Mistbelt grassland fragmentation in the Umvoti conservancy, KwaZulu-Natal, South Africa

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The existing Mistbelt grassland in the Umvoti Conservancy in KwaZulu-Natal is highly fragmented due to intensive agricultural land use (plantations and pastures), with Mistbelt grassland now occupying less than 3.5% of the area. Patch sizes range from a few hectares to less than 350ha in extent. The plant species composition of remnant patches was sampled and classified using TWINSPAN, and sward structure described in terms of basal cover, sward height, sward density, and aerial cover. Grassland patches were of two main types: (i) *Themeda triandra* grassland with dense basal cover and high species richness (19.4 ± 1.77 species); and (ii) secondary grassland characterised by the absence of *T. triandra* and a high frequency of *Hyparrhenia hirta*. The species richness of the disturbed patches, particularly those in wetter areas, was poor (12.4 ± 1.27 species). *Arisitida junciformis* was ubiquitous and has the potential to invade all grassland patches in the absence of appropriate fire and grazing management. Various numerical indices, calculated using FRAGSTATS, were used to quantify landscape heterogeneity. The question of connectivity was addressed by sampling a powerline servitude, which is a potential corridor through the area. This corridor could also possibly serve as a link through the conservancy between the adjacent Blinkwater Nature Reserve, which contains 492ha of pristine Mistbelt grassland, and the lower-lying Umvoti Vlei.

Introduction

According to Scott-Shaw et al. (1996) only 3% of pristine Natal Mistbelt Ngongoni Veld (Veld Type 45, Acocks 1988) remains in KwaZulu-Natal. The rest has been transformed to agricultural monocultures, mainly forest plantations, pastures and maize. It is the high rainfall and mild temperatures in Mistbelt regions that attracts intensive crop farming and habitation (Scott-Shaw 1999). The Mistbelt grassland that remains exists as small, fragmented patches with high probabilities of species extinction and little chance of dispersal and re-colonisation (Scott-Shaw et al. 1996). A moratorium was passed in 1999 prohibiting any transformation of the remaining Mistbelt grassland areas in KwaZulu-Natal (Natal Witness 1999). This moratorium was passed on the basis of the high conservation priority that the Mistbelt veld type has, since these grasslands have a very high biodiversity, yet only 0.3% of the remaining Mistbelt is protected. Furthermore, 34 species of threatened plants occur in the Mistbelt veld type (Scott-Shaw 1999). The Umvoti Vlei Conservancy (UVC) is an example of a highly transformed landscape where Mistbelt grassland fragments now occupy less than 3.5% of the area in amongst predominantly plantations and cropland.

Human-induced habitat fragmentation is considered to be one of the most important threats to biodiversity (Bredenkamp et al. 1999) due to the reduction of local population sizes of fauna and flora and a decline in species richness (Reed et al. 1996). These consequences have been attributed to: decreased patch size; habitat loss for plant and animal species; decreased connectivity of the remaining vegetation; increased distances between patches, and an increase in edge at the expense of interior habitat (Reed et al. 1996).

Recognition of landscape-scale alterations in ecosystem structure and function resulting from human activities has driven land managers to consider a landscape perspective (Reed et al. 1996). Forman and Godron (1986) define a 'landscape' as a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout. Turner and Gardner (1990) advocate the importance of using quantitative methods in studies of landscape ecology that link spatial patterns and ecological processes, since quantifying landscape structure is a prerequisite to the study of landscape function and change. Attention is therefore drawn to the scale of landscape in

which the remnant grassland fragments occur. This study attempts to quantify the structure and degree of heterogeneity of the UVC landscape as well as the spatial relations among the Mistbelt grassland components.

The objectives of the study were to (i) identify, map, and floristically classify the extant natural grassland patches in the conservancy; (ii) provide a description of the vegetation communities existing within each patch, and their composition and diversity; (iii) characterise the landscape in terms of structure and degree of heterogeneity; (iv) briefly consider the potential for grassland corridors within the UVC; and (v) provide guidelines for the management and monitoring of these fragmented grasslands.

Materials and Methods

The study was conducted in the Umvoti Vlei Conservancy near Greytown in KwaZulu-Natal (29°11'S, 30°32' E) in 1999. The conservancy spans approximately 26 000ha and presently comprises 12 private farms as well as the Umvoti Vlei Nature Reserve situated within the uMvoti River valley. The Blinkwater Nature Reserve forms one of the watersheds of the Umvoti River drainage system and lies adjacent to the conservancy. The UVC has a rolling topography dissected by narrow drainage lines feeding into the Umvoti Vlei, and ranges in altitude from 954m a.s.l. at the vlei to 1 485m a.s.l. towards the top of Blinkwater.

The area receives a mean annual rainfall of 881mm, mostly in summer. Winters are cold with frequent frosts with a mean daily minimum of 10.8°C, while the growing season (October–March) is warm experiencing mean daily maximum temperatures of 22.7°C (Computing Center for Water Research, University of Natal).

The existing 12 natural grassland patches within the UVC were sampled. Blinkwater Nature Reserve forms an important part of the landscape's ecological system, since it contains 497ha of pristine Mistbelt grassland, and was therefore also sampled. The location of each Mistbelt grassland fragment in the conservancy was mapped using a GPS Trimbel Navigation system (GeoExplorer 1994) (Figure 1).

A semi-quantitative assessment of the cover-abundance of each species in each sampling site was made, using Van der Maarel's (1979) 9-point scale. A sampling plot was located in representative vegetation within each patch. A 16 x 16m plot, was determined as appropriate by applying a nested quadrat approach.

To describe sward structure at each site, basal cover, aerial cover, sward height and sward density were measured. Basal cover was measured using the distance-diameter method with 100 random points (Hardy and Tainton 1993). Aerial cover was assessed using a 6-point ranking scale modified from Anderson and Walker's (1974) 5-point scale by adding an additional class (91–100%). Twenty 0.5m x 0.5m quadrats were randomly placed within the sampling plot and the ranking scores averaged in order to determine the mean percentage aerial cover for each site. Sward surface height was measured at 20 random points. Sward surface height was taken as the height below which 80% of the foliage occurred (Hardy 1995). Sward density was measured using a 0.75 x 0.5m density board (MacArthur and

MacArthur 1962).

Concomitant environmental variables measured at each sample site included the following:
(i) altitude, measured with a Trimbel GPS;
(ii) aspect, on a scale of 1 to 7 (Schulze 1975);
(iii) slope, measured with an inclinometer;
(iv) Catenal position, on a scale of 1 to 5 (1 = plateau, 2 = crest, 3 = midslope, 4 = footslope, 5 = toeslope);
(v) soil depth (measured with an auger until rock or hard layer encountered); and
(vi) soil type (Soil Classification Working Group 1991).

Soil samples were analysed by the KwaZulu-Natal Department of Agriculture's Fertiliser Advisory Services, using a routine analysis (Farina and Channon 1988), for the following variables (variable names in square brackets): Soil density (gml⁻¹), Phosphorus [P], Potassium [K], Calcium [Ca], Magnesium [Mg], (all mgl⁻¹), exchangeable acidity (cmoll⁻¹), total cations (cmoll⁻¹), acid saturation (%), soil pH (KCl) [pH], Zinc [Zn] (mgl⁻¹), Manganese [Mn] (mgl⁻¹), and NIRS organic carbon (%). In addition to soil chemistry, soil samples were analysed for particle size distribution using the pipette method (Gee and Bauder 1986). Species nomenclature is given after Arnold and De Wet (1993).

Species composition data were classified using the Two-Way Indicator Species Analysis (TWINSPAN) (Hill 1979). The first pseudo-species was not made available as an indicator species to avoid rare species being used as indicators. The relation between the sites and the environmental variables was investigated with correspondence analysis (CA) and canonical correspondence analysis (CCA) using the program CANOCO (Ter Braak 1987). Rare species were downweighted. Due to multi-collinearity within the environmental data set, Principal Components Analysis (PCA) was used to select a sub-set of relatively independent variables, viz. altitude, catenal position, soil depth, clay, total cations, K, exchangeable acidity and pH.

For each fragment, area (ha), perimeter (m) and nearest neighbour distances (m) were determined using ArcView 3.1 for each individual patch and for the Mistbelt grassland patch type as a whole. ArcView was also used to determine the predominant landuse contrast (>75% of the perimeter length) existing around each patch using digitised landuse coverage (MBB Engineers 1997). A variety of metrics, including area, patch density, size and variability, edge, shape, nearest neighbour, diversity, contagion and interspersion, were calculated using FRAGSTATS 2.0 (McGarigal and Marks 1994) at the scale of patch type and landscape.

Results

Aristida junciformis had a very high relative frequency, occurring in 96% of the samples. *Cymbopogon excavatus*, followed by *Themeda triandra* were the next most frequent species (56% and 52% relative frequency respectively), within the study area, with *C. excavatus* being found predominantly in the *T. triandra*-dominated sites. The most frequently occurring forb *Pentanisia angustifolia* (48%), occurred mainly in the more pristine areas. Although forbs contributed more to species diversity than grasses, most
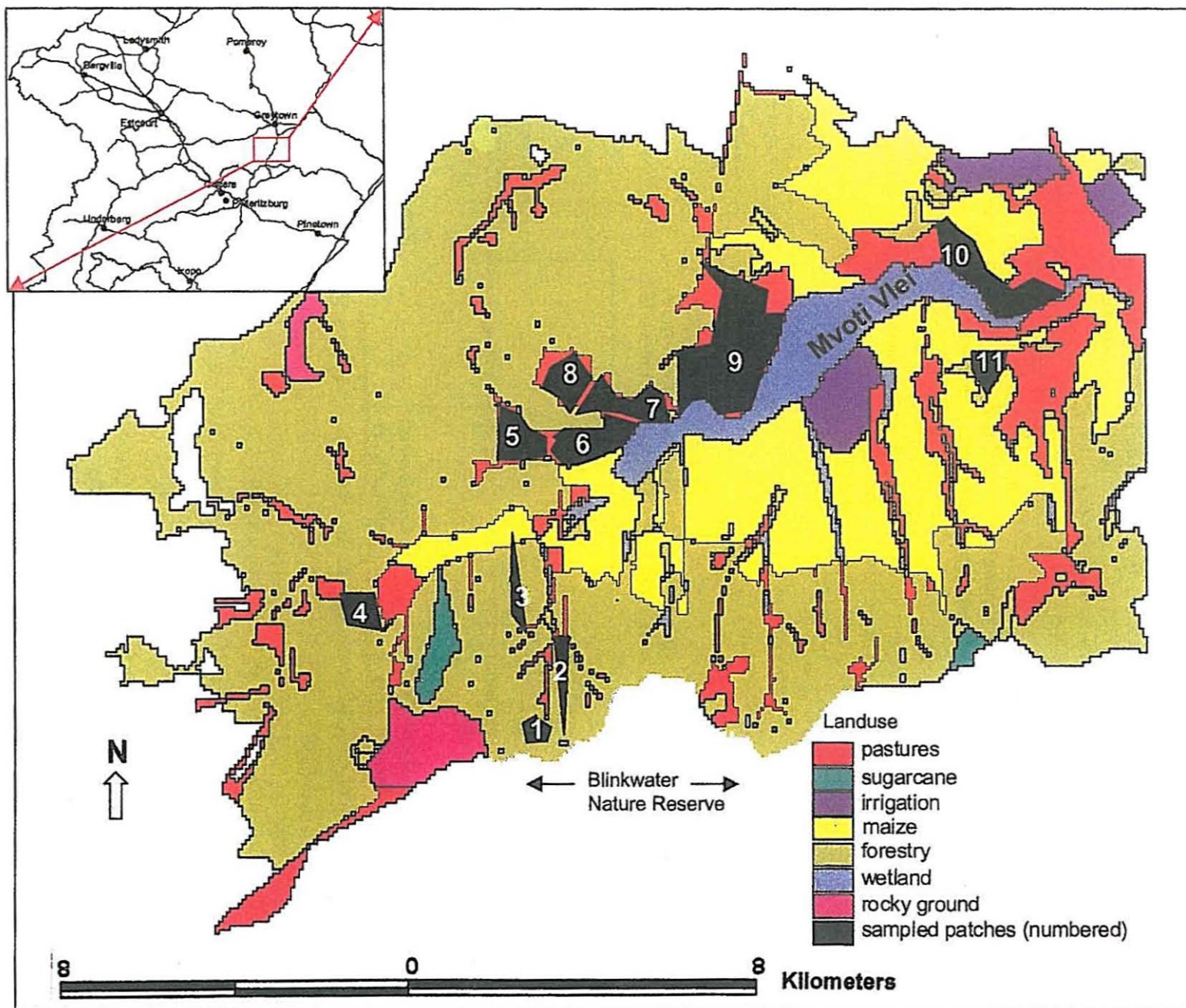
Figure 1: Location of the study area in KwaZulu-Natal showing current land use and the remaining, sampled Mistbelt grassland patches (labelled 1 to 11) within the Umvoti Vlei Conservancy. (Blinkwater Nature Reserve is located just outside the mapped area and is not included in the figure because captured land coverage data was not available for this area)

non-grass species were infrequent and at a low abundance.

The hierarchical classification of the vegetation in the study area is presented in Figure 2. Level one of the classification separates the grassland patches into two main types, characterised as follows: (i) *Themeda triandra* (Forssk.) grassland with dense basal area, high aerial cover and high species richness, similar to the protected grasslands of Blinkwater, and therefore named 'pristine'; and (ii) secondary grassland characterised by the absence of *T. triandra*, and a high frequency of *Hyparrhenia hirta* (L.) Stapf. These two grasslands differed significantly in basal cover ($P < 0.05$), aerial cover ($P < 0.01$) and species richness ($P < 0.01$) (Table 1). However, the pristine grassland was not significantly different from the more disturbed grassland with regards to sward height, sward density, Shannon's diversity and evenness indices, and Simpson's diversity and evenness indices (Table 1).

Seven communities were identified at level three of the dendrogram, on the basis of floristic differences and variation in the abundance of species (Figure 2). Community 1 is a short grassland occurring on the rocky, high-lying, plateaus of the Blinkwater Nature Reserve. The shallow,

Mispah soils have the lowest clay content, Potassium and total cation values amongst the communities of the conservancy (Table 1). The diagnostic species for this community are *Gazania krebsiana* (Less.), *Hypochaeris radiata (L.)*, *Kylinga erecta* (Schumach.) and *Microchloa caffra* (Nees). Dominant species are *Aristida junciformis* (Trin. & Rupr.) subsp. *junciformis* and *Pennisetum sphacelatum* (Nees) Dur. & Schinz var. *sphacelatum*. It is further characterised by the absence of *T. triandra*. Species rare to this community include *Hypoxis filiformis* (Baker) and *Crassula pellusida* (L.).

Community 2 occurs on gently sloping high-lying areas of the Blinkwater Nature Reserve. Soils are deeper, varying from Glenrosa to Oakleaf, with higher levels of clay, and cations, a taller sward, and higher basal cover than the Blinkwater Community 1 (Table 1).This grassland is characterised by the presence of *T. triandra*, *Bulbostylis hispidula* (Vahl) R. Haines, *Monocymbium ceressiforme* (Nees) Stapf, and *Eragrostis racemosa* (Thunb.) Steud. *Aristea woodii*. Rare species in this community include *Hypoxis filiformis*, *Asclepias gibba* (Schltr.), *Lotononis foliosa* (H. Bol.), and *H. hirta*. The dominant species is *A. junciformis*, indicating that
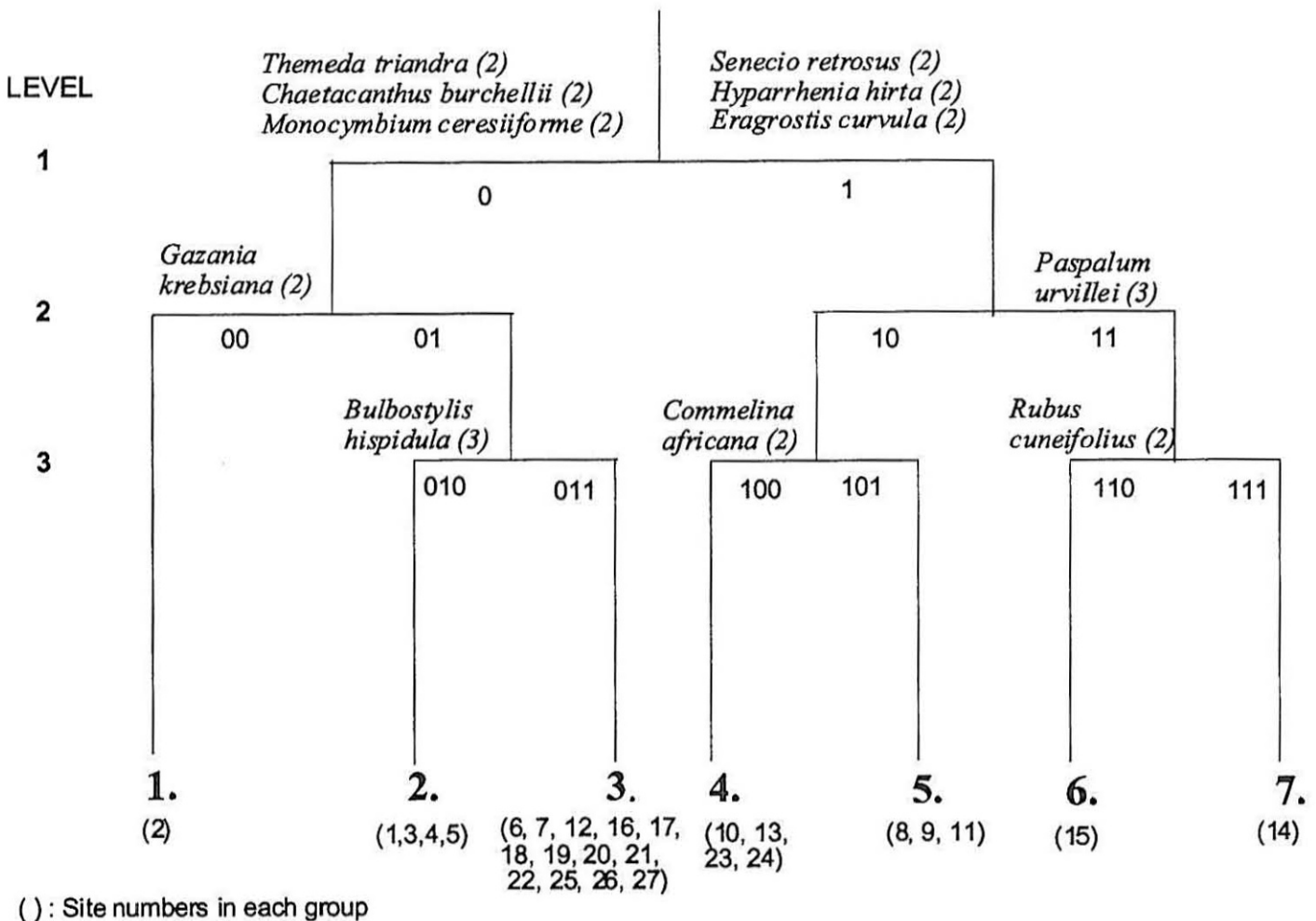

Figure 2: A dendrogram of the TWINSPAN classification of the Mistbelt grassland of the Umvoti Vlei Conservancy. The indicator pseudo-species are displayed at each dichotomy along with the binary codes for the divisions at each level. Community group numbers are indicated at level 3

Table 1: Summary of the biotic characterisitics of the two main grassland types within the Umvoti Vlei Conservancy, and the mean environmental variables for each community group at level 3 of the TWINSPAN classification. Standard errors are in parantheses

	Pristine grassland mean (se)	Disturbed grassland mean (se)	Diff.	t-value
Sward Height (cm)	51.3 (3.0)	59.9 (5.5)	-8.6	-1.37 NS
Sward density	0.37 (0.06)	0.44 (0.07)	0.07	-0.90 NS
Basal cover (%)	19.9 (0.5)	16.7 (1.0)	3.3	3.28 *
Aerial cover (%)	76 (3.1)	60 (4.6)	16	2.96 **
Species richness	19 (1.7)	12 (1.3)	7 3	09 **
Shannon's Diversity	1.995 (0.164)	1.551 (0.210)	0.444	1.66 NS
Shannon's Evenness	0.68 (0.04)	0.610 (0.06)	0.07	0.94 NS
Simpson's Diversity	0.72 (0.05)	0.62 (0.08)	0.10	1.39 NS
Simpson's Evenness	0.76 (0.05)	0.67 (0.08)	0.09	1.01 NS

Group	1	2	3	4	5	6	7
Altitude (m a.s.l.)	1420	1338 (54.9)	1076 (27.1)	1017 (24.5)	1044 (16.1)	1063	1105
Soil depth (cm)	3	29 (11.1)	61 (8.2)	32 (10.2)	59 (24.2)	75	30
Clay (%)	8.5	14.6 (3.1)	51.4 (3.5)	45.7 (5.9)	40.9 (3.3)	33.8	47.4
Potassium (mgl⁻¹)	84	127.5 (14.8)	251.8 (31.2)	232.8 (39.7)	199 (18.0)	177	174
Total cations (cmoll⁻¹)	1.83	2.63 (0.10)	8.47 (1.16)	8.6 (1.05)	6.21 (0.88)	5.24	6.9
Exchangeable acidity (cmoll⁻¹)	0.6	1.15 (0.16)	1.83 (0.43)	0.48 (0.16)	1.94 (0.76)	2.2	5.84
pH	4.61	4.5 (0.03)	4.18 (0.06)	4.28 (0.11)	4.11 (0.07)	4.14	3.93

NS — P > 0.05
* — P # 0.05
** — P # 0.01

although the sites appear to be in the good condition, as suggested by the presence of *T. triandra* and high species richness, the area possibly has a history of disturbance. Overgrazing apparently occurred on these natural grasslands of the Umvoti watershed before the area was declared a nature reserve (pers. comm, Phil Swan, local farmer).

Community 3 is found in lower altitude, bottomland positions on deep soils with a high clay and cation content (Table 1), predominantly on Griffin and Oakleaf soils. The vegetation of this community is characterised by high species richness, basal cover, and aerial cover. *Themeda triandra* and *A. junciformis* are the co-dominants. It is further characterised by the absence of *B. hispidula*, and the presence of *Cymbopogon excavatus* (Hochst. Stapf ex Burtt Davy), *Chaetacanthus burchellii* (Nees), *Eriosema salignum* (E. Mey.) and *Berkheya setifera* (DC). Rare species include *Thesium costatum* (A.W. Hill), *Aster bakerianus* (C.A. Smith), *Athrixia phylicoides* (DC), and *Alysicarpus rugosus* (Willd.) DC.

Community 4 is found in some of the lowest lying areas of the UVC where soils are shallow and well drained (Table 1). The dominant grass species is *H. hirta*, indicating past disturbance. Soil forms include Sepane and Glenrosa. *Aristida junciformis*, *C. excavatus*, *Eragrostis curvula* (Schrad.) Nees, the forb *Chamaecrista plumosa* (E. Mey.), and *Conyza ulmifolia* (Burm. F) Kuntze are diagnostic of this community. Species rare in this community include *Polygala rehmannii* (Chod.), *Corchorus asplenifolius* (Burch.), *Indigophera tristis* (E. Mey.), *Anthospermum streyi* (Puff) and *Hermania grandistipula* (Buchinger ex Hochst.) K. Schum.

Community 5 occurs on mid-slope positions with relatively deep soils. The community is characterised by the absence of *T. triandra* and the dominance of *A. junciformis*. Other diagnostic species include *Panicum scrobiculatum*

(L.), *Commelina africana* (L), *Pentanisia angustifolia* (Hochst.) and *Senecio retrosus* (DC.), which is regarded as a weed. *Hyparrhenia hirta* is common. Rare species include *Polygala hottentotta* (Presl), *Albuca setosa* (Jacq.), *Rhus dentata* (Thunb.) and *Rhyncosia sordida* (E. Mey.) Schinz.

Communities 6 and 7 are similar in species composition, except for invasive species *Rubus cuneifolius* (Pursch) and *Solanum mauritianum* (Scop.), which are present in Community 6 but absent in Community 7. The sward is taller in Community 7 than in Community 6. *Paspalum urvillei* (Steud.), a typical wet site species, is diagnostic of both communities. Species richness is low in both communities.

Community 6 is found on gently sloping, low-lying land on shallow soils. *Paspalum urvillei* dominates the sward which is sparse with mean basal cover of (16.87%). *Sporobolus africanus* (Poir.) Robyns & Tournay and *Cynoglossum geometricum* (Bak. & C.H.Wr.) are diagnostic of this community. *Becium grandiflorum* (Lam.) is a rare species in this community.

Community 7 dominated by *A. junciformis*, is found on similar topography to community 6, but on deep Griffin soils. The basal cover is low (11.36%). The exotic weed *Tagetes minuta* (L.) is diagnostic of this community. *Acanthospermum australe* (Loefl. Kuntzee) is a rare species occurring in this community.

The canonical correspondence analysis summarises the environmental variation among communities and highlights important environmental determinants of floristic composition (Figure 3). The first CCA axis (eigenvalue = 0.361) was closely correlated ($r = 0.954$) to a number of co-varying variables. Altitudinal variation had the greatest influence on species composition, as indicated by the close angle between axis one and the altitudinal arrow and the length of this arrow. However, soil clay and cation content and catenal
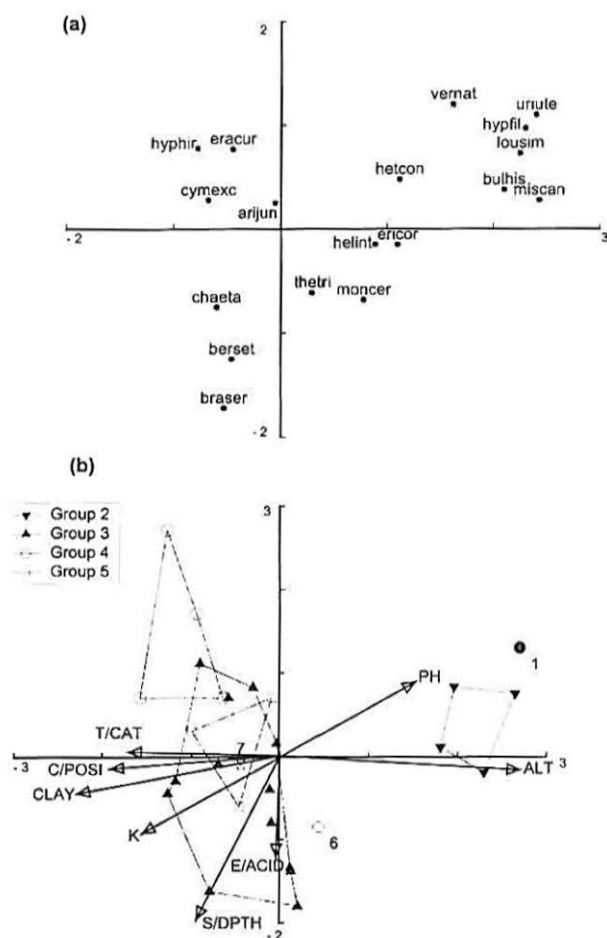
Figure 3: Plot of species along the first two axes of a canonical correspondence analysis for, (a) species with greater than 20% of their variance accounted for, and (b) sites (within TWINSPAN groups or labelled with group number for single-member groups) and environmental variables. Axis 1 and 2 accounted for 9.5% and 5.8% of the total species variability respectively. Of all variance, 33.5% could be attributed to the explanatory variables, of which 45.7% is explained in the diagram. (arijun = *Aristida junciformis*; berset = *Berkheya setifera*; braser = *Brachiaria serrata*; bulbhis = *Bulbostylis hispidula*; chaeta = *Chaetacanthus burchellii*; cymexc = *Cymbopogon excavatus*; eracur = *Eragrostis curvula*; ericor = *Eriosema cordatum*; helint = *Helichrysum interjacens*; hetcon = *Heteropogon contortus*; hypfil = *Hypoxis filiformis*; hyphir = *Hyparrhenia hirta*; lousim = *Loudetia simplex*; miscan = *Miscanthus* sp.; moncer = *Monocymbium ceresiiforme*; thetria = *Themeda triandra*; uriute = *Urica utens*; vernat = *Vernonia natalensis*; ALT = Altitude; CLAY = Soil clay percentage; C/POSI = Catenal position; E/ACID = Exchangeable acidity; K = Soil potassium; PH = Soil pH; S/DPTH = Soil depth; T/CAT = Total cations)

position are negatively correlated to altitude (Figure 3). The high Blinkwater sites (communities 1 and 2) are separated from the other lower-lying communities along this complex topo-edaphic gradient.

Species whose distribution is centered on the acidic, shallow and sandy soils at the upper reaches of UVS are clearly separated in the ordination diagram from those that are more abundant on the deep clays of the bottomlands in the study area (Figure 3).

The second canonical axis (eigen value = 0.217) express-

es further variation related to measured environmental variables (r = 0.887), primarily variation in soil depth and exchangeable acidity of the soil (negatively related to soil pH) (Figure 3). Communities 3 and 4 generally occur on the opposite extremes of this gradient but there is considerable overlap among communities on axis 2. Judging from the species distribution on the CCA plot (e.g. *E. curvula, T. triandra, H. hirta*), disturbance history (unmeasured) could be partly responsible for floristic variation in UVC.

The extant grassland fragments are irregular in shape with convoluted boundaries. They are unevenly distributed across the landscape (Figure 1), also indicated by large variation in mean nearest neighbour (MNN) distances (Table 2) and the greatest value for nearest neighbor standard deviation (NNSD) (Table 3). Patch size varies greatly, resulting in a large value for patch size coefficient of variation (PSCV) (Table 3). A quarter of the patches are less than 10ha in size, half of all the patches are less than 25ha in extent, while only a quarter are greater than 100ha in size (Table 2). Seven of the 12 fragments have more than 50% of the edge in contact with forestry (Table 2).

The landscape structure of the UVC can be summarised as follows. Forestry occupies more than half of the UVC and is the least fragmented of land uses, also indicated by having the largest mean patch size (MPS) and highest mean proximity index (MPI) (Table 3). Grassland is the most fragmented patch type since it has the greatest value for the number of patches, patch density, and total edge. The diversity of the landscape is high (Shannon Diversity Index = 1.27) while patch richness density is low (0.04 patches per 100 ha). Patch types are generally fairly evenly interspersed and dispersed since the contagion and interspersion (CON = 64.5) and juxtaposition (IJI = 54.1) indices are greater than 50%, indicating considerable landscape heterogeneity (Table 3).

Discussion

The primary influence of altitude on floristic variation within UVC grasslands is similar to that identified in other mesic grasslands in Southern Africa (Walker 1988, Morris *et al.* 1993). High altitude soils are typically acidic, and infertile due to their upland positions. In contrast, lower altitude sites (groups 3 to 7) accumulate more cations and clay, due to their association with bottomlands.

Considering the ubiquitous distribution of *A. junciformis* (in 96% of sites) within the UVC, there exists the potential for *A. junciformis* to dominate all extant grassland patches in UVC without appropriate management. In comparison, *T. triandra* has a low frequency (in 52% of sites) and, if not correctly managed, could rapidly decline and be replaced by *A. junciformis*.

Management

Regular burning in the dormant season is the only way to maintain *T. triandra* and associated grasses in mesic grassland and thereby maintain composition and cover, as well as combat an increase in *A. junciformis* (Everson *et al.* 1985). With regular burning and rest from grazing, *A. junciformis*

Table 2: Quantitative descriptors for each natural grassland fragment calculated using ArcView 3.1. Fragment #12 was not mapped, hence no Mean Nearest Neighbour value. Fragment dimensions estimated in the field to derive Area and Perimeter values for #12

Fragment Number	Area (ha)	Perimeter (m)	Nearest Neigbour distance (m)	Mean Nearest Neigbour (m)	Mean Nearest Neighbour standard deviation	CONTRAST (% of perim.)
1	12.90	1 438.05	2 878.74	5 521.51	3 201.40	forestry (>75)
2	5.29	2 442.00	613.18	4 631.75	3 780.40	forestry (>75)
3	12.12	2 255.92	1 412.83	4 482.43	3 816.27	maize (>75)
4	9.19	1 319.57	2 878.00	6 662.34	4 251.52	forestry (60)
5	38.92	2 765.34	5.00	11 054.77	21 479.41	forestry (>75)
6	134.34	6 385.76	5.00	3 081.59	3 026.85	forestry (50) maize (40)
7	70.50	4 531.43	0.00	3 248.55	2 985.63	forestry (50) grass (50)
8	36.71	2 408.60	5.00	3 874.49	3 293.70	forestry (60)
9	330.35	9 601.91	575.57	3 714.46	2 753.16	wetland (55)
10	139.56	7 470.32	854.45	8 941.14	4 244.38	wetland (50) maize (50)
11	23.12	2 106.34	854.45	8 501.38	3 854.86	maize (70)
12	2.31	1 184.00	645.41	*	*	forestry (45)

declines in abundance (Morris et al. 1992), but is very difficult or virtually impossible to eliminate with normal grazing management practices (Van Oudtshoorn 1992). Burning should be implemented in the dormant season to maintain composition and cover (Everson 1994) while burning every two to three years for the same reasons, will maximise diversity (Morris et al. 1999)

In terms of implementing correct management, smaller patches are more difficult to burn since adequate firebreak widths must be adhered to. According to the new National Veld and Forest Fire Act (1998), firebreaks should be wide and long enough to have a reasonable chance of preventing a veldfire from spreading to or from neighbouring land, and in practice widths of approximately 9m are used. For this reason, the integrity of the larger patches in the conservancy, such as patches 6, 9 and 10 (Figure 1) should be conserved. Fortunately, since the moratorium on Mistbelt destruction was passed in 1999, these conservation aims can be achieved.

Landscape fragmentation

Fragmentation increases the amount of edge relative to area, which may be disadvantageous for species affected by 'edge effects' (Noss 1983). For example, in South Africa introduced pine trees can cause the attrition of the grasshopper assemblage up to 30m into the surrounding grassland (pers. comm., E Wildy 1999, Invertebrate Conservation Research Centre, UNP).

For a meaningful interpretation of the patch and landscape indices to be made, comparison with landscape metrics derived from a study of the area earlier in time, would be necessary. Such data were, however, not available for the UVC. It is worthy to note for purposes of future research in the area, that in an increasingly transformed and fragmented landscape, it is predicted (Godron and Forman 1983) that the number of patches will increase, patches will become smaller and the shape of patches will become more circular and regular. These predictions were supported by a study on

the fragmentation of a forested rocky mountain landscape (Reed et al. 1996). In this study, increased fragmentation between 1950 and 1993 was characterised by increased metric values for number of patches, total perimeter, and Shannon's diversity, whereas mean patch size, mean patch shape, mean patch perimeter, and contagion all decreased with fragmentation.

Debate continues over whether one large reserve, such as Blinkwater Nature Reserve, or several smaller reserves, such as the larger patches (numbers 6, 9, 10, Figure 1) within the UVC are optimal for preservation of regional diversity (Noss 1983). This is referred to as the single large or several small (SLOSS) argument (Forman 1995). Fragmentation theory states that species richness increases with remnant size (Prober and Thiele 1995). Based on observation, it was found within the UVC that there were no direct links between patch size and species richness, although this was not formerly tested. This is possibly as a consequence of the differing degrees of disturbance amongst the patches. Patches of different size can only be compared if disturbance history, geology, topography, and other environmental variables are similar.

Some sampling sites in UVC were located along a powerline servitude which extends through the conservancy. This servitude (approximately 50m in width) could serve as a link or corridor between the Blinkwater Nature Reserve and the Umvoti Vlei. Empirical evidence is lacking as to the optimum width required for linking and maintaining grassland assemblages. The optimum width of a corridor will vary according to the species in question. For example Pryke's (1999) study on the movement of grassland butterflies through grassland corridors in a commercial forested area in KwaZulu-Natal, revealed that local and endemic butterflies would only make use of a corridor if the width was greater than 250m. Common and widespread butterfly species, however, did not adjust their flight patterns according to corridor width. Furthermore, open grassland habitat butterflies would not fly close to any commercial forest boundary.

Table 3: Metric values calculated by FRAGSTATS for each patch class within the conservancy, and the landscape. Included are the metrics manually calculated without FRAGSTATS for the class of natural Mistbelt grassland (nat. grass) fragments. (* indicates metrics unable to be calculated due to ArcView limitations)

TYPE	CA	%LAND	NP	MPS	PSSD	PSCV	TE	MNN	NNSD	NNCV	MPI	IJI
nat.grass	815.3	3.3	12	62.7	91.6	146.1	43909	5310	3036.3	57.2	*	*
pasture	3686.8	15.2	115	32.1	127.8	398.8	303497	150	156.0	104.1	70.9	48.9
maize	4317.6	17.8	19	227.2	356.1	156.7	169662	174	199.8	115.0	825.2	59.7
forest	13969.4	57.6	20	698.5	2783.2	398.5	297782	436	740.2	169.7	7920.6	51.9
indigenous	17.5	0.1	1	17.5	0.0	0.0	3241				0.0	12.6
sugarcane	152.1	0.6	2	76.0	38.2	50.2	8786	11005	0.0	0.0	0.0	8.8
irrigation	499.1	2.1	3	166.4	58.0	34.8	16378	1439	1496.1	103.9	6.0	63.2
informal	93.9	0.4	9	10.4	5.2	49.4	15354	1391	2253.0	162.0	8.3	78.3
dams	86.6	0.4	24	3.6	3.3	91.6	20557	1059	697.1	65.8	0.5	65.8
wetland	1055.0	4.4	34	31.0	141.9	457.1	76258	223	244.9	110.0	132.4	56.8
rocky	388.5	1.6	2	194.3	107.7	55.4	13136	6662	0.0	0.0	0.0	16.0
landscape	24266.5	.	229	106.0	857.6	809.3	462326	502	1346.5	268.3	816.0	54.1

CA — Class Area (ha): area of each patch type
%LAND — Percent of landscape (%) area occupied by each patch type
NP — Number of patches
MPS — Mean Patch Size (ha)
PSSD — Patch Size standard deviation
PSCV — Patch Size Coefficient of Variation (%): relative variability in patch size
TE — Total Edge (m): total edge length or perimeter
MNN — Mean Nearest Neighbour (m): mean distance between patches of the same type
NNSD — Nearest Neighbour distance standard deviation
NNCV — Nearest Neighbour Coefficient of Variation (%): relative variability in nearest neighbour distance
MPI — Mean Proximity Index: degree of isolation and fragmentation
IJI — Interspersion and Juxtaposition Index (%): extent to which patch types are interspersed (i.e. intermixing of units of different patch types), based on patch adjacencies

Corridors of perennial vegetation can provide numerous economic and ecological benefits to croplands (Forman and Baudry, 1984 cited by Rodenhouse *et al.* 1992). A study on the effects of uncultivated corridors on arthropod abundances (Rodenhouse *et al.* 1992) revealed that the presence of corridors in soybean monocultures suppressed populations of leaf and stem sucking pests. For example, vegetation of uncultivated corridors can create a microclimate favourable for crop growth, provide soil barriers to soil movement, and possibly enhance the parasitism levels of crop pests (Rosenberg *et al.* 1983 cited by Rodenhouse *et al.* 1992). These multiple effects of uncultivated corridors can generate economically significant yield increases (Kort 1988). Consequently, it is recommended that uncultivated corridors be established within the croplands of the UVC. It is likely that such uncultivated strips, being of a secondary nature, will be prone to weed invasion and invasive species might have to be controlled manually or with a biodegradable herbicide. Research focusing on optimal corridor width and placement of corridors within fields is also needed.

Management plans for UVC also need to consider establishing more linkages or expanding the linkages that are in place, such as the powerline servitude, possibly through rehabilitation of disturbed land. This will allow a greater degree of movement of animal and plant species between the remaining patches within the UVC. A connected landscape is preferable to a fragmented landscape (Beier and Noss 1998). Natural landscapes are generally more connected than landscapes altered by humans, and corridors are essentially a strategy to retain or enhance some of this natural connectivity (Noss 1987). Conservation biologists generally agree that landscape connectivity enhances population viability for many species (Beier and Noss 1998).

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