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Vegetation-environment relationships in a catchment containing a dambo in central Zimbabwe

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Keywords: Canonical Correspondence Analysis, dambo, plant-water relations, vegetation classification, Zimbabwe

ABSTRACT

Seasonally saturated wetlands, known as dambos, are a common landscape element throughout much of southern Africa. The diversity of species composition within catchments containing dambos is widely attributed to hydrological conditions, but plant-water relationships are poorly established. In this paper a detailed classification and a vegetation map are presented for a small catchment in central Zimbabwe containing a dambo. Canonical Correspondence Analysis has been applied to explore the link between vegetation composition and environmental variables. This confirms that water is a key influence in species distribution and small-scale patterning of vegetation within the catchment.

INTRODUCTION

Many factors influence the composition of vegetation, including the supply of nutrients, micro-climate, soil moisture, intraspecific competition, grazing and management practices (Gimingham 1972). In some environments, the relationship between water and vegetation has been shown to be particularly important. For example, Gurnell (1981) and Gurnell & Gregory (1987) illustrated that the vegetation composition of heathland areas in temperate climates is particularly 'fine-tuned' to the underlying soil moisture regime. In a vegetation survey of Zimbabwe, Rattray (1957) concluded that soil moisture 'appeared to be the most important single factor affecting the distribution of grasses.' Dye & Walker (1980) illustrated how the influence of soil properties on the infiltration of water had a marked effect on floristic distribution in areas of Zimbabwe where sodic soils are prevalent.

Dambos (sometimes termed vleis) are seasonally waterlogged, predominantly grass covered, shallow depressions bordering headwater drainage lines. They are a widespread land feature in southern Africa. In Zimbabwe they occupy about 4% of the land surface (Whitlow 1984). Field observations indicate that soil moisture is one of the major variables influencing floristic variation within catchments containing dambos. Perera (1982) surmised that the most important controls on the distribution of plant communities within dambos are micro-relief, the water table and the physical and chemical properties of the soil. Whitlow (1985) states that within dambos 'vegetation generally comprises a mosaic of plant communities which changes in character from the margins to the central portions of the dambo dependent upon the degree and duration of waterlogging.'

The current study is believed to be one of the first to statistically validate the relationship between vegetation distribution and environmental factors for a dambo. There were two elements to the study. Firstly, a detailed vegetation classification and a vegetation map, based on floristic dominance and physiognomy, was derived for a small catchment in the highveld of central Zimbabwe. Secondly, the link between species composition and environmental variables was investigated independently of the mapping exercise using Canonical Correspondence Analysis (Ter Braak 1988a). The results indicate that vegetation associations may provide a basis for identifying characteristic soil moisture regimes in highveld catchments containing dambos.

STUDY AREA

The study area (Figure 1), is located in the headwaters of the Manyame River at the Grasslands Research Station, near Marondera, 70 km southeast of Harare. Relief over the catchment is low (gradients less than 4%) and the elevation varies from 1 611 to 1 654 m above sea level. In Zimbabwe, land at elevations greater than 1 200 m is known as highveld. The catchment area of 3.33 km^2 comprises two parts: the upland region, known as the interfluve (2.12 km^2) and a single dambo (1.21 km^2). The dambo extends the whole length of the catchment and incorporates a narrow spur on the northern slope (Figure 1). This spur crosses the catchment boundary and joins another dambo in a neighbouring catchment. The main road and railway line from Harare to Mutare pass through the eastern end.

Rainfall is seasonal and largely dependent on the movement of the Intertropical Convergence Zone over southern Africa. Average annual rainfall is 859 mm, but varies considerably from year to year. Rainfall occurs predominantly during the wet summer (October to April), and the winter months (May to September) are usually dry. During the winter, the mean temperature is about 12.5°C, although it is not uncommon for night temperatures to drop below freezing. During the summer, the mean temperature is 19.5°C. Average potential evaporation is about 1 700 mm.

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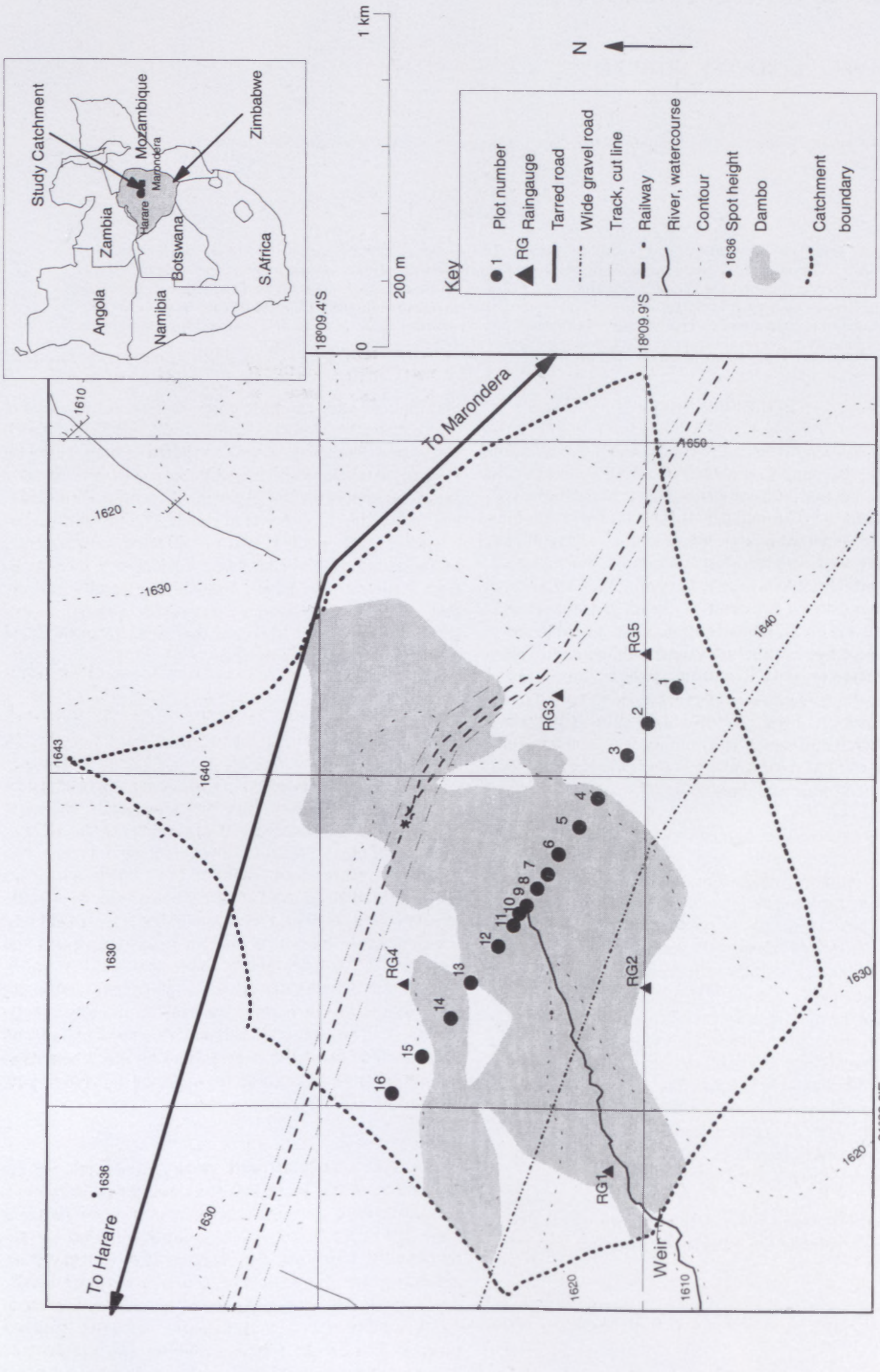

FIGURE 1.—Grasslands research catchment area showing the dambo, which is at the head waters of Manyame River, near Marondera, 70 km southeast of Harare.

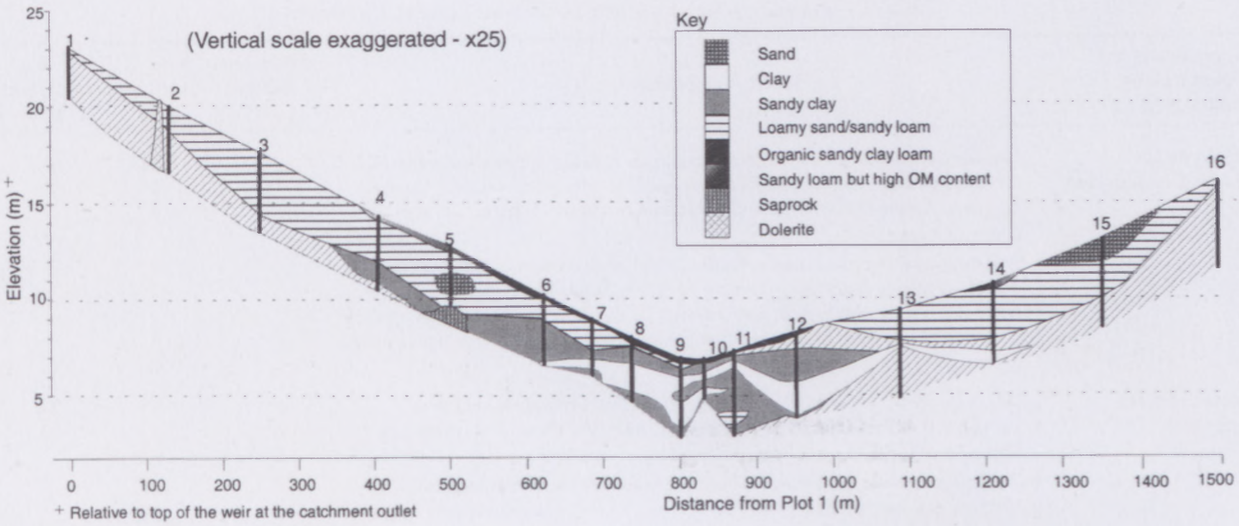

FIGURE 2.—Cross section showing soil profile, location of vegetation sampling plots and dipwells along transect across the grasslands research catchment, near Marondera.

Soils within the catchment have been derived predominantly from the underlying granite. However, in places, soil mineralogy and texture have been influenced by the presence of dolerite dykes. A distinct catena exists on the slopes of the catchment (Figure 2). The interfluve soils are acidic, strongly leached and have reached an advanced stage of weathering. They are moderately deep, coarse to medium-grained loamy sands overlying sandy clay loams. The dambo soils are hydromorphic with high organic matter content in the topsoils and gleying of the subsoils (Whitlow 1985). At shallow depth within the dambo, there is a well-defined clay wedge of irregular shape that is embedded within a lens of sandy clay. It is the presence of these heavy textured subsoils that impedes vertical drainage and results in the wet season saturation of the dambo.

METHODS

Two approaches were employed, one for vegetation mapping and the other for detailed environmental correlation. For vegetation mapping, inventory and classification, the method employed by Timberlake *et al.* (1993) was followed. Black-and-white aerial photographs (scale 1 : 25 000, 1983) were interpreted using a mirror stereoscope, and the vegetation was stratified on the basis of the textural differences on the photographs. To see if there were any significant changes since 1983, aerial colour photographs were taken in the wet season of 1995. Sampling was done in both the dry and wet seasons. A total of 22 samples were randomly located in the stratified areas (stratified random sampling). At each sampling point all species were identified and their cover-abundance values assessed according to the Braun-Blanquet scale (Mueller-Dombois & Ellenberg 1974). Since the number of samples was few and the size of the catchment area is small, it was possible to produce a floristic classification directly from the field sheets, in conjunction with both the black-and-white and the colour aerial photographs, without computer-aided classification.

For environmental correlations, detailed inventories were made of species within a radius of 5 m around each of 16 markers laid out along a transect across the middle of the catchment. The markers ran from the interfluve on the southern slope to the interfluve on the northern slope of the catchment crossing the valley bottom immediately to the east of the stream channel (Figure 1). Species presence/absence data were obtained, and later used to relate species composition directly to environmental variables measured within each plot.

Environmental factors were determined at each of the 16 plots. Soil characteristics determined for the surface soil horizon were: bulk density (BDEN), pH (H_2O), electrical conductivity (EC) and percentage carbon (%C). Dry bulk density was determined from the weight of undisturbed core samples oven dried at 105°C for 24 hours. Soil pH and EC were measured electrometrically in a 1:5 suspension in distilled water. The percentage of carbon in the soil was determined by the colorimetric method using potassium dichromate (Chapman 1987).

Within each plot, depth to the water table was measured daily from November 1995 to October 1996 in narrow diameter (32 mm) dipwells and the mean depth was calculated for each month. At each location, the mean value for February 1996 (February water table depth—FWTD) was taken as an index of the wet season water level, and the mean level for September 1996 (September water table depth—SWTD) was taken as an index of the end of dry season water level. These were used as surrogate indicators of the soil moisture regime within each plot.

Species and environmental data from the 16 plots were subjected to Canonical Correspondence Analysis (CCA) (Ter Braak 1988b) to elucidate the relationships between vegetation composition and the six measured environmental variables. CCA is a direct ordination technique commonly used in community ecology studies. It integrates regression and ordination techniques into a method of multivariate direct gradient analysis that is used to detect unimodal relationships between species and environmental variables (Ter Braak 1986, 1987, 1988a). The relationships can be shown in an ordination diagram by vectors for the environmental variables with lengths proportional to their

TABLE 1.—Summary of land cover in the Grasslands Research Catchment

Vegetation type determined by dominant species	Species composition	Area on dambo km²	Area on interfluve km²	% catchment area
Hyparrhenia filipendula grassland	Grasses: *Hyparrhenia filipendula, Setaria incrassata, Sporobolus pyramidalis, Loudetia simplex, Pogonarthria squarrosa, Hyperthelia dissoluta, Cynodon dactylon, Eragrostis chapelieri, Setaria pumila, Stereochlaena cameronii* and *Eragrostis superba* Woody species/weeds: *Lannea edulis, Lopholaena coriifolia* and *Syzygium guineense* subsp. *huillense, Cynodon dactylon, Solanum delagoense, Bidens biternata, Tagetes minuta, Bidens pilosa, Conyza albida, Sesbania microphylla, Oldenlandia corymbosa, Dactyloctenium aegyptium* and *Eleusine indica* subsp. *africana*	0.29	0.25	16.2
Mixed channel grassland	Grasses/ sedges: *Hemarthria altissima, Paspalum urvillei, Arundinella nepalensis, Aristida junciformis, Themeda triandra, Cyperus digitatus* and *Typha latifolius* Herbs: *Ranunculus multifidus, Verbena bonariensis, Senecio strictifolius, Helichrysum* species, *Kniphofia linearifolia* and *Polygonum senegalense* Aquatic macrophyte: *Potamogeton thunbergii*	0.08	0.00	2.4
Sporobolus subtilis grassland	Grasses/sedges: *Sporobolus subtilis, Pogonarthria squarrosa, Aristida junciformis, Arundinella nepalensis, Eragrostis capensis, Digitaria scalarum, Andropogon eucomus, Monocymbium ceresiiforme, Cyperus tenax* and *Kylinga erecta* Herbs/weeds: *Bidens pilosa, Euphorbia cyparissoides, Oldenlandia herbacea, Conyza welwitschii, C. albida* and *Tagetes minuta*	0.31	0.06	11.1
Aristida junciformis grassland	Grasses/sedges: *Aristida junciformis, Hyparrhenia filipendula, Andropogon gayanus, Digitaria scalarum, Sporobolus pyramidalis, Cyperus tenax, Sporobolus subtilis* and *Kyllinga erecta* var. *erecta* Herbs/weeds: *Euphorbia cyparissoides, Ranunculus multifidus* and *Senecio strictifolius*	0.08	0.01	2.7
Sporobolus pyramidalis grassland	Grasses/sedges: *Sporobolus pyramidalis, Melinis repens, Eragrostis chapelieri, Setaria pumila, Dactyloctenium aegyptium, Pogonarthria squarrosa, Brachiaria deflexa, Cyperus esculenta* and *Kyllinga erecta* and *Cynodon dactylon* Wetter areas: *Arundinella nepalensis, Andropogon eucomus, Pycreus aethiops, Aristida junciformis* Herbs/weeds: *Haumaniastrum sericeum, Bidens pilosa* and *Ceratotheca triloba*	0.30	0.08	11.4
Mixed wooded grassland	Grasses: *Hyparrhenia filipendula, Hyperthelia dissoluta, Pogonarthria squarrosa, Cynodon dactylon, Perotis patens, Heteropogon contortus* and *Eragrostis* species Shrubs: *Eriosema ellipticum, Lopholaena coriifolia, Helichrysum kraussii, Pycnostachys urticifolia, Eriosema engleranum, Sida cordifolia, Parinari capensis, Syzygium guineense* subsp. *huillense, Pavetta schumanniana* and *Maytenus senegalensis* Larger trees (mainly confined to termitaria): *Brachystegia spiciformis, Julbernardia globiflora, Syzygium guineense* subsp. *guineense* and *Acacia sieberiana*	0.00	0.14	4.2
Miombo woodland	Trees: *Brachystegia spiciformis, Julbernardia globiflora, Parinari curatellifolia, Cussonia arborea, Burkea africana* and *Ochna pulchra* Shrubs: *Eriosema engleranum, Pavetta schumanniana, Lopholaena coriifolia, Helichrysum kraussii, Rhynchosia resinosa* and *Leptactina benguelensis* Grasses: *Sporobolus pyramidalis, Melinis repens* and *Pogonarthria squarrosa* Weeds: *Achyranthes aspera* and *Bidens pilosa, Amaranthus hybridus, Solanum delagoense* and *Datura stramonium*	0.00	0.30	9.0
Mixed woodland	Trees: *Combretum molle, Strychnos spinosa, Burkea africana, Albizia antunesiana, Vangueria infausta, Cussonia arborea, Ekebergia benguelensis, Ozoroa insignis, Acacia sieberiana* and *Faurea speciosa* Shrub layer: *Euclea crispa, Lippia javanica, Maytenus senegalensis, Eriosema ellipticum, E. engleranum, Pavetta schumanniana, Lopholaena coriifolia* and *Maytenus heterophylla* Grasses: *Hyparrhenia filipendula, Pogonarthria squarrosa, Sporobolus pyramidalis, Aristida junciformis, Hyperthelia dissoluta* and *Perotis patens*	0.00	0.09	2.7
Eucalyptus plantations	Exotic trees: *Eucalyptus camaldulensis* and other *Eucalyptus* species Other trees: *Julbernardia globiflora, Brachystegia spiciformis* and *Pinus patula* Indigenous shrubs: *Eriosema engleranum, Pavetta schumanniana, Helichrysum kraussii, Gnidia kraussiana, Rhynchosia resinosa, Lippia javanica, Indigofera arrecta, Blumea alata* and *Euclea crispa*	0.00	0.80	24.0
Cultivation and settlements	Main crop is maize	0.15	0.39	16.2

importance and directions showing their correlation with each axis. The statistical validity of the ordination was tested using an unrestricted Monte-Carlo permutation test available in CANOCO (Ter Braak 1988b).

RESULTS AND INTERPRETATION

Vegetation classification

The results of the vegetation classification are shown in Table 1 and mapped in Figure 3. The vegetation was classified into 10 types based on floristic dominance and physiognomy. Physiognomically, the types range from woodland through wooded grassland to grassland and plantations of exotic timber species. Physiognomic classes follow Pratt *et al.* (1966). A woodland is defined as a stand of trees with canopy cover of 20–80%, a grassland is land dominated by grasses, sometimes with widely scattered herbs with canopy cover not exceeding 2%, and a wooded grassland as grassland with scattered or grouped trees with canopy cover less than 20% (Pratt *et al.* 1966). Woody species and grass nomenclature follow Drummond (1975) and Bennett (1980), respectively, with a few species name updates in both cases. Herb nomenclature follows various *Flora zambesiaca* volumes dealing with specific plant families.

Grassland is the most extensive of all the vegetation types in the catchment, covering 48% of the area. Six distinct types can be recognized, based on differing floristic dominance (Table 1). The most extensive is *Hyparrhenia filipendula*-dominated grassland. This is a medium-height grassland of up to 1.2 m high which extends from the channel grassland to the woodland and wooded grassland on the upper slopes. Very localized dominance of other grass species (i.e. *Setaria incrassata*, *Sporobolus pyramidalis* and *Loudetia simplex*) is also evident.

In the dambo itself, along the stream channel, there is a narrow belt, up to 10 m wide, characterized by grass and sedge species that can tolerate periodic waterlogging. Species dominance is not uniform, occurring in mosaics of local dominance of different species. The most common aquatic macrophyte is *Potamogeton thunbergii* which is quite abundant in pools in the channel.

Two patches of short grassland up to 1 m tall, dominated by *Sporobolus subtilis*, occur in the midslopes of the dambo area. Grass cover is generally high, with over 80% ground cover. The areas where this grassland is found become waterlogged during the rainy season and may remain so for long periods.

A patch of grassland dominated by *Aristida junciformis* occurs in the western part of the catchment area. *Hyparrhenia filipendula* is an important component of this grassland, becoming more or less co-dominant in some places. The grasses are generally short, most being less than 1 m, and the cover is less than 70%.

Sporobolus pyramidalis grassland is found on both well-drained soils on the upper slopes and on dark, heavy, periodically waterlogged soils closer to the valley bottom. It is composed of medium-height grasses of up to 1 m with more than 90% ground cover. In the wetter areas, *Arundinella nepalensis* becomes co-dominant.

Two patches of wooded grassland occur in the west of the catchment area. Larger trees, *Brachystegia spiciformis, Julbernardia globiflora, Syzygium guineense* subsp. *guineense* and *Acacia sieberiana*, are mainly confined to termitaria. The most common grass on termitaria is *Cynodon dactylon*.

Natural woodland occurs on the interfluve and covers about 12% of the catchment. Much of the miombo woodland is dominated by *Brachystegia spiciformis* which forms almost pure stands in places. The canopy cover is about 60%. The canopy layer is up to 10 m high and consists of more or less even-aged trees. Scattered tall emergent trees are found in places. The shrub layer is sparse with occasional bare patches of ground.

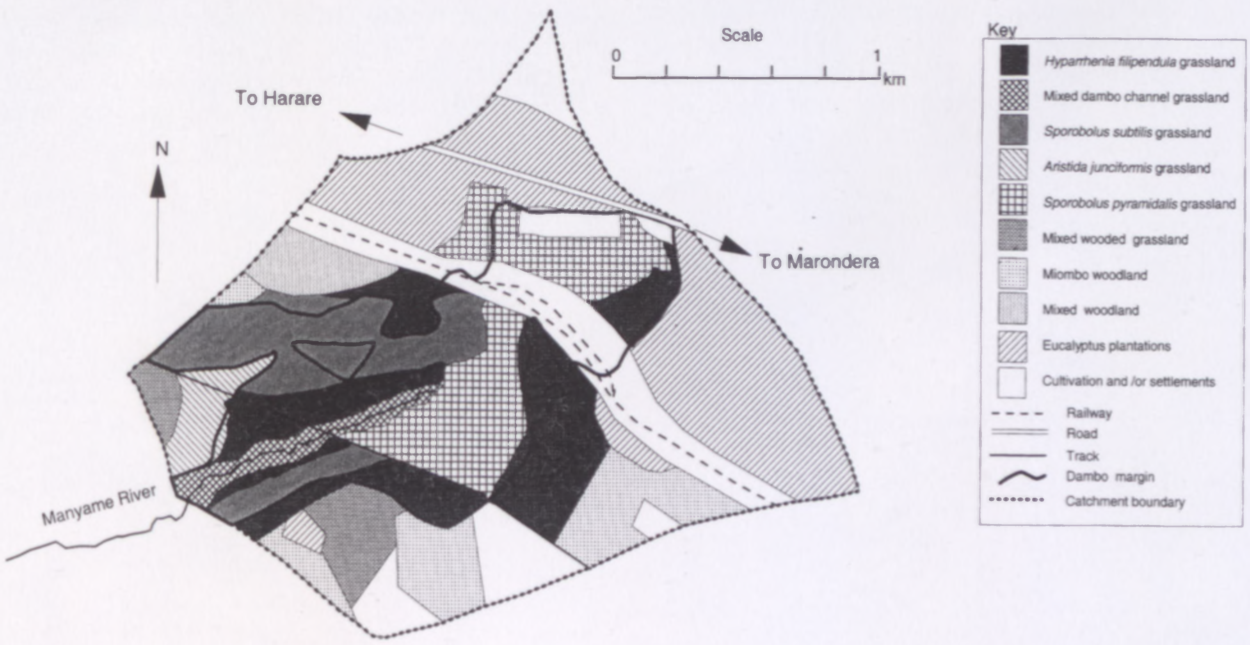

FIGURE 3.—Map showing vegetation types in grasslands catchment area near Marondera.

One small patch of miombo woodland occurring in the northwest of the catchment area is somewhat different in character. *Julbernardia globiflora* is co-dominant with *Brachystegia spiciformis* and there are a significant number of large *Parinari curatellifolia* trees on the edges. The area is heavily disturbed by livestock and the shrub layer is very poor. The herb layer is characterized by high densities of *Achyranthes aspera* and *Bidens pilosa*.

A mixed woodland is found on the sandy soils in the northwestern part of the catchment area. It is a sparse woodland of up to 8 m with a canopy cover of 30–40%. In some places it assumes the structure of a wooded grassland and comprises a mixture of species whose dominance varies from place to place. The most common trees in this woodland are *Combretum molle*, *Strychnos spinosa*, *Burkea africana*, *Albizia antunesiana* and *Vangueria infausta*.

Cultivated land and settlements occupy just over 16% of the catchment area. Much of the cultivation takes place either side of the railway line embankment, with other small areas close to settlements between the road and the railway (Figure 3). There is also some cultivation on the interfluve in the southwestern part of the catchment area. These fields are used by the Grasslands Research Station for experimental trials. In all the cultivated areas, the main crop is maize.

About 24% of the catchment, primarily either side of the dambo at the eastern end of the catchment, comprises plantations of exotic trees, particularly *Eucalyptus camaldulensis* and other *Eucalyptus* species. These are old trees (estimated to be at least 20 years) which have grown to heights of up to 30 m.

Vegetation-environment relationships

A total of 63 species were encountered in the 16 detailed inventory plots. Each of the 16 plots was assigned to one of the 10 vegetation types identified in Table 1. Several plots (i.e. 2, 4 and 9 to 12) were located on or near the mapped lineation between vegetation types (i.e. in ecozone regions), but in all cases it was possible, through observation, to place each of them in one of the types. Of the natural vegetation types, only *Aristida junciformis* and mixed wooded grassland were not represented by any plots (Table 2).

TABLE 2.—Plot numbers of the vegetation types

Vegetation class	Plot number
Miombo woodland	1
Mixed woodland	16
Hyparrhenia filipendula grassland	2, 3, 11, 12
Mixed channel grassland	9, 10
Sporobolus subtilis grassland	13, 14, 15
Aristida junciformis grassland	-
Sporobolus pyramidalis grassland	4, 5, 6, 7, 8
Mixed wooded grassland	-
Eucalyptus plantations	-
Cultivation and settlements	-

The results of the CCA technique applied to the six environmental variables and 63 species, indicates that Axis 1 accounts for 84.6% of the observed variation in vegetation, whereas Axes 2, 3 and 4 account for 54.3%, 48.6% and 38.7% respectively. Relationships between plots and Axes 1 and 2 are shown in Figure 4. The 16 plots were separated, by eye, into seven groups, two consisting of one plot each, four consisting of two or three plots each, and one with four plots.

There is greater separation of the groups along Axis 1 than along Axis 2. Group I are the plots in the dambo centre. Group II are the plots situated away from the dambo centre, but otherwise in wetter parts of the dambo. Group III contains the plots in drier parts of the dambo generally closest to the dambo-interfluve margin, and includes plot 14, which is located in the dambo spur. Group IV and V are the plots found in a more or less transitional zone between the woodland on the interfluve crest and the dambo grassland on the northern and southern slopes respectively. Groups VI and VII are both found in woodland on the interfluve crests, but differ in species composition. These groups are defined by characteristic indicator species (Table 3), generally conforming to those described by Whitlow (1985).

The analysis shows strong positive correlation between bulk density (BDEN) and September water table depth (SWTD) (r = 0.71), electrical conductivity (EC) and pH (r = 0.70), and percentage carbon (%C) and EC (r = 0.79). There is strong negative correlation

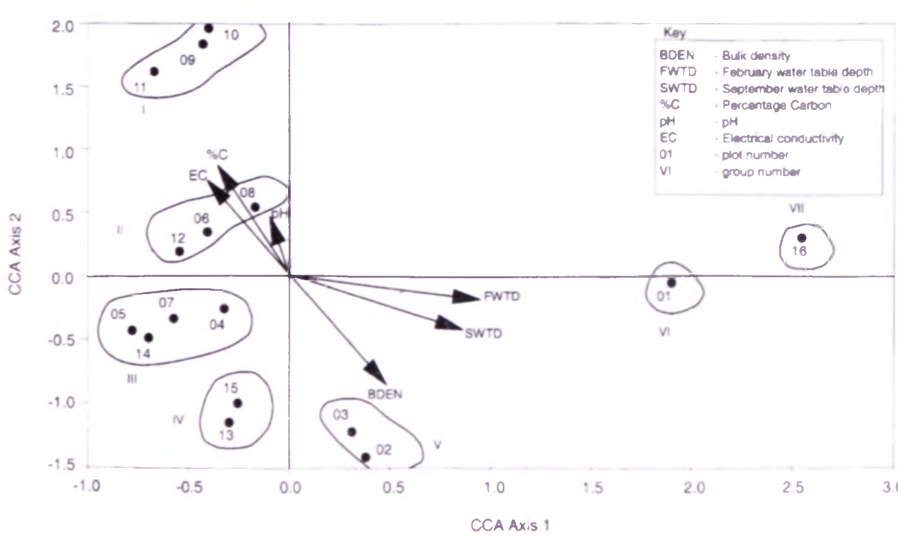

FIGURE 4.—Canonical Correspondence Analysis ordination showing the separation of the 16 plots.

TABLE 3.—Indicator species in identified groups

Group	Plots	Location	Indicator species
I	9,10,11	Dambo centre; valley bottom	*Arundinella nepalensis, Aristida junciformis, Sporobolus subtilis*
II	6, 8,12	Wet regions of dambo, but away from centre	*Sporobolus pyramidalis, Hyparrhenia filipendula*
III	4,5,7,14	Dry regions of dambo	*Sporobolus pyramidalis, Monocymbium ceresiiforme*
IV	13,15	Grassland on northern interfluve	*Sporobolus subtilis, Hyparrhenia filipendula*
V	3,2	Grassland on southern interfluve	*Hyparrhenia filipendula, Melinis repens, Cynodon dactylon*
VI	1	Interfluve crest, southern slope	*Brachystegia spiciformis, Dicerocaryum senecioides*
VII	16	Interfluve crest, northern slope	*Julbernardia globiflora, Parinari curatellifolia*

between BDEN and EC (r = –0.76), and BDEN and %C (r = –0.94). SWTD and February water table depth (FWTD) both show strong positive correlation with Axis 1 (r = 0.87 and r = 0.96, respectively). %C and EC show positive correlations with Axis 2 (r = 0.88 and r = 0.73, respectively). BDEN shows a strong negative correlation with Axis 2 (r = –0.83). The Monte-Carlo permutation test shows significant differences in floristic composition in relation to environmental variables ($p < 0.01$). However, the test is not significant for the first canonical axis alone. Plots 1, 2, 3 and 16 are more influenced by levels of the water table and the bulk density of the soil, whereas %C, pH and EC are more important determinants for the remaining plots, particularly those close to the dambo centre. The depth of the water table is much larger on the interfluve, where woodland predominates, than in the dambo, where grassland predominates (Figure 5).

DISCUSSION

Vegetation classification

The vegetation associations described in this paper represent two major structural types, woodland and grassland. The crests of the interfluves comprise woodland with a transition to grassland downslope. The dambo is entirely grassland. Ten vegetation types were defined and mapped on the basis of species dominance and composition.

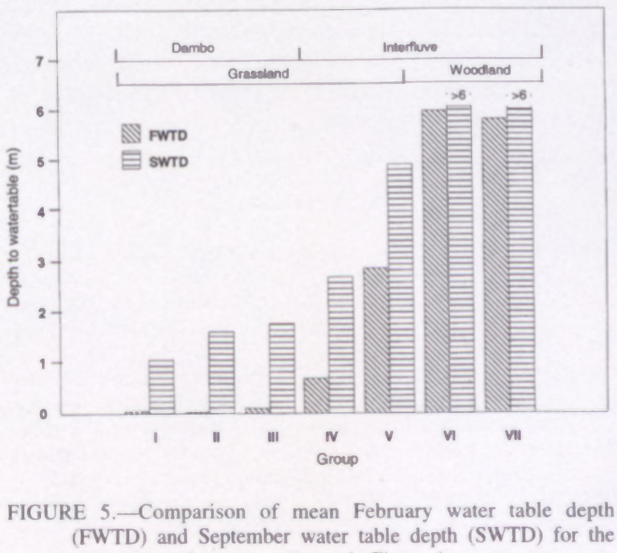

FIGURE 5.—Comparison of mean February water table depth (FWTD) and September water table depth (SWTD) for the seven vegetation groups shown in Figure 4.

A spatial successional sequence was observed along the catena from the woodland areas on the upper slopes down to the dambo channel. Definitive indicator species include *Monocymbium ceressiiforme* marking the dambo margin with woodland areas, while *Sporobolus subtilis*, *Andropogon eucomus* and *Aristida junciformis* dominate the wetter areas. The dambo centre vegetation is, however, different from that described by Whitlow (1985) and in the wetter regions, particularly towards the catchment outlet, it is characterized by *Arundinella nepalensis*, *Verbena bonariensis* and *Euphorbia cyparissoides*.

It is evident that the vegetation structure and composition have been influenced by past and present management practices in the catchment, particularly livestock grazing and land clearance for crop farming. Intensive grazing leads to changes in species composition with a tendency towards increasing dominance of unpalatable tuff grasses such as *Sporobolus pyramidalis* (Noy-Meir 1981; O'Connor 1995; Kennan 1969). It is, therefore, hypothesized that the current composition of the *Sporobolus pyramidalis* grassland is related to past management practices, and that it could have resulted from a gradual conversion of *Hyparrhenia filipendula* grassland owing to the impacts of grazing. Presently, cattle are stocked at about 3–4 hectares per livestock unit on a rotational basis (L. Lungu, late researcher at the Grasslands Research Station, pers. comm.). However, there is a tendency to concentrate animals in the paddocks close to the channel. Localized degradation effects by cattle on vegetation is further seen in the prevalence of weeds such as *Bidens biternata*, *Tagetes minuta*, *Achyranthes aspera* and *Conyza albida* in large sections of the grassland and under the trees in the miombo woodland.

The miombo woodland shows evidence of management. Campbell *et al.* (1995) described a miombo site in the area and noted that much of the woodland cover was removed after the establishment of the Grasslands Research Station in 1929. Subsequently, the area has been protected for the last 30 years which could explain the even-aged structure of trees noted in the present study.

Vegetation-environment relationships

There is a general trend of increasing soil depth to the water table from left to right along CCA Axis 1, which is also associated with increasing species woodiness. This is the key determinant separating dambo and interfluve vegetation; the former lying at the negative end and the latter lying at the positive end of Axis 1. The only exception is Group IV which contains plots lying immediately up and down slope of the dambo spur on the northern side of the catchment. Although located on the interfluve this group falls on the negative end of Axis 1. However, in terms of water table regime this group is intermediate between the dambo and interfluve proper (Figure 5).

Within the dambo it is not possible to directly link floristic composition to February water table depth (FWTD) and September water table depth (SWTD). This may be because FWTD and SWTD have been derived from a single year's data which are atypical and do not reflect subtle long-term differences in the water table regime across the dambo. Interpretation is further complicated by management practices, which, as discussed above, have altered vegetation composition within the dambo. Nevertheless, a link between vegetation composition and soil moisture regime is revealed through the interrelationship between the identified groups and the other environmental variables used in the analysis. Figure 4 shows that the groups of dambo vegetation are spread along CCA Axis 2. Since there is a trend of increasing soil pH, EC and %C from the negative to the positive end of Axis 2, these are the key environmental variables associated with differences in species composition within the dambo. However, pH and EC are highly correlated with organic matter content (expressed as %C) which is largely governed by the extent and duration of waterlogging (Savory 1965). It is therefore probable that, over long periods of time, the variation in floristic composition would correlate with differences in water table regime. Thus, while not directly identified by FWTD and SWTD, it is very likely that differences in vegetation composition within the dambo are influenced by subtle variation in the water table regime over time. Considering the whole catchment, it is evident that the amount of soil moisture and extent of waterlogging are major factors influencing vegetation composition.

Comparison of Tables 2 and 3 reveals that in several of the groups identified in the CCA, plots located in more than one of the natural vegetation classes identified independently in the classification and mapping exercise. For instance, Group I comprises Plots 9 and 10 which occur in the region classified as mixed dambo channel grassland, as well as Plot 11 which is located in region of *Hyparrhenia filipendula* grassland. Similarly, in Group II, Plots 6 and 8 lie in a region classified as *Sporobolus pyramidalis* grassland, but Plot 12 occurs in a region classified as *Sporobolus subtilis* grassland, while in Group III, plots 4, 5 and 7 are in a region classified as *Sporobolus pyramidalis* grassland, but Plot 14 is located in a region of *Sporobolus subtilis* grassland. Nevertheless, within each group, the majority of the plots lie within one type, as shown in Table 4.

TABLE 4.—Links between vegetation type and group

Group	Vegetation Type
I	Mixed channel grassland
II	*Sporobolus pyramidalis* grassland
III	*Sporobolus pyramidalis* grassland
IV	*Sporobolus subtilis* grassland
V	*Hyparrhenia* grassland
VI	Miombo woodland
VII	Mixed woodland

These results indicate that there is a strong, but not unambiguous, correspondence between the mapped vegetation classes and the environmental variables identified by the CCA which are associated with floristic composition. The lack of a clearer relationship can be attributed to two factors. Firstly, the common link between plots within a group are the indicator species rather than the dominant species which identify the class. Secondly, plots are effectively spot samples and may not be truly representative of the vegetation of the area within which they are situated. This second factor in particular explains the lack of correspondence for those plots that lie in ecozones, where the vegetation is transient between vegetation types.

CONCLUSION

Although land management policies have influenced vegetation composition to some extent, there is nevertheless a clear relationship between vegetation composition and environmental variables within the catchment. The amount of soil moisture and extent of waterlogging (as indicated by the levels of the water table in the wet and dry seasons) is the overriding factor distinguishing the floristic composition of the interfluve and the dambo. Furthermore, within the dambo, the study findings strongly suggest that the extent and duration of waterlogging is a key influence in determining the presence/absence of indicator species.

The results strongly support qualitative observations made elsewhere in Zimbabwe. Subtle differences in soil moisture resulting from slight variation in water table regime can result in noticeable differences in vegetation composition. The relationship between the identified vegetation classes and the environmental variables used in the CCA suggests that with additional data collection and analysis, vegetation associations may provide a basis for identifying characteristic soil moisture regimes in similar highveld catchments containing dambos.

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