Plant communities of a wetland in western Ethiopia

by

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Abstract

This thesis is part of a larger ongoing study of the vegetation of Benishangul Gumuz National Regional State. Wetlands are a little studied part of this vegetation, and have not been subject to ecological analysis before. This study aims to analyse the vegetation community structure of a wetland near Assosa, the capital of the region.

The study was conducted over the first three days of October 2005, at the end of the rainy season in western Ethiopia. The site consisted of a tall grass and sedge dominated wetland surrounded by mixed broadleaf woodland and thickets of *Oxytenanthera abyssinica*. A total of 29 2m^2 plots were analysed for species abundance, and soil was collected for chemical analysis and seed bank experiments.

TWINSPAN and DCA analysis of the species abundance data and correlation tests with soil variables led to the conclusion that two main ‘community types’ were present in the wetland: The *Scleria* community at the wetter core of the wetland and the *Aneilema* community in the margins and drier parts of the wetland. The main environmental gradient governing species composition was hypothesised to be a gradient in wetness, in part determined by distance to the water table

The seed bank was investigated using the emergence method. The seedlings that germinated from each sample were counted and identified. A total of 28 species in 13 families were found, and the average number of seeds/kg of soil was 49.5. There was a 1:1 ratio of annual to perennial species and of species of wet and dry habitats. Many of the species germinated were weedy species and this element of the vegetation could increase if the wetland is subject to disturbance.

1 Introduction

1.1 Definitions

Wetlands have been defined in many different ways. Some definitions encompass everything from seasonally flooded ground to permanent lakes and estuaries, while others are more narrowly circumscribed. Wetlands can be defined according to their soil type, water regime or vegetation (Yilma Abebe, 2003).

The following definitions are those of Davis (1994), given in Wood (2001) and the Ramsar Convention for wetlands (www.ramsar.org).

"Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life. They occur where the water table is at or near the surface of the land, or where the land is covered by shallow water."

"Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres"

1.2 Importance of wetlands

Wetlands fulfil a range of environmental functions, depending on their type and location. They provide valuable resources for rural communities, especially in developing countries. The following sections discuss the importance of wetlands with a focus on African countries.

1.2.1 Hydrological functions

Wetlands provide a number of important functions in regulating water flow through a hydrological system. They slow the speed of water moving through the system and act as natural reservoirs, storing large amounts of water. This regulates the downstream flow, maintaining it during the dry season and controlling flooding during the wet season. Wetlands recharge groundwater and are important for maintaining the water table. All of these factors are extremely important for communities living and farming around or downstream of a wetland. Any changes to the wetland itself or the hydrological regime upstream of the wetland will have consequences for these functions.

Large wetlands can also have an effect on rainfall, humidity and stabilisation of the local microclimate through the high potential evapotranspiration rates of dense wetland vegetation. (Messele Fisseha, 2003)

Wetlands act as efficient filters for cleansing and stripping water of soluble nutrients from agricultural run-off and contamination by heavy metals and other pollutants. They also provide filters for waste water and sewage, provided there is a balance between in and out-flow. Wetlands trap large amounts of sediment and therefore prevent sediment and nutrient loss from the system, which is important in regions with high soil erosion.

1.2.2 Wetland resources

Wetlands provide a number of resources for people and animals living nearby, the most important of these being water itself. They provide a reliable and relatively clean source of drinking water for the local population and their livestock, and for local wildlife. They also provide dry season grazing for livestock. Other resources provided by a wetland, often of greater importance to the poorer members of the community, include reeds for roof thatching and basket making, clay and sand for brick making, and a source of plants used in traditional medicine and food. (Wood, 2003)

Finally, wetlands are invaluable for the dry season cultivation of crops, have a high productivity, and can sometimes support up to three crop cycles a year in areas of high rainfall, due to the continuous supply of water and nutrients. Wetlands can be managed for agriculture in a sustainable way provided the water balance and natural biota of the wetland are not irreversibly altered by the interventions. (Dixon & Wood, 2003)

1.2.3 Biodiversity

Wetlands provide a habitat for many species of plants, animals and other organisms that depend on the reliable source of water and nutrients in the wetland to survive, and cannot live elsewhere. These are wetland dependent organisms, and are those most at risk if a wetland is threatened. Many animals, especially birds, use wetlands as a source of food, water and shelter but do not rely entirely on wetlands as their habitat. Many plant species grow well in wetlands due to the ample water and nutrients they provide, but are not obligate wetland plants as they are found in other habitats too. These are wetland associated organisms, as defined by Zerihun Woldu and Kumlachew Yeshitela (2003).

The overall species diversity of a wetland can be higher than surrounding habitats due to the high productivity of wetlands and the fact that many have quite complex niche structuring, providing a variety of microhabitats for different species, which form a continuum of different microhabitats from a dry terrestrial to an aquatic environment.

All the above attributes of wetlands mean they have a high *functional diversity*, a recognised element of the total biodiversity of an area at the ecosystem level (Zerihun Woldu, 2000).

1.2.4 Threats to wetlands

There is increasing pressure on African wetlands as the human population continues to grow, and more land for agriculture and development are needed. The threats posed to wetlands by this development are therefore becoming increasingly acute, and the rate of wetland loss is increasing (Schuyt, 2005; Denny, 1994). Some of the main threats to wetlands are outlined below.

Physical alteration of the hydrology of the drainage basin of a wetland will affect the input of water to a wetland and/or its outflow. The construction of dams above or below a wetland will either reduce or increase the water flow to such an extent that the wetland is permanently damaged. Artificial stabilisation of water levels by damming would also harm a wetland since the rise and fall of the water level drives nutrient cycling. Drainage of a wetland or unsustainable extraction of groundwater in the area will dry it out and may cause permanent damage, and will impair a wetland's ability to control flooding, since the soil has a reduced capacity to reabsorb water (Berhanu Tekaligne, 2003).

One of the main threats to wetlands, especially ones in or close to urban settlements, is development. A wetland can be completely removed by filling in and building over the wetland area, or development and industry nearby may impact on the water table so much that the wetland dries out. Mining is one such activity that will disturb the water table and destroy wetland areas (Yilma Abebe, 2003).

Another serious threat to wetlands from industry and development is pollution. As yet there is little control on industrial emissions in developing countries. Pollution from heavy industry, in the form of heavy metals and chemicals, will usually exceed a wetland's capacity to filter out such pollutants and can do serious damage to life in the wetland and make the water unfit for use by communities in the area. Sewage pollution will also become a problem if the input of sewage exceeds a wetland's capacity to filter it, and such pollution will quickly lead to eutrophication of any open water; alter the species structure of the vegetation and make the water unfit for use. (Berhanu Tekaligne, 2003).

Overexploitation of any wetland resources mentioned above, such as over- gathering reeds for thatching, will lead to an imbalance in the wetland ecosystem and may change its structure and species composition permanently.

The complete drainage of wetlands for agriculture has lead to a number of ecological and economic problems. These include a scarcity of thatching reeds, change in the vegetation composition, lowered water tables and an accompanying reduction in accessible water (Wood, 1996).

Other problems that develop over time include a decline in agricultural productivity in the cultivated wetlands which may eventually lead to reduced overall availability of land for crop production.

In the same way as continuous cultivation of crops around a wetland will dry it out, afforestation of land upstream of a wetland may reduce the amount of water in lower reaches of the catchment, leading to a lowering of the water table and wetland drying.

Not all threats to wetlands are anthropogenic. Natural processes such as flood and drought may pose a threat to wetlands but the damage is not usually permanent unless the effects are exacerbated by other factors such as damming, irrigation and drainage systems. Erosion of substrates upstream and/or the wetland itself is also a natural process, but again any damage to the wetland will be greater if the hydrological system is greatly altered by man. The high productivity of wetlands can sometimes spell their own demise, albeit very slowly, by the process of succession. The build up of biomass in the wetland can sometimes be so great that the water balance is altered, and the wetland dries out as open swamp vegetation is replaced by shrubs, and eventually, woodland. This natural process is greatly speeded up by wetland drainage and by the increase of sediment and nutrient input from upstream. (Dixon & Wood, 2003)

1.3 *Wetlands in Ethiopia*

Wetlands, as defined in the Ramsar Convention, include all lakes and open water as well as different types of permanently or seasonally wet ground. If one takes into account all areas covered by this definition, the wetlands of Ethiopia cover a total of 18,587 km^2. This is approximately 1.5 % of the total area of the country.

Types of Wetland	Area (km^2)	Percent
Freshwater lakes	5766.6	31
Saline lakes	1770	9.5
Marshlands	2330	12.5
Seasonally inundated wetlands	8720	47
Total	18587	100

Table 1. Area in km^2 of major wetlands in Ethiopia. Source: Ethiopian Environmental Protection Authority, 2003

The conservation of these wetland areas through sustainable use is a crucial part of the management of Ethiopia's valuable fresh water resources in a country where only a quarter of the population has access to safe water and sanitation (Yilma Abebe, 2003).

1.3.1 Policy concerning wetlands

International policies concerning wetlands include the Convention on Biological Diversity (CBD) (United Nations Environment Programme, 1992) and the Ramsar Convention (www.ramsar.org). Ethiopia has signed the former but not the latter.

At the national level, two policies are important: The Conservation Strategy of Ethiopia (CSE), and the Water Resources Policy. Both concern wetlands directly, but the former focuses on ecosystem functions and biodiversity (Anon, 2000), whilst the latter concentrates on hydrological functions. Non wetland policies with an impact on wetlands include national government policy on food security, policy on production of cash crops, especially coffee, and the resettlement policy which moved groups of people hit by drought and famine to regions in the south and west of Ethiopia. The effect of all these policies has been an increase in the use of wetlands for agriculture due to a shortage of land (Wood, 2001).

Most communities in wetland areas in Ethiopia have local policies concerning the wetlands, often in the form of 'unwritten' rules based on tradition and the fact that the wetlands are usually in common ownership. These rules must be taken into account by policy makers at higher levels.

1.4 Plant Diversity in Benishangul-Gumuz

Ethiopia has a diverse flora and a broad range of ecosystems, due to its very variable terrain. The vegetation types range from the Afromontane vegetation in the highlands, some of which rises above 4000 metres over sea level, to the semi desert scrubland vegetation of the lowlands in the east and savannah vegetation in the western lowlands. The vegetation is often greatly altered by man due to the high population pressure in most regions of Ethiopia.

The region of Benishangul Gumuz in western Ethiopia still has large areas of relatively undisturbed vegetation and up to 60% of the region is covered by forest and woodland. This is due to the relative inaccessibility of the region and to its low population density- 10.9 individuals per square kilometre, compared to the national average of 57.7. However, this figure is expected to double by 2030, as the population growth of the region matches that of the rest of the country (Sebsebe Demissew *et al.* 2005).

This woodland vegetation has been defined as a separate vegetation unit, named *Undifferentiated woodlands (Ethiopian type)*, marked in green on the map in Figure 2. This unit is in a transition zone between the Afromontane highlands to the east, which have a complex mosaic of different vegetation types, and the Sudanian phytogeographical region to the west. This vegetation type is burnt annually and many of the species are fire adapted (Sebsebe Demissew *et al.* 2005).

The wetland vegetation of the region consists of two main types: open, treeless swamps dominated by grasses, Cyperaceae species and herbs, and riparian woodland along watercourses, with a high diversity of woody species including the palm *Phoenix reclinata* and species of *Acacia* and *Ficus*. Some of the species found in these vegetation types are unusual or not found elsewhere in Ethiopia.

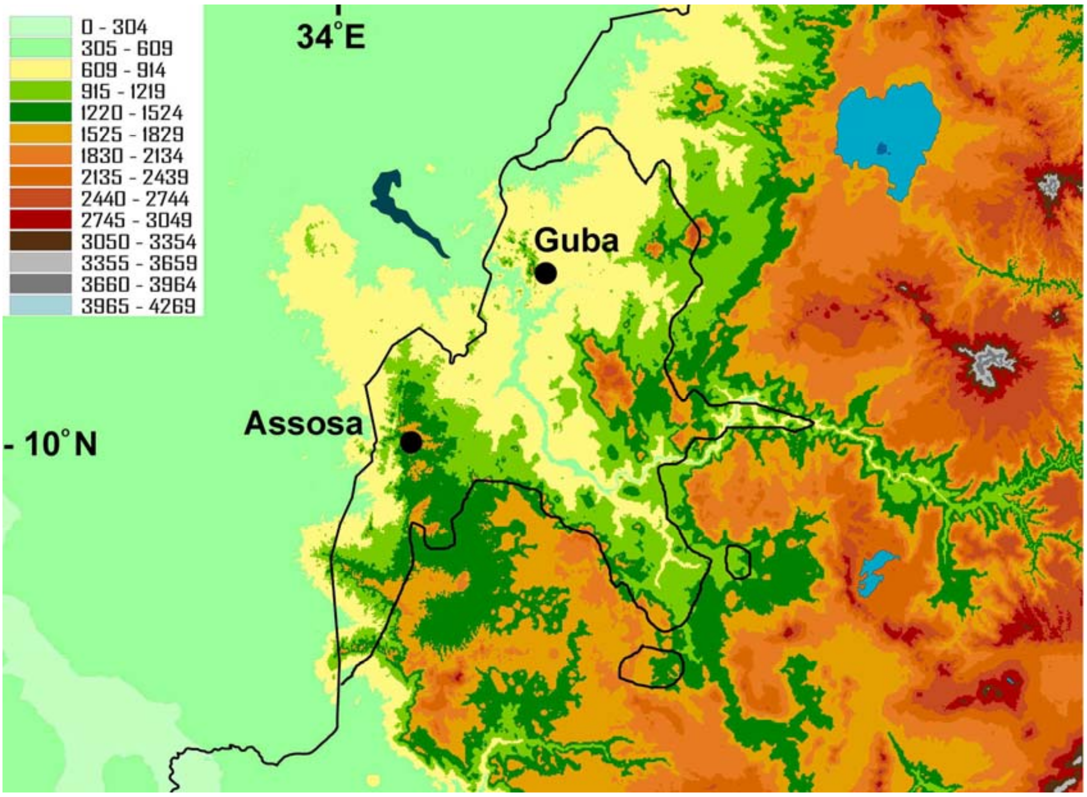

Figure 1. Topographical map with Benishangul Gumuz National Regional State outlined in black. Altitude in metres is given in the legend.

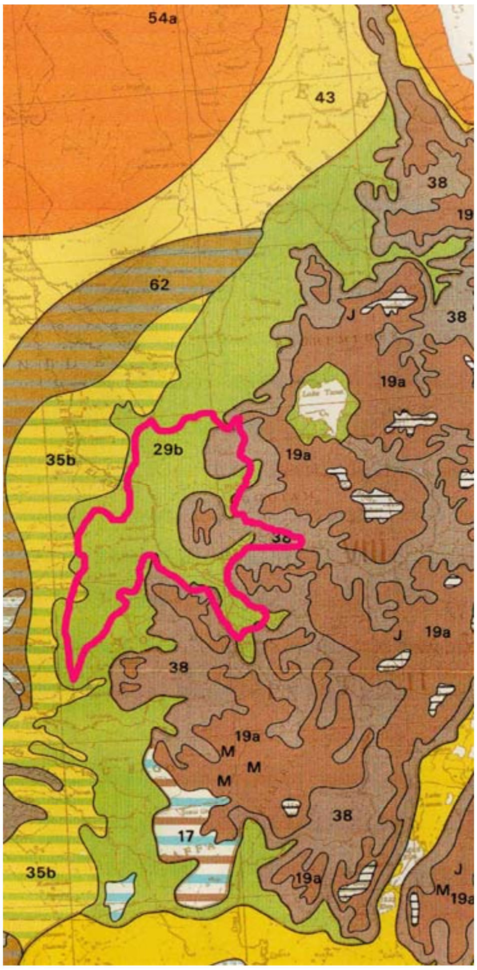

Figure 2. Section of the vegetation map of Africa (White, 1983) showing mapping unit 29b, "Undifferentiated woodlands (Ethiopian type)"in green, with the outline of Benishangul Gumuz in pink.

1.5 Aims of the study

This study is part of a larger study of the vegetation of the Benishangul Gumuz region being undertaken by Tesfaye Awas. It aims to analyse the vegetation community structure of a grass and sedge dominated wetland. No ecological analysis has been done before on wetland vegetation in Benishangul Gumuz.

Questions:

1) What is the taxonomic composition of the wetland flora and what can be said about its affinities?

2) Is there a vegetation community structure in the wetland and if so, what communities can be identified?

3) What is the composition of the (dry soil) seed bank of the wetland, how does it compare to the above ground flora, and what implications does this have for the wetland flora in case of disturbance?

2 Materials and Methods

2.1 Study site

A preliminary survey of the vegetation of the Benishangul Gumuz region (Sebsebe Demissew *et al*. 2005) had identified areas of wetland vegetation in the form of open swamps and riverine forests, as outlined in the Introduction. On previous visits to the region, Tesfaye Awas identified areas of wetland near Assosa that warranted further exploration.

One such wetland, on the road from Assosa to Bambasi, is the subject of this study. The wetland is located at 09º 54.3' N and 34º 40.0' E, at 1480m elevation, in an area of *Oxytenanthera abyssinica* (lowland bamboo) thickets and mixed open broadleaf woodland (see Appendix E for species list), known locally as 'Anbesa Chaka', the Lion Forest. The wetland consisted of an open treeless area about 250 metres long by 20-80 metres wide (see marked outline in Figure 4.). The vegetation was largely composed of a mixture of tall perennial grasses and sedges, with some dicots interspersed among them. The ground was almost flat, with a narrow, slow flowing stream winding down the middle of the wetland.

Figure 3. Part of the wetland site, showing the surrounding woodland and a stand of the lowland bamboo *Oxytenanthera abyssinica* in the distance.

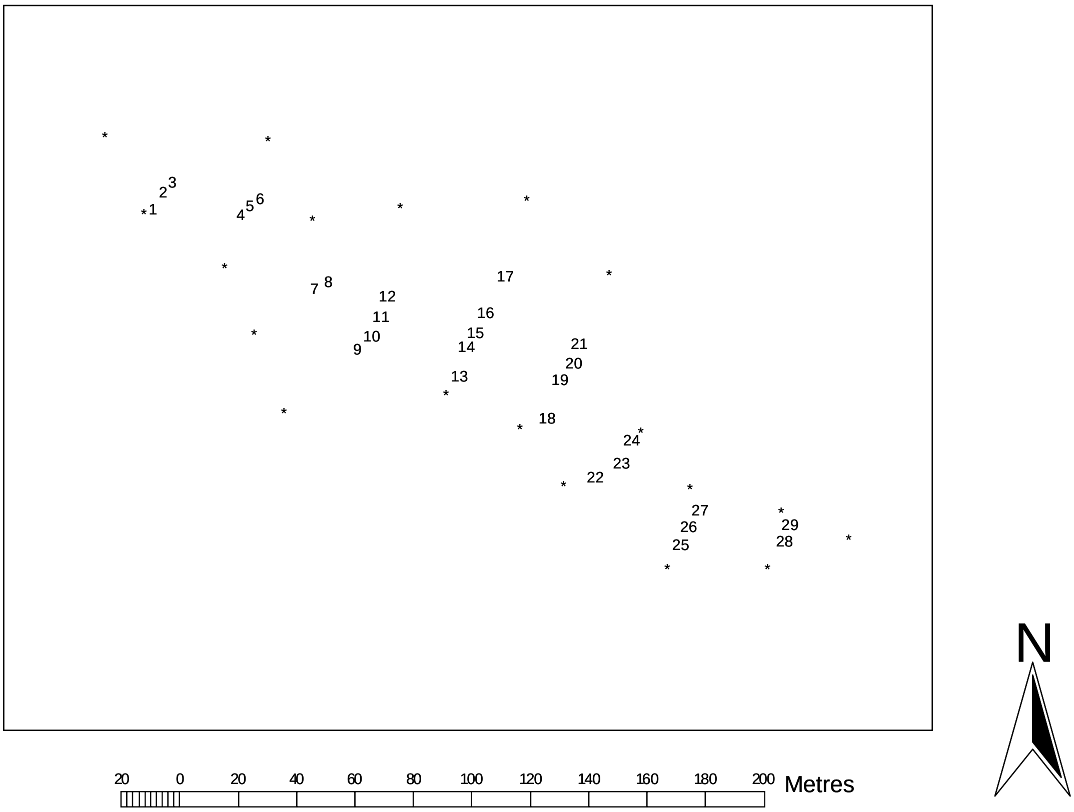

Figure 4. Position of the 29 plots along the 9 transects across the wetland. The edge of the woods surrounding the open wetland area is marked with *.

The site is located on the western flank of the western Ethiopian escarpment, about half way between the highland plateau to the east and the lowlands to the west on the border with Sudan. The geology consists of outcrops of very old Precambrian formations, with rich mineral deposits and occurrences of marble, which is mined in the area.

The climate of the area, with a mean annual rainfall of just over 1000mm and temperatures not exceeding a mean annual maximum of 28 ºC, is part of the temperate zone in Ethiopia, found at intermediate altitudes in the west between the colder highlands and the hot dry lowlands.

Month	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Total**	**Mean**
Rainfall (mm)	0	4	21	52	109	146	189	197	197	103	18	1	**1038**	**87**
Temp max ºC	30	31	32	31	28	25	24	24	25	26	28	29	**335**	**28**
Temp min ºC	14	15	16	15	16	15	15	14	14	14	14	14	**175**	**15**

Table 2. Mean monthly rainfall in mm and mean maximum and minimum temperatures in ºC for Assosa measured at the Assosa Meteorological Station over the period 1960- 2004. Source: National Meteorological Services Agency of Ethiopia

The site was chosen mainly because it showed no evidence of recent human disturbance and could be considered an example of near pristine wetland vegetation.

The fieldwork was carried out over 4 days, from the 30th of September to the 3rd of October 2005. The first day consisted of site evaluation, when several wetland sites were visited, and the wetland at Anbesa Chaka was chosen as the study site. Also on the first day alternative methods of plot data collection were tested in the wetland. Over the next three days the plots were analysed and soil and plant material was collected.

2.2 Species abundance analysis

The higher plant species present were recorded using percentage cover in 2× 2 metre plots distributed every 5 metres along transects across the wetland, the transects being spaced 50 metres apart. This ensured an even and unbiased coverage. The whole wetland was analysed using 9 transects and a total of 29 plots (see map, Figure 4).

The transects were measured out using 25m measuring tapes and were started at what was deemed to be the wetland edge, a clear dip in the terrain and a transition from short grass to tall grass vegetation. The first plot was placed at the datum, the wetland edge, and spanned the first two metres of the transect. Which side of the transect line the plot was placed was chosen at random. The second plot was placed 5 m from the first, i.e. 7 m from the datum, and the third plot 5 m from the end of the second, 14 metres from the datum, etc. The next transect was laid out 50 metres further along the wetland, this distance measured in a perpendicular direction from the last transect using 25m measuring tapes and canes to mark the end points. In total, 400m were covered by the transects, almost the entire wetland.

A GPS recorder was used to find the latitude and longitude of each plot down to an accuracy of 1-2 metres, making it possible to map the plots using ArcView GIS 3.3. Points around the edge of the wetland were also recorded in this way, making it possible to produce an outline of the wetland area on the map (see Figure 4).

Our intention was to use the subplot frequency method developed by Rune Økland (1990) for the species abundance recording. In this method the plot is divided into 16 subplots as a grid and presence/ absence of each species is recorded in each subplot. This method is, in principle, more objective than percentage cover analysis of the whole plot, and gives a higher representation of the abundance of species that are frequent, but not physically large.

However, the plot took over 2 hours to analyse by this method, and in order to get enough (about 30) plots analysed in the remaining 3 days of fieldwork, the simpler, less time consuming but more subjective method of percentage cover estimated by eye was employed. The speed and accuracy of this analysis method was improved by splitting the plot into 4 × $1m^2$ units and estimating percentage cover in each unit of the plot, then averaging the values obtained for each unit. This work was divided between the 4 of us standing at the corners of the plot, analysing one m^2 unit each (see Figure 5)

Figure 5. Recording species abundance

The species found were collected and pressed for later identification at the National Herbarium in Addis Ababa (ETH). A total of 150 specimens were collected. Most of the specimens, especially those with flowering material, were identified to species or genus using the Flora of Ethiopia and authenticated herbarium specimens. Duplicates of all specimens were deposited at ETH, some specimens were transported to Norway for further identification.

Nomenclature follows The Flora of Ethiopia and Eritrea throughout (Hedberg and Edwards (1989), Phillips (1995), Edwards *et al.* (1995, 1997, 2000), Hedberg *et al.* (2003) and Mesfin Tadesse (2004)).

Habitat information for the fully identified species was obtained from the species descriptions in the Flora of Ethiopia and Eritrea volumes 2, 3, 4, 6 and 7 (see above). Information on the distribution range within Ethiopia was also obtained from the Flora and from species lists of regional floras updated after the publication of the relevant Flora volume. New localities for species are frequently found in Ethiopia, especially in little studied regions such as Benishangul. Information on the international distribution range of the majority of species collected was obtained from the web database GBIF (Global Biodiversity Information Facility)

2.3 Soil analysis

Soil moisture/ wetness was qualitatively assessed using a gross separation into the groups ‘wet’ (very damp soil or surface water present), ‘intermediate’ (soil damp but no water present) and ‘dry’ (soil crumbly, no water present when a hole was dug)

Soil samples were collected from each plot using a trowel. The top 5mm of soil was removed and a block of about 10 cm × 10 cm and 5-10 cm deep was collected and dried in the sun. Pieces of root and other plant material were removed. Nine of the soil samples, one from each transect, were selected in order to get a representative range with regard to soil moisture, and were sent to The National Soil Research Centre in Addis Ababa for analysis. The soil was analysed for pH at a ratio of 1:2.5 soil to water, and for electrical conductivity, total nitrogen and carbon content, average extractable phosphate (Olsen method), sodium, potassium, calcium and magnesium levels in Cmol / kg, cation exchange capacity and base saturation.

2.4 Seed bank analysis

Soil samples for seed bank analysis were taken from each plot using a trowel. The site for soil removal was cleared of plant material and the top 5 mm layer of soil was removed. A block of soil about 10 cm × 10 cm and 5-10 cm deep was collected and dried in the sun. Pieces of root and other plant material were removed. When completely dry, the soil was packed in paper bags and transported to the University of Oslo for the seed bank study.

The weight and volume of each soil sample was recorded and the samples were spread evenly on a 4 cm deep layer of sterile potting compost mixed with Perlite in individual seed trays 50 cm long by 30 cm wide. A thin layer of sharp sand was spread on top of the soil samples to reduce algal growth. The trays were watered well and placed under clear plastic sheets on a greenhouse bench. The light was controlled to 12 hours of light and dark, with a daytime temperature of approximately 25ºC, reduced to 20ºC at night. The samples were kept well watered and the plastic sheets removed when germination had begun.

The emerging seedlings were counted and identified to genus and species as this became possible. The seedling development was checked regularly and the number recorded about once a week for a period of six weeks. After this time few new seedlings emerged. Some seedlings of each species were potted on and kept until they could be identified. Not all species flowered before the end of the experiment and could only be identified to family or genus level. The species that were slow to flower were placed in a closed Phytotron chamber for more precise temperature and light control, with the night temperature reduced to 15ºC and the watering reduced to initiate flowering. Only angiosperms were included in the study, cryptogams (including extensive growth of a hornwort, *Anthoceros*) were not included.

The seedling numbers per sample were divided by the mass in kilos of the original soil sample in order to get an estimate of seed number per kilo of soil, a value important for comparison with other seed bank studies. The mass of the samples varied slightly depending on how much soil was obtained from the plot during collection and this calculation standardised the results.

2.5 Data analysis

The percentage cover data from the 29 plots were converted to a scale of Ordinal Transform Values from 1 to 9 (OTV scale), a modified version of the Braun-Blanquet cover/abundance scale (van der Maarel, 1979 and 2005). See Table 3 below.

Percentage cover	0-1	1	2-3	4-5	6-12	13-25	26-50	51-75	76-100
OTV scale	1	2	3	4	5	6	7	8	9
Braun-Blanquet scale	r	+	1	2m	2a	2b	3	4	5

Table 3. Ordinal Transform Value scale compared to percentage cover and a differentiated version of the Braun-Blanquet scale with value ‘2’ split into three abundance categories. (from van der Maarel, 1979, 2005)

2.5.1 TWINSPAN analysis

The data matrix of species abundance of 88 species in 29 plots (see Appendix B) was analysed using the vegetation community analysis program TWINSPAN (TWo-way

INdicator SPecies ANalysis), Version 1.0 (Hill, 1979). It is a divisive polythetic method of vegetation classification which sorts, divides and classifies the species and plots into a two-way table. The table diagram produced by TWINSPAN divides both the samples (plots) and the species into groups and these groups can be interpreted as plant community types.

The analysis was run using default settings (see Hill, 1979) except the pseudospecies cut levels were set to 5 levels: 0, 5, 25, 50, and 75. The total number of species in the final table was set to 60. This last change made no difference to the outcome in terms of the position of plots and species, but served to remove most of the species with only one occurrence as these were not contributing to the divisions made by the programme. It also condensed the size of the table making the groupings easier to interpret.

2.5.2 Detrended Correspondence Analysis

The species-data matrix (Appendix B) was also analysed using Detrended Correspondence Analysis (DCA) (Hill & Gauch, 1980) using the CANOCO programme, version 4.53 (ter Braak and Šmilauer, 2004), producing an ordination plot of the samples distributed along the axes of greatest variation in species composition. In this analysis, two of the sample plots were removed; plots 1 and 22, and 6 species were removed; *Coelorhachis afraurita, Digitaria longiflora, Disperis sp., Eleusine indica, Hypericum lalandii,* and *Laggera crispata.* These were removed because they were extreme outliers in both the plot and species ordinations and their removal made the ordination diagrams easier to interpret since the remaining plots and species points were less clustered.

A DCA ordination was also produced in the statistics programme R, version 2.3.1. This ordination differed slightly from the one produced in CANOCO, most clearly in the reversal of axis 1, making the plots at the positive end in the CANOCO ordination appear at the negative end of axis 1 in the ordination produced in R. The axis scores from this ordination were used to compare the species diversity of each plot with the plot scores along axis1 and the soil variables with both axes (see below).

2.5.3 Analysis of environmental variables

The soil analysis data from the 9 plots sampled was compared with soil samples from the surrounding woodland, using one way ANOVA performed in the statistics programme R, to establish how each soil variable differed between the two areas. The woodland samples were taken from surrounding woodland plots analysed by Tesfaye *et al.* (in prep.), which were identified as the '*Securidaca longepedunculata- Albizia malacophylla* community' in that paper.

3 Results

3.1 Species composition

A total of 88 species were used in the final analysis. This included all the species found in the 29 sampled plots that could be identified at least to genus level, plus one that could not, the ‘petiolate grass’ which was included because of its significant presence in many plots. The species belonged to 29 families, with the most important families represented being Poaceae (19 species), Fabaceae (11), Asteracae (10) and Cyperaceae (9). In addition a further 12 species were collected and identified from the wetland outside the sampled plots. These brought the species total to 100 and contributed 5 new families, bringing the family total to 34. The complete species list can be found in Appendix A. The number of species in each plot varied greatly, from 8 species in plot 8 to 28 species in plot 29. The average species number for the 29 plots was 16.6.

Of the 88 species, 3 are endemic to Ethiopia: *Plectocephalus varians*, *Pycnostachys* sp. aff. *niamniamensis* (possibly an endemic subspecies of the species *P. niamniamensis* (Sebsebe Demissew *et al*, 2005)) and *Vernonia cylindrica.* A few species collected in the wetland were new records for Benishangul, including the grasses *Brachiaria jubata, Eriochrysis brachypogon* and *Sacciolepis rigens*, recorded in the Flora only in Kaffa (now in Southern NRS). The dominant sedge *Scleria woodii* and the herb *Drosera madagascariensis* were also new records for Benishangul. One of the indicator species found, the large sedge *Scleria greigiifolia*, is a new species for the Ethiopian flora.

In terms of their habitat, 29 (33%) of the species in the final analysis were plants of damp or wet habitats. Of the rest, 37 species (42%) were said to grow in both wet and dry habitats. Many of these were weeds or plants of marginal habitats. Sufficient habitat information was not available for the remaining 22 species (25%).

3.2 TWINSPAN analysis

The output of the TWINSPAN analysis in the form of a two- way table diagram is shown in Figure 6. The species codes are explained in Table 4.

The first division of the plots separated them into two main groups, marked by the thick line in Figure 6 between plots 26 and 27, containing 17 and 12 species respectively. The indicator species for the split were *Scleria woodii* (SCLE WOOD) and *Loudetia phragmitoides* (LOUD PHRA) separating out the main group on the left containing plot groups 1 and 2 (marked in blue and green on Figure 6) and *Arthraxon micans* (ARTH MICA) and *Vernonia cylindrica* (VERN CYLI).separating out the main group on the right containing plot groups 3 and 4 (marked in yellow and pink).

A further subdivision of each group was then made. The indicator species *Scleria greigiifolia* (SCLE GREI), found exclusively in group 1 (marked in blue on Figure 6), divided this group from group 2 (green). The subdivision of the main group on the right created groups 3 and 4, based on the presence of *Panicum sp.* 1. (PANI CSP1), *Aneilema hirtum* (ANEI HIRT) and the petiolate grass (PETI OLAT), found exclusively in group 4 (plots 1-3 and 6)

The species were split up into associations (horizontal lines on Figure 6) based on the division of plots with the abundance of each species in the plot deciding the groupings. Association A at the top left of the TWINSPAN table contains 15 species, most with their main distribution in plot groups 1 and 2. Characteristic species of this association (as well as the indicator species mentioned above and marked out in blue on Figure 6), include the possible *Berula* species, and a number of grasses and sedges of wet habitats such as *Leersia hexandra* and *Rhynchospora subquadrata*. Association B contains 10 species with their main distribution in plot groups 2 and 3. Characteristic species include *Commelina schweinfurthii* and *Scleria foliosa.* Association C contains 7 species with their main weight of distribution in plot group 3. This association mostly contains species that are common (found in many plots) but not abundant (with a low OTV value, and a value of 1 in the TWINSPAN species/ abundance classification), such as *Spermacoce chaetocephala* and *Kotschya africana*. Association D, the largest, contains 24 species, distributed almost exclusively in plot groups 3 and 4 (marked in pink). Characteristic species include indicator species already marked out, such as *Chamaecrista mimosoides* and *Vernonia cylindrica.*

```
                1112112  1 11122222  12222
                56911207908478346794538251236

76 PYCN NIAM    1-11111--------1111--1-------     1111
60 MURD TENU    1111-------1------1-----------     1111
40 GNID CHRY    1---11---1--------1-----1----     1111
82 SCLE WOOD    2222222--2-21-----1--1-------     111011
81 SCLE GREI    1222222----------------------     111011
 9 BERU LASP    -111111----------------------     111011
77 RHYN SUBQ    22-2-1-----12----------------     111010
85 SETA PUMI    11-1--1----1---1----1--------     11100
79 SACC RIGE    -2----1----211------1-------     11100
 4 ANAG TENU    -11-----11-------------------     11100
71 PLEC PUNC    --1----2-21--1--1------------     11011
73 PLEC VARI    -----------1-2-11----1-------     11010
52 LEER HEXA    ----------111121---------2---     11010
84 SETA INCR    1-1-1122-1-1112222-11---1----     110011
62 OLDE LANC    --------1----11----1---------     110011
55 LOUD PHRA    22212112222222221----2-22221-     110011
27 CYPE HASP    ---1--1111-1-111-1-1-1-------     110011
53 LIPO CHIN    --1---11-2--------11---------     110010
28 CYPE RUSP    11--1-------11-----------2---     11000
70 PLAT ROTU    ----1-1-22212--1----12-------     1011
80 SCLE FOLI    --11------22221----1-22-21---     101011
65 PANI CSP2    -------------1-1111----------     101011
22 CROT ASP1    -----------1--1-11---1-------     101011
66 PASP SCRO    -------11---1-1----1------11-     101010
19 COMM SCHW    --11---12-1-11111-2-12-11----     101010
39 FIMB FERR    -11--1--2---------11----1----     10100
33 DISS CANE    -11-1111-1111-----12-11-----1     10100
68 PHYL BOEH    ----1-1-11-1111-1-11-1-112111     100
44 HYPA BRAC    ----12--2121-211222231221-111     100
56 LUDW EREC    ------1----1-11--111--1------     0111
50 KOTS AFRI    ---------1-1-1---1----111----     0111
42 HABE NASP    1-----------1------1----11----     0111
36 ERIO ABYS    11-----------1-----11-----1----     0111
21 CRAS RUBE    ---------2-1---------111-21--     0110
86 SPER CHAE    ------------1--1111-11111---1     010
 3 AGER CONY    -------------11----2--111---1     010
54 LOUD ARUN    ------------------22------2-     001111
48 INDI GOSP    -----------------1-----11--1-     001101
26 CYPE AETH    ---------1--------12----1----     001100
11 BIOP UMBR    -------------1----11-11---1-1     00101
 6 ANTH NAUD    --------1--------11-------1--     00101
15 CHAM MIMO    -----------------1--11--1-111     001001
 7 ARTH MICA    -----------------112-21--222-     001001
69 PILI THON    ------------------1-1-----11-     001000
23 CROT ASP2    ------------------1---1-1--2-     001000
87 SPER SPHA    ---------------1------1112--1     0001
57 MICR ACSP    -------1----------111----21--     0001
10 BIDE PRES    --1-------------1----11---211-     0001
 2 ACAN POLY    -------------2-----2-22--221-     0001
91 VERN CYLI    -------------------111---2111     00001
43 HIBI CANN    ---------------------1-1-11-1     00001
16 CHLO RISP    ------------------11-------22     00001
74 POLY PERS    ------------------1------21--     000001
67 PETI OLAT    -----------------1-----1-2122     000001
64 PANI CSP1    ------------------------12221     000001
41 GUIZ SCAB    -------------1-----11-----222     000001
18 COMM ELSP    -------------------------2-1-     000001
17 CLER ALAT    --------------------------21-     000001
 5 ANEI HIRT    -------------------------211-     000001
78 ROTT COCH    -------------1-----------21-1     000000

                00000000000000000111111111111
                00000001111111111000000001111
                0000111000111111100000011
                   0001111001111
```

A

B

C

D

Figure 6. Ordered two-way table of plots and species produced by TWINSPAN (Hill, 1979) Groups marked out by vertical lines are plot groups 1, 2, 3 and 4. Horizontal lines separate species associations A, B, C and D. 60 species are included in the final table. See text for further explanation.

Table 4. Species list for the codes used in the TWINSPAN and DCA analyses

Code	Species name and authority	Family
Acalvill	*Acalypha villicaulis* Hochst. ex A. Rich.	EUPHORBIACEAE
Acanpoly	*Acanthus polystachyus* Delile	ACANTHACEAE
Agercony	*Ageratum conyzoides* L	ASTERACEAE
Anagtenu	*Anagallis tenuicaulis* Bak.	PRIMULACEAE
Aneihirt	*Aneilema hirtum* A. Rich	COMMELINACEAE
Anthnaud	*Antherotoma naudinii* Hook.	MELASTOMATACEAE
Arthmica	*Arthraxon micans* (Nees) Hochst.	POACEAE
Aspikots	*Aspilia kotschyi* (Sch. Bip.) Oliv.	ASTERACEAE
Berulasp	*Berula cf. sp.* Coll. no. 1357	APIACEAE
Bidepres	*Bidens prestinaria* (Sch.Bip.) Cuf.	ASTERACEAE
Biopumbr	*Biophytum umbraculum* Welw.	OXALIDACEAE
Bracbriz	*Brachiaria brizantha* (A. Rich) Stapf.	POACEAE
Chammimo	*Chamaecrista mimosoides* (L) Greene	FABACEAE
Chlorisp	*Chloris sp.*	POACEAE
Cleralat	*Clerodendrum alatum* Gürke	VERBENACEAE
Coelafra	*Coelorhachis afraurita* (Stapf.) Stapf.	POACEAE
Commelsp	*Commelina sp.* Coll. no. 1294	COMMELINACEAE
Commschw	*Commelina schweinfurthii* C.B. Clarke	COMMELINACEAE
Crascrep	*Crassocephalum crepidioides* (Benth.) S. Moore	ASTERACEAE
Crasrube	*Crassocephalum rubens* (Juss ex. Jacq) S. Moore	ASTERACEAE
Crotkara	*Crotalaria karagwensis* Taub.	FABACEAE
Crotasp1	*Crotalaria sp.* Coll. no. 1370 (vegetative material)	FABACEAE
Crotasp2	*Crotalaria sp.* Coll. no. 1412	FABACEAE
Cypeaeth	*Cyperus aethiops* Ridley	CYPERACEAE
Cypehasp	*Cyperus haspan* L	CYPERACEAE
Cyperusp	*Cyperus sp.* Coll. no. 1298	CYPERACEAE
Cyphossp	*Cyphostemma sp.* Coll. no. 1372	VITACEAE
Desmunci	*Desmodium uncinatum* (Jacq.) DC	FABACEAE
Digilong	*Digitaria longiflora* (Retz.) Pers.	POACEAE
Dispersp	*Disperis sp.* Coll. no.1410	ORCHIDACEAE
Disscane	*Dissotis canescens* (Graham) Hook. F.	MELASTOMATACEAE
Dorstrop	*Dorstenia tropaeolifolia* (Schweinf.) Burr.	MORACEAE
Eleuindi	*Eleusine indica* (L) Gaertn.	POACEAE
Erioabys	*Eriocaulon abyssinicum* Hochst.	ERIOCAULACEAE
Eriobrac	*Eriochrysis brachypogon* (Stapf.) Stapf.	POACEAE
Eriosesp	*Eriosema sp.* Coll. no. 1312b (vegetative material)	FABACEAE
Fimbferr	*Fimbristylis ferruginea* (L) Vahl. ssp. *sieberiana*	CYPERACEAE
Gnidchry	*Gnidia chrysantha* (Solms-Laub.) Gilg.	THYMELAEACEAE
Guizscab	*Guizotia scabra* Vis.(Chiov.)	ASTERACEAE
Habenasp	*Habenaria sp.* Coll. no.1380	ORCHIDACEAE
Hibicann	*Hibiscus cannabinus* L	MALVACEAE
Hypabrac	*Hyparrhenia bracteata* (Humb. & Bonpl. Ex Willd.) Stapf.	POACEAE
Hypelala	*Hypericum lalandii* Choisy	CLUSIACEAE
Hyposchi	*Hypoxis schimperi* Baker	HYPOXIDACEAE
Indibrev	*Indigofera brevicalyx* Baker	FABACEAE
Indigosp	*Indigofera sp.* Coll. no.1397	FABACEAE
Kohacocc	*Kohautia coccinea* Royle	RUBIACEAE
Kotsafri	*Kotschya africana* Endl.	FABACEAE
Laggcris	*Laggera crispata* (Vahl) Hepper & Wood	ASTERACEAE

Leerhexa	*Leersia hexandra* Sw.	POACEAE
Lipochin	*Lipocarpha chinensis* (Osb.) Kern.	CYPERACEAE
Loudarun	*Loudetia arundinacea* (Hochst. ex A. Rich) Steud.	POACEAE
Loudphra	*Loudetia phragmitoides* (Peter) C.E. Hubb.	POACEAE
Ludwerec	*Ludwigia erecta* (L) H. Hara.	ONAGRACEAE
Mukimade	*Mukia maderaspatana* (L) M.J. Roem.	CUCURBITACEAE
Murdtenu	*Murdannia tenuissima* (A. Chev) Brenan	COMMELINACEAE
Micracsp	*Micractis cf. sp.* Coll. no.1301	ASTERACEAE
Nephundu	*Nephrolepis undulata* (Sw.) J. Sm.	OLEANDRACEAE
Oldelanc	*Oldenlandia lancifolia* (Schumach) DC var. *scabridula*	RUBIACEAE
Oxalanth	*Oxalis anthelmintica* A. Rich.	OXALIDACEAE
Panicsp1	*Panicum sp.* Coll. no. 1288	POACEAE
Panicsp2	*Panicum sp.* Coll. no. 1403	POACEAE
Paspscro	*Paspalum scrobiculatum* (L)	POACEAE
Petiolat	*Unknown petiolate grass* Coll. nos. 1307,1311	POACEAE
Phylboeh	*Phyllanthus boehmii* Pax. *var. boehmii*	EUPHORBIACEAE
Pilithon	*Piliostigma thonningii* (Schumach.) Milne-Redh.	FABACEAE
Platrotu	*Platostoma rotundifolium* (Briq.) A. J. Paton	LAMIACEAE
Plecpunc	*Plectranthus punctatus* L. Herit.	LAMIACEAE
Plectrsp	*Plectranthus sp.* Coll. no. 1398	LAMIACEAE
Plecvari	*Plectocephalus varians* (A.Rich.) C. Jeffrey ex Cufod.	ASTERACEAE
Polypers	*Polygala persicarifolia* DC	POLYGALACEAE
Polypeti	*Polygala petitiana* A. Rich.	POLYGALACEAE
Pycnniam	*Pycnostachys sp. aff. P. niamniamensis* Gürke	LAMIACEAE
Rhynsubq	*Rhynchospora subquadrata* Cherm.	CYPERACEAE
Rottcoch	*Rottboellia cochinchinensis* (Lour.) Clayton	POACEAE
Saccrige	*Sacciolepis rigens* (Mez) A. Chev.	POACEAE
Sclefoli	*Scleria foliosa* Hochst. ex A. Rich.	CYPERACEAE
Sclegrei	*Scleria greigiifolia* (Ridley) C.B. Clarke	CYPERACEAE
Sclewood	*Scleria woodii* C.B.Cl. var. *ornata* (Cherm) Sch.-Motel	CYPERACEAE
Sennobtu	*Senna obtusifolia* (L.) Irwin & Barneby	FABACEAE
Setaincr	*Setaria incrassata* (Hochst) Hack.	POACEAE
Setapumi	*Setaria pumila (*Poir.) Roem. & Schult.	POACEAE
Sperchae	*Spermacoce chaetocephala* DC	RUBIACEAE
Sperspha	*Spermacoce sphaerostigma* (A. Rich) Vatke	RUBIACEAE
Swerabys	*Swertia abyssinica* Hochst.	GENTIANACEAE
Termlaxi	*Terminalia laxiflora* Engl. & Diels	COMBRETACEAE
Verncyli	*Vernonia cylindrica* Sch. Bip. ex Walp	ASTERACEAE
Vitedoni	*Vitex doniana* Sweet	VERBENACEAE

3.3 Detrended Correspondence Analysis

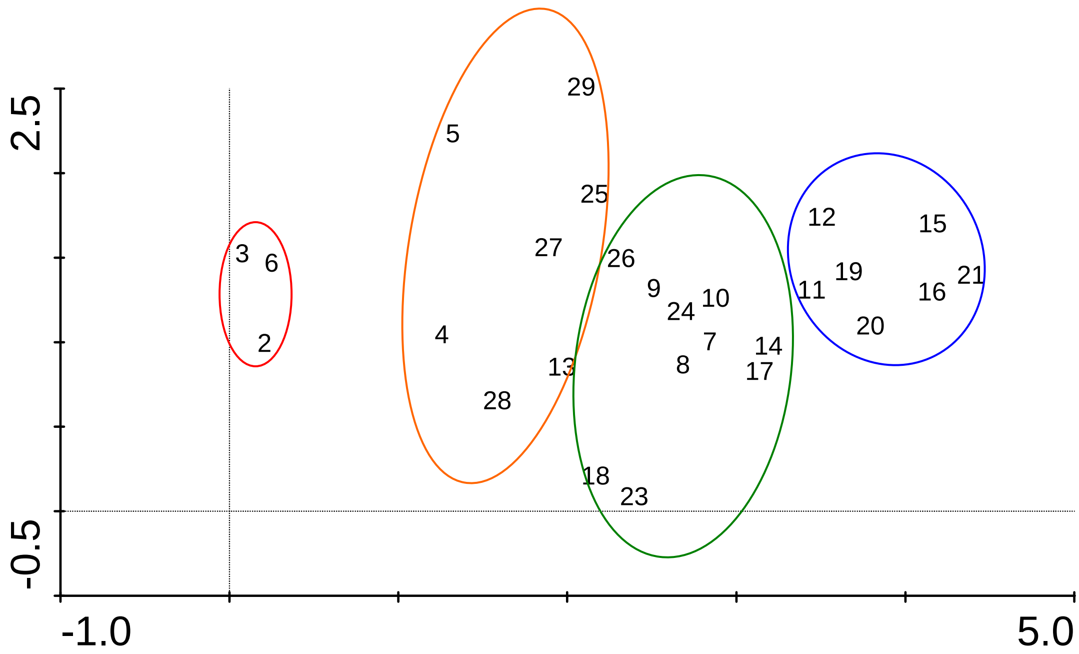

Figure 7. Detrended Correspondence Analysis (DCA) ordination diagram of 27 plots, arranged by DCA axis 1 and 2. The x-axis is DCA axis 1 (eigenvalue = 0.617), the y-axis is DCA axis 2 (eigenvalue = 0.219). The axes are scaled in S.D. units. The circles outline the four plot groups identified by TWINSPAN. Two outlying plots, 1 and 22, and six outlying species were removed from the data before analysis.

The ordination diagram in Figure 7 was prepared using a modified version of the species-plot matrix, with two outlying plots, 1 and 22, and six outlying species: *Coelorhachis afraurita, Digitaria longiflora, Disperis sp., Eleusine indica, Hypericum lalandii,* and *Laggera crispata* removed from the matrix before analysis to make the ordination diagram clearer.

Axis 1 had an Eigenvalue of 0.617, which explained 18.7% of the total variation (total inertia) in the dataset. This is 5 times the expected average (2.7%) for each axis if there was no structure in the dataset. Axis 2 explained 6.6% of the remaining variation with an Eigenvalue of 0.219 and axis 3 explained a further 4.3%. The total inertia of the ordination was 3.302. The lengths of the axes were 4.2 S.D. units for Axis 1 and 2.3 for Axis 2.

The ordination was based entirely on the variation in species occurrence and abundance in the plots and therefore reflects the same patterns as the TWINSPAN table. The 4 plot associations found in TWINSPAN can be found in the ordination diagram, with group 1 (plots 11, 12, 15, 16, 19, 20, 21) being concentrated at the high/positive end of axis 1 and group 4 (plots 2, 3, 6) at the lower end of axis 1. Groups 2 and 3 are located between these in a central position on both axes. The close clustering of many of the plots suggests a strong correlation between them.

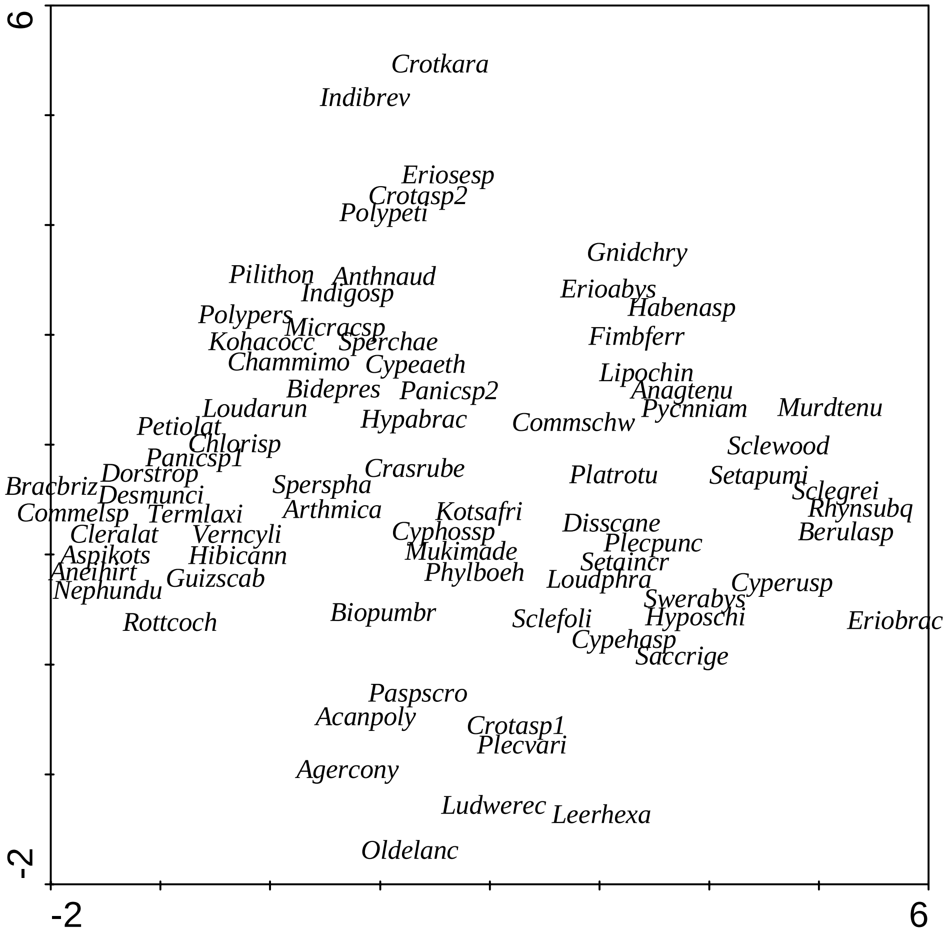

Figure 8. DCA ordination diagram of species optima along a gradient of S.D. units produced using CANOCO. The x-axis is DCA axis 1 (eigenvalue = 0.617), the y-axis is DCA axis 2 (eigenvalue = 0.219) Two outlying plots, 1 and 22, and six outlying species: *Coelorhachis afraurita, Digitaria longiflora, Disperis sp., Eleusine indica, Hypericum lalandii* and *Laggera crispata* were removed from the data before analysis.

The species arrangement in the ordination in Figure 8 corresponds largely to the species sequence generated by TWINSPAN in terms of species groupings in different parts of the diagram (but note that 82 species are included in the ordination diagram and only 60 in the final TWINSPAN output). There is a general division down the middle of the diagram between species found in TWINSPAN associations A and B on the right hand side of the diagram, with positive scores on DCA axis 1, and those on the left, at the negative end of the axis, which correspond largely to the species found in TWINSPAN species associations C and D.

DCA axis 1, which displays the main axis of variation in species composition of the plots in Figure 7 and the species optima of all species in Figure 8, is taken to represent the main environmental gradient determining species composition in the vegetation sampled. Axis 2 represents another unknown gradient governing species distribution, which acts on the species composition in a perpendicular and unrelated direction to the main gradient on axis 1.

The following graph, Figure 9, was made using axis 1 scores from an ordination produced in the statistics programme R. This ordination was similar to the one produced in CANOCO, but with axis 1 reversed. This means the plots found at the positive end of the scale in Figure 9 and also in Figures 10 and 11 in the next section, are the same as those at the lower end of the scale in the ordinations in Figures 7 and 8. The axis values are also different with respect to the position of the origin/ intersection of the axes, this being more central in the plot cluster in the ordination produced in R.

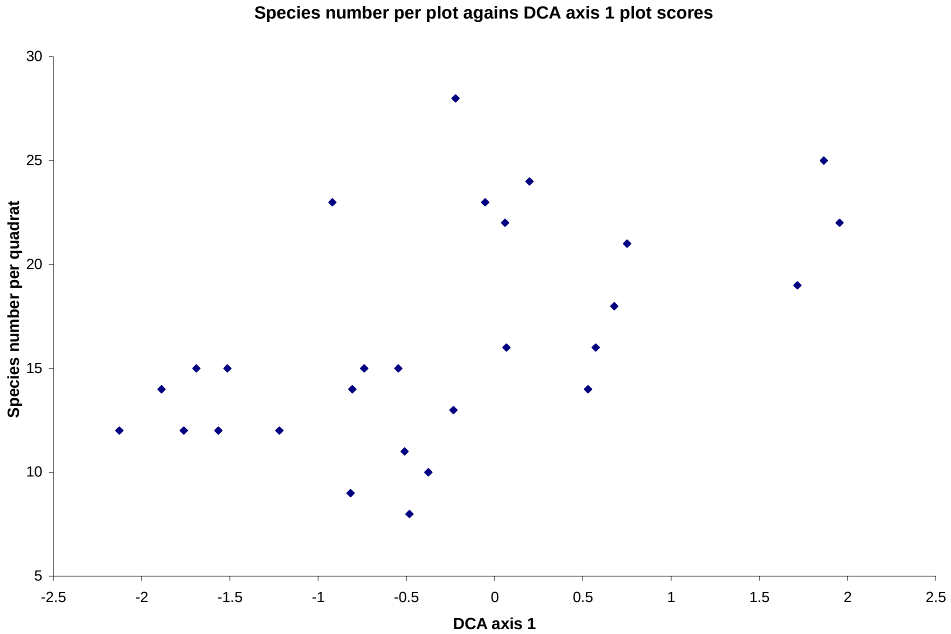

Figure 9. Scatter diagram of correlation between total number of species per plot and the DCA axis 1 scores for each plot.

In Figure 9, a weak but significant positive correlation (Kendall's Rank Correlation Coefficient: $\tau = 0.409$, p-value= 0.0023 (significant to 0.005)) can be seen between species number in the plots and their scores distributed along axis 1 of the DCA ordination from negative to positive scores. (The raw data for this figure is in Appendix C)

3.4 Environmental variables

3.4.1 Moisture gradient

A qualitative assessment of wetness of the soil in each plot is presented below in Table 5. The wetness was hard to estimate and is temporally very variable due to changes in weather and seasonal climate, but a gross separation of the soil moisture into wet (very damp soil or surface water present), intermediate (soil damp but no water present) and dry (soil crumbly, no water present when a hole was dug) was estimated in the field

Wet	Intermediate	Dry
4, 7, 9, 10, 11, 12, 14, 15, 16, 19, 20, 21	5, 8, 13, 17, 18, 23, 24, 26, 27, 28, 29	1, 2, 3, 6, 22, 25

Table 5. Qualitative wetness assessment for each plot

The categories of wetness correspond well to the main environmental gradient on DCA axis 1, with high positive scores on the right representing the 'wet' end of the wetness gradient, while the lower scores on axis 1 represent the dry end. (Note that this is reversed in Figures 9, 10 and 11)

3.4.2 Soil analysis

Soil analysis samples collected from 9 plots in the wetland were compared with soil samples from plots in the surrounding woodland ('Community 3', *Securidaca longipedunculata- Albizia malacophylla* woodland, in Tesfaye Awas, in prep) to establish which variables in the wetland soil analysis were different. (Raw data in Appendix D) An ANOVA analysis was carried out in R:

Soil variable	Mean value wetland	Mean value woodland	p-value (>F)
pH	5.3	5.7	0.007849 **
EC	0.1	0.05	0.001621 **
Total Nitrogen	0.5	0.2	6.324e-06 ***
Organic Carbon	7.6	3.5	1.107e-05 ***
C/N ratio	16.3	15.6	0.3686 n.s.
Phosphorus	9.6	2.8	8.082e-07 ***
Sodium	0.1	0.1	0.2867 n.s.
Potassium	0.1	0.05	0.1569 n.s.
Calcium	6.8	6.3	0.7458 n.s.
Magnesium	2.7	4.2	0.1528 n.s.
Sum Bases	9.7	10.6	0.7442 n.s.
Cation Exchange	34.4	22.2	0.00552 **
Base Saturation	28.1	44.5	0.002528 **

Table 6. Results of ANOVA of wetland soil samples and soil samples from *Securidaca longipedunculata- Albizia malacophylla* woodland surrounding the site.
Significance codes: ‘***’ 0.001 ‘**’ 0.01

Soil variables where P- values are significant (i.e. probability of F value arising by chance alone is lower than 0.05) include pH, Electrical Conductivity, Total Nitrogen, Organic Carbon, Phosphorus, Cation Exchange Capacity (CEC) and Base Saturation.

For pH and Base saturation, the values were significantly lower in the wetland samples than for the surrounding woodland, whereas for Electrical Conductivity, Total Nitrogen, Organic Carbon, Phosphorus and CEC the values were significantly higher in the wetland samples.

A correlation analysis of the soil data variables for the 9 plots sampled with the corresponding plot scores along DCA axes 1 and 2 was carried out using Kendall's Rank Correlation Coefficient to try to establish a link between the main gradients in species composition in the wetland and the soil variables.

The output is shown below in Table 7. The value τ (tau) is the correlation coefficient and in such a small sample its value needs to be over 0.5 for a correlation to be significant (or below -0.5 for a negative correlation to be significant) i.e. have a significance probability (P-value) below 0.05.

	Axis 1		**Axis 2**	
Soil variable	**τ**	**p-value**	**τ**	**p-value**
pH	0.03	0.91	0.15	0.59
EC	0	1	0.11	0.76
Total Nitrogen	-0.22	0.47	0.11	0.76
Organic Carbon	-0.33	0.26	0	1
C/N ratio	0.25	0.34	-0.31	0.25
Phosphorus	0.55	0.045 *	-0.22	0.48
Sodium	-0.087	0.74	-0.14	0.59
Potassium	0.286	0.28	0.06	0.83
Calcium	0.055	0.92	0.28	0.36
Magnesium	0.16	0.61	0.056	0.92
Sum Bases	0	1	0.22	0.48
Cation Exchange	0.11	0.76	0.22	0.48
Base Saturation	-0.17	0.52	0.57	0.035 *

Table 7. Kendall's Rank Correlation Coefficient of soil variables against plot scores of DCA axis 1 and 2 for the 9 plots with soil data. (Plots 1, 4, 8, 10, 17, 19, 23, 27, 28) A significance probability below 0.05 is marked with *

Significant correlations were found between axis 1 and phosphorus concentration, and between axis 2 and base saturation. These are displayed in the scatter plots overleaf.

The weak positive correlation between axis 1 and soil phosphorus can be seen below in Figure 10.

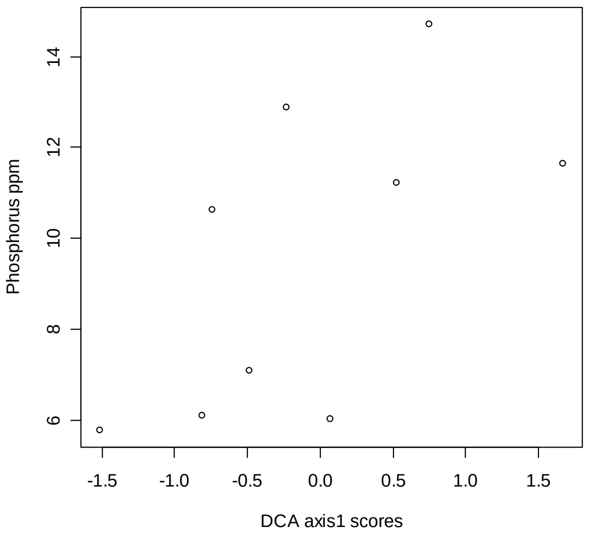

Figure 10. Scatter plot made in R of correlation between Phosphorus and DCA axis 1 scores.
$\tau = 0.55$, P- value = 0.045 (significant to 0.05)

The weak positive correlation between DCA axis 2 scores for the 9 wetland plots and Base Saturation is shown below.

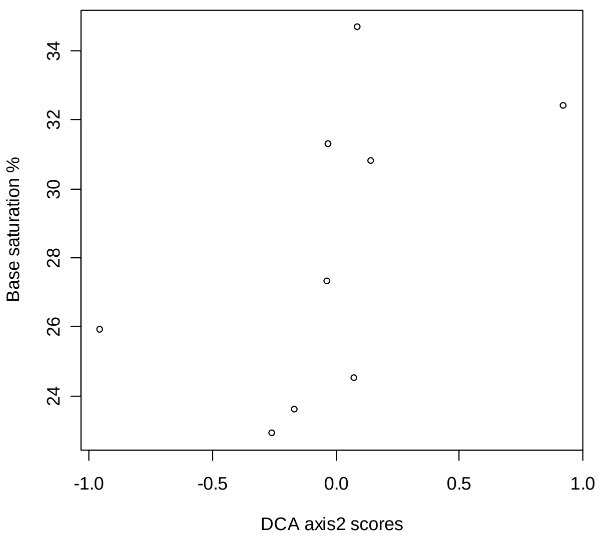

Figure 11. A scatter plot of the correlation between DCA axis 2 plot scores and Base Saturation %.
$\tau = 0.57$, P- value = 0.035 (significant to 0.05)

3.5 Seed bank analysis

The species composition and seedling number of the soil seed bank samples from the 29 plots is summarised in Table 8. A total of 703 seedlings germinated. These comprised 28 different species in 13 families and at least 25 different genera. Of all the species germinated, 19 were fully identified to species level, and a further 4 to genus level and 5 to family level. Over half the species, 16 (57%) were found in the seed bank only, while the remaining 12 were also found during the species abundance analysis in the field.

The fully identified species could be divided into 6 annual species, 3 annual or short lived perennial species and 10 perennial species, giving an approximate 1:1 ratio of annual to perennial species. Of the germinated species represented, 6 (21%) were monocots, of the families Poaceae and Cyperaceae, 21 (75%) of the species were herbaceous dicots, and 1 species was a dicot tree in the genus *Ficus,* Moraceae. Habitat information found in the Flora of Ethiopia and Eritrea indicated that 9 of the identified species were plants of wet or damp habitats and 10 were plants of both wet and dry or mainly dry habitats.

The most common family in the seed bank was Asteraceae with 6 (21%) of the species but this was not the most abundant family, representing only 4% of the total seedling number. Another speciose but less abundant family was Lamiaceae, with 4 (14%) of the species total but only 2% of the seedling total. These were not possible to identify since the Lamiaceae volume of the Flora of Ethiopia and Eritrea is not yet published.

The most abundant families in the seed bank were Rubiaceae with 49% of the seedling total and Cyperaceae with 31% of the seedling total, but each family represented only 11% of the total species number, each having 3 species. This abundance is due to the presence of the following species with a high seedling number: *Cyperus haspan*, with 189 seedlings (27% of total abundance), *Oldenlandia goreensis* and *O. lancifolia* with 217 seedlings (31%) and 123 seedlings (17%), respectively.

In terms of the species and seedlings distribution in the plot samples, the numbers were very variable. The sample with the highest diversity was from plot 4, with a total of 10 species. The lowest diversity was found in sample 21, with 1 species, the unidentified *Cyperus*. The average species diversity per plot was 4.7. The highest seedling number was found in sample 8 with 133 seedlings, nearly all of them *Oldenlandia.* The lowest seedling number germinated was 2, in sample 11. The average seedling number germinated was 24, but this number is not very representative of the samples, since many samples had a low number of seedlings whilst a few had a large number of seedlings. The standardised mean number of seeds per kg of soil was 49.5, calculated from the seedling number per plot divided by the weight of the soil sample.

Figure 12. The seed bank samples approximately three weeks after the start of the experiment. The plants in the centre at the front are *Galinsoga parviflora* and *Bidens pilosa.*

Seed bank result tables overleaf:

Table 8 a) Seed bank results: Number of seedlings of each species in each sample, samples 1 to 17. W/B: W= wetland plant, B= 'Both' wet and dry habitats recorded. A/P: A= annual, P= perennial, A/P= annual or short lived perennial. Species found in the seed bank only are marked in red and include their authority. Dominant species in the seed bank are marked in bold.

Table 8 b) Seed bank results: Number of seedlings of each species in each sample, samples 18 to 29. 'T Seedling': Total number of seedlings per species, 'T Sample': Total number of samples the species occurs in. The mean values in the lower right corner of the table relate to the samples, and are the mean number of seedlings per sample (24.2), mean number of species per sample (4.76), and the mean number of seeds per kg of soil (S/kg) (49.5)

W/B	A/P	Family	**Species** **Sample >**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
B	A	Asteraceae	*Ageratum conyzoides*				6													
W	P	Primulaceae	*Anagallis tenuicaulis*					1				11			2			1		
B	A	Asteraceae	*Bidens pilosa* L			2		1												
W	P	Cyperaceae	*Bulbostylis clarkeana* Bodard				6			4				1				1	1	3
B	A/P	Fabaceae	*Chamaecrista mimosoides*						1											
W	P	Poaceae	*Coelorhachis afraurita*			1														
B	A	Asteraceae	*Conyza sumatrensis* (Retz.) E.H. Walker										1							
B	A	Asteraceae	*Crassocephalum crepidioides*				1													
W	A/P	Cyperaceae	***Cyperus haspan***	2		2	10			9	7	53	1			3	23		1	17
B	A	Asteraceae	*Dichrocephala integrifolia* Kuntze																	
W	P	Melastomataceae	*Dissotis canescens*				1			2		1	1	1			3	1		
B	A	Asteraceae	*Galinsoga parviflora* Cav.																	
B	P	Malvaceae	*Hibiscus calyphyllus* Cav.		7	1														
W	P	Clusiaceae	*Hypericum lalandii*		1			1							9		1			
W	P	Poaceae	*Leersia hexandra*				1													
W	P	Onagraceae	*Ludwigia erecta*							2	2		1			1				
B	A/P	Rubiaceae	***Oldenlandia goreensis* L.**	2		1		1	16		70					3	4	2		6
W	P	Rubiaceae	***Oldenlandia lancifolia* var. *scabridula***	2			37	1			50	10	1			1				2
B	P	Poaceae	*Paspalum scrobiculatum*			1	3				3		1			1		1		
		Cyperaceae	Unidentified *Cyperus* sp.				1									1				
		Fabaceae	Unidentified Fabaceae													1				
		Moraceae	Unidentified *Ficus* sp.	2																
		Lamiaceae	Unidentified Lamiaceae A				2									2?				
		Lamiaceae	Unidentified Lamiaceae B	2																
		Lamiaceae	Unidentified Lamiaceae C								1		1							
		Campanulaceae	Unidentified *Lobelia* sp.																	
		Lamiaceae	Unidentified *Plectranthus* sp.																	
		Rubiaceae	Unidentified woody Rubiaceae													2			4	
			Total seedling number in sample	10	8	8	68	5	17	17	133	75	7	2	11	13	31	6	6	28
			Total sp number in sample	5	2	6	10	5	2	4	6	4	7	2	2	8	4	5	3	4
			Seed number per kg of soil	13	7.4	12	105	7.8	16	30	268	164	23	6.6	23	24	65	21	19	60

Table 8a) Seed bank results: W/B: W= wetland plant, B= 'Both' wet and dry habitats recorded. A/P: A= annual, P= perennial, A/P= annual or short lived perennial.

Family	**Species** **Sample >**	18	19	20	21	22	23	24	25	26	27	28	29	T Seedling	T Sample
Asteraceae	*Ageratum conyzoides*					12			1					19	3
Primulaceae	*Anagallis tenuicaulis*							1		1		1	2	20	8
Asteraceae	*Bidens pilosa* L	2												5	3
Cyperaceae	*Bulbostylis clarkeana* Bodard		2						1					19	8
Fabaceae	*Chamaecrista mimosoides*													1	1
Poaceae	*Coelorhachis afraurita*						2							3	2
Asteraceae	*Conyza sumatrensis* (Retz.) E.H. Walker								1					2	2
Asteraceae	*Crassocephalum crepidioides*			1				1						3	3
Cyperaceae	***Cyperus haspan***		2	1		1	22			4		25	6	189	18
Asteraceae	*Dichrocephala integrifolia*			1										1	1
Melastomataceae	*Dissotis canescens*	1				2			2					15	10
Asteraceae	*Galinsoga parviflora*	1												1	1
Malvaceae	*Hibiscus calyphyllus*													8	2
Clusiaceae	*Hypericum lalandii*		1				1			1	1		1	17	9
Poaceae	*Leersia hexandra*													1	1
Onagraceae	*Ludwigia erecta*						1	1					1	9	7
Rubiaceae	***Oldenlandia goreensis* L.**	20	2	2			15		35		2	29	7	217	17
Rubiaceae	***Oldenlandia lancifolia* var. *scabridula***	1					15	1			2			123	12
Poaceae	*Paspalum scrobiculatum*		1	2							1	1		15	10
Cyperaceae	Unidentified *Cyperus* sp.		1		5									8	4
Fabaceae	Unidentified Fabaceae					3								4	2
Moraceae	Unidentified *Ficus* sp.													2	1
Lamiaceae	Unidentified Lamiaceae A										1			3	2
Lamiaceae	Unidentified Lamiaceae B	1								1		1		5	4
Lamiaceae	Unidentified Lamiaceae C											1		3	3
Campanulaceae	Unidentified *Lobelia* sp.										1			1	1
Lamiaceae	Unidentified *Plectranthus* sp.					3								3	1
Rubiaceae	Unidentified woody Rubiaceae													6	2
	Total seedling number in sample	26	9	7	5	21	56	4	40	7	8	58	17	**703**	24.2
	Total sp number in sample	6	6	5	1	5	6	4	5	4	6	6	5	4.76	< ^ means
	Seed number per kg of soil	54	31	25	14	67	95	8.7	84	18	17	118	40	49.5	Mean S/kg

Table 8 b)

4 Discussion

4.1.1 What is the taxonomic composition of the wetland flora and what can be said about its origins/ affinities?

In terms of abundance, wetland vegetation was clearly dominated by monocots, with the tussock forming grasses *Hyparrhenia bracteata, Loudetia phragmitoides* , and the three Cyperaceae species in the genus *Scleria* being the most dominant elements in the vegetation, with 6, 8 and 9% of the total abundance values, respectively (work out % abundance!) The two dominant grasses were dominant in 68% of the plots, and the *Scleria* species in 20% of the plots. Non tussock forming grasses such as *Setaria incrassata* (4% of total abundance) and sedges such as *Cyperus haspan* (2% of total abundance) were a further important element of the monocots present. Common dicots included *Phyllanthus boehmii, Dissotis canescens,* and *Commelina schweinfurthii*, found in 62, 51 and 51% of the plots, respectively. These grew intermingled with the tussock grasses or below them as part of the ground layer in the case of *Phyllanthus.*

This type of *Loudetia* dominated wetland vegetation can be found in other areas of similar climate and elevation in North East Africa, most notably as part of the *Miscanthus violaceus* zone in the high altitude *Cyperus papyrus* swamps in Uganda, where the grass is dominant or co dominant with *Miscanthus* in the centre of the zone. A number of species common in the wetland such as *Cyperus haspan, Dissotis canescens* and the wetland grass *Leersia hexandra* are also associates of this *Miscanthus* community (White, 1983).

In terms of associations with other wetland communities within Ethiopia, the analysed wetland has many species in common with the large wetlands in Gambela and Kaffa (the old *woreda* name for a region in the Southern Regional State). From the few studies conducted on wetlands in Ethiopia (Zerihun Woldu, 2000, Dixon, 2002) it is clear that many of these are dominated by Cyperaceae species especially *Cyperus latifolius*, known as *cheffe.*

Information on patterns outside Ethiopia for the species in the analysed wetland was found on the web database GBIF (Global Biodiversity Information Facility). This database is still in its infancy and had relatively few records for most of the species, but proved useful in getting an approximate idea of centres of distribution within Africa. The number of accessions of a species in the database when compared to the number of countries the species was distributed in also gave an indication of its rarity/ commonness.

The species in the wetland ranged from narrow endemics to near cosmopolitan in their distribution ranges, and from common pantropical weeds to rare wetland species.

Many of the wetland plants such as the three Commelinaceae species *Murdannia tenuissima, Commelina schweinfurthii* and *Aneilema hirtum* have their main centres of distribution to the west and south of Ethiopia in central Africa and reach the eastern end of their range in Benishangul. The local and possibly endemic subspecies *Pycnostachys* sp. aff. *niamniamensis* is closely allied to the species *P. niamniamensis* from Sudan. The Sudd and the swamps of southern Sudan are likely to have similar associate species to the wetlands of southern and western Ethiopia. Other species with a western distribution, which have the eastern edge of their range in western Ethiopia include the dominant sedge *Scleria woodii* and the wetland grass *Sacciolepis rigens.*

4.1.2 Is there a vegetation community structure in the wetland and if so, what communities can be identified?

From comparison with surrounding vegetation, analysed by Tesfaye Awas (in prep.) it is clear that the vegetation in the wetland is significantly different, having only 9 species in common with plots analysed in nearby vegetation, these species being either trees found as individual seedlings in the wetland or overhanging the edge of the sampled part of the wetland, or non wetland plants characteristic of the margins of the wetland.

The comparison of soil analysis results from the wetland and the surrounding woodland using ANOVA revealed significantly higher values in the wetland for a number of soil variables. The organic carbon, nitrogen and phosphorus content of the soil was higher than in the surrounding woodland, as were values for Electrical Conductivity and Cation Exchange Capacity (CEC). Values for pH and Base Saturation were lower in the wetland than in surrounding woodland. These two soil variables are of course linked, both being based on the balance of positive and negative free ions in the soil.

The differences in some of these soil variables are largely due to differences in the hydrological regime and distance to the water table. The wetland stays moist for all or most of the year and anaerobic conditions in the soil lead to a build up of organic matter, increasing the organic carbon value. The wetland soil also has a higher clay content, as indicated by the high CEC.

The trace nutrient content of a wetland is affected by the type of materials washed into it from the surroundings and in this wetland a lot of the nutrients, especially phosphorous, come from ash washed into the wetland from the surrounding vegetation, which burns annually. This accounts for the higher phosphorous content in the wetland.

It is clear that the wetland forms a vegetation community separate from the surrounding woodland but what about the vegetation structure within the wetland?

The results of TWINSPAN identified four main divisions of the plots into ‘communities’ based on indicator species found only or predominantly in one of the plot groups. A similar division of the species also produced four main ‘species associations’. The middle two divisions of the plots contained species distributed throughout all the plots and do not have any clear indicator species. The division on the left, matching the group at the positive end of Axis 1 on the DCA, groups the 7 plots found in the wettest part of the wetland. The indicator species for this group included the 2 species of *Scleria*, *Scleria woodii* and *Scleria greigiifolia,* so this can be considered the ‘*Scleria* community’. The group on the far right included the 4 plots found at the negative end of DCA axis 1, at the dry end of the hypothesised environmental gradient. These plots were marginal in the wetland and contained many non wetland plants. Many indicator species for this split were put forward by TWINSPAN, but only a few are found exclusively in group 4. *Aneilema hirtum* is one of these, so this plot group could be considered the ‘*Aneilema* community’.

The correlation between plot species diversity and position along DCA axis1, interpreted as the main gradient of environmental variation, in this case, soil moisture, shows that ‘drier’ plots such as 1, 2, 3, and 6, and found in groups 3 and 4 of the TWINSPAN analysis have a higher species diversity than ‘wet’ plots such as 15, 16, 20 and 21. Some possible reasons for this can be found when the features of the drier plots are studied more closely. The drier plots are marginal between the forest and the wetland, and marginal habitats usually have a higher species diversity. They may also be subject to greater disturbance than plots at the core of the wetland. The ecotone between forest and wetland may provide a more mesic environment, which a greater number of species can tolerate, than the wetland or the forest itself provides. This explains the lower species number in the ‘wet’ plots at the wetland’s core. These plots are in a more stable environment and are subject to less disturbance, and contain species with different life history traits to those on the wetland margins.

4.1.3 What is the composition of the (dry soil) seed bank of the wetland, how does it compare to the above ground flora, and what implications does this have for the wetland flora in case of disturbance?

The species composition of the seed bank comprised 28 different species in 13 families. Of these, 57% were species found in the seed bank only and not in the field during data collection. There was an approximate 1:1 ratio of annual to perennial species, and about a quarter of the species were monocots, of the families Poaceae and Cyperaceae, while a further three quarters were herbaceous dicots in the families Asteraceae, Lamiaceae and Rubiaceae. Weedy species in these families are known to produce copious seeds. Habitat information indicated that 9 of the identified species were plants of wet or damp habitats and 10 were plants of both wet and dry or mainly dry habitats.

There seemed to be no correlation between the seed bank species composition and the plots they were sampled from. This is perhaps not surprising since seed deposition is highly stochastic and variable across such a small area and the sample number was low. A larger area and more samples would have to be studied to find spatial patterns in the seed bank.

The mean number of seeds per kg of soil was 49.5, a value that appears to be low, but again relates to the variable nature of the wetland seed bank, with some samples containing no seeds at all while others have hundreds or even thousands of seeds, often of one predominant species (Leck *et al.* 1989)

Over half the species present in the seed bank were not found in the wetland during data collection. It is likely that some of these species grow in the wetland at a different time of year, whilst others may have germinated from seeds of species dispersed into the wetland which do not normally grow there. This may be the case for a number of the weedy species found in the seed bank, which have dispersed to the wetland thanks to their large production of seed with good dispersal potential, and are opportunists which germinate as a response to disturbance. If the wetland is subject to any major disturbance in the future, such as drainage and crop cultivation, these species will become more dominant elements of the vegetation, and the abundance and species diversity of wetland plants will decline

A limitation of this seed bank study was the use of dry rather than wet soil in the analysis. This was a necessity since the samples were to be stored and transported and could not be germinated immediately. The consequence of this is that any seeds that do not tolerate drying will be missed by the analysis, since we followed the 'emergence method' (Gross, 1990) and only counted seeds that germinated from the soil. The soil treatments prior to germination will most likely have destroyed any other underground perennating organs like corms and turions.

It is perhaps surprising that so few Poaceae and Cyperaceae species occurred in the seed bank, since these were dominant in the above ground vegetation sampled. There are two possible reasons for this. One is that the seeds of many of the species found in the field do not tolerate drying, but this seems unlikely considering the nature of grass and sedge seeds. The other more likely explanation is that many of the species of perennial grasses and sedges do not have a dormant seed bank in the soil, but that new plants germinate from last years seeds, and that all of these seeds either germinate or die and do not have the longevity required to establish a seed bank. The seed bank samples collected did not contain this element, perhaps because the seeds from the same year were removed along with the top layer of soil, or because many of the dominant grass species had not reached maturity. These species appear not to flower and shed their seeds until the start of the dry season, which occurred after our sampling in October.

5 Conclusion

The wetland was dominated by the tall grasses *Loudetia phragmitoides* and *Hyparrhenia bracteata* as well as a diverse collection of Cyperaceae species. Many of the species found had a west African distribution pattern, and others were elements of the *Miscanthus* swamp community found in East Africa. Some species found were rare in Ethiopia and 3 endemic species were also found.

The interpretation of the data analysis output from TWINSPAN , DCA and the correlation tests led to the conclusion that two main ‘community types’ were present in the wetland: The *Scleria* community at the wetter core of the wetland and the *Aneilema* community in the margins and drier parts of the wetland. The main environmental gradient governing species composition was hypothesised to be a gradient in wetness, determined by distance to the water table and duration of flooding during the year.

The seed bank experiment showed that few of the ‘obligate’ wetland plants found in the field data had a seed bank, or at least one which tolerated drying. The wetland soil did however contain a seed bank of many non wetland species, many of them opportunist weeds, and these are likely to become more dominant in the vegetation if the wetland is subject to disturbance and/or drying out in the future.

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Appendix A: Complete species list

with species code (n/a = not in data matrix), habitat information and collection number (Tesfaye Awas' accession numbers)
Habitat codes:
W= only found in damp or wet habitats- wetlands, ditches, seasonally flooded grassland and streambanks.
B= found both in wet and dry habitats, mostly opportunistic weeds.
N= habitat information does not include wet or damp habitat.

Species code	Species name and authority	Family	Habitat type	Collection number
Acalvill	*Acalypha villicaulis* Hochst. ex A. Rich.	EUPHORBIACEAE	B	870
Acanpoly	*Acanthus polystachyus* Delile	ACANTHACEAE	B	1196
Agercony	*Ageratum conyzoides* L	ASTERACEAE	B	1317
Anagtenu	*Anagallis tenuicaulis* Bak.	PRIMULACEAE	B	1353
Aneihirt	*Aneilema hirtum* A. Rich	COMMELINACEAE	B	1296, 1448
Anthnaud	*Antherotoma naudinii* Hook.	MELASTOMATACEAE	B	1284, 1309
Arthmica	*Arthraxon micans* (Nees) Hochst.	POACEAE	N	1295, 1489
n/a	*Ascolepis capensis* (Kunth) Ridley	CYPERACEAE	W	1390A
Aspikots	*Aspilia kotschyi* (Sch. Bip.) Oliv.	ASTERACEAE	B	437
Berulasp	*Berula* cf. *sp.* Coll. no. 1357	APIACEAE	W	1357
Bidepres	*Bidens prestinaria* (Sch.Bip.) Cuf.	ASTERACEAE	B	1349B, 1487
Biopumbr	*Biophytum umbraculum* Welw.	OXALIDACEAE	B	1364, 1369
Bracbriz	*Brachiaria brizantha* (A. Rich) Stapf.	POACEAE	N	1310, 1457
n/a	*Brachiaria jubata* (Fig & De Not.) Stapf.	POACEAE	B	1306
n/a	*Canarina abyssinica* Engl.	CAMPANULACEAE	-	1422
Chammimo	*Chamaecrista mimosoides* (L) Greene	FABACEAE	B	1303
Chlorisp	*Chloris sp.*	POACEAE	-	-
Cleralat	*Clerodendrum alatum* Gürke	VERBENACEAE	-	1421
Coelafra	*Coelorhachis afraurita* (Stapf.) Stapf.	POACEAE	W	1400
Commelsp	*Commelina sp.* Coll. no. 1294	COMMELINACEAE	-	1294
Commschw	*Commelina schweinfurthii* C.B. Clarke	COMMELINACEAE	N	1327
Crascrep	*Crassocephalum crepidioides* (Benth.) S. Moore	ASTERACEAE	W	1291
Crasrube	*Crassocephalum rubens* (Juss ex. Jacq) S. Moore	ASTERACEAE	B	1394, 1444

Crotkara	*Crotalaria karagwensis* Taub.	FABACEAE	N	1395
n/a	*Crotalaria lachnophora* Hochst ex. A. Rich.	FABACEAE	B	1339
Crotasp1	*Crotalaria sp.* Coll. no. 1370 (vegetative material)	FABACEAE	-	1370
Crotasp2	*Crotalaria sp.* Coll. no. 1412	FABACEAE	-	1313B, 1412
Cypeaeth	*Cyperus aethiops* Ridley	CYPERACEAE	W	1320, 1354
Cypehasp	*Cyperus haspan* L	CYPERACEAE	W	1322
Cyperusp	*Cyperus sp.* Coll. no. 1298	CYPERACEAE	W	1298
Cyphossp	*Cyphostemma sp.* Coll. no. 1372	VITACEAE	-	1372
n/a	*Delphinium dasycaulon* Fresen.	RANUNCULACEAE	N	1418
Desmunci	*Desmodium uncinatum* (Jacq.) DC	FABACEAE	N	1312C, 1430
Digilong	*Digitaria longiflora* (Retz.) Pers.	POACEAE	N	1388
Dispersp	*Disperis sp.* Coll. no.1410	ORCHIDACEAE	-	1410
Disscane	*Dissotis canescens* (Graham) Hook. F.	MELASTOMATACEAE	W	1314
Dorstrop	*Dorstenia tropaeolifolia* (Schweinf.) Burr.	MORACEAE	N	1366a
n/a	*Drosera madagascariensis* DC	DROSERACEAE	W	1382
Eleuindi	*Eleusine indica* (L) Gaertn.	POACEAE	B	1405
n/a	*Eleocharis* cf. *acutangula* (Roxb.) Schult.	CYPERACEAE	W	1391
Erioabys	*Eriocaulon abyssinicum* Hochst.	ERIOCAULACEAE	W	1377
Eriobrac	*Eriochrysis brachypogon* (Stapf.) Stapf.	POACEAE	W	1381
Eriosesp	*Eriosema sp.* Coll. no. 1312b (vegetative material)	FABACEAE	-	1312B
Fimbferr	*Fimbristylis ferruginea* (L) Vahl. ssp. *sieberiana*	CYPERACEAE	W	1389, 1404
Gnidchry	*Gnidia chrysantha* (Solms-Laub.) Gilg.	THYMELAEACEAE	B	-
Guizscab	*Guizotia scabra* Vis.(Chiov.)	ASTERACEAE	N	1341, 1342
Habenasp	*Habenaria sp.* Coll. no.1380	ORCHIDACEAE	-	1380
Hibicann	*Hibiscus cannabinus* L	MALVACEAE	B	-
Hypabrac	*Hyparrhenia bracteata* (Humb. & Bonpl. Ex Willd.) Stapf.	POACEAE	B	1304, 1359, 1411
Hypelala	*Hypericum lalandii* Choisy	CLUSIACEAE	W	1413
Hyposchi	*Hypoxis schimperi* Baker	HYPOXIDACEAE	W	1376
Indibrev	*Indigofera brevicalyx* Baker	FABACEAE	N	-
Indigosp	*Indigofera sp.* Coll. no.1397	FABACEAE	-	1397
Kohacocc	*Kohautia coccinea* Royle	RUBIACEAE	B	1338
Kotsafri	*Kotschya africana* Endl.	FABACEAE	N	-
Laggcris	*Laggera crispata* (Vahl) Hepper & Wood	ASTERACEAE	N	1365
Leerhexa	*Leersia hexandra* Sw.	POACEAE	W	1346

Lipochin	*Lipocarpha chinensis* (Osb.) Kern.	CYPERACEAE	W	1325
Loudarun	*Loudetia arundinacea* (Hochst. ex A. Rich) Steud.	POACEAE	B	1343
Loudphra	*Loudetia phragmitoides* (Peter) C.E. Hubb.	POACEAE	W	1344, 1250
Ludwerec	*Ludwigia erecta* (L) H. Hara.	ONAGRACEAE	W	1386
Micracsp	*Micractis* cf. *sp.* Coll. no.1301	ASTERACEAE	W	1301
Mukimade	*Mukia maderaspatana* (L) M.J. Roem.	CUCURBITACEAE	W	1368
Murdtenu	*Murdannia tenuissima* (A. Chev) Brenan	COMMELINACEAE	W	1360
n/a	*Mussaenda arcuata* Poir.	RUBIACEAE	N	1308
Nephundu	*Nephrolepis undulata* (Sw.) J. Sm.	OLEANDRACEAE	W	1385
n/a	*Nervilia crociformis* (Zoll. & Mor.) Seidenf.	ORCHIDACEAE	N	1366b
n/a	*Nicandra physaloides* (L) Gaertn.	SOLANACEAE	B	1424
Oldelanc	*Oldenlandia lancifolia* (Schumach) DC var. *scabridula*	RUBIACEAE	W	1319
Oxalanth	*Oxalis anthelmintica* A. Rich.	OXALIDACEAE	-	899B
Panicsp1	*Panicum sp.* Coll. no. 1288	POACEAE	-	1288
Panicsp2	*Panicum sp.* Coll. no. 1403	POACEAE	-	1403
Paspscro	*Paspalum scrobiculatum* (L)	POACEAE	B	1305, 1401
Petiolat	*Unknown petiolate grass* Coll. nos. 1307,1311	POACEAE	-	1307, 1311
Phylboeh	*Phyllanthus boehmii* Pax. *var. boehmii*	EUPHORBIACEAE	W	1293
Pilithon	*Piliostigma thonningii* (Schumach.) Milne-Redh.	FABACEAE	B	-
Platrotu	*Platostoma rotundifolium* (Briq.) A. J. Paton	LAMIACEAE	W	1242
Plecpunc	*Plectranthus punctatus* L. Herit.	LAMIACEAE	B	1363
Plectrsp	*Plectranthus sp.* Coll. no. 1398	LAMIACEAE	-	1398
Plecvari	*Plectocephalus varians* (A.Rich.) C. Jeffrey ex Cufod.	ASTERACEAE	B	1371
Polypers	*Polygala persicariifolia* DC	POLYGALACEAE	B	1290
Polypeti	*Polygala petitiana* A. Rich.	POLYGALACEAE	B	1332, 1406
n/a	*Pycnocycla ledermannii* Wolff	APIACEAE	B	1416
Pycnniam	*Pycnostachys sp. aff. P. niamniamensis* Gürke	LAMIACEAE	W	1352
Rhynsubq	*Rhynchospora subquadrata* Cherm.	CYPERACEAE	W	1362, 1375
Rottcoch	*Rottboellia cochinchinensis* (Lour.) Clayton	POACEAE	B	1191
Saccrige	*Sacciolepis rigens* (Mez) A. Chev.	POACEAE	W	1367
n/a	*Schoenoplectus corymbosus* (Roth ex Roem. & Schult.)	CYPERACEAE	W	1383
Sclefoli	*Scleria foliosa* Hochst. ex A. Rich.	CYPERACEAE	W	1297
Sclegrei	*Scleria greigiifolia* (Ridley) C.B. Clarke	CYPERACEAE	W	1355
Sclewood	*Scleria woodii* C.B.Cl. var. *ornata* (Cherm) Sch.-Motel	CYPERACEAE	W	1351

Sennobtu	*Senna obtusifolia* (L.) Irwin & Barneby	FABACEAE	B	-
Setaincr	*Setaria incrassata* (Hochst) Hack.	POACEAE	B	1345, 1373, 1385
Setapumi	*Setaria pumila* (Poir.) Roem. & Schult.	POACEAE	B	1329, 1379
Sperchae	*Spermacoce chaetocephala* DC	RUBIACEAE	N	1328
Sperspha	*Spermacoce sphaerostigma* (A. Rich) Vatke	RUBIACEAE	N	1289, 1451
Swerabys	*Swertia abyssinica* Hochst.	GENTIANACEAE	W	1265, 1419
Termlaxi	*Terminalia laxiflora* Engl. & Diels	COMBRETACEAE	N	238
Verncyli	*Vernonia cylindrica* Sch. Bip. ex Walp	ASTERACEAE	B	1238
Vitedoni	*Vitex doniana* Sweet	VERBENACEAE	N	-

Explanation of labels in **Appendix B**:

TA = Sum of abundance of a species in all plots
TP = Total number of plots a species was present in

`Total ab.` = Sum of abundance values of all species in a plot
`Total sp.` = Total number of species present in a plot

The values in bold in the bottom right hand corner of the table are the total sum abundance of all species in all plots (1713), the mean number of plots per species (5.47) and the mean number of species per plot (16.6).

Appendix B: Species/ plot data matrix

Plots	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	TA	TP
Acalvill	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	1
Acanpoly	6	6	4	5	-	-	-	-	-	-	-	-	6	-	-	-	-	5	-	-	-	-	-	-	-	-	-	6	-	38	7
Agercony	-	-	-	7	-	3	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	3	3	-	2	-	-	3	-	25	7
Anagtenu	-	-	-	-	-	-	-	-	2	3	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	7	4
Aneihirt	7	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	3
Anthnaud	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	4	4
Arthmica	8	6	-	6	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	3	2	2	32	7
Aspikots	-	4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	2
Berulasp	-	-	-	-	-	-	-	-	-	-	1	3	-	-	-	3	-	-	4	4	4	-	-	-	-	-	-	-	-	19	6
Bidepres	5	2	2	-	3	-	-	-	-	-	-	-	2	-	-	-	-	-	2	-	-	-	-	1	-	-	-	-	-	17	7
Biopumbr	-	2	-	1	-	2	-	-	-	-	-	-	3	-	-	-	-	2	-	-	-	-	-	-	-	-	-	2	1	13	7
Bracbriz	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	1
Chammimo	-	1	2	-	4	4	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	1	-	3	-	-	18	7
Chlorisp	-	-	6	3	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	18	4
Cleralat	-	6	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	2
Coelafra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	4	1
Commelsp	7	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	2
Commschw	-	-	-	-	4	-	3	3	5	-	-	-	5	-	-	-	3	2	3	-	3	3	2	4	4	3	-	-	5	52	15
Crascrep	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	5	1
Crasrube	9	3	-	-	-	-	-	-	-	6	-	-	2	2	-	-	-	-	-	-	-	3	-	-	-	-	-	1	-	26	7
Crotasp1	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	2	-	-	1	1	-	-	6	5

Plots	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	TA	TP
Crotasp2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	3	5	3
Crotkara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	1	-	-	-	3	7	3
Cypeaeth	-	-	-	5	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	12	4
Cypehasp	-	-	-	2	-	-	4	-	4	4	-	-	1	2	-	-	-	3	-	4	3	-	4	2	-	-	3	-	-	36	12
Cyperusp	8	-	-	-	-	-	-	-	-	-	2	-	-	-	4	3	2	2	-	-	-	-	-	-	-	-	-	-	-	21	6
Cyphossp	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Desmunci	-	-	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	2
Digilong	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2	1
Dispersp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1
Disscane	-	-	-	5	-	2	4	4	-	3	4	3	3	3	-	4	3	-	3	3	-	-	-	-	-	-	-	3	3	50	15
Dorstrop	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2
Eleuindi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2	1
Erioabys	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	2	-	-	-	-	-	-	-	-	2	-	2	-	3	14	6
Eriobrac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	3	3	-	-	-	-	-	-	-	-	8	3
Eriosesp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	-	-	3	7	3
Fimbferr	-	-	-	2	-	-	-	-	4	-	-	3	-	-	-	3	-	-	2	-	-	-	-	-	3	-	-	-	3	20	7
Gnidchry	-	-	-	-	-	-	-	-	-	1	1	3	-	-	3	-	-	-	-	-	-	-	-	-	1	-	-	-	3	12	6
Guizscab	-	5	8	3	3	5	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	27	6
Habenasp	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	-	-	-	-	-	-	1	-	-	3	-	-	-	1	10	5
Hibicann	4	4	-	-	-	1	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	12	5
Hypabrac	-	4	4	7	8	4	-	6	7	3	4	8	3	3	-	-	-	5	-	-	-	8	2	4	4	9	7	9	9	118	21
Hypelala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1
Hyposchi	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Indibrev	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	2

Plots	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	TA	TP
Indigosp	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	3	-	-	6	4
Kohacocc	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	2
Kotsafri	-	-	-	-	-	-	-	-	-	3	-	-	-	1	-	-	-	3	-	-	-	3	-	-	3	-	4	3	-	20	7
Laggcris	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Leerhexa	6	-	-	-	-	-	-	4	-	-	-	-	-	3	-	-	3	4	-	-	-	-	6	4	-	-	-	-	-	30	7
Lipochin	-	-	-	1	-	-	3	-	-	5	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-	2	15	6
Loudarun	-	-	6	6	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	3
Loudphra	8	6	4	-	-	-	9	9	8	6	8	4	7	7	6	5	7	9	6	2	3	6	6	7	9	-	-	-	-	142	22
Ludwerec	-	-	-	2	-	-	-	-	-	-	-	-	-	1	-	-	-	3	-	2	-	-	4	-	-	-	1	3	1	17	8
Mukimade	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	7	2
Murdtenu	-	-	-	-	-	-	-	-	-	-	-	2	-	2	3	2	-	-	2	-	3	-	-	-	-	-	-	-	1	15	7
Micracsp	5	3	-	4	3	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	19	6
Nephundu	9	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	2
Oldelanc	-	-	-	3	-	-	-	-	2	-	-	-	-	-	-	-	-	3	-	-	-	-	3	-	-	-	-	-	-	11	4
Oxalanth	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1
Panicsp1	9	8	6	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	28	5
Panicsp2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	4	-	4	3	-	3	16	5
Paspscro	-	1	3	4	-	-	2	-	1	-	-	-	-	-	-	-	2	-	-	-	-	-	2	-	-	-	-	-	-	15	7
Petiolat	7	4	6	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	4	-	-	32	6
Phylboeh	9	2	3	3	-	3	-	-	2	3	3	-	3	3	-	-	3	2	-	3	-	2	3	-	3	3	-	-	2	55	18
Pilithon	-	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	4
Platrotu	-	-	-	-	4	-	-	5	5	5	4	-	6	3	-	-	5	-	-	4	-	-	-	2	-	-	-	-	-	43	10
Plecpunc	-	-	-	-	-	-	5	3	-	5	-	-	-	-	-	-	-	2	3	-	-	-	-	-	-	2	-	-	-	20	6
Plectrsp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	6	1

Plots	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	TA	TP
Plecvari	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	5	-	-	-	-	-	4	-	3	-	-	-	14	5
Polypers	6	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	9	3
Polypeti	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	5	2
Pycnniam	-	-	-	-	-	-	-	-	-	-	4	3	3	-	3	-	-	-	3	4	4	-	-	2	-	2	3	-	3	34	11
Rhynsubq	-	-	-	-	-	-	-	-	-	-	-	2	-	1	6	5	5	-	-	-	6	-	-	-	-	-	-	-	-	25	6
Rottcoch	8	3	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	17	4
Saccrige	-	-	-	-	-	-	-	-	-	-	-	-	3	6	-	5	4	3	-	2	-	-	-	-	-	-	-	-	-	23	6
Sclefoli	4	-	-	1	-	-	-	5	-	-	-	-	5	6	-	-	6	5	3	-	2	-	-	-	5	-	-	5	-	47	11
Sclegrei	-	-	-	-	-	-	-	-	-	-	6	6	-	-	4	5	-	-	6	6	6	-	-	-	-	-	-	-	-	39	7
Sclewood	-	-	-	-	-	-	-	-	-	6	6	6	2	6	8	7	3	-	7	7	7	-	-	-	-	-	-	-	3	68	12
Sennobtu	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1
Setaincr	-	-	-	1	2	-	5	-	-	4	4	3	-	3	3	-	4	4	4	5	-	-	6	8	2	6	8	-	-	72	17
Setapumi	-	-	-	-	2	-	-	-	-	-	-	-	-	2	3	4	-	-	-	2	3	-	-	3	-	-	-	-	-	19	7
Sperchae	-	-	-	-	4	4	-	-	-	-	-	-	3	-	-	-	2	-	-	-	-	3	-	1	4	2	2	2	3	30	11
Sperspha	8	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	2	2	-	-	2	-	21	6
Swerabys	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Termlaxi	-	5	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	2
Verncyli	7	4	3	2	1	4	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	7
Vitedoni	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	6	1
Total ab.	153	89	80	73	49	64	36	39	41	60	47	46	76	62	49	51	52	75	51	53	47	65	47	49	63	35	49	43	69	**1713**	**5.47**
Total sp.	23	25	22	21	16	19	9	8	11	15	12	12	24	23	12	14	14	22	15	15	12	18	13	15	23	10	16	14	28	**16.6**	

Appendix C: Plot DCA scores and plot species total

Plot	Total sp. no.	DCA1	DCA2
1	**23**	**1.67122**	**0.92477**
2	25	1.86655	-0.07244
3	22	1.95435	-0.8433
4	**21**	**0.75091**	**-0.95744**
5	16	0.57336	-1.30385
6	19	1.71474	-0.43739
7	9	-0.81615	-0.1633
8	**8**	**-0.48277**	**0.0731**
9	11	-0.5092	-0.16859
10	**15**	**-0.73944**	**0.09047**
11	12	-1.21898	0.07304
12	12	-1.56473	-0.05651
13	24	0.1972	-0.04644
14	23	-0.91907	0.25855
15	12	-1.76087	0.47256
16	14	-1.88779	0.12881
17	**14**	**-0.80707**	**0.14331**
18	22	0.05997	-0.01974
19	**15**	**-1.51449**	**-0.02983**
20	15	-1.6888	-0.25764
21	12	-2.12668	0.05251
22	18	0.67718	1.31941
23	**13**	**-0.23302**	**-0.1671**
24	15	-0.54485	0.03353
25	23	-0.05267	0.28311
26	10	-0.37455	-0.23312
27	**16**	**0.06704**	**-0.03547**
28	**14**	**0.5287**	**-0.25941**
29	28	-0.22221	-0.20217

The DCA axis scores are from the ordination produced in R. Plots highlighted in bold are the 9 plots for which soil variable data was obtained.

Appendix D: Soil analysis data

Plot	pH	E.C.	T.N.	O.C.	C/N	Av. P	Na	K	Ca	Mg	Sum Base	CEC	Base Sat
1	5.3	0.08	0.42	7.06	17	11.64	0.00	0.10	9.88	3.87	13.85	42.8	32
4	5.0	0.09	0.45	8.03	18	14.72	0.10	0.09	6.39	3.13	9.70	37.4	26
8	5.1	0.12	0.62	9.15	15	7.08	0.00	0.09	7.88	2.30	10.28	42.0	24
10	5.2	0.10	0.62	10.51	17	10.62	0.38	0.06	10.53	4.28	15.26	44.0	35
17	5.2	0.06	0.34	4.18	12	6.08	0.12	0.02	4.64	1.81	6.59	21.4	31
19	5.2	0.07	0.59	9.32	16	5.76	0.03	0.07	7.83	2.88	10.82	34.6	31
23	5.3	0.04	0.37	7.29	20	12.88	0.00	0.05	4.94	2.06	7.05	29.8	24
27	5.0	0.09	0.29	3.90	14	6.02	0.07	0.04	3.59	1.65	5.34	19.6	27
28	6.3	0.05	0.47	8.92	19	11.22	0.21	0.05	5.84	2.55	8.65	37.8	23
Top-soil 01	5.3	0.03	0.17	2.86	17	2.22	0.12	0.03	1.85	1.48	3.48	12.2	29
Top-soil 02	5.9	0.04	0.16	2.99	18	1.66	0.05	0.02	13.02	6.83	19.92	34.8	57
Top-soil 03	5.9	0.06	0.39	5.08	13	3.42	0.08	0.04	16.67	9.63	26.41	42.0	63
Top-soil 04	5.4	0.03	0.27	4.54	17	2.12	0.01	0.01	5.19	1.81	7.03	27.2	26
Top-soil 05	5.9	0.06	0.27	5.11	19	3.72	0.12	0.08	6.29	3.21	9.70	22.4	43
Top-soil 06	5.7	0.05	0.22	3.96	18	4.10	0.07	0.07	3.44	1.98	5.56	13.8	40
Top-soil 07	5.2	0.03	0.18	2.37	13	2.38	0.19	0.02	3.94	1.32	5.47	16.6	33
Top-soil 32	6.1	0.04	0.20	2.83	14	2.20	0.10	0.02	2.74	2.06	4.93	13.4	37
Top-soil 43	5.8	0.06	0.23	3.25	14	2.92	0.00	0.08	4.49	5.76	10.33	25.8	40
Top-soil 45	5.5	0.07	0.17	1.91	11	3.00	0.00	0.06	2.69	1.89	4.65	12.4	37
Top-soil 50	5.8	0.05	0.21	3.02	14	2.38	0.00	0.03	5.14	6.50	11.67	23.8	49
Top-soil 52	5.9	0.03	0.19	3.16	16	2.70	0.00	0.05	5.59	4.12	9.75	19.0	51
Top-soil 61	5.8	0.06	0.24	4.08	17	3.78	0.00	0.09	10.83	7.41	18.33	25.0	73
Top-soil 33	5.8	0.04	0.27	5.26	19	5.58	0.02	0.13	8.03	3.37	11.56	21.8	53
Top-soil 34	6.4	0.12	0.36	5.29	15	33.16	0.03	0.84	15.97	4.61	21.44	32.4	66
Top-soil 44	5.7	0.06	0.19	3.16	17	5.20	0.61	0.03	5.39	6.50	12.54	24.4	51
Top-soil 46	5.4	0.04	0.22	3.40	15	5.66	0.00	0.03	4.44	4.36	8.83	22.0	40
Top-soil 57	5.4	0.05	0.22	3.23	15	3.08	0.00	0.04	9.98	5.76	15.78	23.8	66

(‘Top-soil’ plots are from surrounding woodland in ‘Community 3’, Tesfaye Awas (in prep.))

Appendix E: List of woody species surrounding wetland

Albizia malacophylla (A.Rich.)Walp	Fabaceae
Annona senegalensis Pers.	Annonaceae
Bridelia sp.	Euphorbiaceae
Combretum collinum Fresen.	Combretaceae
Dahlbergia sp.	Fabaceae
Dombeya torrida (J.F.Gmel) P.Bamps	Sterculiaceae
Erythrina abyssinica Lam. ex DC.	Fabaceae tribe Phaseolae
Ficus ovata Vahl	Moraceae
Gardenia ternifolia Schumach. & Thonn.	Rubiaceae
Grewia sp.	Tiliaceae
Kotschya africana Endl	Fabaceae
Lannea welwitschii (Hiern) Engl.	Anacardiaceae
Lonchocarpus laxiflorus Guillemin & Perrottet	Fabaceae
Oxytenanthera abyssinica (A.Rich) Munro	Poaceae
Piliostigma thonningii (Schum.)Milne-Redh.	Fabaceae tribe Cercideae
Polyscias farinosa Harms	Araliaceae/ Apiaceae
Protea gaguedi J F Gmel.	Proteaceae
Securidaca longipedunculata Fresen.	Polygalaceae
Strychnos innocua Delile	Loganiaceae
Strychnos spinosa Lam	Loganiaceae
Syzygium guineense (Willd.) DC.	Myrtaceae
Terminalia laxiflora Engl. & Diels	Combretaceae
Terminalia macroptera Guill & Perr	Combretaceae
Vitex doniana Sweet	Verbenaceae