic *Kniphofia foliosa* (Edwards et al. 1996) in Transect 2, site 26 species needs to be mentioned.

As with the highland cultivation area, the major effects on vegetation will occur if livestock populations increase in the highlands. Again, the effect of this would be a decrease in species richness and/or cover/abundance, disappearance of the already reduced (in number) of the common highland species and the endemic ones.

Highland grazing
Within this LU/LC type, Transect 3 shows the highest number of species, while Transect 1 shows the least. The number of rare species is highest in Transect 3 and lowest in Transect 2.

The presence of endemic *Thymus schimperi* (Sebsebe Demissew 1993) in Transect 3, sites 46 and 48 needs to be mentioned.

The presence of *Acritochaete volkensii*, the only species of this genus occurring in mountainous areas in western, southern and eastern Ethiopia and in east and west tropical Africa also should be noted.

In general this LU/LC type is very poor in species richness compared to grazing areas in the highlands of other parts of Ethiopia. The absence of various species of *Andropogon, Hyparrhenia*, *Pennisetum, Eragrostis, Cyperus* and *Trifolium* may not only be due to differences in environmental conditions, but also due to human interference. Grazing pressure may have eliminated these species altogether as they are highly palatable (Zerihun Woldu 1985, 1986).

As in the other highland LC/LU types, the only major vegetation changes would be with increased livestock numbers where a decrease in species richness and/or cover/abundance, and a disappearance of rare species would be expected.

Lowland open bushland
Within this LU/LC type, Transect 2 shows the highest number of species, while Transect 5 shows the least. The number of rare species is highest in Transect 2 and lowest in Transect 1.

This LU/LC type includes about eight species of *Acacia,* two species of *Combretum*, one species of *Commiphora*, three species of *Grewia*, two species of *Terminalia* and two species of *Ziziphus*. These are commonly occurring species in such vegetation types, but are comparatively few in number compared to the same LU/LC types elsewhere in the country.

The presence of endemic *Aloe* species: *A. gilbertii and A. pirottae* (Gilbert and Sebsebe Demissew 1992; Sebsebe Demissew and Brandham 1992; Sebsebe Demissew et al. 2001) in Transect 3, sites 34 and 35 shows the importance of such areas.

If the number of livestock population increases in the lowlands, which is the target area for tsetse control, the herbaceous vegetation cover will be overgrazed, and the shrub species will be heavily browsed. Thus the vegetation cover would be diminished exposing the land and resulting in severe erosion.

Note that the vegetation cover at present is less than 100%, which indicates sparse vegetation cover.

Lowland wooded grassland
Within this LU/LC type, Transect 4 shows the highest number of species, while Transect 5 shows the least. The number of rare species is highest in Transect 4 and lowest in Transect 1.

This LU/LC type includes about five species of *Acacia,* three species of *Combretum*, two species of *Commiphora*, five species of *Grewia*, one species of *Terminalia* and two species of *Ziziphus*.

These are commonly occurring species in such vegetation types, but are comparatively fewer in number in comparison to the same LU/LC types elsewhere in the country.

The presence of endemic *Aloe* species: *A. gilbertii* in Transect 1 sites 4, 5 and transect 2 site 20*, A. otallensis* in transect 2 sites 20 and *A. pirottae* in Transect 5 site 57 is significant and highlights the importance of protecting these areas (Sebsebe Demissew et al. 2001).

The presence of orchid species (*Eulophia petersii* and *E. streptopetala*) in Transect 4, site 57 also deserves special mention.

If the number of livestock population increases, which is the target area for tsetse control, the herbaceous vegetation cover will be overgrazed, and the shrub species will be heavily browsed. Thus the vegetation cover would be diminished exposing the land and resulting in severe erosion.

Note that the distinction between open bushland and wooded grassland sometimes is not always clear.

Lowland riparian woodlands
Within this LU/LC type, Transect 5 shows the highest number of species, while Transect 1 shows the least. The number of rare species also shows a similar trend.

This is the most diverse LU/LC type compared to the other LU/LC types in the study area. This LC/LU type includes eight species of *Acacia,* three species of *Combretum*, four species of *Grewia*, and two endemic *Aloe* species (*A. gilbertii* and *A. otallensis*).

It also includes the characteristic species that are known in such vegetation types in other areas in the country. These include: *Lepidotrichilia volkensii, Mimusops kummel, Teclea* *simplicifolia, Saba comorensisi, Teclea simplicifolia, Vepris dainelli and Zanthoxylum chalybeum*.

If the number of livestock population increases in the lowlands (in the bushland, wooded grassland and riparian LU/LC types), it is likely that more grazing and browsing pressure will be placed on the riparian LU/LC type. This pressure will come from livestock in the open bushland and wooded grassland LU/LC types accessing water and shade provided by the riparian vegetation. This would also encourage settlement, which may lead to the removal of more of the woody species (trees and shrubs).

Moreover, the overgrazing of the vegetation and the trampling of the area by livestock would discourage seedling re-establishment of the woody species, which may lead to eventual decrease in number or replacement by weedy species.

Mammals (Wilson and Reid)

There were 30 species of medium to large-sized mammals recognised by informants in the highland and lowland landscapes (Table 5). Comparing across land-use types in either the highlands or lowlands, farmers saw about the same number of mammal species in each of the land-use types except for the highland grazing areas. Interestingly, in the highlands, croplands appear to support just as many species as do riparian woodlands, forests and bushlands. Here, it is only the grasslands, grazed heavily by livestock, where farmers see the fewest mammals. In the lowlands, all land-use types support between 19 and 22 mammal species. The big difference is in the number of mammals in the highlands and the lowlands. On average, only half as many species are present in highland land-use types compared to the same types in the nearby lowlands.

Table 5. *Percentage of surveyed farmers who said that they regularly saw different wildlife species within each LU/LC type.*

Animal species	Riparian		Forest		Bushland		Grassland		Cropland			
	% low	% highl	% low	% highl	% low	% highl	% low	% highl	% low	% highl	mean % low	mean % high
Baboon	71	33	71	33	100	33	71	0	100	0	82.9	20.0
Monkey, grivet	43	33	43	67	57	33	43	0	57	33	48.6	33.3
Monkey, vervet	57	0	57	0	71	0	43	0	71	0	60.0	0.0
Monkey, Colobus	71	0	43	0	0	0	0	0	0	0	22.9	0.0
Zebra	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Warthog	71	33	57	33	86	33	57	0	57	0	65.7	20.0
Bushpig	57	0	100	0	57	0	29	0	43	0	57.1	0.0
Hippotamus	57	0	0	0	0	0	0	0	0	0	11.4	0.0
Kudu, Greater	43	33	57	33	57	0	29	0	29	33	42.9	20.0
Waterbuck (defarsa)	71	0	14	0	0	0	0	0	14	0	20.0	0.0
Hartebeest	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Oribi	29	0	43	33	71	33	29	0	43	33	42.9	20.0
Klipspringer	0	0	0	0	43	0	0	0	0	0	8.6	0.0
Dikdik	71	33	71	33	100	33	86	0	100	33	85.7	26.7
Duiker	29	67	29	67	43	67	43	33	29	100	34.3	66.7
Bat-eared fox	0	0	0	0	43	0	43	0	0	0	17.1	0.0
Jackal	86	33	100	33	100	33	100	0	57	67	88.6	33.3
Hunting Dog	0	0	0	0	29	0	0	0	0	0	5.7	0.0
Hyaena	100	33	100	33	100	33	100	33	100	67	100.0	40.0
Leopard	57	0	71	0	14	33	29	0	14	0	37.1	6.7
Lion	43	0	57	0	43	0	14	0	14	0	34.3	0.0
Wildcat	57	0	71	0	57	0	57	0	57	0	60.0	0.0
Serval Cat	43	33	57	33	43	67	29	33	29	67	40.0	46.7
Caracal	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Aardvark	57	33	57	67	86	67	71	33	71	100	68.6	60.0
Porcupine	100	67	100	67	100	67	100	33	100	100	100.0	66.7
Cheetah	14	0	14	0	29	0	14	0	14	0	17.1	0.0
Bushbuck	14	0	14	0	14	0	0	0	0	0	8.6	0.0
Mt. Nyala	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Gazelle	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Number of Species	22	11	21	11	22	8	19	5	19	10		

Low = lowland, highl = highland.

The interpretation of these data is difficult. In other studies, large mammals are very sensitive to the intensity of land use (e.g. Reid 1997; Hoare and du Toit 1999). In the highlands, farmers see large mammals as often in croplands as other types, implying that the expansion of land-use will have little effect on wildlife populations. Another interpretation is that the highlands are so heavily used that it is unlikely that there will be any difference in wildlife populations in the different land-use types. Here, patches of bush and forest are very rare, and when they do exist, they are small. Thus, because most large mammals use extensive areas for foraging, any species in these small patches would also use the nearby-cultivated fields at the same time. In the lowlands, farmers complain vigourously about wildlife in their fields. In areas with little cropping, it is common for wildlife to invade farmer's fields to graze on the crops themselves and on stubble after harvest. It is only when cropland areas expand that farmers are able to exclude wildlife from their fields (Newmark 1994). Thus, for very different reasons, the distribution of wildlife may become quite similar among the land-use types in the highlands and the lowlands.

Could the large difference in species numbers in the highlands and lowlands be caused by differences in land-use between these two landscapes? There are twice as many species in lowland landscapes where land-use intensity is low compared with highland landscapes where land is intensively used. We think that this difference is partly due to elevation, and partly caused by land use. For example, species like cheetah and hippo are unlikely to be found in highland habitats; these differences in species composition are probably caused by elevation. However, other species, like Colobus monkey and Mountain nyala, should be found in the highlands and have probably been extirpated by people.

A possible reason for the high records of animal sightings in the survey in croplands could be because the croplands are very small and located near to where the people live; therefore they are likely to see any animals that enter their fields. Many said that animals would hide in the bush/forest during the day and come out to eat their crops at night.

We also asked people to locate the most wildlife-rich parts of the region. Informants on all transects surveyed indicated that most of the remaining wildlife exist in the areas which are dense bush near the lake, in Nechisar Park or high in the mountains. Lions and other predators were reported near the lake north of Mirab Abaya and on the opposite side of the lake to the west of Mt. Goda in tsetse-infested areas. We expect that the wildlife populations in these areas in the lowlands will be most affected by the influx of people that will follow tsetse control. Even in the Nechisar Park, we expect grazing pressure and wood collection to increase as a result of tsetse control. In many areas of Africa, it is not land-use change *per se* that impacts wildlife, but the heavy hunting (and poaching) that occurs when people first start moving into an area.

The wooded grasslands in the lowlands were mostly heavily grazed; therefore, we expect wildlife numbers to be low here. In Nechisar the grasslands are healthier and most of the large herbivores thrive there (zebra, Swayne's hartebeest (an endangered species), and Grant's gazelle). This is the only place in the entire project area where these native herbivores can be found. Even these grasslands (inside a park) are becoming degraded (increased bareground and non-palatable herbaceous species). If the density of cattle increases in the reserve this grassland will become even more degraded and these species will be most likely lost as well.

Elephant, buffalo and giraffe have not been in the area for more than 50 years. These largest of the mammals are the first to disappear when human population increases.

There is only one endemic mammal known to still exist in this region and it is Swayne's hartebeest (*Tragelaphus buxtoni*).

Conclusions

Although land-use change and biodiversity changes will take place due to other factors if the tsetse fly is not controlled, controlling the fly will likely accelerate these changes, particularly in some sites. It will be important to monitor changes in migration and human settlement and changes in tsetse and trypanosomiasis challenge to attribute changes correctly. Key indicators to monitor will be changes in cultivated lands, plus the changes in woody and other vegetation cover and changes in animal and bird populations monitored in this study.

It is very difficult to predict the potential changes in environmental indicators with respect to expansion of cultivated land using the current situation, since there is so little cultivated land in the study transects. The following is an extrapolation of what we have seen from other areas in Ethiopia. We feel that this scenario is very likely.

Birds

- We expect that, when cultivation expands, there may be no change or a slight increase in the overall number of bird species in the bushland and grassland habitats. This is analogous to changes seen in the Ghibe Valley of southwestern Ethiopia (Wilson et al. 1997).
- Even with this increase, we expect to see a loss in the more rare bird species that were unique to each of these habitats.
- The riparian and lakeshore habitats support very unique bird faunas. We expect these areas to change the most if heavily used.

Plants

- The abundant unique species currently found in the grassland, bushlands and woodlands will largely disappear when cropping and grazing expands.
- Riparian woodlands will be particularly vulnerable to change, as has been shown elsewhere in Ethiopia and across Africa (Gardiner and Reid 1997a; Reid et al. 1997, Wilson et al. 1997; Kiema and Reid 1998).
- Overall species and genetic diversity will be lost. Depending on the level of use, newly cultivated areas in the lowlands may support more or less species overall, but many of the native and more rare species will disappear. The native and rare species will be replaced by more common species easily found elsewhere.

Mammals

- We expect wildlife to be hardest hit by the expansion of grazing and cultivation in the lowlands. In other systems like these, large mammals are lost long before people expand cultivation into the area (Reid et al. 1995; Hoare and du Toit 1999). Thus, the mammal populations in this area are probably already depauperate. However, in Nechisar Park and along the lake, there are still abundant wildlife and we expect these areas to lose whole populations if not carefully conserved.

Other changes in lowland ecosystems can only be speculated. However, potential scenarios can be monitored

- Soil nutrients need to be monitored. A net loss of nutrients is possible (transferred from lowlands to highlands) if: highlanders graze their cattle during the day in the lowlands and move them back to the highlands at night and 2) if lowlanders sell manure to highlanders, nutrient transfers will happen as often as sales take place. Because rainfall in the lowlands is low and thus nitrogen inputs from rainfall are low (rainfall brings in nitrogen through rain droplets), this nutrient mining in the lowlands could become significant.

- Expansion of cultivation and grazing in the lowlands will put increased pressure on the management of Nechisar Park to allow increased human use in this valuable protected area. Either through competition with cattle grazing or poaching, we predict this will heavily impact the wildlife in this park.

Regarding the highlands, if cultivated areas contract, then some of the land will shift from cultivation to fallow and grazing lands. Some of the unused cultivated areas may eventually revert to forestland. We think this scenario is not very likely; however, if this occurs, we predict the following changes in biodiversity:

Birds

- Contraction of cropland in the highlands will open up more grazing and fallow land. Because croplands support more birds than grazing lands, the overall number of bird species may decrease, but grazing and fallow lands will support more unique and less-common species.

Plants

- Weedy plant species in the cultivated areas will be replaced by native species.
- Overall number of species will fall, because the weedy species will become less common and the heavily grazed lands, which are currently species poor, will become more common.
- Habitat for some unique will change and these species may be lost.

Mammals

- Contraction of cultivation may attract some wildlife back into these landscapes. However, because wildlife populations are low, there will be few populations nearby ready to re-populate abandoned land. The animals that do return will be small in size and only from species that survive well near people (baboons, bushpig).

If tsetse control even reduces pressures on the highlands only to a limited extent, we expect the following additional effects on highland systems:

- Recovery of the marginal lands, that are most likely to come out of cultivation first, may increase biodiversity in the system, but not significantly because these areas are naturally poor in species. If this happens in the highlands in the study area, this would have strong environmental benefits in these steep lands. Note that the costs of expansion of agriculture in the lowlands will far outweigh the benefits of contraction of agriculture in the highlands because highland habitats have already lost much of their ecological capacity through heavy use. Thus, highland habitats will not recover to their original state unless expensive ecosystem restoration is attempted.

Recommendations

1. Future land management

A Land-use Management Plan is necessary to assure that the areas that may be opened up by tsetse control are not overused and degraded.

Socio-economic studies should be completed as soon as possible so that these data can be incorporated into a management plan. In addition, impacts of tsetse control can be better understood.

The communities should be provided with information about sustainable agricultural practices both in the highlands and lowlands to ensure the future productivity of the environment and the people.

Ecotourism in Nechisar Park should be explored as a possible income opportunity for the surrounding communities. This reserve is a gem in the Rift Valley; it is the only area left with somewhat intact flora and fauna. However, it is also very isolated and very susceptible to further human encroachment. If tsetse is controlled in this area the human populations in the area will increase and pressure on the park for wood collection, grazing and fish poaching will accelerate. If specific efforts to protect this reserve are not taken, it may not survive. Preserving such a rich and diverse natural area is extremely important both for conserving the genetics of some of the rare wildlife present but also the natural of this unique site.

2. Monitoring

Based on the methods used in this study of the vegetation, birds and mammals, surveys should be conducted every year (at least during one season) to monitor the effects of successful tsetse control. In addition, data from the socio-economic surveys should be analysed with these data to better distinguish the effects of tsetse control from other influences on the environment in the project area (e.g. political, ethnic, natural).

3. Future studies and monitoring

Additional biodiversity surveys should be conducted around the shoreline of Lakes Abaya and Chamo. If tsetse is controlled, much of the land near the shoreline could be converted to irrigated agricultural land. If this happens shoreline and marsh species will lose their habitat. The shorelines could be surveyed by boat.

A detailed soil survey of the project area is needed. Around Sodo and Awassa the lands that have been under heavy grazing pressure are extremely eroded (see photo in Annex VII). The potential for degradation in other areas is moderate to high given the soil types in the area (see Project Area—Soils section, also EMA 1988). Soil erosion studies should be conducted to predict what degradation could occur under different grazing intensities. A livestock management plan could be developed to avoid the most fragile lands (see *Future Land Management* section below).

Future land-use/land cover change analysis will be necessary to assess rates of change in land use in the study area as tsetse control/elimination operations are implemented.

There was not enough time or resources during this study to sample butterfly diversity. Butterflies can also be a reliable indicator of land use/land cover change because many butterfly species are dependent on specific habitat types and plant species (Gardiner and Reid 1997a). We observed high butterfly diversity in parts of the study area, especially in the riparian areas and in Nechisar.

As mentioned in the introduction, the effects of tsetse suppression methods (using insecticidal pour-ons) on biodiversity should be properly assessed. This is especially important for aquatic invertebrate species and non-targeted insects that are killed in baited traps.

Studies should be conducted in Nechisar Park to see how to deal with the human encroachment (fish and mammal poaching, cattle grazing and wood collection) that has become increasingly frequent in the park (Duckworth 1992; Chemere Zewedie, personal communication). The accelerated human and livestock population growth that will likely result from tsetse control is an added strain to an already troubled protected area. Also additional rangers are desperately needed to patrol the park, especially as the human populations around the reserve grow. Therefore the impacts of tsetse control in this protected area will be critical and could threaten the few remaining wildlife and forest populations.

References

Belsky A.J. 1984. Role of small browsing mammals in preventing woodland regeneration in Serengeti National Park, Tanzania. *African Journal of Ecology* 22:217–279.

Bourn D., Reid R., Rogers D., Snow B.and Wint W. 2001. *Environmental change and the autonomous control of tsetse and trypanosomosis in sub-Saharan Africa.* ERGO, Oxford, UK.

Brown L., Urban E.K and Newman K. (eds). 1982. *The birds of Africa.* Volume I. Academic Press, London, UK.

Clark J.R., Larry R.G., Patrick W.B., James M.P. Jr., Geraldine M.C., Paul H.M., James C.M. and Emile M.L. 1989. Toxicity of pyrethroids to marine invertebrates and fish: A literature review and test results with sediment-absorbed Chemicals. EPA/600/J-89/040. *Environ. Toxicol. Chem.* 8(5):393–401. (ERL, GB 618). (Avail. from NTIS, Springfield, VA: PB90-103599)

Davies B. 1993. *A review of tsetse and trypanosomosis control in Kenya and the effects on land-use and the environment*. ODA/KETRI, Animal Trypanosomiasis Research Project, Nairobi, Kenya.

Douthwaite R.J. and Tingle C.C.D. (eds). 1994. *DDT in the tropics: The impact on wildlife in Zimbabwe of ground spraying for tsetse fly control.* Natural Resources Institute, Catham, UK. 195 pp.

Duckworth J.W., Evans M.I., Safford R.J., Telfer M.G., Timmins R.J. and Chemere Zewede. 1992. *A survey of Nechisar Park, Ethiopia. A report of the Cambridge Ethiopia Ground-water Forest Expedition 1990.* ICBP Study Report 50.

Edwards S. and Hedberg I. (eds). 1989. *Pittosporaceae to Araliaceae. Flora of Ethiopia.* Volume 3. Addis Ababa, Ethiopia, and Uppsala, Sweden. pp. 1–658.

Edwards S., Mesfin Tadesse and Hedberg I. (eds). 1995. *Canellaceae to Euphorbiaceae. Flora of Ethiopia and Eritrea.* Volume 2 (2). Addis Ababa, Ethiopia, and Uppsala, Sweden. pp. 1–456.

Edwards S., Sebsebe Demissew and Hedberg I. (eds). 1997. *Hydrocharitaceae to Arecaceae. Flora of Ethiopia and Eritrea.* Volume 6. Addis Ababa, Ethiopia, and Uppsala, Sweden. pp. 1–586.

Edwards S., Mesfin Tadesse, Sebsebe Demissew and Hedberg I. (eds). 2000. *Magnoliaceae to Flacourtiaceae. Flora of Ethiopia and Eritrea.* Volume 2 (1). Addis Ababa, Ethiopia, and Uppsala, Sweden. pp. 1–532.

EMA (Ethiopian Mapping Authority). 1988. *National atlas of Ethiopia.* Ethiopian Mapping Authority, Addis Ababa, Ethiopia.

Fairhead J. and Leach M. 1996. *Misreading the African landscape.* Cambridge University Press, Cambridge, UK.

Frost P.G.H. 1996. The ecology of miombo woodlands. In: Campbell B. (ed), *The miombo in transtion: Woodland and welfare in Africa.* Center for International Forestry Research, Bogor, Indonesia. pp. 11–57.

Fry C.H., Keith S. and Urban E.K. (eds). 1988. *The birds of Africa.* Volume III. Academic Press, London, UK.

Fry C.H., Keith S. and Urban E.K. (eds). 2000. *The birds of Africa.* Volume VI. Academic Press, London, UK.

Gardiner A.J. 1997. Effects of land-use on butterflies. In: Reid R.S. and Gardiner A.J. (eds), *Collaborative research on the environmental and socio-economic impacts of tsetse and trypanosomiasis control in southern Africa.* Final technical report for the Department for International Development (DFID). ILRI (International Livestock Research Institute), Nairobi, Kenya. pp. 88–98.

Gardiner A.J. and Reid R.S. 1997a. Impacts of land-use on mammals. In: Reid R.S. and Gardiner A.J. (eds), *Collaborative research on the environmental and socio-economic impacts of tsetse and trypanosomiasis control in southern Africa.* Final Technical Report for the Department for International Development (DFID). ILRI (International Livestock Research Institute), Nairobi, Kenya. pp. 64–69.

Gardiner A.J. and Reid R.S. 1997b. Impact of land-use on birds. In: Reid R.S. and Gardiner A.J. (eds), *Collaborative research on the environmental and socio-economic impacts of tsetse and trypanosomiasis control in southern Africa.* Final Technical Report for the Department for International Development (DFID). ILRI (International Livestock Research Institute), Nairobi, Kenya. pp. 78–87.

Gardiner A.J. and Reid R.S. 1999. Effects of land-use change after tsetse control on biological diversity in northwestern Zimbabwe. In: Proceedings of the 24th meeting of the ISCTRC, Maputo, Mozambique, 29 September–3 October 1997.

Gardiner A.J., Reid R.S. and Wilson C.J. 1998. *Impacts of land-use change on the diversity of large mammals, rodents, birds, dung beetles, butterflies, and plants following tsetse control in the mid-Zambezi Valley, Zimbabwe.* The 49th meeting of the Ecological Society of America, Baltimore, Maryland, USA, 2–7 August 1998.

Gilbert M.G. and Sebsebe Demissew. 1992. Notes on the genus Aloe in Ethiopia: Misinterpreted taxa. *Kew Bull* 47(4):647-653.

FDRE (Federal Democratic Republic of Ethiopia). 1997. *Integrating the sterile insect technique to eradicate tsetse from the southern Rift Valley (2.5 million hectares). A report.* FDRE, Addis Ababa, Ethiopia.

Hoare R.E. and Du Toit J.T. 1999. Coexistence between people and elephants in African savannas. *Conservation Biology* 13(3):633–639.

Jongman R.H.G, Ter Braak C.J.F and Van Tongeren O.F.R (eds). 1997. *Data analysis in community and landscape ecology.* Cambridge University Press, Cambridge, UK. 299 pp.

Jordan A.M. 1986. *Trypanosomiasis control and African rural development*. Longman, London, UK.

Keith S., Urban E.K and Fry C.H. (eds). 1992. *The birds of Africa.* Volume IV. Academic Press, London, UK.

Kiema S. and Reid R.S. 1998. Impacts of tsetse control and land use on biological diversity and vegetative structure in southwestern Burkina Faso. In: Reid R.S. and Swallow B.M. (eds), *An integrated approach to the assessment of trypanosomiasis control technologies and their impacts on agricultural production, human welfare and natural resources in tsetse-affected areas of Africa.* Final report to IFAD. ILRI (International Livestock Research Institute), Nairobi, Kenya.

Kingdon J. 1997. *The Kingdon field guide to African animals.* Academic Press, Elsevier, USA. 465 pp.

Leak S.G.A. 1999. *Tsetse biology and ecology: Their role in the epidemiology and control of trypanosomosis.* CAB (Commonwealth Agricultural Bureau) International, Wallingford, Oxon, UK, and ILRI (International Livestock Research Institute), Nairobi, Kenya. 568 pp.

van der Maarel E. 1979. Transformation of cover abundance values and its effects on community similarity. *Vegetatio* 39:97–114.

Monroe B.L. and Sibley C.G. 1993. *A world checklist of birds*. Yale University Press, New Haven, USA.

Muller P. and Nagel P. 1994. *Tsetse fly eradication on Zanzibar Island—Environmental Surveys.* Report to IAEA (International Atomic Energy Agency), Vienna, Austria.

Nagel P. (ed). 1993. *Environmental monitoring of tsetse control operations in Zambia and Zimbabwe: Impact of aerial spraying and odour-baited targets on ecosystems.* A report 1987–1990. SEMG, University of Saarbruken, Germany.

Phillips S. 1997. Poaceae (Gramineae). In: Edwards S. and Hedberg I (eds), *Flora of Ethiopia and Eritrea.* Volume 7. Addis Ababa, Ethiopia, and Uppsala, Sweden. pp. 1–420.

Pomeroy D. and Tengecho B. 1986. Studies of birds in semi-arid area of Kenya. III. The use of 'Timed species-counts' for studying regional avifauna. *Journal of Tropical Ecology* 2:231–247.

van Perlo B. 1995. *Birds of eastern Africa: Collins illustrated checklist*. Harper Collins, Hong Publishers Ltd, London, UK.

Pratt D.J. and Gwynne M.D. 1977. *Rangeland management and ecology in East Africa*. Hodder and Stoughton, London, UK.

Rapport D.J., Costanza R. and McMichael A.J. 1998. Assessing ecosystem health. *Trends in Ecology and Evolution* 13(10):397–402.

Ray D.E. 1991. Pesticides derived from plants and other organisms. In. Hayes W.J. Jr. and. Laws E.R. (eds), *Handbook of pesticide toxicology.* Volume 2. Academic Press, Toronto, Canada. pp. 585–593.

Reid R.S. 1999. Impacts of controlling trypanosomosis on land-use and the environment: State of our knowledge and future directions. In: *Proceedings of the 24th meeting of the International Scientific Council for Trypanosomiasis Research and Control, Maputo, Mozambique, 29 September–3 October 1997*. pp. 500–514.

Reid R.S. and Pender J. 1998. Collaborative research on the environmental and socio-economic impacts of tsetse and trypanosomosis control in southern Africa. In: Warham E.J. (ed), *The Department for International Development (DFID) and the Consultative Group on International Agricultural Research (CGIAR): The competitive Research Facility: 1990–97.* DFID, London, UK. pp. 89–91.

Reid R.S., Wilson C.J. and Kruska R.L. 1996. The influence of human use on rangeland biodiversity in Ghibe Valley, Ethiopia, as affected by natural resource use changes and livestock disease control. In: West N.E. (ed), *Proceedings of the fifth international rangeland congress, Salt Lake City, Utah, USA, 23–28 July 1995.* Society for Range Management, Denver, Colorado. pp. 468–469.

Reid R.S., Wilson C.J, Kruska R.L. and Woudyalew Mulatu. 1997. Impacts of tsetse control and land-use on vegetative structure and tree species composition in south-western Ethiopia. *Journal of Applied Ecology* 34:731–747.

Reid R.S., Gardiner A.J., Kiema S., Maitima J.M. and Wilson C.J. 1999*. Impacts of land use on biological diversity in eastern, western and southern Africa.* In: *People and rangelands—Building the future: Proceedings of the sixth International Rangeland Congress, Townsville, Australia.* pp. 670–671.

Reid R.S., Kruska R.L., Muthui N., Taye A., Wotton S., Wilson C.J. and Wudyalew Mulatu. 2000. Land use and land cover dynamics in response to changes in climatic, biological and socio-political forces: The case of south-western Ethiopia. *Landscape Ecology* 15:339–335.

Safford R.J., Duckworth J.W., Evans R.J., Telfer M.G. and Timmins R.J. 1993. The birds of Nechisar Park, Ethiopia. *Scopus* (16):16–80.

Sebsebe Demissew. 1993. The genus *Thymus (Labiatae)* in Ethiopia. *Opera Bot.* 121:57–60.

Sebsebe Demissew and Brandham P.E. 1992. A new species of *Aloe* from the Ethiopian Rift Valley. *Kew Bull.* 47(3): 509-512.

Sebsebe Demissew, Inger N. and Odd S. 2001. Endemism and patterns of distribution of the genus *Aloe (Aloaceae)* in the flora of Ethiopia and Eritrea. *Biol. Skr.* 54:233–246.

Shannon C.I. and Wiener W. 1949. *The mathematical theory of communication*. Illinois Books, Urbana, USA.

Slingenburgh J. 1992. Tsetse control and agricultural development in Ethiopia. *World Animal Review* 70/71:30–36.

Stevenson T. and Fanshawe J. 2002. *A field guide to the birds of East Africa*. T and A.D. Poyser Ltd., London, UK.

Stuart C. and Stuart T. 1997. *Field guide to the larger mammals of Africa*. Struik Publishers Ltd., Cape Town, South Africa.

Stuart C. and Stuart T. 2000. *Field guide to the larger mammals of Africa*. Struik Publishers Ltd., Cape Town, South Africa. 318 pp.

Tomlin C. (ed). 1994. *A world compendium. The pesticide manual. Incorporating the agrochemicals handbook.* (10th ed.). Crop Protection Publications, Bungay, Suffolk, UK.

Urban E. and Brown L.H. 1971. *A checklist of the Birds of Ethiopia*. Haile Sellasie I University Press, Addis Ababa, Ethiopia.

Urban E.K., Fry C.H. and Keith S. (eds). 1986. *The birds of Africa.* Volume II. Academic Press, London, UK.

Urban E.K., Fry C.H. and Keith S. (eds). 1997. *The birds of Africa.* Volume V. Academic Press, London, UK.

Wilson C.J., Reid R.S., Stanton N.L. and Perry B.D. 1997. Effects of land use and tsetse fly control on bird species richness in south-western Ethiopia. *Conservation Biology* 11(2):435–447.

Wauchope R.D., Butler T.M., Hornsby A.G., Augustijn-Beckers P.M. and. Burt J.P. 1992. *The SCS/ARS/CES pesticide properties database for environmental decision* making. [Online].

Zerihun Woldu. 1985. Variation in grassland vegetation on the central plateau of Shewa, Ethiopia in relation to edaphic factors and grazing conditions. *J. Cramer* 84:1–114.

Zerihun Woldu. 1986. Grassland communities on the central plateau of Ethiopia. *Vegetatio* 67:3–16.

Zimmerman D.A., Turner D.A. and. Pearson D.J. 1996. *Birds of Kenya and northern Tanzania*. Russel Friedman Books, Johannesburg, South Africa.

Annexes

Annex I: Administrative Report

Final report to the

International Atomic Energy Agency (IAEA), Vienna

on the project

Environmental impact assessment of the control of the tsetse fly using SIT in the southern Rift Valley of Ethiopia

IAEA P.O. No.: ETH5012-82249E

Submitted on 28 February 2002

by

Cathleen J. Wilson
Ecologist/GIS Specialist
International Livestock Research Institute (ILRI)
Nairobi, Kenya

John McDermott,
Veterinary Epidemiologist
International Livestock Research Institute (ILRI)
Nairobi, Kenya

Robin S. Reid
Ecologist
International Livestock Research Institute (ILRI)
Nairobi, Kenya

Zerihun Woldu and Sebsebe Demissew
National Herbarium
Addis Ababa University (AAU)
P.O. Box 3434
Addis Ababa, Ethiopia

Administrative information

Purchase Order No.: ETH5012-82249E

ILRI Project Number: LH1-NBO-IAE001

Project Title: Environmental impact assessment of the control of the tsetse fly using SIT in the southern Rift Valley of Ethiopia.

Name of Expert: Cathleen J. Wilson
Ecologist/GIS Specialist
ILRI
Nairobi, Kenya

John McDermott,
Veterinary Epidemiologist
ILRI
Nairobi, Kenya

Name and Address of Counterparts:
Prof. Zerihun Woldu and Prof. Sebsebe Demissew
National Herbarium
Addis Ababa University (AAU)
P.O. Box 3434
Addis Ababa, Ethiopia

Purchase Order No.: ETH5012-82249E

Dates: 1 March 2001–28 February 2002

Title

Environmental impact assessment of the control of the tsetse fly using SIT in the southern Rift Valley of Ethiopia.

Terms of reference

There are three sets of terms of reference listed here. The first is for the ILRI team. The second is for the AAU team (Zerihun Woldu and Sebsebe Demissew) who were subcontracted to complete the activities for the vegetation sampling on the project. The last is for the consultancy of Tesfaye Korme of AAU.

Terms of reference for ILRI:

TOR 1: Co-ordinate and facilitate the management of the AAU–ILRI collaborative monitoring efforts;
TOR 2: Guide and assist in the assessment of existing environmental data and assist in the design and collection of additional data;
TOR 3: Guide and assist in the identification of representative areas for the collection of environmental data, preferably where veterinary and entomological data already exist;
TOR 4: Train staff and other individuals involved in the collection and evaluation of the data, as needed;
TOR 5: Assist in the establishment of baseline environmental data against which to assess the future impacts of SIT control;
TOR 6: Complete a quantitative assessment of the probable impacts of the evolution of agricultural systems after tsetse control on birds (diversity and abundance) in the major vegetation types in the study area. This will be done by measuring bird diversity and abundance in areas with little human use (grazed but not cultivated) with areas already converted to agriculture;
TOR 7: Complete a qualitative assessment of the probable impacts of the evolution of agricultural systems after tsetse control on large mammals (presence/absence) in the study area;
TOR 8: Assist in integrating socio-economic, environmental (vegetation, bird and large mammals), veterinary and tsetse entomological data in preparation of a summary report on the situation;
TOR 9: Complete a report on the impacts of SIT control on birds and mammals and compile a comprehensive summary report on environmental impacts;

Terms of Reference for AAU:

TOR 1: Guide and assist in the assessment of existing environmental data and assist in the design and collection of additional data;
TOR 2: Guide and assist in the identification of representative areas for the collection of environmental data, preferably where veterinary and entomological data already exist;

TOR 3: Train staff and other individuals involved in the collection and evaluation of the data, as needed;
TOR 4: Assist in the establishment of baseline environmental data against which to assess the future impacts of SIT control;
TOR 5: Complete a quantitative assessment of the probable impacts of the evolution of agricultural systems after tsetse control on vegetation (diversity, abundance and structure) in the major vegetation types in the study area;
TOR 6: Assist in integrating socio-economic, environmental (vegetation, bird and large mammals), veterinary and tsetse entomological data in preparation of a summary report on the situation;
TOR 7: Complete a report on the impacts of SIT control on vegetation and contribute to the compilation of a comprehensive summary report on environmental impacts;
TOR 8: GIS and remote sensing analysis. *See terms of reference for Dr. Tesfaye in Annex I.*

Terms of reference for Tesfaye Korme of AAU

TOR 1: Digitise socio-economic transects (T1–T4) for block one of IAEA SIT study area and in Nechisar Park area.
TOR 2: Overlay the transect data over the classified TM image for the study area.
TOR 3: Delineate LU/LC types (as discussed–open bush land, wooded-grassland, highlands cultivation, highland forest, highland grazing land, riparian) within each transect T1–T4 and Nechisar Park area.
TOR 4: Within each LU/LC type in each transect, randomly select 3250 m × 250 m plots with the following criteria:

a. The plots should fall within 2 km from a 1º or 2º road.
b. The plots should fall completely within a single LU/LC type.
c. Along the riparian LU/LC type, select centre points around which plots can be measured.

TOR 5: Produce files of these plots both in a text and shape file format with central points of 250 m × 250 m plots listed in the text files by transect number and LU/LC type.
TOR 6: Copy to CD all GIS layers available for the study area (as previously discussed) and the classified TM image in ArcView and/or IDRISI format and deliver to ILRI, Nairobi via ILRI, Addis.
TOR 7: Help with production of final maps for reports.

Status of project—ILRI

TOR 1: Co-ordinate and facilitate the management of the AAU–ILRI collaborative monitoring efforts. **COMPLETED**

Two trips have been made to Addis Ababa since the beginning of this contract to coordinate and manage the project. Wilson and McDermott traveled to Addis from 8–14 March 2001, where they met with IAEA, ESTC, AAU and ILRI collaborators. A trip to the study area was made for an overview of the project. In April (17–27), Wilson traveled to Addis and made a trip to the field with the AAU collaborators (Zerihun and Sebsebe). Additionally, Wilson, Reid, McDermott and Mulatu of ILRI had several meetings with the AAU collaborators in October of 2000 before this contract was signed. *See Annex III A, B, C in Phase I report for detailed trip reports.*

During the mission in March, the TOR's for the subcontracts for the AAU consultants were agreed upon. After return to ILRI, Nairobi, contracts were prepared and these contracts were signed in April by the AAU collaborators.

TOR 2: Guide and assist in the assessment of existing environmental data and assist in the design and collection of additional data. **COMPLETED**

Dr. Korme collected and/or digitised existing GIS data prior to the initiation of this contract. Other census data available for Nechisar Park was not immediately available for this report. Cambridge conducted a survey of the park in 1990 (see references) and sampled butterflies birds and some mammals.

The study design was discussed with our AAU colleges in October 2000 and March and April 2001.

TOR 3: Guide and assist in the identification of representative areas for the collection of environmental data, preferably where veterinary and entomological data already exist. **COMPLETED**

Experimental design for Bird/plant Diversity sampling
The land-use/land cover (LU/LC) types selected to be sampled were: open bushland, wooded grassland, highland cultivation, highland forest, highland grazing land and riparian zones. Within each LU/LC type in each transect, 3 plots (250 m × 250 m) were randomly selected (see Annex II for plot coordinates). The diversity of birds and plants will be sampled in these plots. There will be two 20 m × 20 m vegetation plots selected within each of the larger 250 m × 250 m plots. Dr. Korme of AAU was subcontracted to select the sample sites using GIS and remote sensing (see above for his TOR's) within each of the four previously selected socio-economic survey transects using the following criteria:

a) The plots should fall within 2 km from a primary or secondary road.
b) The plots should fall completely within a single LU/LC type.
c) Along the riparian LU/LC type, select centre points around which plots can be measured.

In conjunction with the Ethiopian Science and Technology Commission and the Southern Region Team conducting the socio-economic survey, five study transects were identified in the study area for the environmental impact study. In this study area, a total of 6 LU/LC types were identified. Not all LU/LC types are found in each transect. Three large and 2 subplots were to be sampled in each unique LU/LC types in each transect. A total of 78 large plots and 156 subplots were identified. The sample plot coordinates (Annex II) were put into the GPS in UTM format and then the GPS guided the researchers to each sample plot.

TOR 4: Train staff and other individuals involved in the collection and evaluation of the data, as needed. **COMPLETED**

During mission travel to the study area 24–27 April, the AAU botany technicians were trained in the use of Global Positioning Systems (GPS) and UTM grid reading.

TOR 5: Assist in the establishment of baseline environmental data against which to assess the future impacts of SIT control. **COMPLETED**

C. Wilson collected bird and mammal data during the period of 6 November–4 December 2001. Plots as described in TOR 3 were sampled for bird diversity using a modification of the 'Timed Species Count' (TSC) method as described by Pomperoy (1986). This method allows a plot to be sampled thoroughly for approximately 30 minutes. All birds seen or heard within the plot during that time period are recorded. This results in a species list, which can be used to calculated species richness for each LU/LC type. Three plots in each LU/LC type in each transect were sampled once. Attempts were made to sample one plot in each of three time periods (0600–1030, 1031–1430, 1431–1800). There were some areas (specifically in Transects 3 and 4) where this was not logistically possible as plots were scattered throughout the area. The reason for sampling in each LU/LC types in various times of the day is to ensure that maximum number of species are seen.

A total of 66 plots were sampled in the project area. In addition, on 28 November 2001, C. Wilson accompanied the Nechisar Park warden Chemere Zewedie in the park boat for a survey of bird species along the Nechisar/Lake Chamo coast for a period of 6 hours.

A total of 223 bird species were positively identified (see Annex VI for list of references used for identification) during the study. In the final report the number of species in each LU/LC type will be summarised. (See Annex IV for Bird Species List.)

Highland forest LU/LC types in the area consisted of plantations only. There are no native highland forests of measurable size remain the study area. The highland plantations were often logistically difficult to reach and were therefore not sampled by C. Wilson.

Additional plots were added to Nechisar Park area. Nechisar plots 70,72 and 73 were originally classified as bushland plots; however, upon inspection they were found to more appropriately fit a wooded grassland vegetation type. Also plots 71, 74 and 75 were classified as grasslands. There were no highland grazing, highland cultivation, LU/LC types in the park.

During this phase of the project, C. Wilson spent 29 days in Ethiopia (21 of these were in the project area).

TOR 6: Complete a quantitative assessment of the probable impacts of the evolution of agricultural systems after tsetse control on birds (diversity and abundance) in the major vegetation types in the study area. This will be done by measuring bird diversity and abundance in areas with little human use (grazed but not cultivated) with areas already converted to agriculture. **COMPLETED**

A total of 223 bird species were positively identified during the study (see Annex IIIa for Bird Species List). Six endemic bird species were found in the project area during this study (see Annex IIIa). These were Blue-winged Goose (*Cyanochen cyanoptera*), Rouget's Rail (*Rallus rougetii*), Wattled Ibis (*Bostrychia carunculata),* Thick-billed Raven (*Corvus crassirostris*), White-winged Cliff Chat (*Myrmecocichla semirufa), and* Abyssinian Black-headed Forest Oriole (*Oriolus monocha).*

The Cambridge survey found in Nechisar the Northern White-tailed bushlark *(Mirafra albicauda*) in grasslands of Nechisar Park; this is its only known locality in Ethiopia (Duckworth et al. 1993; Safford et al. 1993).

Bird species data by transect

There were no detectable patterns of bird species richness among transects (Table 1). Overall the riparian areas showed the highest number of species. And grassland had by far the least. As will be mentioned in the following sections the number of unique species (species found only in specific habitat types) is very important. These unique species numbers were summarised in the following section.

Table 1. *Number of bird species (=richness) in each LU/LC type by transect.*

	Average species richness/plot by transect				
LU/LC Type	**T1**	**T2**	**T3**	**T4**	**T5**
Highlands:					
Cultivation	15.7	11.3	5.0	12.0	N/A
Grazing	11.7	11.0	6.3	N/A	N/A
Lowlands:					
Open Bushland	10.7	14.0	8.7	9.3	*
Wooded Grassland	11.3	10.7	10.7	9.0	6.0
Riparian	16.0	9.4	11.3	8.7	11.3
Grassland	N/A	N/A	N/A	N/A	2.3
Lakeshore	N/A	N/A	N/A	N/A	22.5

*Open bushland plots inside Nechisar fell within transect 4.

Bird species data by land-use/land cover types

Summing across all transects, Table 2 demonstrates how LU/LC types with a high species richness may not necessarily have a very high number of species that are specific to that habitat type.

Table 2. *Bird species richness and percent unique species in each LU/LC type in the study area.*

LU/LC type	Total number of species/plot	Number of unique species	Percent unique species (of total species)
Highlands:			
Cultivation	132	8	6.0
Grazing	87	14	16.1
Lowlands:			
Open bushland	128	20	15.6
Riparian	155	19	12.3
Wooded grassland	143	16	11.2
Grassland*	7	2	*
Lakeshore**	45	17	37.8

* Only 3 plots were sampled from this land cover type, thus richness data may not be compatible across types.
** A different method was used for sampling the lakeshore.

Highland cultivation
The cultivated areas of the highlands appear to have a high number of bird species per plot. The complex vertical structure of the vegetation, availability of water and seed crops explains this richness. However if one looks more closely at the number of unique species found in this land-use type it can be seen that not very many of these species would be dependent on this habitat alone to survive. In other words there are many 'weedy' species like, the Common Bulbul (*Pycnonotus barbatus*), Red-eyed Dove (*Streptopelia semitorquata*), species of weavers (*Ploceus*).

Therefore conversion of this land-use type to some other would mean a loss of 6% of the species seen in this habitat.

Highland grazing
The grazing areas of the highlands were very low in the number of species found there yet there were many that are dependent on this habitat type (16% of total species found there). These areas are very important to Rougets Rail (*Rallus rougetii*), and Blue-winged Goose (*Cyanochen cyanoptera*) both Ethiopian endemics, as well as the Red-breasted Wheatear (*Oenanthe bottae frenata*) and several lark species.

This habitat may not be affected by tsetse control unless more of it is converted to cultivation or it is grazed more intensely.

Open bushland
Open Bushlands of the lowlands have very high species richness. These areas are somewhat variable but in general provide good cover and foraging. The average number of species per plot for this LU/LC type was 128. Nearly 16 % of these species were found only in this habitat type. This is the second highest percent unique species of all the LU/LC types sampled in this study. A variety of species are supported here including Quails, Falcons, Hornbills, Larks, Nightjars, Tchagras, Barbets, Parrots, Shrikes, Chats, Hoopoes, Grenadiers and Kingfishers.

The Cambridge survey of Nechisar also found a high number of species in this habitat type during their study there in 1990 (Duckworth 1992). They attributed this to the fact that there is a lot of bushland outside of the park and therefore some connectivity of this habitat and fauna flow. Having large unfragmented areas with diverse vegetation types often lends to very rich habitat types.

Many of these bushlands are infested with tsetse and therefore will most likely be converted to either cultivation or grazing land-use types in the future. As these habitats are fragmented we expect the species numbers to decline.

Wooded grassland
The wooded grasslands had the second highest number of species per plot but the number of unique species was lower than both the riparian areas and the open bushlands in the lowlands. These habitat types were in general more used for grazing than the open bushland and therefore more open.

Some of the species that were seen only in wooded grasslands were: Red-headed Malimbe (*Anaplectes rubiceps*) White-headed buffalo weaver (*Dinemellia dinemelli),* Lesser kestrel *(Falco naumanni),* Upchers Warbler *(Hippolais languida),* Little Rock Thrush *(Monitcola rufocinerea),* Spotted Flycatcher (*Muscicapa striata),* Northern Brubru (Nilaus afer), Chestnut-crowned Sparrow-weaver (*Plocepasser supercilliosus),* Red-winged Pytillia (*Pytelia phoenicoptera), and* Chesnut-bellied Sandgrouse (*Pterocles exustus).*

It is likely that these areas could become more heavily used if the tsetse is controlled and the populations of humans and livestock increase.

Riparian
The riparian areas were the most species rich and had a highest percentage of unique species as well. These habitats were difficult to find anywhere outside the park. The Deme River area is still fairly intact and some riparian woodlands to the west of Dila also remain

Some of the species found only in this habitat type were: Malachite Kingfisher (*Alcedo cristata*), Eastern Plantain-eater (*Corythaixoides zonurus*), Grey Woodpecker *(Dendropicos goertae),* White-winged Cliffchat (*Myrmecocichla semirufa)* an Ethiopian endemic*, Black Scimitarbill (Phoeniculus arterrimus),* Abyssinian Scirmitarbill *(Rhinopomastus mino*), and the Rufous Chatterer (Turdoides rubiginosus).

Riparian woodlands are also often tsetse infected and if control is successful then the degradation of these habitats will be accelerated by increased clearing for cultivation, wood collection and livestock grazing.

Grassland (in Nechisar only)
This land cover type was only found in Nechisar Park. The area of the park where the grasslands are found is somewhat of an island. There are no similar habitats remaining outside the park.

Only 3 plots were sampled in this habitat type and an average of 7 species seen. There were only 2 unique species found in this habitat type during this study the Saker (*Falco cherrug*) is worth mentioning here. The Cambridge survey had similar results in this grassland; however, they found the Northern White-tailed bushlark *(Mirafra albicauda*) here. This is its only known locality in Ethiopia (Duckworth et al. 1993; Safford et al. 1993).

Shoreline

The lakeshore was surveyed only one day by boat. The sampling technique for this survey differs from the other LU/LC types therefore cannot be precisely compared. However, looking at the numbers in general it can be seen that species richness here is very high as well as the unique number of species.

Some species found only along the lakeshore in this study were: Goliath Heron (*Ardea goliath),* Senegal Thicknee (*Burhinus senegalensis),* Great Egret *(Egretta alba),* Black Heron (*Egretta ardesiaca),* Little Egret (*Egretta garzetta),* Black-backed Gull (*Larus ridibundus),* Pelican (*Pelecanus onocrotalus),* Pink Pelican (*Pelecanus rufescens),* Long-tailed Comorant (*Phalacrocorax africanus),* Great Comorant (*Phalacrocorax carbo), and* African Darter (*Anhinga rufa).*

If cultivation or grazing use is increased near to the lakeshore than these areas will be impacted and some species, especially those that nest near the shore and are sensitive to human disturbance will be lost (e.g. Pelicans).

Bird species composition

Figure 6a shows how the species composition of birds (names of birds are presented as the first three letters of the genus and species) of all the land-use/vegetation types, in both the highlands and lowlands, were related to each other. As one might expect, the biggest difference among the plots is not how they were used, but where they are in relation to elevation and the lakeshore. Thus, the birds in the two highland types, highland cultivation (HC) and grazing (HG) were more like each other and thus appeared near each other on the graph (they are in the same part of the ordination space). Compared to all other types, more unique species of birds were found in highland grazing areas than in the highland cultivated areas, because the highland grazing areas were farther removed from the centre point of the graph and in a different quadrant of the graphic from all the other types. The bird fauna in the 3 lowland types (OB, WG, RIP) were similar to each other in comparison to the highland types. The birds at the lakeshore (CST) were entirely different from those either in the highlands or the lowlands.

Figure 6a. *Bird species Canonical Correlation Analysis (CCA)–all LU/LC types (HC, HC, OB, WG, RIP, CST).*

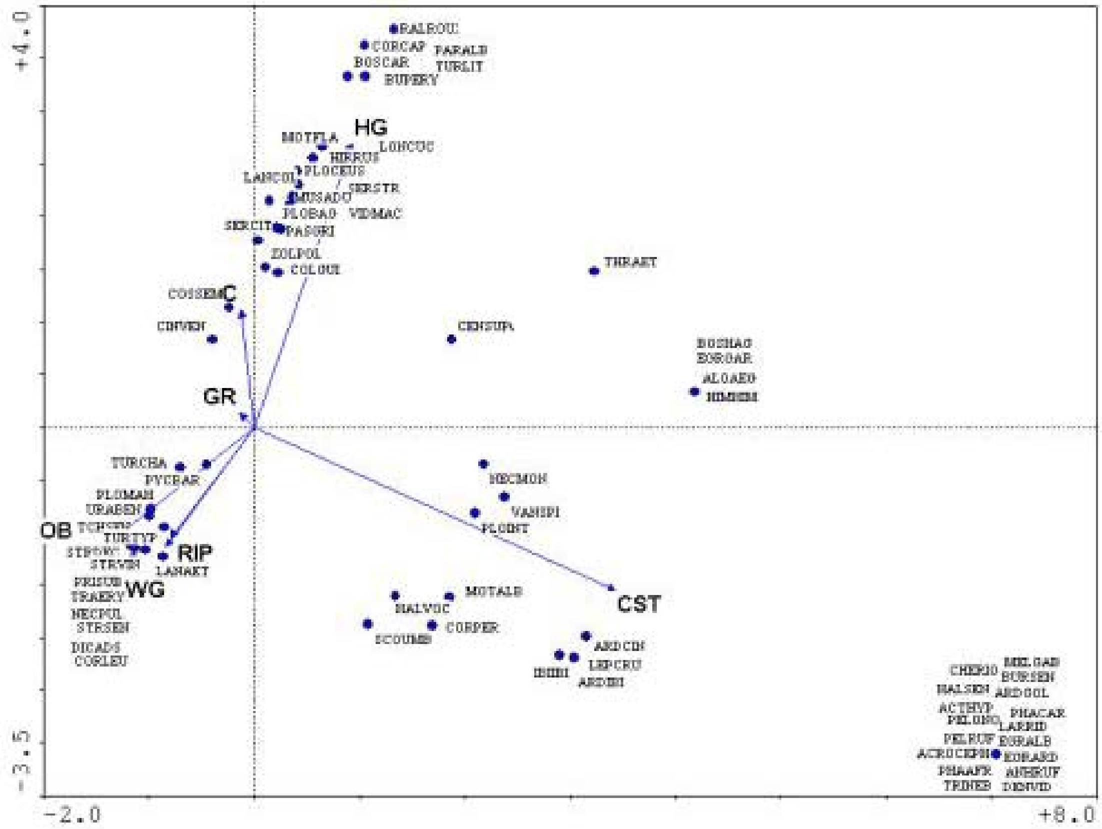


Figure 6b. *Bird species Canonical Correlation Analysis (CCA)–lowlands LU/LC types only (OB, WG, RIP)*

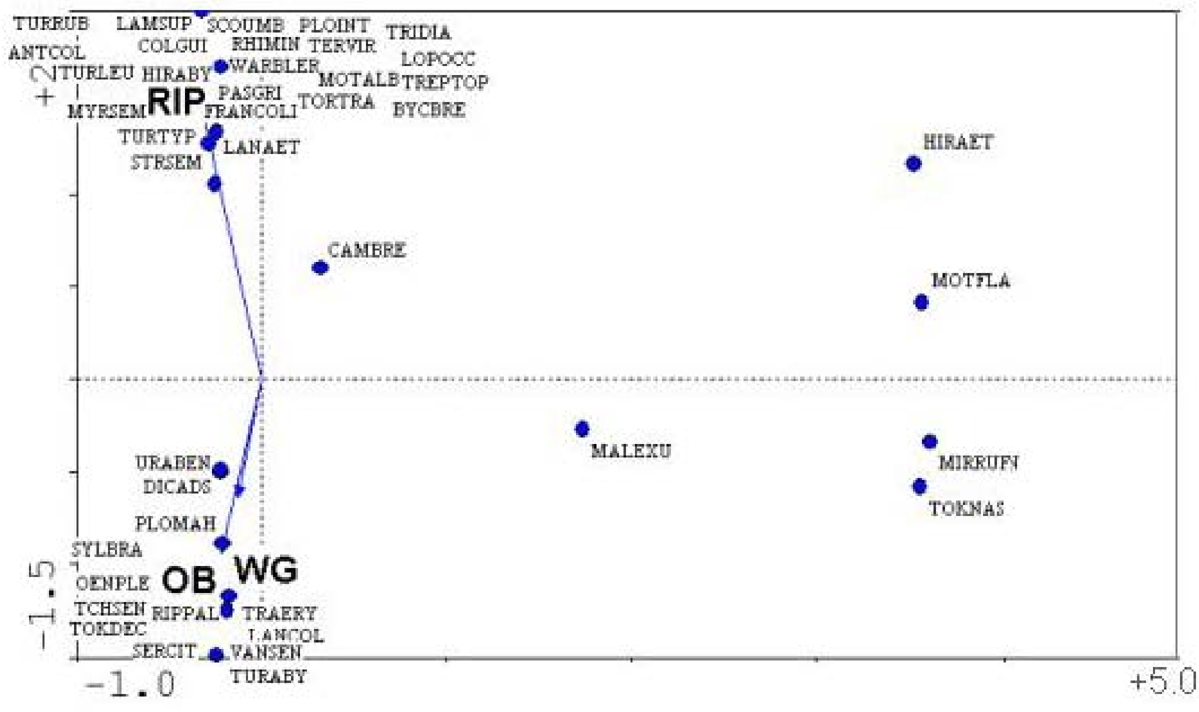
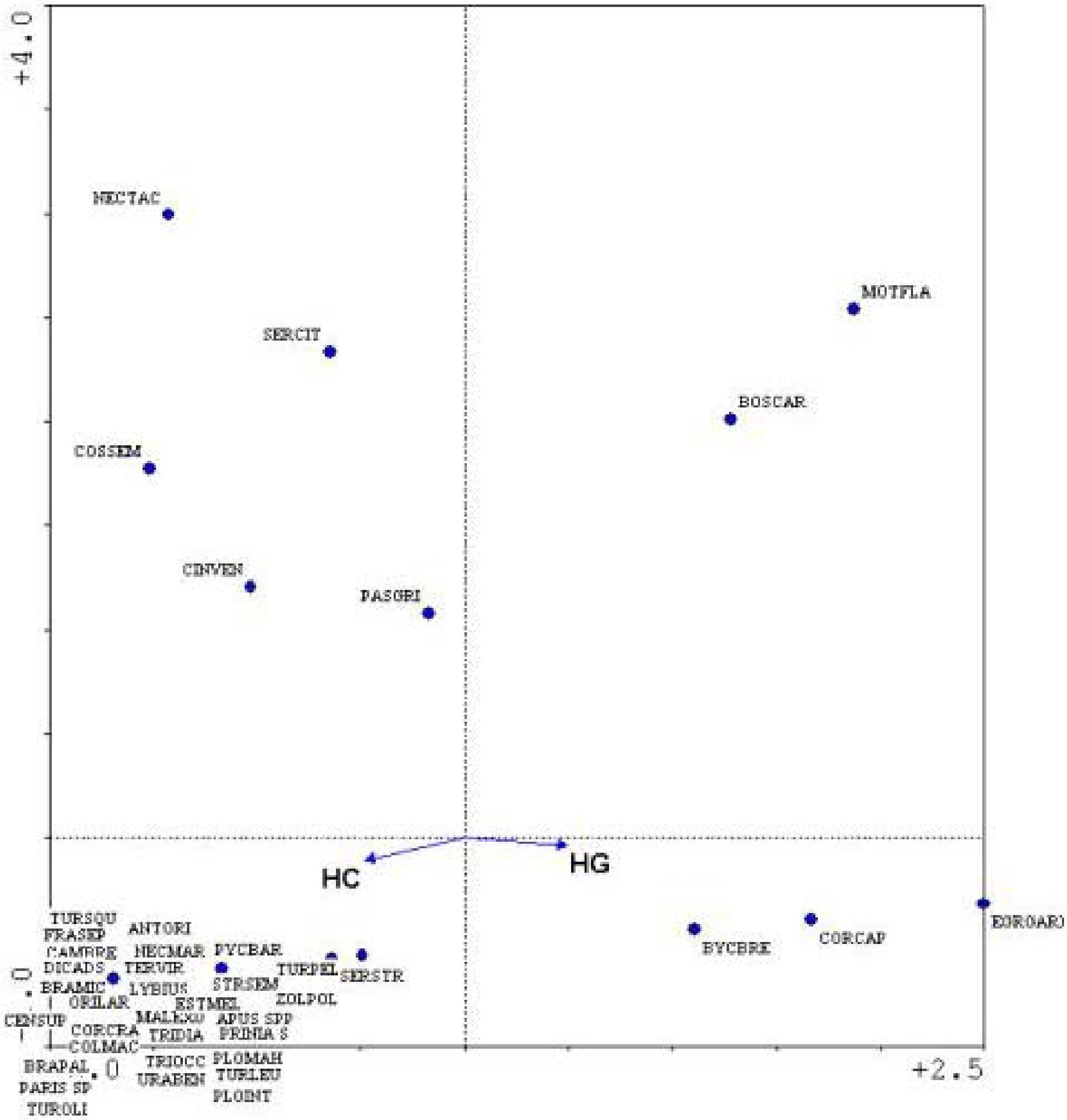


Figure 6c. *Bird species Canonical Correlation Analysis (CCA)–highland LU/LC types only (HC, HC).*



To tease apart the effects of land use, we created separate ordinations for the bird species in highland and lowland areas. As shown in the impact scenario for the lowlands (Figure 2), we expect that as farmers and their livestock move into the lowlands, grazing pressure and wood collection will rise. This will likely cause riparian woodlands and bushlands to become more open, converted into bushlands and wooded grasslands respectively. In Figure 6b, we see that the riparian woodlands support a unique bird fauna that will be lost if these areas are converted into less woody areas. The birds in the bushlands and grasslands are quite similar to each other, such that conversions between these two types will not have strong impacts on birds.

These effects are similar to what has been seen across Africa. SA mentioned preciously in this paper upland areas are less affected by intensified human use after tsetse/trypanosomosis control partly because the species in these habitats are better adapted to stress and partly because these areas are used less intensively than the wetter areas (Gardiner and Reid 1997a;

Reid et al. 1997; Wilson et al. 1997; Kiema and Reid 1998). Thus, expansion of farming and grazing after tsetse/trypanosomosis control (or after human population growth more generally) is likely to affect some parts of the landscape more than others. There are therefore good opportunities to target better natural resource management efforts on crucial habitats is important

If farmers move out of the highlands, we might expect cultivated areas to be left fallow and converted into grazing areas. In Figure 6c, we see that cultivated areas support more birds than grazing areas, although there are several unique bird species found in the grazing areas and nowhere else (as is clear in Figure 6a also). Thus, if farmers move out of the highlands and leave areas fallow, we expect that the bird fauna will become more diverse (because grasslands are more common), but the total number and abundance of birds may fall.

TOR 7: Complete a qualitative assessment of the probable impacts of the evolution of agricultural systems after tsetse control on large mammals (presence/absence) in the study area. **COMPLETED**

There were 30 species of medium to large-sized mammals recognised by informants in the highland and lowland landscapes (Table 5). Comparing across land-use types in either the highlands or lowlands, farmers saw about the same number of mammal species in each of the land-use types, with one exception. For example, in the highlands, croplands appear to support just as many species as do riparian woodlands, forests and bushlands. Here, it is only the grasslands, grazed heavily by livestock, where farmers see the fewest mammals. Similarly, in the lowlands, all land-use types support between 19 and 22 mammal species. The big difference is in the number of mammals in the highlands and the lowlands. On average, there are half as many species in highland land-use types than in the same types in the nearby lowlands.

Table 5. *Percentage of surveyed farmers who said that they regularly saw different wildlife species within each LU/LC type. .*

Animal species	Riparian		Forest		Bushland		Grassland		Cropland		mean % low	mean % high
	% low	% highl	% low	% highl	% low	% highl	% low	% highl	% low	% highl		
Baboon	71	33	71	33	100	33	71	0	100	0	82.9	20.0
Monkey, grivet	43	33	43	67	57	33	43	0	57	33	48.6	33.3
Monkey, vervet	57	0	57	0	71	0	43	0	71	0	60.0	0.0
Monkey, Colobus	71	0	43	0	0	0	0	0	0	0	22.9	0.0
Zebra	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Warthog	71	33	57	33	86	33	57	0	57	0	65.7	20.0
Bushpig	57	0	100	0	57	0	29	0	43	0	57.1	0.0
Hippotamus	57	0	0	0	0	0	0	0	0	0	11.4	0.0
Kudu, Greater	43	33	57	33	57	0	29	0	29	33	42.9	20.0
Waterbuck (defarsa)	71	0	14	0	0	0	0	0	14	0	20.0	0.0
Hartebeest	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Oribi	29	0	43	33	71	33	29	0	43	33	42.9	20.0
Klipspringer	0	0	0	0	43	0	0	0	0	0	8.6	0.0
Dikdik	71	33	71	33	100	33	86	0	100	33	85.7	26.7
Duiker	29	67	29	67	43	67	43	33	29	100	34.3	66.7
Bat-eared fox	0	0	0	0	43	0	43	0	0	0	17.1	0.0
Jackal	86	33	100	33	100	33	100	0	57	67	88.6	33.3
Hunting Dog	0	0	0	0	29	0	0	0	0	0	5.7	0.0
Hyaena	100	33	100	33	100	33	100	33	100	67	100.0	40.0
Leopard	57	0	71	0	14	33	29	0	14	0	37.1	6.7
Lion	43	0	57	0	43	0	14	0	14	0	34.3	0.0
Wildcat	57	0	71	0	57	0	57	0	57	0	60.0	0.0
Serval Cat	43	33	57	33	43	67	29	33	29	67	40.0	46.7
Caracal	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Aardvark	57	33	57	67	86	67	71	33	71	100	68.6	60.0
Porcupine	100	67	100	67	100	67	100	33	100	100	100.0	66.7
Cheetah	14	0	14	0	29	0	14	0	14	0	17.1	0.0
Bushbuck	14	0	14	0	14	0	0	0	0	0	8.6	0.0
Mt.Nyala	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Gazelle	0	0	0	0	0	0	0	0	0	0	0.0	0.0
number of species	22	11	21	11	22	8	19	5	19	10		

Low = lowland, highl = highland

The interpretation of these data is difficult. In other studies, large mammals are very sensitive to the intensity of land use (e.g. Reid 1997; Hoare and du Toit 1999). Here, farmers see large mammals as often in croplands as other types, implying that the expansion of land-use will have little effect on wildlife populations. Another interpretation is that the highlands are so heavily used that it is unlikely that there will be any difference in wildlife populations in the different land-use types. Here, patches of bush and forest are very rare, and when they do exist, they are small. Thus, because most large mammals use extensive areas for foraging, any species in these small patches would also use the nearby-cultivated fields at the same time. In the lowlands, farmers complain vigourously about wildlife in their fields. In areas with little cropping, it is common for wildlife to invade farmer's fields to graze on the crops themselves and on stubble after harvest. It is only when cropland areas become extensive that farmers are able to exclude wildlife from their fields (Newmark 1994). Thus, for very different reasons, wildlife may be similar among the land-use types in the highlands and the lowlands.

Could the large difference in species numbers in the highlands and lowlands be caused by differences in land-use between these two landscapes? There are twice as many species in lowland landscapes where land-use intensity is low compared with highland landscapes where land is intensively used. We think that this difference is partly due to elevation, and partly caused by land use. For example, species like cheetah and hippo are unlikely to be found in highland habitats; these differences in species composition are probably caused by elevation. However, other species, like Colobus monkey and Mountain nyala, should be found in the highlands and have probably been extirpated by people.

A possible reason for the high records of animal sightings in the survey in croplands could be because the croplands are very small and located near to where the people live; therefore they are likely to see any animals that enter their fields. Many said that animals would hide in the bush/forest during the day and come out to eat their crops at night.

We also asked people to describe the most wildlife-rich parts of the region. Informants on all transects surveyed indicated that most of the remaining wildlife exist in the areas which are dense bush near the lake, in Nechisar Park or high in the mountains. Lions and other predators were reported near to the lake north of Mirab Abaya and on the opposite side of the lake to the west of Mt. Goda in tsetse infested areas. These are areas that are currently little used by people; the lowland areas are now infested by tsetse. We expect that the wildlife populations in these areas in the lowlands will be most affected by the influx of people that will follow tsetse control. Even in the Nechisar Park, we expect grazing pressure and wood collection to increase as a result of tsetse control. In many areas of Africa, it is not land-use change *per se* that impacts wildlife, but the heavy hunting (and poaching) that occurs when people first start moving into an area.

The wooded grasslands in the lowlands were mostly heavily grazed lands, therefore we expect wildlife to be low here. In Nechisar the grasslands are more healthy and most of the large herbivores thrive there (zebra, Swayne's hartebeest (an endangered species), Grant's gazelle). This is the only place in the entire project area where these native herbivores can be found. Even these grasslands (inside a park) are becoming degraded (increased bareground and non-palatable herbaceous species). If the density of cattle increases in the reserve the grassland there will become more degraded and these species will be most likely be lost as well.

Elephant, buffalo and giraffe have not been in the area for more than 50 years. These largest of the mammals are the first to disappear when human population becomes high.

There is only one endemic mammal known to still exist in this region and it is Swayne's hartebeest (*Tragelaphus buxtoni*).

TOR 8: Assist in integrating socio-economic, environmental (vegetation, bird and large mammals), veterinary and tsetse entomological data in preparation of a summary report on the situation. **COMPLETED**

Socio-economic data are not available at the time of the submission of this report.

Refer to technical report for summary report.

TOR 9: Complete a report on the impacts of SIT control on birds and mammals and compile a comprehensive summary report on environmental impacts. **COMPLETED**

Please refer to Technical Report.

Status of project—AAU Team

TOR 1: Guide and assist in the assessment of existing environmental data and assist in the design and collection of additional data. **COMPLETED**

Dr. Tesfaye Korme collected and/or digitised existing GIS data prior to the initiation of this contract.

The study design was discussed between C. Wilson and ourselves in October 2000 and March and April 2001.

TOR 2: Guide and assist in the identification of representative areas for the collection of environmental data, preferably where veterinary and entomological data already exist. **COMPLETED**

Experimental design for bird/plant diversity sampling
The land-use/land cover (LU/LC) types selected to be sampled were: open bushland, wooded grassland, highland cultivation, highland forest, highland grazing land and riparian zones. Within each LU/LC type in each transect, 3 plots (250 m × 250 m) were randomly selected (see Annex II for plot coordinates). The diversity of birds and plants will be sampled in these plots. There will be two 20 m × 20 m vegetation plots selected within each of the larger 250 m × 250 m plots. Dr. Korme of AAU was subcontracted to select the sample sites using GIS and remote sensing (see above for his TOR's) within each of the four previously selected socio-economic survey transects using the following criteria:

a) The plots should fall within 2 km from a primary or secondary road.
b) The plots should fall completely within a single LU/LC type.
c) Along the riparian LU/LC type, select centre points around which plots can be measured.

In conjunction with the Ethiopian Science and Technology Commission and the Southern Region Team conducting the socio-economic survey, five study transects were identified in the study area for the environmental impact study. In this study area, a total of 6 LU/LC types were identified. Not all LU/LC types are found in each transect). Three large and 2 subplots were to be sampled in each unique LU/LC types in each transect. A total of 78 large plots and 156 subplots were identified. The sample plot coordinates (Annex II) were put into the GPS in UTM format and then the GPS guided the researchers to each sample plot.

TOR 3: Train staff and other individuals involved in the collection and evaluation of the data, as needed. **COMPLETED**

Two technicians were trained: 1) use of the GPS units and UTM coordinate System, 2) to recognise the various LU/LC types and the characteristic species in each of the LU/LC types and 3) collect the necessary field note such as Grid references, altitude, plant cover and abundance.

TOR 4: Assist in the establishment of baseline environmental data against which to assess the future impacts of SIT control. **COMPLETED**

Zerihun Woldu and Sebsebe Demissew (together with their field assistants) collected plant species during the period 25 April to 14 May 2001, 1 to 5 August, 20–27 November 2001 and 14 to 21 January 2002.

The rainy season was ideal for the collection of vegetation data. This was accomplished during the field study in April–May 2001. A total of 53 out of 78 large plots and 106 out of 156 subplots (two subplots per large plot) were sampled. Because of the high intensity of the rain in May 2001, which made the road to Nechisar inaccessible the plots in the transect were not sampled. The 13 plots (26 subplots) in Nechisar were sampled between 1–5 August 2001.

A master plant species list including all species together with physical environmental data is shown in Annex IIIb. Because of the need to check the identity of some sterile and difficult (for naming) plant specimens, two field trips were conducted between November 20–27 2001 and January 14–21 2002. The total number of plots sampled adds up to 66 (132 subplots). The reasons for not being able to sample the 12 plots (24 subplots), and the adjustments made to some plots are shown in Annex V of the Phase II report**.**

Most of the suggested Plots as per TOR 4 were sampled. Relevées or subplots were established in the suggested sites. Percent cover of plans species encountered were estimated following the modified Braun Blanquet approach (van der Mareel (1978). This method enables a visual estimation of the cover-abundance of plant species in a relvé. Except the most common and well-known ones, plant species encountered were collected, identified and voucher specimens deposited at the National Herbarium Addis Ababa University. Identifications were carried out using the Flora of Ethiopia and Eritrea (Edwards and Inga 1989; Edwards et al. 1995; Edwards et al. 1996; Philips 1997; Edwards et al. 2000) (See References in the technical report above). An Excel table was constructed consisting of the plant species on the rows and sites, relevés, coordinates, altitudes, LU/LC, percent cover on the columns.

TOR 5: Complete a quantitative assessment of the probable impacts of the evolution of agricultural systems after tsetse control on vegetation (diversity, abundance and structure) in the major vegetation types in the study area. **COMPLETED**

A total of 331 plant species were sampled in the study area. The baseline data and the current status in each transect and LU/LC types, and the LU/LC types in the entire area will be presented in the final report.

SEE Annexes V–VI and technical report for final results on the number of unique species in each LU/LC type.

The current status of the different LU/LC types is as follows:

Table 1. *Species richness and number of rare species (*) in the Transects and LU/LC types.*

	Transect	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5
LU/LC types/	Species richness	132	172	138	128	91
Highland Cultivation	110	64 (10*)	63 (9*)	28 (3*)	38 (5*)	–
Highland Forest	86	–	35 (7*)	32 (5*)	30 (4*)	–
Highland Grazing	48	17 (4*)	21 (1*)	25 (5*)	–	–
Open bushland	117	31 (-)	59 (6*)	35 (2*)	35 (3*)	21 (5*)
Riparian	176	53 (7*)	58 (9*)	54 (13)	–	70 (12*)
Wooded Grassland	134	42 (2*)	49 (3*)	51 (1*)	63 (9*)	24 (3*)

(Note that the number of species in each transect does not correspond to the total number of species in the LU/LC type; this is due to common occurrence of some of the species in the LU/LC types concerned).

The control of tsetse fly population mainly in the lowlands (Open bushland, wooded grassland and riparian LU/LC types) would undoubtedly create a favorable condition for an increase in livestock population. This would have a direct and an indirect effect on the agriculture, vegetation and land use both in the lowlands and in the highlands (Highland cultivation, Highland Forest and Highland Grazing LU/LC types).

Highland cultivation

There are 110 species in all the transects of this LU/LC type. It is the fourth highest in species richness compared to the other LU/LC types. Within this LU/LC type, Transect 1 shows the highest number of species, while Transect 3 shows the least. The number of rare species also shows a similar trend.

This LU/LC type has the commonly cultivated species of crops such as *Ensete ventricosum* (enset), which is the widely edible root crop and *Catha edulis* (Chat), a cash crop.

The presence of *Prunus africana* in Transect 2, sites 23 and 24 needs to be mentioned as this is one of the species that is being threatened elsewhere in Africa for its medicinal properties. The presence of *Sauromatum venosum*, one of the two species occurring in the genus in this and in the highland Forest LU/LC types is quite remarkable and need also to be noted.

If the number of livestock population increases in the lowlands where tsetse control is effected the highlanders would have a better access to livestock at affordable prices. This is expected to increase the livestock population also in the highlands which may induce the expansion of agricultural land. The effect of this would be a decrease in species richness and/or cover/abundance, disappearance of rare species and expansion of cultivated area.

Highland forest
There are 86 species in all transects of this LU/LC type. It is the fifth in rank in species richness compared to the other 6 LU/LC types. Within this LU/LC type, Transect 2 shows the highest number of species, while Transect 4 shows the least. The number of rare species also shows a similar trend.

The scattered presence of common highland species in this LU/LC type such as *Hagenia abyssinica, Olea europaea* subsp. *cuspidata* is cause for concern. These species are on the decline. The common tree species, *Juniperus procera* is not encountered in the sampled sites, showing the decline on the density of the species.

The presence of endemic *Kniphofia foliosa* (Edwards et al. 1996) in Transect 2, site 26 species need to be mentioned.

If the number of livestock population increases in the lowlands where tsetse control is effected the highlanders would have a better access to livestock at affordable prices. This is expected to increase the livestock population also in the highlands which may lead among other things to cutting more trees to expand the grazing and cultivation sites. The effect of this would be a decrease in species richness and/or cover/abundance, disappearance of the already reduced (in number) of the common highland species and the endemic ones.

Highland grazing
There are 48 species in all transects of this LU/LC type. It is the least in rank in species richness compared to the other 6 LU/LC types. Within this LU/LC type, Transect 3 shows the highest number of species, while Transect 1 shows the least. The number of rare species is highest in Transect 3 and lowest in Transect 2.

The presence of endemic *Thymus schimperi* (Sebsebe Demissew 1993) in Transect 3, sites 46 and 48 needs to be mentioned.

The presence of *Acritochaete volkensii*, the only species in the genus occurring only in mountainous areas in western, southern and eastern Ethiopia and in east and west tropical Africa need also to be noted.

In general this LU/LC type is very poor in species richness compared to grazing areas in the highlands of other parts of Ethiopia. The absence of various species of *Andropogon, Hyparrhenia*, *Pennisetum, Eragrostis, Cyperus* and *Trifolium* may not only be due to differences in environmental conditions, but also due to human interference. Grazing pressure may have eliminated the species altogether as these species are highly palatable (Zerihun Woldu 1985, 1986).

If the number of livestock population increases in the lowlands where tsetse control is effected the highlanders would have a better access to livestock at affordable prices. This is expected to increase the livestock population also in the highlands which may lead among other things to overgrazing. The effect of this would be a decrease in species richness and/or cover/abundance, disappearance of rare species and expansion of cultivated area.

Open bushland
There are 117 species in all transects of this LU/LC type. It is the third highest in species richness compared to the other 6 LU/LC types. Within this LU/LC type, Transect 2 shows the highest number of species, while Transect 5 shows the least. The number of rare species is highest in Transect 2 and lowest in Transect 1.

This LU/LC type includes about 8 species of *Acacia,* 2 species of *Combretum*, 1 species of *Commiphora*, 3 species of *Grewia*, 2 species of *Terminalia* and 2 species of *Ziziphus*. These are commonly occurring species in such vegetation types, but are comparatively fewer in number in comparison to the same LU/LC types elsewhere in the country.

The presence of endemic *Aloe* species: *A. gilbertii and A. pirottae* (Gilbert and Sebsebe Demissew 1992; Sebsebe Demissew and Brandham 1992; Sebsebe Demissew et al. 2001) in Transect 3, sites 34 and 35 shows the importance of such areas.

If the number of livestock population increases in the lowlands, which is the target area for tsetse control, the herbaceous vegetation cover will be overgrazed, and the shrub species will be heavily browsed. Thus the vegetation cover would be diminished exposing the land for severe erosion.

Note that the vegetation cover at present is less than 100%, which indicates that the sparse vegetation cover

Wooded grassland
There are 134 species in all transects of this LU/LC type. It is the second highest in species richness compared to the other 6 LU/LC types. Within this LU/LC type, Transect 4 shows the highest number of species, while Transect 5 shows the least. The number of rare species is highest in Transect 4 and lowest in Transect 1.

This LU/LC type includes about 5 species of *Acacia,* 3 species of *Combretum*, 2 species of *Commiphora*, 5 species of *Grewia*, 1 species of *Terminalia* and 2 species of *Ziziphus*. These are commonly occurring species in such vegetation types, but are comparatively fewer in number in comparison to the same LU/LC types elsewhere in the country.

The presence of endemic *Aloe* species: *A. gilbertii* in Transect 1 sites 4, 5 and transect 2 site 20*, A. otallensis* in transect 2 sites 20 and *A. pirottae* in Transect 5 site 57 shows the importance of such areas (Sebsebe Demissew et al. 2001).

The presence of orchid species (*Eulophia petersii* and *E. streptopetala*) in Transect 4, site 57 needs a special mention.

If the number of livestock population increases which is the target area for tsetse control, the herbaceous vegetation cover will be overgrazed, and the shrub species will be heavily browsed. Thus the vegetation cover would be diminished exposing the land for severe erosion.

Note that the distinction between open bushland and wooded grassland sometimes is not clear-cut.

The Riparian
There are 176 species in all transects of this LU/LC type. It is the highest in species richness compared to the other 6 LU/LC types. Within this LU/LC type, Transect 5 shows the highest number of species, while Transect 1 shows the least. The number of rare species also shows a similar trend.

This the most diverse LU/LC type compared to the other LU/LC types in the study area. This LC/LU type includes 8 species of *Acacia,* 3 species of *Combretum*, 4 species of *Grewia*, and two endemic *Aloe* species (*A. gilbertii* and *A. otallensis*).

It also includes the characteristic species that are known in such vegetation types in other areas in the country. These include: *Lepidotrichilia volkensii, Mimusops kummel, Teclea simplicifolia, Saba comorensisi, Teclea simplicifolia, Vepris dainelli and Zanthoxylum chalybeum*.

If the number of livestock population increases in the lowlands (in the bushland, wooded grassland and Riparian LU/LC types) where tsetse control is effected, there will b a move to transfer more livestock population to the Riparian LU/LC type from the Open bushland and wooded grassland LU/LC types. This is due to access to water sources and shade provided by the riparian vegetation. This would also encourage settlement, which may lead to the removal of more of the woody species (trees and shrubs).

Moreover, the overgrazing of the vegetation and the trampling of the area by livestock would discourage seedling re-establishment of the woody species, which may lead to eventual decrease in number or replacement by weedy species.

Mitigation measures
The following mitigation measures could be suggested to help reduce the impact on the vegetation with the increase in livestock population.

- the inevitable increase in livestock population must be counteracted by extracting the livestock for sale and export
- prior arrangement must be made to protect the Nechisar National Park from the invasion by livestock of the surrounding transhumance population
- mechanism for the management of grazing areas through participatory approach should be introduced
- mechanism to limit the number of livestock per household through participatory approach should be introduced

TOR 6: Assist in integrating socio-economic, environmental (vegetation, bird and large mammals), and veterinary and tsetse entomological data in preparation of a summary report on the situation. **COMPLETED**

All information provided as shown in TOR 4 and 5 above.

TOR 7: Complete a report on the impacts of SIT control on vegetation and contribute to the Compilation of a comprehensive summary report on environmental impacts.

In general the study area has fewer species than similar LU/LC types in other parts of the country. Regular monitoring of the species occurrence, their abundance and diversity will help to establish if there is a trend in the decrease of these attributes or if it has stabilised. The monitoring activities should focus on the presence and absence of the unique and rare species, which could be considered as indicators of human interference.

The presence and absence of the species plant cover (% Tot. cover) and (H) Shannon-Wiener (1949) diversity index could be used as useful parameters to measure the relative dominance of one species over the other, resulting from human interference or recovery process.

TOR 8: GIS and remote sensing analysis. **COMPLETED.** *See terms of reference for Dr. Tesfaye in Annex I.*

Annex II: Plot locations

Key: OB = Open Bushland, WG = Wooded Grassland, HC = Highland Cultivation, HG = Highland Grazing, Rip = Riparian, GR = Grassland, CS = Coastal; Plot numbers in bold indicate those that were added or altered by C. Wilson in November 2001.							
Plot No.	**Transect**	**LU/LC Type**	**UTM coordinates**				
			E	N			
1	1	OB	396965	760273			
2	1	OB	398717	755625			
3	1	OB	396684	759361			
4	1	WG	394168	759678			
5	1	WG	393575	759780			
6	1	WG	406115	766687			
7	1	HC	440571	768273			
8	1	HC	424952	768273			
9	1	HC	431643	751011			
10	1	HG	438591	757553			
11	1	HG	423710	759402			
12	1	HG	435246	752160			
13	1	RIP	Not sampled				
14	1	RIP	397439	749050			
15	1	RIP	398119	750756			
16	2	OB	414986	707707			
17	2	OB	405578	703473			
18	2	OB	412113	707098			
19	2	WG	415534	709737			
20	2	WG	414222	709657			
21	2	WG	411537	706225			
22	2	HC	424337	709451			
23	2	HC	416815	697633			
24	2	HC	414175	684770			
25	2	HF	Not sampled				
26	2	HF	438035	696561			
27	2	HF	Not sampled				
28	2	HG	415338	697134			
29	2	HG	419649	701222			
30	2	HG	412400	687829			
31	2	RIP	409481	710222			
32	2	RIP	400064	703436			
33	2	RIP	410839	712818			
34	3	OB	363476	697861			
35	3	OB	361360	706199			

Key: OB = Open Bushland, WG = Wooded Grassland, HC = Highland Cultivation, HG = Highland Grazing, Rip = Riparian, GR = Grassland, CS = Coastal; Plot numbers in bold indicate those that were added or altered by C. Wilson in November 2001.								
36	3	OB	357803	687429				
37	3	WG	363197	716927				
38	3	WG	342333	676859				
39	3	WG	342562	677703				
40	3	HC	341296	694057				
41	3	HC	341247	697750				
42	3	HC	342206	698984				
43	3	HF	Not sampled					
44	3	HF	Not sampled					
45	3	HF	Not sampled					
46	3	HG	342602	699894				
47	3	HG	341397	696549				
48	3	HG	344954	704436				
49	3	RIP	308834	711334				
50	3	RIP	337846	724567				
51	3	RIP	341782	732115				
52	4	OB	341984	661469				
53	4	OB	343683	660434				
54	4	OB	341501	661681				
55	4	WG	346054	659927				
56	4	WG	338613	660885				
57	4	WG	345756	659544				
58	4	HC	332294	665632				
59	4	HC	332428	665630				
60	4	HC	334698	664730				
61	4	HF	Not sampled					
62	4	HF	Not sampled					
63	4	HF	Not sampled					
64	4	HG	Not sampled					
65	4	HG	Not sampled					
66	4	HG	Not sampled					
67	4	RIP	345036	669888				
68	4	CS	345033	665785				
68’	4	RIP	342074	663218				
69	4	RIP	340070	663693				
70	Nechisar	WG	349791	657570				

Key: OB = Open Bushland, WG = Wooded Grassland, HC = Highland Cultivation, HG = Highland Grazing, Rip = Riparian, GR = Grassland, CS = Coastal; Plot numbers in bold indicate those that were added or altered by C. Wilson in November 2001.							
71	Nechisar	GR	350548	656061			
72	Nechisar	WG	351000	659486			
73	Nechisar	WG	350380	658440			
74	Nechisar	GR	350404	654594			
75	Nechisar	GR	350147	651364			
76	Nechisar	RIP	354969	649668			
77	Nechisar	RIP	354494	652335			
78	Nechisar	RIP	354615	652288			

Annex IIIa: Bird species list (Species followed by an * are endemic to Ethiopia).

Common name	*Species name*
Abyssinian Black-headed Forest Oriole*	*Oriolus monocha*
Abyssinian Ground-hornbill	*Bucorvus abyssinicus*
Abyssinian Scirmitarbill	*Rhinopomastus minor*
African Citril	*Serinus citrinelloides*
African Darter	*Anhinga rufa*
African Firefinch	*Lagonosticta rubicata*
African Fish Eagle	*Haliaeetus vocifer*
African Harrier Hawk	*Polybroides typus*
African Short-toed Lark	*Calandrella cinerea*
African Swallow-tailed Kite	*Chelictinia riocourii*
African Thrush	*Turdus pelios*
Augur Buzzard	*Buteo rufofuscus*
Baglefetch Weaver	*Plocus b. baglafecht*
Banded Martin	*Riparia cincta*
Banded Parisoma	*Parisoma boehmi*
Barefaced Go-away Bird	*Corythaixoides personata*
Barn Swallow	*Hirundo rustica*
Bateleur	*Terathopius ecaudatus*
Bearded Woodpecker	*Dendropicos namaquus*
Beautiful Sunbird	*Nectarinia pulchella*
Black Heron	*Egretta ardesiaca*
Black Kite	*Milvus migrans*
Black Scimitarbill	*Phoeniculus arterrimus*
Black-backed Gull	*Larus ridibundus*
Black-bellied Sunbird	*Cinnyris nectarinoides*
Black-billed Barbet	*Lybius guifsobalito*
Black-billed Blue-spotted Wood Dove	*Turtur abyssinicus*
Black-billed Wood Hoopoe	*Phoeniculus somaliensis*
Blackcap	*Sylvia atricapilla*
Black-cheeked waxbill	*Estrilda erythronotos*
Black-crowned Tchagra	*Tchagra senegala*
Black-headed Forest Oriole	*Oriolus larvatus*
Black-shouldered Kite	*Elanas caeruleus*
Blue-breasted Bee-eater	*Merops variegatus*
Blue-napped mousebird	*Colius macrourus*
Blue-winged Goose*	*Cyanochen cyanoptera*
Broad-Billed Roller	*Eurystomus glaucurus*
Bronze Mannikins	*Lonchura cucullata*
Brown-throated Sand Martin	*Riparia paludicola*
Buff-bellied Apalis	*Phyllolais pulchella*
Cape Rook	*Corvus capensis*
Carmine-Bee-eater	*Merops nubicus*
Cattle Egret	*Ardeola ibis*
Chesnut-bellied Sandgrouse	*Pterocles exustus*

Common name	*Species name*
Chestnut-crowned Sparrow-weaver	*Plocepasser superciliosus*
Chiffchaf Plot	*Phylloscopus collybita*
Chough	*Pyrrhocorax pyrrhocorox*
Cisticola spp.	*Cisticola sp.*
Collared Sunbird	*Antreptes collaris*
Common Bulbul	*Pycnonotus barbatus*
Common Fiscal Shrike	*Lanius collaris*
Common Sandpiper	*Actitis hypoleucos*
Common Stilt	*Himantopus himantopus*
Common Tern	*Sterna hirundo*
Common Whitethroat	*Sylvia communis*
Crested Francolin	*Francolinus sephaena*
Crowned Hornbill	*Tockus alboterminatus*
Crowned Plover	*Vanellus coronatus*
Cuckoo	*Cuculus canorus*
Dark-chanting Goshawk	*Melierax metabates*
Double-toothed barbet	*Lybius bidentatus*
Drongo	*Dicrurus adsimilis*
Dusky Flycatcher	*Muscicapa adusta*
Eastern Plantain-eater	*Corythaixoides zonurus*
Eastern Violet-backed sunbird	*Anthreptes orientalis*
Egyptian Goose	*Alopochen aegyptiaca*
Emerald-spotted Wood Dove	*Turtur chalcospilos*
Ethiopian swallow	*Hirundo aethiopica*
Eurasian Coot	*Fulica atra*
Fan-tailed Raven	*Corvus rhipidurus*
Flappet Lark	*Mirafra rufocinnamomea*
Gabar goshawk	*Melierax gabar*
Glossy Ibis	*Plegadis falcinellus*
Goliath Heron	*Ardea goliath*
Great Comorant	*Phalacrocorax carbo*
Great Egret	*Egretta alba*
Greater Blue-eared Glossy Starling	*Lamprotornis chalybaleus*
Greenshank	*Tringa nebularia*
Grey Flycatcher	*Bradornis microrhynchus*
Grey Heron	*Ardea cinerea*
Grey Hornbill	*Tokus nasutus*
Grey Woodpecker	*Dendropicos goertae*
Grey-backed Cameroptera	*Camaroptera brevicaudata abessinica*
Grey-backed Fiscal Shrike	*Malaconotua exubitorius*
Grey-headed Sparrow	*Passer griseus*
Grey-rumped Swallow	*Hirundo griseopyga*
Grosbeak Weaver	*Amblyospiza albifrons*
Ground-scraper thrush	*Turdus litsipsirupa*
Hadada Ibis	*Bostrychia hagedash*
Hammerkop	*Scopus umbretta*
Harlequin Quail	*Coturix delegorguei*
Helmeted Guinea Fowl	*Numida meleagris somaliensis*

Common name	*Species name*
Hooded Vulture	*Necrosyrtes monachus*
Hoopoe	*Upupa epops epops*
Horus Swift	*Apus horus*
Isabelline Wheatear	*Oenanthe isabellina*
Jacana	*Actophilornis africana*
Klaas' Cuckoo	*Chyrsococcyx klaas*
Kori bustard	*Otis kori*
Lappet-faced Vulture	*Torgos tracheliotus*
Laughing Dove	*Streptopelia senegalensis*
Lesser kestrel	*Falco naumanni*
Lilac-breasted Roller	*Coracias caudata*
Little Egret	*Egretta garzetta*
Little Rock Thrush	*Monitcola rufocinerea*
Long-billed Pipit	*Anthus similus*
Long-crested Eagle	*Lophoaetus occipitalis*
Long-tailed Comorant	*Phalacrocorax africanus*
Long-tailed Widowbird	*Euplectes progne*
Malachite Kingfisher	*Alcedo cristata*
Marabou Stork	*Leptoptilos crumeniferus*
Marico Sunbird	*Nectarinia mariquensis*
Masked weaver	*Plocus intermedius*
Montane White-eye	*Zosterops poliogaster*
Mottled Swift	*Apus aequatorialus*
Mountain Wagtail	*Motacilla alba*
Mourning Dove	*Streptopelia decipiens*
Mouse-coloured Pendaline Tit	*Remiz musculus*
Namaqua Dove	*Oena capensis*
Northern Black Flycatcher	*Melaenornis edolioides*
Northern Brubru	*Nilaus afer*
Northern Crombec	*Sylvietta brachyura*
Northern Wheatear	*Oenanthe oenanthe*
Olivaceaous Warbler	*Hippolais pallida*
Olive Thrush	*Turdus olivaceus*
Orange-bellied Parrot	*Poicephalus rufiventris*
Pallid Flycatcher	*Bradornis pallidus*
Pallid Harrier	*Circus macrourus*
Paradise Flycatcher	*Terpsiphone viridis*
Pelican	*Pelecanus onocrotalus*
Peregrine Falcon	*Falco peregrinus*
Pied Crow	*Corvus albus*
Pied Wheatear	*Oenanthe pleschanka*
Pink Pelican	*Pelecanus rufescens*
Pin-tailed Whydah	*Vidua macoura*
Plain-backed Pipit	*Anthus leucophrys*
Purple Grenadier	*Uraeginthus ianthinogaster*
Rattling cisticola	*Cisticola chiniana*
Red and Yellow Barbet	*Trachyphonus erythrocephalus*
Red-billed Oxpecker	*Buphagus erythrorhynchus*

Common name	*Species name*
Red-billed Qualea	*Quelea quelea*
Red-breasted Wheatear	*Oenanthe bottae frenata*
Red-cheeked Cordon Blue	*Uraeginthus bengalus*
Red-chested cuckoo	*Cuculus solitaius*
Red-collared Widowbird	*Euplectes ardens*
Red-eyed Dove	*Streptopelia semitorquata*
Red-faced Crombec	*Sylvietta whytii*
Red-fronted Barbet	*Tricholaema diadematum*
Red-Fronted Warbler	*Spiloptila rufifrons*
Red-headed Malimbe	*Anaplectes rubiceps*
Redstart	*Phoenicurus phoenicurus*
Red-winged Prinia	*Prinia erythroptera*
Red-winged Pytillia	*Pytelia phoenicoptera*
Reed Warbler	*Acrocephalus spp.*
Ring-necked Dove	*Streptopelia capicola*
Rouget’s Rail	*Rallus rougetii*
Rufous Chatterer	*Turdoides rubiginosus*
Rufous-crowned Roller	*Coracias naevia*
Ruppell’s Long-tailed starling	*Lamprotornis purpuropterus*
Ruppells Robin-Chat	*Cossypha semirufa*
Sacred Ibis	*Threskiornis aethiopica*
Saker	*Falco cherrug*
Scaly Babbler	*Turdoides squamulatus*
Scaly Francolin	*Francolinus squamatus*
Scarlet-chested Sunbird	*Chalcomitra amethystina*
Senegal Thicknee	*Burhinus senegalensis*
Shining Sunbird	*Cinnyris habessinica*
Short-toed Snake-eagle	*Circaetus gallicus*
Silvery-cheeked Hornbill	*Bycanistes brevis*
Singing Cisticola	*Cistcola cantans*
Slate-coloured Boubou	*Lanarius funebrus*
Slender-tailed Nightjar	*Caprilmulgus clarus*
Song Thrush	*Turdus philomelos*
Speckled Mousebird	*Colius striatus*
Speckled Pigeon	*Columba guinea*
Spotted Flycatcher	*Muscicapa striata*
Spotted MorningThrush	*Cichladusa guttata*
Spur-winged Plover	*Vanellus spinosus*
Stonechat	*Saxicola torquata*
Straw-tailed Whydah	*Vidua fischeri*
Streaky Seed-eater	*Serinua striolatus*
Striped Kingfisher	*Halcyon chelicuti*
Striped Swallow	*Hirundo abyssinica*
Superb Starling	*Lamprotornis suberbus*
Tacazze Sunbird	*Nectarinia tacazze*
Tambourine Dove	*Turtur typanistria*
Tawny Eagle	*Aquila rapax*
Tawny-flanked Prinia	*Prinia subflava*

Common name	*Species name*
Thekla Lark	*Galerida malabarica*
Thick-billed Raven*	*Corvus crassirostris*
Tropical Boubou	*Lanarius aethioipicus*
Upchers Warbler	*Hippolais languida*
Variable Sunbird	*Cinnyris venusta*
Village Indigobird	*Vidua chalybeata*
Vinaceous Dove	*Streptopelia vinacea*
Violet Wood-hoopoe	*Phoeniculus granti*
Von der Decken's Hornbill	*Tockus deckeni*
Wattled Ibis	*Bostrychia carunculata*
Wattled Plover	*Vanellus senegallus*
Western Turtle Dove	*Streptopelia turtur*
White Helmetshrike	*Prionops plumata cristata*
White-bellied Black Tit	*Parus albiventris*
White-bellied Go Away Bird	*Corythaixoides leucogaster*
White-browed Coucal	*Centropus superciliosus*
White-browed Scrub Robin	*Cossypha heuglini*
White-browed Sparrow Weaver	*Plocepasser mahali*
White-cheeked Turaco	*Tauraco leucotis*
White-crowned shrike	*Prionops rueppellii*
White-faced Tree Duck	*Dendrocygna viduata*
White-headed buffalo weaver	*Dinemellia dinemellia*
White-headed Vulture	*Trigonoceps occipitalis*
White-rumped Babbler	*Turdoides leucopygius*
White-rumped Babbler	*Turdoides leucopygius*
White-rumped Swift	*Apus caffer*
White-winged Cliffchat*	*Myrmecocichla semirufa*
Willow Warbler	*Phylloscopus trochilus*
Wire-tailed Swallow	*Hirundo smithii*
Woodland Kingfisher	*Halcyon senegalensis*
Yellow Wagtail	*Motacilla flava*
Yellow-bellied Eremeola	*Eremomela icteropygialis*
Yellow-bellied waxbill	*Estrilda melanotis*
Yellow-Billed Stork	*Ibis ibis*
Yellow-necked Spurfowl	*Francolinus leucoscepus*
Yellow-rumped seedeater	*Serinus atrogularis*

Annex IIIb: Plant species list.

Species
Abrus precatorius
Abutilon fruitcosum
Abutilon villosa
Acacia brevispica
Acacia hockii
Acacia mellifera
Acacia nilotica
Acacia polyacantha
Acacia senegal
Acacia seyal
Acacia tortilis
Acalypha fruticosa
Acanthus arboreus
Acanthus sp.
Acanthus polystachyus
Acokanthera schimperi
Achyranthus
aspera
Acritochaete
volkensii
Adenia venenata
Adenium obesum
Aeschynomene abyssinica
Aeschynomene elaphroxylon
Agave americana
Ageratum
conyzoides
Albizia gummifera
Alchemilla
abyssinica
Alchymella rothii
Alium sativum
Allophylus abyssinicus
Aloe gilbertaie
Aloe otallensis
Aloe pirrottae
Amaranthus
hybridus
Amorphophallus
sp.
Anonna
senegalensis
Anthemis tigreensis
Areva javanica
Arisaema schimperianum
Arundinaria alpina

Species
Asparagus falcatus
Asparagus
flagellaris
Asparagus racemosus
Aspilia africana
Balanites aegyptica
Balanitus
rotundifolia
Barleria eranthemoides
Barleria
quadrispina
Becium filamentosa
Bersama
abyssinica
Bidens pilosa
Bidens
sp.
Boscia
senegalensis
Botriochloa
radicans
Brassica nigra
Bridelia micrantha
Brucea antidysenterica
Buddleja
polystachya
Cadaba farinosa
Calpurnia aurea
Canthium oligocarpum
Capparis spinosa
Capparis
tomentosa
Cardus chamaecephalus
Cardus
leptacanthus
Carrisa edulis
Caryx sp.
Cassia
didymobotrya
Cassimiroa edulis
Cassipora
malasona
Catha edulis
Celosia argentea
Celtis africana
Cenchrus sp.

Species
Chloris
roxburghiana
Chrysopogon plumulosus
Cirsium vulgare
Cissampelos mucronata
Cissus quadrangularis
Cissus
rotundifolius
Citrus sinensis
Clausena anistata
Clematis simensis
Clerodendron myricoides
Clutia abyssinica
Coccinia
abyssinica
Coffea arabica
Combretum
collinum
Combretum aculeatum
Combretum molle
Commelina benghalensis
Commicarpus sinuatus
Commiphora
africana
Commiphora terebinthina
Cordia africana
Crepis reuppellii
Crinipes
longifolius
Croton macrostachyus
Croton
sp.
Cucurbita peppo
Cuppressus lusitanica
Cycnium herzteldianus
Cynodon dactylon
Cyperus
rigidifolius
Cyperus rotundus
Cyperus dives
Cyperus impubes
Cyperus longus
Datura stramonium
Desmodium
Dichondra repens
Dichrostachys

Species	Species	Species
cinerea		
Digitria velutina	*Digitria velutina*	*Digitria velutina*
Dioscorea sp.	*Dioscorea sp.*	*Dioscorea sp.*
Diospyros mespiliformis	*Diospyros mespiliformis*	*Diospyros mespiliformis*
Dischoryste	*Dischoryste*	*Dischoryste*
radicans	*radicans*	*radicans*
Dodonaea angustifolia	*Dodonaea angustifolia*	*Dodonaea angustifolia*
Dovyalis	*Dovyalis*	*Dovyalis*
abyssinica	*abyssinica*	*abyssinica*
Dracena steudneri	*Dracena steudneri*	*Dracena steudneri*
Dregea schimperi	*Dregea schimperi*	*Dregea schimperi*
Echinochloa	*Echinochloa*	*Echinochloa*
colona	*colona*	*colona*
Echinops sp.	*Echinops sp.*	*Echinops sp.*
Ekebergia capensis	*Ekebergia capensis*	*Ekebergia capensis*
Eleusine floccifolia	*Eleusine floccifolia*	*Eleusine floccifolia*
Elytrophorus	*Elytrophorus*	*Elytrophorus*
spicatus	*spicatus*	*spicatus*
Endostemon sp.	*Endostemon sp.*	*Endostemon sp.*
Ensete ventricosum	*Ensete ventricosum*	*Ensete ventricosum*
Enteropogon macrostachyus	*Enteropogon macrostachyus*	*Enteropogon macrostachyus*
Eragrostis	*Eragrostis*	*Eragrostis*
botryodes	*botryodes*	*botryodes*
Eragrostis	*Eragrostis*	*Eragrostis*
japonica	*japonica*	*japonica*
Eragrostis	*Eragrostis*	*Eragrostis*
japonica	*japonica*	*japonica*
Eragrostis	*Eragrostis*	*Eragrostis*
tenuifolia	*tenuifolia*	*tenuifolia*
Eragrostis tremula	*Eragrostis tremula*	*Eragrostis tremula*
Erythrina	*Erythrina*	*Erythrina*
abyssinica	*abyssinica*	*abyssinica*
Erythrina brucei	*Erythrina brucei*	*Erythrina brucei*
Eucalyptus	*Eucalyptus*	*Eucalyptus*
globulus	*globulus*	*globulus*
Euclea divinorum	*Euclea divinorum*	*Euclea divinorum*
Euclea schimperi	*Euclea schimperi*	*Euclea schimperi*
Eulophia petersii	*Eulophia petersii*	*Eulophia petersii*
Eulophia sp.	*Eulophia sp.*	*Eulophia sp.*
Euphorbia sp.	*Euphorbia sp.*	*Euphorbia sp.*
Euphorbia	*Euphorbia*	*Euphorbia*
cotonifolia	*cotonifolia*	*cotonifolia*
Euphorbia	*Euphorbia*	*Euphorbia*
obovalifolia	*obovalifolia*	*obovalifolia*
Euphorbia polyacantha	*Euphorbia polyacantha*	*Euphorbia polyacantha*
Euphorbia tirucalli	*Euphorbia tirucalli*	*Euphorbia tirucalli*
Evolvulus	*Evolvulus*	*Evolvulus*
alsinoides	*alsinoides*	*alsinoides*

Species
Festuca sp.
Ficus sp.
Ficus sur
Ficus sycomorus
Ficus umbellata
Ficus vasta
Flacourtia indica
Flueggea virosa
Foeniculum
vulgare
Galiniera
coffeoides
Galinsoga
parviflora
Gardenia lutea
Geranium
arabicum
Gomphocarpus fruitcosus
Grewia bicolor
Grewia tenax
Grewia
trichocarpa
Grewia velutina
Grewia villosa
Guizotia scabra
Hagenea
abyssinica
Haplocarpha
ruepelli
Harissonia
abyssinica
Harpachne
schimperi
Heteropogon contortus
Hippocratea
africana
Hordeum vulgare
Hybanthus enneaspermus
Hydnora johannis
Hydrocotyle manii
Hypericum
annulatum
Hypoestes
forsskaoli
Hypparhenia
cymbari
Impatiens
athiopica

Species
Impatiens tinctoria
Indigofera
schimperi
Ipomea cairica
Jacaranda mimosifolia
Jasminum floribundum
Juniperus procera
Justicia flava
Justicia ladanoides
Kalanchoe
densiflora
Kalanchoe
lanceolata
Kalanchoe
petitiana
Knipohofia foliosa
Kyllingiella microcephala
Kyllingiella
polyphylla
Laggera crispata
Lannea schimperii
Lantana camara
Leonitis ocymifolia
Lepidotrichilia volkensii
Leptochloa
rupestris
Leucas
martinicensis
Lippia adoensis
Mangifera indica
Maytenus
arbutifolia
Maytenus obscura
Maytenus senegalensis
Maesa lanceolata
Medicago
polymorpha
Melhania velutina
Melinis repens
Melia azedarach
Milletia ferruginea
Mimusops kummel
Monechma debile
Moringa
stenopetala
Morus nigra
Musa paradisca
Myrica salcifolia

Species
Ochna inermis
Ochthochloa sp.
Ocimum
gratissimum
Ocimum
lamiifolium
Olea europaeassp. Cuspidata
Oplismenus sp.
Osyris
quadripartita
Oxalis radicosa
Oxygonum
sinuatum
Ozoroa insignis
Panicum deustum
Panicum maximum
Pappea capensis
Paspalum
orbiculare
Pennisetum mezianum
Pennisteum maximum
Pentaschistis pictigluma
Periploca sp.
Perotis patens
Persea americana
Persicaria senegalensis
Phaseolus vulgaris
Phoenix reclinata
Phyllantus
ovalifolius
Phytolacca dodecandra
Pilostigma
thonningii
Plantago palmata
Plectranthus
barbatus
Plectranthus punctatus
Podocarpus
falcatus
Polyscias fulva
Prunus africana
Prunus persica
Psidum guajava
Pterolobium
stellatum
Pulchea discoridis
Pycnostachys abyssinica
Ranunculus multifides

Species

Rapanea melanophloes
Rhamnus prinoides
Rhoicisus revoilii
Rhus natalensis
Rhynchosia malacophylla
Ricinus communis
Ritichia albersii
Rosa abyssinica
Rubus steudneri
Rumex abyssinica
Rumex nepalensis
Saba comorensis
Saccarhum officinarum
Sacrostemma viminale
Salvadora persica
Salvia coccinea
Salvia nilotica
Sansevieria forskaolina
Sansevieria
erythreae
Satureja punctata
Sauromatum
verosum
Schefflera
abyssinica
Scirpus sp
Sclerocarya birrea
Sehima nervosum
Senecio sp
Sesbania sesban
Setaria megaphylla
Sida alba
Sida
ovata
Sida schimperiana
Solanum capsicum
Solanum incanum
Solanum nigrum
Solanum tobacum
Solanum tubersom
Sonchus sp
Sorghum verticilliflorum
Sphaeranthus suaveolens
Spheranthus sp.
Spilantus
mauritiana
Sporobilous
festuvis

Species

Sporobolus pyramidalis
Stephania
abyssinica
Sterculia africana
Syzigium guineense
Tagetes minuta
Talinum sp
Tamarindus indica
Teclea nobilis
Teclea simplifolia
Tephrosia pumila
Terminalia
browinii
Terminalia schimperiana
Terminalia sp.
Thalictrum rynchocarpum
Themeda triandra
Thymus schimperi
Trichia
sp
Trichilia dregeana
Trifolium
sempilosum
Triumfetta brachyceras
Tylosema fassoglensis
Typha domingensis
Vepris dainellii
Vernonia adoensis
Vernonia
amygdalina
Vernonia
auriclifolia
Vernonia sp.
Ximenia caffra
Zanha golungensis
Zanthoxylum chalybeum
Zea mays
Zehneria scabra
Ziziphus
mucronata
Ziziphus spina-
christi

Annex IV: Large mammal survey sheet.

Wildlife PRA's IAEA Project southern Rift Valley, Ethiopia

Date: Key informant name:

Recorder: Age (>=20yrs):

Transect: How long have they lived in this area?

GPS coordinates of interview:

Land use/land cover types: Grass = wooded grassland, crop = cultivated area, forest = forested, bush = open bushland, river

		Land use/ land cover type										
		Grass		Crop		Forest		Bush		River		
Animal species	**Page #**	**+/–**	**Rank**	**+/–**	**Rank**	**+/–**	**Rank**	**+/–**	**Rank**	**+/–**	**Rank**	**Notes…**
Baboon	25											
Monkey, grivet	37(60b)											
Monkey, vervet	37(60d)											
Monkey, Colobus	61											
Zebra	75											
Warthog	82											
Bushpig	85											
Hippopotamus	91											
Kudu, Greater	115											
Waterbuck (Defarsa)	135											
Hartebeest	149											
Oribi	187											
Klipspringer	193											
Dikdik	199											
Duiker	199											
Bat-eared fox	227											
Jackal	233											
Hunting Dog	237											
Hyaena	267											
Leopard	275											
Lion	277											
Wildcat	279											
Serval Cat	283											
Caracal	285											
Aardvark	289											
Porcupine	301											
Cheetah												
Other												

Annex V. Summary of plant species within each transect:

1) *The plant species found in each land-use/land cover (LU/LC) type;*
2) *Plant species richness for each LU/LC type;*
3) *Plant species that are LU/LC specific (unique species to specific LU/LC types*).

1) Plant species found in highland cultivation within each transect

LU/LC	Trasnsect 1	Trasnsect 2	Trasnsect 3	Trasnsect 4

LU/LC	Trasnsect 1	Trasnsect 2	Trasnsect 3	Trasnsect 4
Highland cultivation	Achyranthus aspera Ageratum conyzoides Albizia gummifera Amaranthus hybridus Anonna senegalensis Bidens pilosa Brassica nigra Cadaba farinosa Calpurnia aurea Caryx sp. Cassimiroa edulis Catha edulis Citrus sinensis Coffea arabica Commelina benghalensis Cordia africana Croton macrostachyus Cuppressus lusitanica Cynodon dactylon Cyperus rotundus Datura stramonium Digitria velutina Dioscorea sp. Dovyalis abyssinica Ensete ventricosum Eragrostis tenuifolia Eucalyptus globulus Euphorbia cotonifolia Ficus vasta Foeniculum vulgare Galinsoga parviflora Geranium arabicum Guizotia scabra Leucas martinicensis Milletia ferruginea Morus nigra Musa paradisca Ocimum gratissimum Olea europaeassp. Cuspidata Oxalis radicosa Panicum maximum Persea americana Phaseolus vulgaris Phoenix reclinata Podocarpus falcatus Psidum guajava Pycnostachys abyssinica Rhamnus prinoides Ricinus communis Rumex abyssinica Rumex nepalensis Saccarhum officinarum Sesbania sesban Sida alba Solanum capsicum Solanum tobacum Solanum tubersom Sonchus sp Spilantus mauritiana Tagetes minuta Vernonia amygdalina Vernonia auriclifolia Zea mays Ziziphus spina-christi	Achyranthus aspera Albizia gummifera Alium sativum Aloe gilbertaie Amaranthus hybridus Anonna senegalensis Aspilia africana Bidens pilosa Brassica nigra Calpurnia aurea Caryx sp. Cassia didymobotrya Catha edulis Celosia argentea Celtis africana Coffea arabica Combretum collinum Commelina benghalensis Cordia africana Croton macrostachyus Cucurbita peppo Cuppressus lusitanica Cynodon dactylon Cyperus rigidifolius Dioscorea sp. Dracena steudneri Ekebergia capensis Ensete ventricosum Eragrostis tenuifolia Erythrina brucei Eucalyptus globulus Evolvulus alsinoides Galinsoga parviflora Hypparhenia cymbari Justicia flava Kalanchoe densiflora Leonitis ocymifolia Melia azedarach Milletia ferruginea Musa paradisca Ocimum gratissimum Pappea capensis Persea americana Phaseolus vulgaris Polyscias fulva Prunus africana Prunus persica Rhamnus prinoides Rhus natalensis Ricinus communis Salvia coccinea Sauromatum verosum Sesbania sesban Sida alba Solanum capsicum Solanum incanum Solanum tobacum Solanum tubersom Sonchus sp Tagetes minuta Vernonia amygdalina Vernonia auriclifolia Zea mays	Achyranthus aspera Alchemilla abyssinica Alium sativum Arisaema schimperianum Arundinaria alpina Asparagus flagellaris Brassica nigra Commelina benghalensis Cuppressus lusitanica Ensete ventricosum Erythrina brucei Eucalyptus globulus Galinsoga parviflora Hagenea abyssinica Haplocarpha ruepelli Hordeum vulgare Maesa lanceolata Pycnostachys abyssinica Ricinus communis Salvia nilotica Senecio sp Solanum incanum Solanum nigrum Solanum tubersom Tagetes minuta Vernonia adoensis	Acanthus polystachyus Alium sativum Arisaema schimperianum Bidens pilosa Brassica nigra Cadaba farinosa Canthium oligocarpum Cirsium vulgare Commelina benghalensis Croton macrostachyus Cucurbita peppo Ensete ventricosum Erythrina brucei Eulophia petersii Ficus sur Galinsoga parviflora Geranium arabicum Guizotia scabra Hordeum vulgare Hypoestes forsskaoli Juniperus procera Medicago polymorpha Milletia ferruginea Ocimum lamiifolium Olea europaeassp. Cuspidata Oxygonum sinuatum Persicaria senegalensis Phaseolus vulgaris Pycnostachys abyssinica Rumex nepalensis Sacrostemma viminale Salvia nilotica Sida schimperiana Solanum incanum Solanum nigrum Solanum tubersom Spilantus mauritiana Vernonia amygdalina Zea mays Zehneria scabra

1) Plant species found in highland forest within each transect

LU/LC	Trasnsect 2	Trasnsect 3	Trasnsect 4
Highland forest	*Acanthus sp.* *Alchemilla abyssinica* *Alchymella rothii* *Amaranthus hybridus* *Anthemis tigreensis* *Arundinaria alpina* *Asparagus falcatus* *Asparagus flagellaris* *Bidens sp.* *Brucea antidysenterica* *Cadaba farinosa* *Cardus chamaecephalus* *Celosia argentea* *Commelina benghalensis* *Cuppressus lusitanica* *Cynodon dactylon* *Cyperus rotundus* *Eragrostis botryodes* *Eragrostis tenuifolia* *Eucalyptus globulus* *Galiniera coffeoides* *Hagenea abyssinica* *Hypericum annulatum* *Impatiens athiopica* *Impatiens tinctoria* *Justicia flava* *Kalanchoe densiflora* *Knipohofia foliosa* *Leonitis ocymifolia* *Maytenus obscura* *Phaseolus vulgaris* *Phytolacca dodecandra* *Plantago palmata* *Rubus steudneri* *Rumex abyssinica* *Stephania abyssinica* *Trifolium sempilosum* *Vernonia adoensis*	*Abutilon villosa* *Achyranthus aspera* *Alchemilla abyssinica* *Alium sativum* *Allophylus abyssinicus* *Arisaema schimperianum* *Arundinaria alpina* *Asparagus flagellaris* *Brassica nigra* *Commelina benghalensis* *Cuppressus lusitanica* *Ensete ventricosum* *Erythrina brucei* *Eucalyptus globulus* *Galinsoga parviflora* *Hagenea abyssinica* *Haplocarpha ruepelli* *Hordeum vulgare* *Maesa lanceolata* *Pycnostachys abyssinica* *Ricinus communis* *Salvia nilotica* *Senecio sp* *Solanum incanum* *Solanum nigrum* *Solanum tubersom* *Tagetes minuta* *Vernonia adoensis*	*Abutilon villosa* *Acanthus arboreus* *Achyranthus aspera* *Albizia gummifera* *Amorphophallus sp.* *Arisaema schimperianum* *Arundinaria alpina* *Asparagus flagellaris* *Asparagus racemosus* *Bersama abyssinica* *Bidens pilosa* *Cadaba farinosa* *Canthium oligocarpum* *Cirsium vulgare* *Clausena anistata* *Combretum aculeatum* *Croton macrostachyus* *Dovyalis abyssinica* *Ekebergia capensis* *Erythrina brucei* *Euphorbia obovalifolia* *Hypoestes forsskaoli* *Impatiens tinctoria* *Justicia flava* *Leonitis ocymifolia* *Maytenus arbutifolia* *Phyllantus ovalifolius* *Rubus steudneri* *Rumex nepalensis* *Salvia nilotica* *Sauromatum verosum* *Solanum incanum* *Spilantus mauritiana* *Tagetes minuta* *Thalictrum rynchocarpum* *Vernonia amygdalina* *Vernonia sp.*

1) Plant species found in highland grazing within each transect

LU/LC	Trasnsect 1	Trasnsect 2	Trasnsect 3	T4
Highland grazing	*Caryx sp.* *Cycnium herzteldianus* *Cynodon dactylon* *Cyperus rigidifolius* *Cyperus rotundus* *Dichondra repens* *Dischoryste radicans* *Eleusine floccifolia* *Eragrostis japonica* *Eragrostis tenuifolia* *Eragrostis tremula* *Harpachne schimperi* *Hydrocotyle manii* *Paspalum orbiculare* *Pennisteum maximum* *Sida alba* *Sporobolus pyramidalis*	*Becium filamentosa* *Bidens pilosa* *Bidens sp.* *Caryx sp.* *Combretum collinum* *Commelina benghalensis* *Croton macrostachyus* *Cuppressus lusitanica* *Cynodon dactylon* *Cyperus rigidifolius* *Dischoryste radicans* *Eragrostis tenuifolia* *Hypparhenia cymbari* *Lantana camara* *Maytenus obscura* *Melinis repens* *Rhynchosia malacophylla* *Satureja punctata* *Sauromatum verosum* *Solanum incanum* *Trifolium sempilosum* *Vernonia auriclifolia*	*Acritochaete volkensii* *Alchemilla abyssinica* *Asparagus flagellaris* *Cardus chamaecephalus* *Caryx sp.* *Commelina benghalensis* *Cynodon dactylon* *Dischoryste radicans* *Eragrostis japonica* *Eragrostis tenuifolia* *Eragrostis tremula* *Festuca sp.* *Haplocarpha ruepelli* *Harpachne schimperi* *Hypericum annulatum* *Kalanchoe petitiana* *Ochthochloa sp.* *Paspalum orbiculare* *Pennisteum maximum* *Salvia nilotica* *Setaria megaphylla* *Sporobolus pyramidalis* *Themeda triandra* *Thymus schimperi* *Trifolium sempilosum*	Not sampled

1) Plant species found in open bushland within each transect
2)

LU/LC	Trasnsect 1	Trasnsect 2	Trasnsect 3	Trasnsect 4	Trasnsect 5
Open bushland	*Acacia brevispica* *Acacia mellifera* *Acacia senegal* *Acacia seyal* *Acacia tortilis* *Acokanthera schimperi* *Achyranthus aspera* *Asparagus flagellaris* *Balanites aegyptica* *Barleria quadrispina* *Cadaba farinosa* *Calpurnia aurea* *Capparis tomentosa* *Combretum collinum* *Cynodon dactylon* *Dichrostachys cinerea* *Dodonaea angustifolia* *Gardenia lutea* *Harissonia abyssinica* *Hypparhenia cymbari* *Kalanchoe densiflora* *Leonitis ocymifolia* *Maytenus senegalensis* *Ocimum gratissimum* *Pentaschistis pictigluma* *Solanum incanum* *Terminalia sp.* *Ximenia caffra* *Ziziphus mucronata* *Ziziphus spina-christi*	*Acacia brevispica* *Acacia hockii* *Acacia seyal* *Acalypha fruticosa* *Acanthus sp.* *Achyranthus aspera* *Albizia gummifera* *Asparagus flagellaris* *Balanites aegyptica* *Bidens pilosa* *Botriochloa radicans* *Cadaba farinosa* *Canthium oligocarpum* *Cassia didymobotrya* *Cissus quadrangularis* *Clerodendron myricoides* *Combretum collinum* *Combretum molle* *Commiphora africana* *Commiphora terebinthina* *Croton macrostachyus* *Dichrostachys cinerea* *Echinops sp.* *Eragrostis tenuifolia* *Ficus umbellata* *Flueggea virosa* *Gardenia lutea* *Grewia velutina* *Harissonia abyssinica* *Heteropogon contortus* *Hypparhenia cymbari* *Jasminum floribundum* *Justicia flava* *Kyllingiella microcephala* *Kyllingiella polyphylla* *Laggera crispata* *Lantana camara* *Leucas martinicensis* *Maytenus obscura* *Maytenus senegalensis* *Melinis repens* *Moringa stenopetala* *Myrica salcifolia* *Ocimum gratissimum* *Ozoroa insignis* *Pappea capensis* *Pennisteum maximum* *Rhus natalensis* *Rhynchosia malacophylla* *Rosa abyssinica* *Sansevieria forskaolina* *Solanum incanum* *Spilantus mauritiana* *Sporobolus pyramidalis* *Terminalia schimperiana* *Terminalia sp.* *Themeda triandra* *Ziziphus mucronata*	*Acacia brevispica* *Acacia hockii* *Acacia seyal* *Acalypha fruticosa* *Acanthus sp.* *Achyranthus aspera* *Albizia gummifera* *Asparagus flagellaris* *Balanites aegyptica* *Bidens pilosa* *Botriochloa radicans* *Cadaba farinosa* *Canthium oligocarpum* *Cassia didymobotrya* *Cissus quadrangularis* *Clerodendron myricoides* *Combretum collinum* *Combretum molle* *Commiphora africana* *Commiphora terebinthina* *Croton macrostachyus* *Dichrostachys cinerea* *Echinops sp.* *Eragrostis tenuifolia* *Ficus umbellata* *Flueggea virosa* *Gardenia lutea* *Grewia velutina* *Harissonia abyssinica* *Heteropogon contortus* *Hypparhenia cymbari* *Jasminum floribundum* *Justicia flava* *Kyllingiella microcephala* *Kyllingiella polyphylla* *Laggera crispata* *Lantana camara* *Leucas martinicensis* *Maytenus obscura* *Maytenus senegalensis* *Melinis repens* *Moringa stenopetala* *Myrica salcifolia* *Ocimum gratissimum* *Ozoroa insignis* *Pappea capensis* *Pennisteum maximum* *Rhus natalensis* *Rhynchosia malacophylla* *Rosa abyssinica* *Sansevieria forskaolina* *Solanum incanum* *Spilantus mauritiana* *Sporobolus pyramidalis* *Terminalia schimperiana* *Terminalia sp.* *Themeda triandra* *Ziziphus mucronata*	*Acacia brevispica* *Acacia mellifera* *Acacia polyacantha* *Acacia seyal* *Acalypha fruticosa* *Acanthus polystachyus* *Achyranthus aspera* *Aeschynomene abyssinica* *Asparagus falcatus* *Balanites aegyptica* *Barleria quadrispina* *Boscia senegalensis* *Cadaba farinosa* *Cenchrus sp.* *Chrysopogon plumulosus* *Cissus quadrangularis* *Cissus rotundifolius* *Croton sp.* *Enteropogon macrostachyus* *Eragrostis japonica* *Euphorbia sp.* *Euphorbia tirucalli* *Flueggea virosa* *Grewia velutina* *Harissonia abyssinica* *Heteropogon contortus* *Justicia flava* *Justicia ladanoides* *Kalanchoe lanceolata* *Ocimum gratissimum* *Rhus natalensis* *Sansevieria forskaolina* *Sansevieria erythreae* *Tephrosia pumila* *Ximenia caffra*	*Acacia brevispica* *Acacia mellifera* *Acacia nilotica* *Acalypha fruticosa* *Balanites aegyptica* *Barleria quadrispina* *Cadaba farinosa* *Digitria velutina* *Enteropogon macrostachyus* *Eragrostis tenuifolia* *Flueggea virosa* *Heteropogon contortus* *Justicia ladanoides* *Kalanchoe lanceolata* *Lannea schimperii* *Pennisetum mezianum* *Rhus natalensis* *Sehima nervosum* *Sorghum verticilliflorum* *Tephrosia pumila* *Ximenia caffra*

1) Plant species found in riparian vegetation within each transect

LU/LC	Trasnsect 1	Trasnsect 2	Trasnsect 3	Trasnsect 5
Riparian	Abutilon fruitcosum	Abutilon villosa	Acacia senegal	Abutilon villosa
	Acacia brevispica	Acacia brevispica	Acacia seyal	Acacia brevispica
	Acacia senegal	Acacia mellifera	Acokanthera schimperi	Acacia mellifera
	Acacia seyal	Acacia polyacantha	Balanites aegyptica	Acacia polyacantha
	Acanthus sp.	Acacia seyal	Bersama abyssinica	Acacia tortilis
	Achyranthus aspera	Acalypha fruticosa	Bidens sp.	Acalypha fruticosa
	Aloe otallensis	Acokanthera schimperi	Botriochloa radicans	Achyranthus aspera
	Asparagus flagellaris	Achyranthus aspera	Bridelia micrantha	Aeschynomene elaphroxylon
	Cadaba farinosa	Aloe gilbertaie	Cadaba farinosa	Aspilia africana
	Calpurnia aurea	Aloe otallensis	Carrisa edulis	Balanites aegyptica
	Capparis tomentosa	Asparagus flagellaris	Caryx sp.	Balanitus rotundifolia
	Caryx sp.	Balanites aegyptica	Cassia didymobotrya	Barleria quadrispina
	Combretum collinum	Balanitus rotundifolia	Cassipora malasona	Bidens pilosa
	Combretum molle	Cadaba farinosa	Clutia abyssinica	Boscia senegalensis
	Commelina benghalensis	Capparis tomentosa	Combretum collinum	Cenchrus sp.
	Crinipes longifolius	Cissampelos mucronata	Combretum aculeatum	Chloris roxburghiana
	Cynodon dactylon	Combretum collinum	Combretum molle	Chrysopogon plumulosus
	Cyperus rigidifolius	Combretum molle	Commelina benghalensis	Cissus quadrangularis
	Cyperus rotundus	Commelina	Commiphora africana	Cissus rotundifolius
	Dovyalis abyssinica	benghalensis	Crinipes longifolius	Commelina benghalensis
	Eragrostis tenuifolia	Commicarpus sinuatus	Cyperus dives	Commiphora africana
	Eragrostis tremula	Commiphora africana	Cyperus impubes	Cynodon dactylon
	Ficus vasta	Crinipes longifolius	Cyperus longus	Cyperus rigidifolius
	Flueggea virosa	Dichrostachys cinerea	Dichrostachys cinerea	Desmodium
	Galinsoga parviflora	Diospyros mespiliformis	Eragrostis japonica	Dichrostachys cinerea
	Grewia trichocarpa	Dregea schimperi	Eragrostis tremula	Digitria velutina
	Grewia velutina	Ekebergia capensis	Erythrina abyssinica	Echinochloa colona
	Hypoestes forsskaoli	Enteropogon	Erythrina brucei	Enteropogon macrostachyus
	Jacaranda mimosifolia	macrostachyus	Ficus sycomorus	Eragrostis japonica
	Jasminum floribundum	Eragrostis botryodes	Flueggea virosa	Eragrostis tremula
	Kalanchoe densiflora	Eragrostis tenuifolia	Gardenia lutea	Euphorbia tirucalli
	Kalanchoe petitiana	Euphorbia tirucalli	Grewia bicolor	Ficus sur
	Leonitis ocymifolia	Ficus umbellata	Grewia velutina	Galiniera coffeoides
	Leptochloa rupestris	Flueggea virosa	Grewia villosa	Hippocratea africana
	Mangifera indica	Grewia bicolor	Harissonia abyssinica	Hypoestes forsskaoli
	Moringa stenopetala	Grewia trichocarpa	Harpachne schimperi	Hypparhenia cymbari
	Ocimum gratissimum	Grewia velutina	Heteropogon contortus	Ipomea cairica
	Pentaschistis pictigluma	Grewia villosa	Justicia flava	Justicia ladanoides
	Pterolobium stellatum	Hippocratea africana	Lepidotrichilia volkensii	Laggera crispata
	Rhus natalensis	Hybanthus	Maytenus senegalensis	Lepidotrichilia volkensii
	Rhynchosia malacophylla	enneaspermus	Melinis repens	Maytenus senegalensis
	Rubus steudneri	Hypparhenia cymbari	Ocimum gratissimum	Ocimum lamiifolium
	Sansevieria forskaolina	Jasminum floribundum	Oplismenus sp.	Oplismenus sp.
	Sesbania sesban	Justicia flava	Panicum maximum	Panicum maximum
	Sida ovata	Leptochloa rupestris	Paspalum orbiculare	Phyllantus ovalifolius
	Solanum incanum	Mimusops kummel	Pilostigma thonningii	Pulchea discoridis
	Sphaeranthus suaveolens	Myrica salcifolia	Polyscias fulva	Rhus natalensis
	Tagetes minuta	Ocimum gratissimum	Rhus natalensis	Ritichia albersii
	Terminalia sp.	Olea europaeassp.	Rhynchosia malacophylla	Saba comorensis
	Vernonia auriclifolia	Cuspidata	Sansevieria forskaolina	Salvadora persica
	Ziziphus mucronata	Ozoroa insignis	Sansevieria erythreae	Sansevieria forskaolina
	Ziziphus spina-christi	Panicum deustum	Satureja punctata	Scirpus sp
		Panicum maximum	Solanum incanum	Sclerocarya birrea
		Phyllantus ovalifolius	Tamarindus indica	Sesbania sesban
		Phytolacca dodecandra	Terminalia sp.	Solanum nigrum
		Rhus natalensis	Vernonia auriclifolia	Spheranthus sp.
		Ricinus communis	Ximenia caffra	Teclea nobilis
		Sansevieria forskaolina	Ziziphus mucronata	Terminalia browinii
		Sansevieria erythreae	Ziziphus spina-christi	Trichia sp
		Setaria megaphylla		Trichilia dregeana
		Solanum incanum		Typha domingensis
		Teclea simplifolia		Ximenia caffra
		Terminalia sp.		Zanha golungensis

1) Plant species found in wooded grassland within each transect

LU/LC	Trasnsect 1	Trasnsect 2	Trasnsect 3	Trasnsect 4	Trasnsect 5
Wooded grassland	*Abrus precatorius* *Abutilon fruitcosum* *Acacia brevispica* *Acacia mellifera* *Acacia senegal* *Acacia seyal* *Acanthus sp.* *Acokanthera schimperi* *Aloe gilbertaie* *Balanites aegyptica* *Barleria quadrispina* *Cadaba farinosa* *Calpurnia aurea* *Capparis tomentosa* *Combretum collinum* *Commelina* *benghalensis* *Cyperus rigidifolius* *Dodonaea angustifolia* *Eragrostis tenuifolia* *Euphorbia polyacantha* *Euphorbia tirucalli* *Flueggea virosa* *Gardenia lutea* *Harissonia abyssinica* *Harpachne schimperi* *Heteropogon contortus* *Hypparhenia cymbari* *Jasminum floribundum* *Kalanchoe petitiana* *Maytenus senegalensis* *Melinis repens* *Myrica salcifolia* *Ocimum gratissimum* *Olea europaeassp.* *Cuspidata* *Ozoroa insignis* *Pennisteum maximum* *Pentaschistis pictigluma* *Pterolobium stellatum* *Rhus natalensis* *Solanum incanum* *Sporobolus pyramidalis* *Tylosema fassoglensis* *Ximenia caffra*	*Acacia hockii* *Acacia mellifera* *Acacia seyal* *Aloe gilbertaie* *Aloe otallensis* *Asparagus flagellaris* *Balanitus* *rotundifolia* *Becium filamentosa* *Cadaba farinosa* *Capparis tomentosa* *Cardus leptacanthus* *Caryx sp.* *Cissus* *quadrangularis* *Combretum collinum* *Combretum molle* *Commiphora* *terebinthina* *Dichondra repens* *Dichrostachys* *cinerea* *Dodonaea* *angustifolia* *Endostemon sp.* *Euclea schimperi* *Ficus umbellata* *Flacourtia indica* *Gardenia lutea* *Grewia velutina* *Grewia villosa* *Harissonia* *abyssinica* *Heteropogon* *contortus* *Hypparhenia* *cymbari* *Jasminum* *floribundum* *Leucas martinicensis* *Maytenus* *senegalensis* *Melinis repens* *Myrica salcifolia* *Ocimum gratissimum* *Olea europaeassp.* *Cuspidata* *Ozoroa insignis* *Pennisteum* *maximum* *Ranunculus* *multifides* *Rhus natalensis* *Rhynchosia* *malacophylla* *Setaria megaphylla* *Sida alba* *Sida ovata* *Solanum incanum* *Sonchus sp* *Sporobolus* *pyramidalis* *Terminalia sp.* *Vernonia auriclifolia* *Ximenia caffra*	*Acacia brevispica* *Acacia mellifera* *Acacia senegal* *Acacia seyal* *Acalypha fruticosa* *Asparagus flagellaris* *Balanites aegyptica* *Barleria quadrispina* *Bidens sp.* *Boscia senegalensis* *Botriochloa radicans* *Cadaba farinosa* *Capparis spinosa* *Capparis tomentosa* *Carrisa edulis* *Cissus quadrangularis* *Combretum collinum* *Combretum molle* *Commiphora africana* *Commiphora terebinthina* *Dichrostachys cinerea* *Dodonaea angustifolia* *Enteropogon* *macrostachyus* *Eragrostis japonica* *Euclea divinorum* *Flueggea virosa* *Gardenia lutea* *Grewia bicolor* *Grewia trichocarpa* *Grewia velutina* *Grewia villosa* *Harissonia abyssinica* *Harpachne schimperi* *Heteropogon contortus* *Justicia flava* *Maytenus senegalensis* *Melinis repens* *Ocimum gratissimum* *Olea europaeassp.* *Cuspidata* *Osyris quadripartita* *Ozoroa insignis* *Panicum maximum* *Rhus natalensis* *Rhynchosia malacophylla* *Sclerocarya birrea* *Setaria megaphylla* *Solanum incanum* *Sporobolus pyramidalis* *Tagetes minuta* *Terminalia sp.* *Ziziphus mucronata*	*Abutilon villosa* *Acacia brevispica* *Acacia hockii* *Acacia mellifera* *Acacia senegal* *Acacia seyal* *Acalypha fruticosa* *Aloe otallensis* *Aloe pirrottae* *Asparagus flagellaris* *Balanites aegyptica* *Barleria quadrispina* *Boscia senegalensis* *Botriochloa radicans* *Canthium oligocarpum* *Capparis spinosa* *Capparis tomentosa* *Cenchrus sp.* *Cissus quadrangularis* *Cissus rotundifolius* *Combretum aculeatum* *Combretum molle* *Commiphora africana* *Commiphora* *terebinthina* *Croton sp.* *Dichrostachys cinerea* *Digitria velutina* *Enteropogon* *macrostachyus* *Eulophia petersii* *Eulophia sp.* *Euphorbia polyacantha* *Euphorbia tirucalli* *Flueggea virosa* *Gomphocarpus* *fruitcosus* *Grewia tenax* *Grewia velutina* *Grewia villosa* *Harissonia abyssinica* *Heteropogon contortus* *Hypoestes forsskaoli* *Hypparhenia cymbari* *Indigofera schimperi* *Kalanchoe densiflora* *Kyllingiella* *microcephala* *Melhania velutina* *Osyris quadripartita* *Ozoroa insignis* *Periploca sp.* *Plectranthus barbatus* *Plectranthus punctatus* *Rhus natalensis* *Sacrostemma viminale* *Sansevieria forskaolina* *Sansevieria erythreae* *Solanum nigrum* *Sorghum* *verticilliflorum* *Talinum sp* *Tephrosia pumila* *Terminalia sp.* *Ximenia caffra* *Ziziphus mucronata* *Ziziphus spina-christi*	*Abutilon villosa* *Acalypha fruticosa* *Achyranthus aspera* *Amaranthus hybridus* *Areva javanica* *Barleria eranthemoides* *Cenchrus sp.* *Chloris roxburghiana* *Chrysopogon plumulosus* *Coccinia abyssinica* *Commelina benghalensis* *Cynodon dactylon* *Desmodium* *Guizotia scabra* *Heteropogon contortus* *Justicia ladanoides* *Leucas martinicensis* *Monechma debile* *Ocimum gratissimum* *Osyris quadripartita* *Perotis patens* *Sehima nervosum* *Solanum nigrum* *Tephrosia pumila* *Ximenia caffra*

2) Plant species richness and diversity of LU/LC types in the Transects within each transect.

Plant species richness and diversity (H) in the transects of **highland cultivation**

Transect	Site	Tot. No. Spec	Relevé	No. of spec.	Tot. cov	H	Evenness
Transect 1	Site 7	64	Relevé 7.1	12	61	2.006	0.807
			Relevé 7.2	24	151	1.813	0.57
Transect 1	Site 8		Relevé 8.1	8	48	1.512	0.727
			Relevé 8.2	17	104	1.658	0.585
Transect 1	Site 9		Relevé 9.1	33	187	2.733	0.782
			Relevé 9.2	27	272	2.334	0.708
Transect 2	Site 22	63	Relevé 22.1	23	189	2.307	0.736
			Relevé 22.2	34	194	2.914	0.826
Transect 2	Site 23		Relevé 23.1	11	204	1.865	0.778
			Relevé 23.2	18	130	2.084	0.721
Transect 2	Site 24		Relevé 24.1	19	183	2.218	0.753
			Relevé 24.2	23	200	2.473	0.789
Transect 3	Site 40	26	Relevé 40.1	19	106	1.818	0.617
			Relevé 40.2	4	44	0.986	0.711
Transect 3	Site 41		Relevé 41.1	6	107	1.298	0.724
			Relevé 41.2	8	98	1.184	0.569
Transect 3	Site 42		Relevé 42.1	6	89	1.363	0.761
			Relevé 42.2	8	112	1.44	0.692
Transect 4	Site 58	40	Relevé 58.1	30	102	2.791	0.82
			Relevé 58.2	11	112	1.557	0.649
Transect 4	Site 59		Relevé 59.1	13	54	2.147	0.837
			Relevé 59.2	11	87	1.744	0.727
Transect 4	Site 60		Relevé 60.1	0	0	0	0
			Relevé 60.2	0	0	0	0

Plant species richness and diversity (H) in the transects of **highland forest**

Transect	Site	Tot. No. Spec.	Relevé	No. of spec.	% Tot. cov.	H	Evenness
Transect 2	Site 25	35	Relevé 25.1	10	155	1.749	0.759
			Relevé25.2	8	136	1.559	0.75
Transect 2	Site 26		Relevé 26.1	25	181	2.292	0.712
			Relevé26.2	24	162	2.058	0.648
Transect 2	Site 27		Relevé 27.1	0	0	0	0
			Relevé27.2	0	0	0	0
Transect 3	Site 43	32	Relevé 43.1	20	149	2.163	0.722
			Relevé43.2	16	97	2.438	0.879
Transect 3	Site 44		Relevé 44.1	11	88	0.954	0.398
			Relevé44.2	8	80	0.606	0.291
Transect 3	Site 45		Relevé 45.1	0	0	0	0
			Relevé45.2	0	0	0	0
Transect 4	Site 61	30	Relevé 61.1	13	100	1.296	0.505
			Relevé61.2	12	118	1.321	0.532
Transect 4	Site 62		Relevé 62.1	21	72	2.653	0.871
			Relevé62.2	17	84	2.447	0.864
Transect 4	Site 63		Relevé 63.1	0	0	0	0
			Relevé63.2	0	0	0	0

Plant species richness and diversity (H) in the transects of **highland grazing**

Transect	Site	Tot .No. Spec.	Relevé	No. of spec.	% Tot. cov.	H	Evenness
Transect 1	Site 10	17	Relevé 10. 1	7	141	1.458	0.749
			Relevé 10.2	7	136	1.518	0.78
Transect 1	Site 11		Relevé 11.1	7	115	1.689	0.868
			Relevé11.2	8	117	1.567	0.754
Transect 1	Site 12		Relevé 12.1	8	172	1.725	0.829
			Relevé12.2	8	200	1.8	0.865
Transect 2	Site 28	22	Relevé 28.1	10	116	2.011	0.873
			Relevé28.2	10	141	1.97	0.855
Transect 2	Site 29		Relevé 29.1	12	139	2.096	0.843
			Relevé29.2	7	58	1.748	0.898
Transect 2	Site 30		Relevé 30.1	5	110	1.468	0.912
			Relevé30.2	6	150	1.603	0.894
Transect 3	Site 46	25	Relevé 46.1	10	109	1.478	0.642
			Relevé46.2	9	113	1.254	0.571
Transect 3	Site 47		Relevé 47.1	11	119	1.621	0.676
			Relevé47.2	9	83	1.529	0.696
Transect 3	Site 48		Relevé 48.1	12	146	2.019	0.812
			Relevé48.2	13	131	2.255	0.879
Transect 4	Site 64	0	Relevé 64.1	0	0	0	0
			Relevé64.2	0	0	0	0
Transect 4	Site 65		Relevé 65.1	0	0	0	0
			Relevé65.2	0	0	0	0
Transect 4	Site 66		Relevé 66.1	0	0	0	0
			Relevé66.2	0	0	0	0

Plant species richness and diversity (H) in the transects of **open bushland**

Transect	site	Tot. No. Spec.	Relevé	No. of spec.	% Tot. cov.	H	Evenness
Transect 1	Site 1	30	Relevé 1.1	13	139	1.717	0.67
			Relevé 1.2	13	94	1.44	0.561
Transect 1	Site 2		Relevé 2.1	15	66	1.542	0.569
			Relevé 2.2	10	66	1.361	0.591
Transect 1	Site 3		Relevé 3.1	0	0	0	0
			Relevé 3.2	0	0	0	0
Transect 2	Site 16	58	Relevé 16.1	24	191	2.642	0.831
			Relevé16.2	23	161	2.384	0.76
Transect 2	Site 17		Relevé 17.1	25	87	2.518	0.782
			Relevé17.2	22	72	2.51	0.812
Transect 2	Site 18		Relevé 18.1	0	0	0	0
			Relevé18.2	0	0	0	0
Transect 3	Site 34	39	Relevé 34.1	16	128	1.935	0.698
			Relevé34.2	13	147	1.877	0.732
Transect 3	Site 35		Relevé 35.1	22	156	2.513	0.813
			Relevé35.2	20	149	2.547	0.85
Transect 3	Site 36		Relevé 36.1	12	62	2.288	0.921
			Relevé36.2	12	74	2.204	0.887
Transect 4	Site 52	35	Relevé 52.1	13	84	2.23	0.87
			Relevé52.2	12	95	1.815	0.73
Transect 4	Site 53		Relevé 53.1	7	46	1.2	0.617
			Relevé53.2	9	72	1.465	0.667
Transect 4	Site 54		Relevé 54.1	14	199	2.151	0.815
			Relevé54.2	15	114	2.354	0.869
Transect 5	Site 70	21	Relevé70.1	5	107	1.267	0.787
			Relevé70.2	5	101	0.485	0.301
Transect 5	Site 71		Relevé71.1	4	75	1.137	0.82
			Relevé71.2	2	90	0.637	0.918
Transect 5	Site 72		Relevé72.1	9	65	1.9	0.865
			Relevé72.2	10	120	1.971	0.856

Plant species richness and diversity (H) in the transects of **riparian vegetation**

Transect	Site	Tot. No. spec.	Relevé	No. of spec.	% Tot. cov.	H	Evenness
Transect 1	Site 13	53	Relevé 13.1	0	0	0	0
			Relevé13.2	0	0	0	0
Transect 1	Site 14		Relevé 14.1	29	136	2.846	0.845
			Relevé14.2	19	100	2.337	0.794
Transect 1	Site 15		Relevé 15.1	22	102	2.603	0.842
			Relevé 15.2	18	121	2.315	0.801
Transect 2	Site 31	58	Relevé 31.1	42	341	3.188	0.853
			Relev é31.2	27	371	2.691	0.817
Transect 2	Site 32		Relevé 32.1	18	70	2.077	0.719
			Relevé32.2	11	175	1.551	0.647
Transect 2	Site 33		Relevé 33.1	1	1	0	0
			Relevé 33.2	0	0	0	0
Transect 3	Site 49	54	Relevé 49.1	14	101	2.411	0.914
			Relevé 49.2	10	118	2.131	0.926
Transect 3	Site 50		Relevé 50.1	22	160	2.907	0.94
			Relevé 50.2	27	136	2.968	0.9
Transect 3	Site 51		Relevé 51.1	35	183	3.24	0.911
			Relevé 51.2	35	179	3.315	0.932
Transect 5	Site 67	70	Relevé 67.1	9	77	0.952	0.433
			Relevé 67.2	8	64	1.273	0.612
Transect 5	Site 68		Relevé 68.1	8	92	1.42	0.683
			Relevé 68.2	9	137	1.648	0.75
Transect 5	Site 69		Relevé 69.1	16	140	2.269	0.818
			Relevé 69.2	17	100	2.436	0.86
Transect 5	Site 76		Relevé 76.1	22	135	2.721	0.88
			Relevé 76.2	20	147	2.601	0.868
Transect 5	Site 77		Relevé 77.1	9	88	1.883	0.857
			Relevé 77.2	12	97	1.978	0.796
Transect 5	Site 78		Relevé 78.1	15	153	2.336	0.863
			Relevé 78.2	16	167	2.575	0.929

Plant species richness and diversity in the transects of **wooded grassland**

Transect	Site	Tot. No. Spec.	Relevé	No. of Spec.	Col. Tot.	H	Evenness
Transect 1	Site 4	42	Relevé 4.1	10	105	1.964	0.853
			Relevé 4.2	17	94	2.376	0.839
Transect 1	site 5		Relevé 5.1	19	109	2.278	0.774
			Relevé 5.2	16	161	1.966	0.709
Transect 1	Site 6		Relevé 6.1	17	104	2.325	0.821
			Relevé 6.2	19	75	2.713	0.921
Transect 2	Site 19	49	Relevé 19.1	22	88	2.543	0.823
			Relevé19.2	18	109	2.249	0.778
Transect 2	Site 20		Relevé 20.1	23	86	2.733	0.872
			Relevé 20.2	29	127	2.988	0.887
Transect 2	Site 21		Relevé 21.1	0	0	0	0
			Relevé21.2	0	0	0	0
Transect 3	Site 37	51	Relevé 37.1	11	96	1.814	0.757
			Relevé37.2	15	102	2.385	0.881
Transect 3	Site 38		Relevé 38.1	21	142	2.591	0.851
			Relevé38.2	23	165	2.707	0.863
Transect 3	Site 39		Relevé 39.1	25	104	2.707	0.841
			Relevé39.2	18	79	2.485	0.86
Transect 4	Site 55	63	Relevé 55.1	13	136	2.286	0.891
			Relevé55.2	17	184	2.462	0.869
Transect 4	Site 56		Relevé 56.1	18	121	2.392	0.828
			Relevé56.2	12	66	2.021	0.813
Transect 4	Site 57		Relevé 57.1	32	177	2.76	0.796
			Relevé57.2	20	140	2.634	0.879
Transect 5	Site 73	24	Relevé73.1	9	98	1.636	0.744
			Relevé73.2	5	62	1.094	0.68
Transect 5	Site 74		Relevé74.1	5	92	1.01	0.628
			Relevé74.2	5	89	1.051	0.653
Transect 5	Site 75		Relevé75.1	9	30	1.961	0.892
			Relevé75.2	9	44	1.736	0.79

3) Plant species that are LU/LC specific (unique species to specific LU/LC types) within each transect.

	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5
Highland Forest		*Alchemilla rothii* *Anthemis tigreensis* *Brucea antidysenterica* *Celosia argentea* *Impatiens tinctoria* *Kniphofia foliosa* *Plantago palmata*	*Buddleja polystachya* *Maytenus arbutifolia* *Oplismenus sp.* *Rapanea melanophloes* *Schefflera abyssinica*	*Amorphophallus sp.* *Clausena anisata* *Thalictrum rynchocarpum* *Vernonia sp.*	
Unique highland cultivation	*Citrus sinensis* *Datura stramonium* *Dioscorea sp.* *Euphorbia cotonifolia* *Foeniculum vulgare* *Morus nigra* *Oxalis radicosa* *Phoenix reclinata* *Podocarpus falcatus* *Saccarhum officinarum*	*Dioscorea sp.* *Dracena steudneri* *Evolvulus alsinoides* *Lippia adoensis* *Melia azedarach* *Prunus africana* *Prunus persica* *Psidum guajava* *Salvia coccinea*	*Hagenea abyssinica* *Maesa lanceolata* *Senecio sp*	*Juniperus procera* *Medicago polymorpha* *Oxygonum sinuatum* *Sida schimperiana* *Zehneria scabra*	
Highland grazing	*Cycnium herzteldianus* *Eleusine floccifolia* *Hydrocotyle manii* *Paspalum orbiculare*	*Satureja punctata*	*Acritochaete volkensii* *Festuca sp.* *Ochthochloa sp.* *Paspalum orbiculare* *Thymus schimperi*		
Open bushland		*Clerodendron myricoides* *Echinops sp.* *Kyllingiella polyphylla* *Rosa abyssinica* *Syzygium guineense* *Terminalia schimperiana*	*Elytrophorus spicatus* *Hydnora johannis*	*Aeschynomene abyssinica* *Euphorbia sp.* *Kalanchoe lanceolata*	*Lannea schimperii* *Pennisetum mezianum* *Sorghum verticilliflorum*
Riparian	*Agave americana** *Clematis simensis* *Jacaranda mimosifolia** *Leptochloa rupestris* *Mangifera indica** *Rubus steudneri* *Sphaeranthus suaveolens*	*Cissampelos mucronata* *Commicarpus sinuatus* *Dregea schimperi* *Hippocratea africana* *Hybanthus enneaspermus* *Leptochloa rupestris* *Mimusops kummel* *Panicum deustum* *Teclea simplifolia*	*Clutia abysinica* *Cyperus dives* *Cyperus impubes* *Cyperus longus* *Echinochloa colona* *Erythrina abyssinica* *Ipomea cairica* *Lepidotrichilia volkensii* *Pulchea discoridis* *Scirpus sp* *Tamarindus indica* *Typha domingensis* *Vepris dainellii*		*Aeschynomene elaphroxylon* *Dregea schimperi* *Ritichia albersii* *Saba comorensis* *Salvadora persica* *Scirpus sp* *Sphaeranthus sp.* *Terminalia browinii* *Trichilia dregeana* *Trichia sp.* *Typha domingensis* *Zanha golungensis*
Wooded grassland	*Abrus precatorius* *Tylosema fassoglensis*	*Carduus leptacanthus* *Commiphora terebinthina* *Euclea schimperi* *Flacourtia indica* *Grewia tenax*	*Capparis spinosa*	*Adenia venenata* *Adenium obesum* *Eulophia petersii* *Eulophia streptopetala* *Periploca sp.* *Plectranthus barbatus* *Plectranthus punctatus* *Sacrostemma viminale* *Talinum sp.*	*Braleria eranthemoides* *Monechma debile* *Perotis patens*

Annex VI: Summary plant species information for the entire study area (among all transects):

1) The plant species found in each land-use/land cover (LU/LC) type: 2) plant species richness for each LU/LC type; 3) plant species that are LU/LC specific (unique species to specific LU/LC types);
1. Summary of the plant species the plant species found in each land-use/land-cover (LU/LC) summed among all transects) for the entire area

Highland cultivation	Highland forest	Highland grazing	Open bushland
Acanthus polystachyus	*Abutilon villosa*	*Abutilon villosa*	*Abutilon fruitcosum*
Achyranthus aspera	*Acanthus arboreus*	*Acanthus arboreus*	*Abutilon villosa*
Ageratum conyzoides	*Acanthus sp.*	*Acanthus sp.*	*Acacia brevispica*
Albizia gummifera	*Acanthus polystachyus*	*Acanthus polystachyus*	*Acacia hockii*
Alchemilla abyssinica	*Acokanthera schimperi*	*Acokanthera schimperi*	*Acacia mellifera*
Alium sativum	*Achyranthus aspera*	*Achyranthus aspera*	*Acacia nilotica*
Amaranthus hybridus	*Albizia gummifera*	*Albizia gummifera*	*Acacia polyacantha*
Anonna senegalensis	*Alchemilla abyssinica*	*Alchemilla abyssinica*	*Acacia senegal*
Arisaema schimperianum	*Alchymella rothii*	*Alchymella rothii*	*Acacia seyal*
Arundinaria alpina	*Allophylus abyssinicus*	*Allophylus abyssinicus*	*Acacia tortilis*
Asparagus flagellaris	*Amaranthus hybridus*	*Amaranthus hybridus*	*Acalypha fruticosa*
Aspilia africana	*Amorphophallus sp.*	*Amorphophallus sp.*	*Acanthus arboreus*
Bidens pilosa	*Anthemis tigreensis*	*Anthemis tigreensis*	*Acanthus sp.*
Brassica nigra	*Arisaema schimperianum*	*Arisaema schimperianum*	*Acanthus polystachyus*
Calpurnia aurea	*Arundinaria alpina*	*Arundinaria alpina*	*Acokanthera schimperi*
Canthium oligocarpum	*Asparagus falcatus*	*Asparagus falcatus*	*Achyranthus aspera*
Caryx sp.	*Asparagus flagellaris*	*Asparagus flagellaris*	*Aeschynomene abyssinica*
Cassia didymobotrya	*Asparagus racemosus*	*Asparagus racemosus*	*Albizia gummifera*
Cassimiroa edulis	*Bersama abyssinica*	*Bersama abyssinica*	*Aloe gilbertaie*
Catha edulis	*Bidens pilosa*	*Bidens pilosa*	*Aloe pirrottae*
Celtis africana	*Bidens sp.*	*Bidens sp.*	*Asparagus falcatus*
Cirsium vulgare	*Brucea antidysenterica*	*Brucea antidysenterica*	*Asparagus flagellaris*
Citrus sinensis	*Buddleja polystachya*	*Buddleja polystachya*	*Balanites aegyptica*
Coffea arabica	*Canthium oligocarpum*	*Canthium oligocarpum*	*Balanitus rotundifolia*
Combretum collinum	*Cardus chamaecephalus*	*Cardus chamaecephalus*	*Barleria quadrispina*
Commelina benghalensis	*Caryx sp.*	*Caryx sp.*	*Bidens pilosa*
Cordia africana	*Celosia argentea*	*Celosia argentea*	*Boscia senegalensis*
Croton macrostachyus	*Cirsium vulgare*	*Cirsium vulgare*	*Botriochloa radicans*
Cucurbita peppo	*Clausena anistata*	*Clausena anistata*	*Bridelia micrantha*
Cuppressus lusitanica	*Commelina benghalensis*	*Commelina benghalensis*	*Cadaba farinosa*
Cynodon dactylon	*Crepis reuppellii*	*Crepis reuppellii*	*Calpurnia aurea*
Cyperus rigidifolius	*Croton macrostachyus*	*Croton macrostachyus*	*Canthium oligocarpum*
Cyperus rotundus	*Cuppressus lusitanica*	*Cuppressus lusitanica*	*Capparis tomentosa*
Datura stramonium	*Cynodon dactylon*	*Cynodon dactylon*	*Cassia didymobotrya*
Dioscorea sp.	*Cyperus rotundus*	*Cyperus rotundus*	*Cassimiroa edulis*
Diospyros mespiliformis	*Dovyalis abyssinica*	*Dovyalis abyssinica*	*Cassipora malasona*
Dovyalis abyssinica	*Ekebergia capensis*	*Ekebergia capensis*	*Catha edulis*
Dracena steudneri	*Eragrostis botryodes*	*Eragrostis botryodes*	*Cenchrus sp.*
Ekebergia capensis	*Eragrostis tenuifolia*	*Eragrostis tenuifolia*	*Chrysopogon plumulosus*
Ensete ventricosum	*Erythrina brucei*	*Erythrina brucei*	*Cissus quadrangularis*
Eragrostis tenuifolia	*Eucalyptus globulus*	*Eucalyptus globulus*	*Cissus rotundifolius*
Erythrina brucei	*Euclea divinorum*	*Euclea divinorum*	*Clerodendron myricoides*
Eucalyptus globulus	*Euphorbia obovalifolia*	*Euphorbia obovalifolia*	*Combretum collinum*
Euphorbia cotonifolia	*Galiniera coffeoides*	*Galiniera coffeoides*	*Combretum molle*
Evolvulus alsinoides	*Hagenea abyssinica*	*Hagenea abyssinica*	*Commelina benghalensis*
Ficus sur	*Hypericum annulatum*	*Hypericum annulatum*	*Commiphora africana*
Ficus vasta	*Hypoestes forsskaoli*	*Hypoestes forsskaoli*	*Croton macrostachyus*
Foeniculum vulgare	*Impatiens athiopica*	*Impatiens athiopica*	*Croton sp.*
Galinsoga parviflora	*Impatiens tinctoria*	*Impatiens tinctoria*	*Cynodon dactylon*
Geranium arabicum	*Justicia flava*	*Justicia flava*	*Cyperus rotundus*
Guizotia scabra	*Kalanchoe densiflora*	*Kalanchoe densiflora*	*Dichrostachys cinerea*
Hagenea abyssinica	*Kalanchoe petitiana*	*Kalanchoe petitiana*	*Digitria velutina*
Haplocarpha ruepelli	*Knipohofia foliosa*	*Knipohofia foliosa*	*Dodonaea angustifolia*
Hordeum vulgare	*Leonitis ocymifolia*	*Leonitis ocymifolia*	*Echinops sp.*
Hypparhenia cymbari	*Maytenus arbutifolia*	*Maytenus arbutifolia*	*Elytrophorus spicatus*
Juniperus procera	*Maytenus obscura*	*Maytenus obscura*	*Enteropogon macrostachyus*
Justicia flava	*Ocimum gratissimum*	*Ocimum gratissimum*	*Eragrostis japonica*
Kalanchoe densiflora	*Olea europaeassp. Cuspidata*	*Olea europaeassp. Cuspidata*	*Eragrostis tenuifolia*
Leonitis ocymifolia	*Oplismenus sp.*	*Oplismenus sp.*	*Euphorbia sp.*
Leucas martinicensis	*Phaseolus vulgaris*	*Phaseolus vulgaris*	*Euphorbia polyacantha*
Lippia adoensis	*Phyllantus ovalifolius*	*Phyllantus ovalifolius*	*Euphorbia tirucalli*
Maesa lanceolata	*Phytolacca dodecandra*	*Phytolacca dodecandra*	*Ficus umbellata*
Medicago polymorpha	*Plantago palmata*	*Plantago palmata*	*Flueggea virosa*

Highland cultivation	Highland forest	Highland grazing	Open bushland
Melia azedarach	Polyscias fulva	Polyscias fulva	Gardenia lutea
Milletia ferruginea	Pycnostachys abyssinica	Pycnostachys abyssinica	Grewia trichocarpa
Morus nigra	Ranunculus multifides	Ranunculus multifides	Grewia velutina
Musa paradisca	Rapanea melanophloes	Rapanea melanophloes	Grewia villosa
Ocimum gratissimum	Rhamnus prinoides	Rhamnus prinoides	Harissonia abyssinica
Ocimum lamiifolium	Rhus natalensis	Rhus natalensis	Heteropogon contortus
Olea europaeassp. Cuspidata	Rubus steudneri	Rubus steudneri	Hydnora johannis
Oxalis radicosa	Rumex abyssinica	Rumex abyssinica	Hypparhenia cymbari
Oxygonum sinuatum	Rumex nepalensis	Rumex nepalensis	Jasminum floribundum
Panicum maximum	Salvia nilotica	Salvia nilotica	Justicia flava
Pappea capensis	Sauromatum verosum	Sauromatum verosum	Justicia ladanoides
Persea americana	Schefflera abyssinica	Schefflera abyssinica	Kalanchoe densiflora
Phaseolus vulgaris	Solanum incanum	Solanum incanum	Kalanchoe lanceolata
Phoenix reclinata	Solanum nigrum	Solanum nigrum	Kyllingiella microcephala
Phytolacca dodecandra	Spilantus mauritiana	Spilantus mauritiana	Kyllingiella polyphylla
Podocarpus falcatus	Stephania abyssinica	Stephania abyssinica	Laggera crispata
Polyscias fulva	Sterculia africana	Sterculia africana	Lannea schimperii
Prunus africana	Tagetes minuta	Tagetes minuta	Lantana camara
Prunus persica	Thalictrum rynchocarpum	Thalictrum rynchocarpum	Leonitis ocymifolia
Psidum guajava	Trifolium sempilosum	Trifolium sempilosum	Leucas martinicensis
Pycnostachys abyssinica	Vernonia adoensis	Vernonia adoensis	Maytenus obscura
Rhamnus prinoides	Vernonia auriclifolia	Vernonia auriclifolia	Maytenus senegalensis
Ricinus communis	Vernonia sp.	Vernonia sp.	Melinis repens
Rumex abyssinica			Moringa stenopetala
Rumex nepalensis			Myrica salcifolia
Saccarhum officinarum			Ocimum gratissimum
Salvia coccinea			Osyris quadripartita
Salvia nilotica			Ozoroa insignis
Sauromatum verosum			Panicum maximum
Senecio sp			Pappea capensis
Sesbania sesban			Pennisetum mezianum
Sida alba			Pennisteum maximum
Sida schimperiana			Pentaschistis pictigluma
Solanum capsicum			Pilostigma thonningii
Solanum incanum			Rhus natalensis
Solanum nigrum			Rhynchosia malacophylla
Solanum tobacum			Rosa abyssinica
Solanum tubersom			Sansevieria forskaolina
Sonchus sp			Sansevieria erythreae
Spilantus mauritiana			Sehima nervosum
Tagetes minuta			Solanum incanum
Vernonia adoensis			Sorghum verticilliflorum
Vernonia amygdalina			Spilantus mauritiana
Vernonia auriclifolia			Sporobolus pyramidalis
Zea mays			Sterculia africana
Zehneria scabra			Syzigium guineense
Ziziphus spina-christi			Tephrosia pumila
			Terminalia schimperiana
			Terminalia sp.
			Themeda triandra
			Trifolium sempilosum
			Ximenia caffra
			Ziziphus mucronata
			Ziziphus spina-christi

Riparian	Wooded grassland
Abutilon fruitcosum	*Abrus precatorius*
Abutilon villosa	*Abutilon fruitcosum*
Acacia brevispica	*Abutilon villosa*
Acacia hockii	*Acacia brevispica*
Acacia mellifera	*Acacia hockii*
Acacia nilotica	*Acacia mellifera*
Acacia polyacantha	*Acacia senegal*
Acacia senegal	*Acacia seyal*
Acacia seyal	*Acalypha fruticosa*
Acacia tortilis	*Acanthus sp.*
Acalypha fruticosa	*Acokanthera schimperi*
Acanthus sp.	*Achyranthus aspera*
Acokanthera schimperi	*Adenia venenata*
Achyranthus aspera	*Adenium obesum*
Aeschynomene elaphroxylon	*Aloe gilbertaie*
Agave americana	*Aloe otallensis*
Allophylus abyssinicus	*Aloe pirrottae*
Aloe gilbertaie	*Amaranthus hybridus*
Aloe otallensis	*Areva javanica*
Asparagus flagellaris	*Asparagus flagellaris*
Aspilia africana	*Balanites aegyptica*
Balanites aegyptica	*Balanitus rotundifolia*
Balanitus rotundifolia	*Barleria eranthemoides*
Barleria quadrispina	*Barleria quadrispina*
Becium filamentosa	*Bidens sp.*
Bersama abyssinica	*Boscia senegalensis*
Bidens pilosa	*Botriochloa radicans*
Bidens sp.	*Cadaba farinosa*
Boscia senegalensis	*Calpurnia aurea*
Botriochloa radicans	*Canthium oligocarpum*
Bridelia micrantha	*Capparis spinosa*
Cadaba farinosa	*Capparis tomentosa*
Calpurnia aurea	*Cardus leptacanthus*
Canthium oligocarpum	*Carrisa edulis*
Capparis tomentosa	*Caryx sp.*
Carrisa edulis	*Cenchrus sp.*
Caryx sp.	*Chloris roxburghiana*
Cassia didymobotrya	*Chrysopogon plumulosus*
Cassipora malasona	*Cissus quadrangularis*
Celtis africana	*Cissus rotundifolius*
Cenchrus sp.	*Coccinia abyssinica*
Chloris roxburghiana	*Combretum collinum*
Chrysopogon plumulosus	*Combretum aculeatum*
Cissampelos mucronata	*Combretum molle*
Cissus quadrangularis	*Commelina benghalensis*
Cissus rotundifolius	*Commiphora africana*
Clematis simensis	*Commiphora terebinthina*
Clutia abyssinica	*Croton sp.*
Coccinia abyssinica	*Cynodon dactylon*
Combretum collinum	*Cyperus rigidifolius*
Combretum aculeatum	*Desmodium*
Combretum molle	*Dichondra repens*
Commelina benghalensis	*Dichrostachys cinerea*
Commicarpus sinuatus	*Digitria velutina*
Commiphora africana	*Dodonaea angustifolia*
Cordia africana	*Endostemon sp.*
Crinipes longifolius	*Enteropogon macrostachyus*
Croton macrostachyus	*Eragrostis japonica*
Cynodon dactylon	*Eragrostis tenuifolia*
Cyperus rigidifolius	*Euclea divinorum*
Cyperus rotundus	*Euclea schimperi*
Cyperus dives	*Eulophia petersii*
Cyperus impubes	*Eulophia sp.*
Cyperus longus	*Euphorbia polyacantha*
Desmodium	*Euphorbia tirucalli*
Dichrostachys cinerea	*Ficus umbellata*
Digitria velutina	*Flacourtia indica*
Diospyros mespiliformis	*Flueggea virosa*
Dodonaea angustifolia	*Galiniera coffeoides*
Dovyalis abyssinica	*Gardenia lutea*
Dregea schimperi	*Gomphocarpus fruitcosus*
Echinochloa colona	*Grewia bicolor*
Ekebergia capensis	*Grewia tenax*
Endostemon sp.	*Grewia trichocarpa*
Ensete ventricosum	*Grewia velutina*
Enteropogon macrostachyus	*Grewia villosa*

Riparian	Wooded grassland
Eragrostis japonica	*Guizotia scabra*
Eragrostis tenuifolia	*Harissonia abyssinica*
Eragrostis tremula	*Harpachne schimperi*
Erythrina abyssinica	*Heteropogon contortus*
Erythrina brucei	*Hypoestes forsskaoli*
Euclea divinorum	*Hypparhenia cymbari*
Euphorbia tirucalli	*Indigofera schimperi*
Ficus sp.	*Jasminum floribundum*
Ficus sur	*Justicia flava*
Ficus sycomorus	*Justicia ladanoides*
Ficus umbellata	*Kalanchoe densiflora*
Ficus vasta	*Kalanchoe petitiana*
Flueggea virosa	*Kyllingiella microcephala*
Galiniera coffeoides	*Laggera crispata*
Galinsoga parviflora	*Leucas martinicensis*
Gardenia lutea	*Maytenus senegalensis*
Gomphocarpus fruitcosus	*Melhania velutina*
Grewia bicolor	*Melinis repens*
Grewia trichocarpa	*Monechma debile*
Grewia velutina	*Myrica salcifolia*
Grewia villosa	*Ocimum gratissimum*
Harissonia abyssinica	*Olea europaeassp. Cuspidata*
Heteropogon contortus	*Osyris quadripartita*
Hippocratea africana	*Ozoroa insignis*
Hybanthus enneaspermus	*Panicum maximum*
Hypoestes forsskaoli	*Pennisteum maximum*
Hypparhenia cymbari	*Pentaschistis pictigluma*
Impatiens athiopica	*Periploca sp.*
Indigofera schimperi	*Perotis patens*
Ipomea cairica	*Plectranthus barbatus*
Jacaranda mimosifolia	*Plectranthus punctatus*
Jasminum floribundum	*Pterolobium stellatum*
Justicia flava	*Ranunculus multifides*
Justicia ladanoides	*Rhus natalensis*
Kalanchoe densiflora	*Rhynchosia malacophylla*
Kalanchoe petitiana	*Sacrostemma viminale*
Laggera crispata	*Sansevieria forskaolina*
Leonitis ocymifolia	*Sansevieria erythreae*
Lepidotrichilia volkensii	*Sclerocarya birrea*
Leptochloa rupestris	*Sehima nervosum*
Leucas martinicensis	*Setaria megaphylla*
Mangifera indica	*Sida alba*
Maytenus senegalensis	*Sida ovata*
Melinis repens	*Solanum incanum*
Mimusops kummel	*Solanum nigrum*
Moringa stenopetala	*Sonchus sp*
Myrica salcifolia	*Sorghum verticilliflorum*
Ochna inermis	*Sporobolus pyramidalis*
Ocimum gratissimum	*Tagetes minuta*
Ocimum lamiifolium	*Talinum sp*
Oplismenus sp.	*Teclea nobilis*
Osyris quadripartita	*Tephrosia pumila*
Ozoroa insignis	*Terminalia sp.*
Panicum deustum	*Tylosema fassoglensis*
Panicum maximum	*Vernonia auriclifolia*
Pappea capensis	*Ximenia caffra*
Pennisteum maximum	*Ziziphus mucronata*
Pentaschistis pictigluma	*Ziziphus spina-christi*
Phyllantus ovalifolius	
Pilostigma thonningii	
Pterolobium stellatum	
Pulchea discoridis	
Rhoicisus revoilii	
Rhus natalensis	
Rhynchosia malacophylla	
Ricinus communis	
Ritichia albersii	
Rubus steudneri	
Saba comorensis	
Salvadora persica	
Sansevieria forskaolina	
Sansevieria erythreae	
Scirpus sp	
Sclerocarya birrea	
Sesbania sesban	
Setaria megaphylla	
Sida ovata	

Riparian	Wooded grassland
Solanum incanum *Solanum nigrum* *Sphaeranthus suaveolens* *Spheranthus sp.* *Sporobilous festuvis* *Sporobolus pyramidalis* *Tagetes minuta* *Tamarindus indica* *Teclea nobilis* *Teclea simplifolia* *Terminalia browinii* *Terminalia sp.* *Trichia sp* *Trichilia dregeana* *Triumfetta brachyceras* *Typha domingensis* *Vepris dainellii* *Vernonia auriclifolia* *Ximenia caffra* *Zanha golungensis* *Zanthoxylum chalybeum* *Ziziphus mucronata* *Ziziphus spina-christi*	

2. Plant species richness and diversity (H) (for each LU/LC type) for the entire area summed among transects

Plant species richness and diversity (H) in the LU/LC of Transect 1

LU/LC	Site	Tot. Species No.	Relevé	No. of spec.	% Tot. cov.	H	Evenness
Highland Cultivation	Site 7	64	Relevé 7.1	12	61	2.006	0.807
			Relevé 7.2	24	151	1.813	0.57
Highland Cultivation	Site 8		Relevé 8.1	8	48	1.512	0.727
			Relevé 8.2	17	104	1.658	0.585
Highland Cultivation	Site 9		Relevé 9.1	33	187	2.733	0.782
			Relevé 9.2	27	272	2.334	0.708
Highland grazing	Site 10	17	Relevé 10. 1	7	141	1.458	0.749
			Relevé 10.2	7	136	1.518	0.78
Highland grazing	Site 11		Relevé 11.1	7	115	1.689	0.868
			Relevé11.2	8	117	1.567	0.754
Highland grazing	Site 12		Relevé 12.1	8	172	1.725	0.829
			Relevé12.2	8	200	1.8	0.865
Open Bushland	Site 1	30	Relevé 1.1	13	139	1.717	0.67
			Relevé 1.2	13	94	1.44	0.561
Open Bushland	Site 2		Relevé 2.1	15	66	1.542	0.569
			Relevé 2.2	10	66	1.361	0.591
Open Bushland	Site 3		Relevé 3.1	0	0	0	0
			Relevé 3.2	0	0	0	0
Riparian	Site 13	52	Relevé 13.1	0	0	0	0
			Relevé13.2	0	0	0	0
Riparian	Site 14		Relevé 14.1	29	136	2.846	0.845
			Relevé14.2	19	100	2.337	0.794
Riparian	Site 15		Relevé 15.1	22	102	2.603	0.842
			Relevé15.2	18	121	2.315	0.801
Wooded grassland	Site 4	43	Relevé 4.1	10	105	1.964	0.853
			Relevé 4.2	17	94	2.376	0.839
Wooded grassland	site 5		Relevé 5.1	19	109	2.278	0.774
			Relevé 5.2	16	161	1.966	0.709
Wooded grassland	Site 6		Relevé 6.1	17	104	2.325	0.821
			Relevé 6.2	19	75	2.713	0.921

Plant species richness and diversity (H) in the LU/LC of Transect 2

LU/LC	Site	Total Spcies No.	Relevé	No. of spec.	% Tot. cov.	H	Evenness
Highland Cultivation	Site 22	63	Relevé 22.1	23	189	2.307	0.736
			Relevé 22.2	34	194	2.914	0.826
Highland Cultivation	Site 23		Relevé 23.1	11	204	1.865	0.778
			Relevé 23.2	18	130	2.084	0.721
Highland Cultivation	Site 24		Relevé 24.1	19	183	2.218	0.753
			Relevé 24.2	23	200	2.473	0.789
Highland Forest	Site 25	35	Relevé 25.1	10	155	1.749	0.759
			Relevé25.2	8	136	1.559	0.75
Highland Forest	Site 26		Relevé 26.1	25	181	2.292	0.712
			Relevé26.2	24	162	2.058	0.648
Highland Forest	Site 27		Relevé 27.1	0	0	0	0
			Relevé27.2	0	0	0	0
Open Bushland	Site 16	58	Relevé 16.1	24	191	2.642	0.831
			Relevé16.2	23	161	2.384	0.76
Open Bushland	Site 17		Relevé 17.1	25	87	2.518	0.782
			Relevé17.2	22	72	2.51	0.812
Open Bushland	Site 18		Relevé 18.1	0	0	0	0
			Relevé18.2	0	0	0	0
Riparian	Site 31	59	Relevé 31.1	42	341	3.188	0.853
			Relevé31.2	27	371	2.691	0.817
Riparian	Site 32		Relevé 32.1	18	70	2.077	0.719
			Relevé32.2	11	175	1.551	0.647
Riparian	Site 33		Relevé 33.1	1	1	0	0
			Relevé33.2	0	0	0	0
Wooded Grassland	Site 19	50	Relevé 19.1	22	88	2.543	0.823
			Relevé19.2	18	109	2.249	0.778
Wooded Grassland	Site 20		Relevé 20.1	23	86	2.733	0.872
			Relevé20.2	29	127	2.988	0.887
Wooded Grassland	Site 21		Relevé 21.1	0	0	0	0
			Relevé21.2	0	0	0	0

Plant species richness and diversity (H) in the LU/LC of Transect 3

LU/LC	Site	Total Species No	Relevé	No. of spec.	% Tot. cov.	H	Evenness
		28	Relevé42.2	8	112	1.44	0.692
Highland Forest	Site 43		Relevé 43.1	20	149	2.163	0.722
			Relevé43.2	16	97	2.438	0.879
Highland Forest	Site 44		Relevé 44.1	11	88	0.954	0.398
			Relevé44.2	8	80	0.606	0.291
Highland Forest	Site 45		Relevé 45.1	0	0	0	0
			Relevé45.2	0	0	0	0
Highland Grazing	Site 43	25	Relevé 43.1	20	149	2.163	0.722
			Relevé43.2	16	97	2.438	0.879
Highland Grazing	Site 44		Relevé 44.1	11	88	0.954	0.398
			Relevé44.2	8	80	0.606	0.291
Highland Grazing	Site 45		Relevé 45.1	0	0	0	0
			Relevé45.2	0	0	0	0
Open Bushland	Site 34	39	Relevé 34.1	16	128	1.935	0.698
			Relevé34.2	13	147	1.877	0.732
Open Bushland	Site 35		Relevé 35.1	22	156	2.513	0.813
			Relevé35.2	20	149	2.547	0.85
Open Bushland	Site 36		Relevé 36.1	12	62	2.288	0.921
			Relevé36.2	12	74	2.204	0.887
Riparian	Site 49	59	Relevé 49.1	14	101	2.411	0.914
			Relevé49.2	10	118	2.131	0.926
Riparian	Site 50		Relevé 50.1	22	160	2.907	0.94
			Relevé50.2	27	136	2.968	0.9
Riparian	Site 51		Relevé 51.1	35	183	3.24	0.911
			Relevé51.2	35	179	3.315	0.932
Wooded Grassland	Site 37	51	Relevé 37.1	11	96	1.814	0.757
			Relevé37.2	15	102	2.385	0.881
Wooded Grassland	Site 38		Relevé 38.1	21	142	2.591	0.851
			Relevé38.2	23	165	2.707	0.863
Wooded Grassland	Site 39		Relevé 39.1	25	104	2.707	0.841
			Relevé39.2	18	79	2.485	0.86

Plant species Richness and Diversity (H) in the LU/LC of Transect 4

LU/LC	Site	Total Spcies No.	Relevé	No. of spec.	% Tot. cov.	H	Evenness
Highland Cultivation	Site 58	40	Relevé 58.1	30	102	2.791	0.82
			Relevé58.2	11	112	1.557	0.649
Highland Cultivation	Site 59		Relevé 59.1	13	54	2.147	0.837
			Relevé59.2	11	87	1.744	0.727
Highland Cultivation	Site 60		Relevé 60.1	0	0	0	0
			Relevé60.2	0	0	0	0
Highland Forest	Site 61	24	Relevé 61.1	13	100	1.296	0.505
			Relevé61.2	12	118	1.321	0.532
Highland Forest	Site 62		Relevé 62.1	21	72	2.653	0.871
			Relevé62.2	17	84	2.447	0.864
Highland Forest	Site 63		Relevé 63.1	0	0	0	0
			Relevé63.2	0	0	0	0
Highland Grazing	Site 64	0	Relevé 64.1	0	0	0	0
			Relevé64.2	0	0	0	0
Highland Grazing	Site 65		Relevé 65.1	0	0	0	0
			Relevé65.2	0	0	0	0
Highland Grazing	Site 66		Relevé 66.1	0	0	0	0
			Relevé66.2	0	0	0	0
Open Bushland	Site 52	35	Relevé 52.1	13	84	2.23	0.87
			Relevé52.2	12	95	1.815	0.73
Open Bushland	Site 53		Relevé 53.1	7	46	1.2	0.617
			Relevé53.2	9	72	1.465	0.667
Open Bushland	Site 54		Relevé 54.1	14	199	2.151	0.815
			Relevé54.2	15	114	2.354	0.869
Wooded Grassland	Site 55	62	Relevé 55.1	13	136	2.286	0.891
			Relevé55.2	17	184	2.462	0.869
Wooded Grassland	Site 56		Relevé 56.1	18	121	2.392	0.828
			Relevé56.2	12	66	2.021	0.813
Wooded Grassland	Site 57		Relevé 57.1	32	177	2.76	0.796
			Relevé57.2	20	140	2.634	0.879

Plant species richness and diversity (H) in the LU/LC of Transect 5

LU/LC	Site	Total Secies No.	Relevé	No. of spec.	% Tot. cov.	H	Evenness
Open Bushland	Site 70	21	Relevé70.1	5	107	1.267	0.787
			Relevé70.2	5	101	0.485	0.301
Open Bushland	Site 71		Relevé71.1	4	75	1.137	0.82
			Relevé71.2	2	90	0.637	0.918
Open Bushland	Site 72		Relevé72.1	9	65	1.9	0.865
			Relevé72.2	10	120	1.971	0.856
Riparian	Site 67	63	Relevé 67.1	9	77	0.952	0.433
			Relevé67.2	8	64	1.273	0.612
Riparian	Site 68		Relevé 68.1	8	92	1.42	0.683
			Relevé68.2	9	137	1.648	0.75
Riparian	Site 69		Relevé 69.1	16	140	2.269	0.818
			Relevé69.2	17	100	2.436	0.86
Riparian	Site 76		Relevé76.1	22	135	2.721	0.88
			Relevé76.2	20	147	2.601	0.868
Riparian	Site 77		Relevé77.1	9	88	1.883	0.857
			Relevé77.2	12	97	1.978	0.796
Riparian	Site 78		Relevé78.1	15	153	2.336	0.863
			Relevé78.2	16	167	2.575	0.929
Wooded Grassland	Site 73	25	Relevé73.1	9	98	1.636	0.744
			Relevé73.2	5	62	1.094	0.68
Wooded Grassland	Site 74		Relevé74.1	5	92	1.01	0.628
			Relevé74.2	5	89	1.051	0.653
Wooded Grassland	Site 75		Relevé75.1	9	30	1.961	0.892
			Relevé75.2	9	44	1.736	0.79

3. Plant species that are LU/LC specific (unique species to specific LU/LC types) summed among all transect

Highland Cultivation	Highland Forest	Highland Grazing	Open Bushland
Alium sativum	*Alchemilla rothii*	*Acritochaete volkensii*	*Aeschynomene abyssinica*
Anonna senegalensis	*Amorphophallus sp.*	*Cycnium herzteldianus*	*Cadaba farinosa*
Brassica nigra	*Anthemis tigreensis*	*Dischoriste radicans*	*Clerodendron myricoides*
Capsicum frutescens	*Brucea antidysenterica*	*Eleusine floccifolia*	*Echinops sp.*
Citrus sinensis	*Buddleja polystachya*	*Festuca sp.*	*Elytrophorus spicatus*
Coffea arabica	*Celosia argentea*	*Hydrocotyle manii*	*Euphorbia sp.*
Cucurbita pepo	*Clausena anisata*	*Ochthochloa sp.*	*Hydnora johannis*
Datura stramonium	*Impatiens tinctoria*	*Paspalum orbiculare*	*Kalanchoe lanceolata*
Dioscorea sp.	*Kniphofia foliosa*	*Satureja punctata*	*Kyllingiella polyphylla*
Dracena steudneri	*Maytenus arbutifolia*	*Thymus schimperi*	*Lannea schimperii*
Eucalyptus globulus	*Oplismenus sp.*		*Pennisetum mezianum*
Euphorbia cotonifolia	*Plantago palmata*		*Rosa abyssinica*
Evolvulus alsinoides	*Rapanea melanophloes*		*Sorghum verticilliflorum*
Foeniculum vulgare	*Schefflera abyssinica*		*Syzygium guineense*
Geranium arabicum	*Thalictrum rynchocarpum*		*Terminalia schimperiana*
Hagenea abyssinica	*Vernonia sp.*		
Hordeum vulgare			
Juniperus procera			
Lippia adoensis			
Maesa lanceolata			
Medicago polymorpha			
Melia azedarach			
Milletia ferruginea			
Morus nigra			
*Musa paradisca**			
Nicotina tabacum			
Oxalis radicosa			
Oxygonum sinuatum			
Persea americana			
Phaseolus vulgaris			
Phoenix reclinata			
Podocarpus falcatus			
Prunus africana			
Prunus persica			
Psidum guajava			
Saccarhum officinarum			
Salvia coccinea			
Senecio sp			
Sida schimperiana			
Solanum incanum			
Solanum tuberosum			
Sonchus sp			
Vernonia amygdalina			
Zea mays			
Zehneria scabra			

Riparian	Wooded grassland
Aeschynomene elaphroxylon *Agave americana* *Cissampelos mucronata* *Clematis simensis* *Clutia abysinica* *Commicarpus sinuatus* *Clutia abyssinica* *Cyperus dives* *Cyperus impubes* *Cyperus longus* *Dregea schimperi* *Echinochloa colona* *Erythrina abyssinica* *Gomphocarpus fruitcosus* *Hippocratea africana* *Hybanthus enneaspermus* *Ipomea cairica* *Jacaranda mimosifolia** *Lepidotrichilia volkensii* *Leptochloa rupestris* *Mangifera indica** *Mimusops kummel* *Ochna inermis* *Panicum deustum* *Pulchea discoridis* *Rhoicissus revoilii* *Ritichia albersii* *Rubus steudneri* *Saba comorensis* *Salvadora persica* *Scirpus sp* *Sphaeranthus suaveolens* *Sphaeranthus sp.* *Tamarindus indica* *Teclea simplifolia* *Terminalia browinii* *Trichilia dregeana* *Trichia sp* *Triumfetta brachyceras* *Typha domingensis* *Vepris dainellii* *Zanha golungensis* *Zanthoxylum chalybeum*	*Abrus precatorius* *Adenia venenata* *Adenium obesum* *Barleria eranthemoides* *Capparis spinosa* *Carduus leptacanthus* *Commiphora terebinthina* *Euclea schimperi* *Eulophia petersii* *Eulophia streptopetals* *Flacourtia indica* *Grewia tenax* *Melhania velutina* *Monechma debile* *Periploca sp.* *Perotis patens* *Plectranthus barbatus* *Plectranthus punctatus* *Sacrostemma viminale* *Talinum sp* *Tylosema fassoglensis*

Annex VII: Photos of main land-use/land cover types in the study area. (All photos presented here and on the cover page were taken by C. Wilson).

Riparian

Wooded grassland

Bushland

Grassland

Highland

Highland grazing

Lake shoreline vegetation

Lake shoreline vegetation

Landscape erosion from deforestation and over-use in the study area. (photo above from Sodo area and the photo below is from near Dimtu.