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Soil and sward characteristics of patches and non-patches in the Highland Sourveld of South Africa

B.U. LÜTGE [1], M.B. HARDY[2] AND G.P. HATCH [1]

[1]*Department of Grassland Science, University of Natal, Republic of South Africa*

[2]*Cedara Agricultural Development Institute, Pietermaritzburg, Republic of South Africa*

Abstract

A study to characterise selected sward and soil properties in grazed patches and ungrazed non-patches was conducted in a humid grassland of South Africa. Patches and non-patches could be distinguished in terms of soil moisture, soil depth, certain soil nutrients, hydraulic conductivity, species composition and basal cover. Soil moisture ($P<0.01$) and soil depth ($P<0.05$) were lower and P and K were higher ($P<0.05$) in patches than non-patches. Hydraulic conductivity was also higher in non-patches than patches at supply potentials of −25 mm ($P<0.01$) and −35 mm ($P<0.05$). Patches were characterised by a high proportion of *Microchloa caffra, Heteropogon contortus, Eragrostis curvula, Sporobolus africanus* and *Digitaria tricholaenoides,* and non-patches by *Trachypogon spicatus, Alloteropsis semialata, Eulalia villosa, Diheteropogon amplectens* and sedge and spring-aspect forb species. Patch grazing also seemed to increase mortality of tussocks in the patches. The potential for patch grazing to be the focus for overall range degradation is discussed.

Introduction

Animals selectively graze within an apparently homogeneous sward in response to a number of plant and animal-based determinants (Arnold and Dubzinski 1978). The sward may be heterogeneous in structure, composition and nutritive value, resulting in the animals selecting for areas in the sward which suit their grazing habit and best meet their nutritional requirements. Differences in sward structure, composition and nutritive value are due, in part, to variations in soil characteristics such as soil depth, moisture status and fertility. Variation in soil characteristics, even on a small scale, occurs naturally (Scholes 1990; 1993) and, through its effect on the sward, influences grazing pattern. This results in a mosaic of heavily grazed patches and leniently grazed or ungrazed areas of the sward (non-patches) (Bakker *et al.* 1983), with patches maintained due to regrazing of the higher nutritive regrowth in the patches (Ring *et al.* 1985).

Patch selection may be desirable in that it promotes sward (Arnold 1981) and soil (Williams *et al.* 1993) heterogeneity and allows the animal to graze higher quality herbage than the sward average (Ring *et al.* 1985; Mott 1985, 1987). Although patch grazing may have short-term advantages, it is considered detrimental to both the sward (Tainton 1972; Mott 1987; Hatch and Tainton 1990; Wandera 1993) and the soil (MacDonald 1978) and may influence detrimentally the long-term animal production potential of an area of rangeland.

Rangeland condition in South Africa, particularly in humid rangelands, is determined in terms of species composition and the Increaser and Decreaser categorisation of species (Tainton 1988). Decreaser species decrease in abundance with either heavy (over) or lenient (under) utilisation. The Increaser category is divided into Increaser I and Increaser II species. Increaser I species increase in abundance under lenient utilisation and Increaser II species increase under heavy utilisation or overgrazing. For a particular site, the abundance of species within each group relates to the grazing history. For example, a high proportion of Decreaser species indicates rangeland in good condition, while a

Correspondence: Mr B.U. Lütge, Cedara College of Agriculture, Department of Agriculture-KwaZulu-Natal, P/Bag X9059, Pietermaritzburg 3200, Republic of South Africa. e-mail: blutge@cedara2.agric.za

high proportion of Increaser II species indicates a form of range degradation due to overgrazing. Degraded humid rangelands are characterised generally by a high abundance of Increaser II species (Tainton 1988; Hardy and Hurt 1989). A knowledge of species responses to defoliation/grazing pressure, therefore, allows an interpretation of the degree of degradation between patches and non-patches.

The objective of this study was to: (a) characterise patches and non-patches which had developed due to grazing by cattle and sheep in a humid grassland, in terms of selected soil and sward properties; (b) relate the results to similar studies from other vegetation types; and (c) investigate the extent to which patch grazing may be responsible for range degradation.

Procedure

Local environment

The study was conducted in the Highland Sourveld (Acocks 1988) at the Kokstad Research Station (30°31′S, 29°25′E; 1340 m altitude). The Highland Sourveld is a humid grassland situated in the high elevation and high rainfall areas of the eastern seaboard of South Africa. It is rolling country with numerous steep valleys. The mean annual rainfall at Kokstad Research Station is 790 mm, with the rain falling mainly during the summer months. Winters are cold with regular frosts (mean minimum of 2.1°C) while the summers are warm (mean maximum of 24.5°C). The vegetation may be described as a low, closed grassland with the grasses seldom reaching a height in excess of 0.5 m (Edwards 1983). It is a 'sour' grassland, which is defined by Trollope *et al.* (1990) as a grassland in which the forage becomes unacceptable and of low nutritional value on reaching maturity. Therefore, it provides grazing for only part of the year if no supplementation is provided and animals are usually stall-fed over the winter period. Fire plays a major part in maintaining the Highland Sourveld as a grassland. Fires occur naturally, but fire is also an important management tool to provide herbage free of dead or moribund material. Controlled burning is usually applied in the dormant season (August), once every 4 years after a full growing season of rest from grazing.

Study site

The study was conducted during the 1993–94 growing season in a paddock of an existing trial. The paddock had been grazed for 3 consecutive seasons at a stocking rate of 1.4 ha/AU by cattle and sheep, at a ratio of 1 AU cattle to 1 AU sheep. Prior to grazing, the paddock had been rested for 3 years and burned annually in August to remove the previous season's growth.

Sampling procedure and data analysis

The study comprised two main sections. The first examined selected soil properties and the second examined selected sward properties in patches and non-patches. During June 1993, 30 paired 1 m^2 areas were selected at random and marked to serve as the sampling areas of patches and non-patches for all soil-property measurements. A patch was defined as an area grazed to a mean maximum height of 4 cm (Hatch and Tainton 1990). For the purposes of this study, a non-patch was defined as an area where the sward was not shorter than 10 cm. Soil measurements required the removal of some plants, so an additional forty 1 m^2, paired patches and non-patches were selected at random and marked permanently for sward measurements. Soil measurements were made during October 1993 and sward measurements during December 1993.

Soil moisture (to a depth of 10 cm) was determined in the 60 soil-sampling areas by oven-drying soil samples at 60°C for 48 h and calculating the moisture percentage by mass difference (Hatch and Tainton 1990).

An auger was used to measure soil depth in all soil-sampling areas, by augering until solid material was struck, to a maximum depth of 0.6 m.

Soil nutrient status was determined from samples taken at a depth range of 0–10 cm from 20 patches and 20 non-patches, selected at random. The nutrients examined were phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg). Organic matter (% organic carbon) and pH (KCl) were also determined.

The *in situ* soil hydraulic conductivity was measured using a disc permeameter (Perroux and White 1988). The disc permeameter was used to distinguish hydraulic conductivity due to pore diameters of <1.15 mm and <0.8 mm, using supply potentials (ψ_0) of −25 and −35 mm, respectively, as calculated from the equation given by Marshall and Holmes (1988). Wandera (1993) used supply potentials of –10 mm and –30 mm in his studies on patches in the *Heteropogon* grasslands of central Queensland, but a preliminary study within the present study area determined that a –25 mm supply potential was the minimum tension from which reliable measurements could be taken. Of the 30 patch and 30 non-patch sampling areas, 15 were used for the measurements of hydraulic conductivity at the –25 mm supply potential and 15 at –35 mm supply potential.

Paired t-tests (Steel and Torrie 1980) were used to analyse the differences between patches and non-patches in all the above measurements.

Species presence/absence was used to determine absolute species frequency within a 1 m × 1 m quadrat divided into 25 equal sub-quadrats in each of the 40 paired 1 m^2 sampling areas. Basal cover was measured in all 40 patch and 40 non-patch sampling areas using 3 equally spaced line transects, and was calculated as the length (cm) of rooted material intercepted per 1 m length measured. Rooted live and rooted dead material were measured.

The species composition data were ordinated using Detrended Correspondence Analysis (DCA) (Hill 1979) to assist in the interpretation of the differences in species composition between patches and non-patches. Paired t-tests (Steel and Torrie 1980) were used to examine differences in the absolute frequency of individual species and differences in basal cover between patches and non-patches.

Results

Soil properties

Soil moisture percentage was lower ($P<0.01$) in patches than in non-patches (Table 1). Patches were also characterised by shallower soils than non-patches ($P<0.05$) (Table 1) with no apparent (visual) difference due to erosion between patches and non-patches. Soil P and K were lower ($P<0.05$) in the non-patches than in the patches, while there was a non-significant tendency ($P>0.05$) for Ca and Mg to be lower in the non-patches (Table 1). Organic matter and soil pH were similar in patches and non-patches (Table 1).

The hydraulic conductivity due to pores <1.15 mm in diameter was higher ($P<0.01$) in non-patches than in patches (Table 1), as was that due to pores <0.8 mm in diameter ($P<0.05$), but the difference was smaller than at the larger pore diameter (Table 1).

Sward properties

The DCA Axes 1 and 2 accounted for an accumulated variance of 30% (Table 2). Figure 1 displays the sample sites (40 patches and 40 non-patches) on DCA Axes 1 and 2, and indicates a

Table 1. Soil moisture percentage, soil depth, selected soil nutrients, % organic carbon, pH (KCl), hydraulic conductivity and basal cover of patches and non-patches.

		Patch	Non-patch	Difference	s.e.d.	t-value
% Soil moisture		15.2	16.6	–1.4	0.004	–3.697 **
Soil depth (mm)		277.0	362.0	–85.0	31.50	–2.702 *
P (ppm)		1.7	0.5	1.2	0.50	2.397 *
K (ppm)		345.9	302.0	43.9	17.67	2.482 *
Ca (ppm)		731.9	686.8	45.1	43.45	1.038
Mg (ppm)		317.3	278.1	39.2	19.51	2.009
% Organic carbon		2.0	2.2	–0.2	0.10	–1.814
pH (KCl)		4.8	4.8	–0.0	0.04	–0.700
Hydraulic conductivity (mm/h)		17.3[1]	50.3[1]	–33.0	6.37	–5.175 **
		4.3[2]	6.4[2]	–2.1	0.83	–2.528 *
Basal cover	Live	20.05	18.52	1.53	1.25	1.228
	Dead	7.83	3.94	3.89	0.91	4.290 **
	Total	27.88	22.46	5.42	1.31	4.127 *

[1] Tension (ψ_o) = –25 mm and Pore Diameter = <1.15 mm.
[2] Tension (ψ_o) = –35 mm and Pore Diameter = <0.80 mm.

Table 2. Eigenvalues, gradient lengths and the accumulated percentage variance for the different axes obtained from the DCA ordination.

	Eigenvalues	Gradient length	Accumulated percentage variance
Axis 1	0.093	1.392	18.2
Axis 2	0.066	1.114	30.0
Axis 3	0.042	1.088	39.1
Axis 4	0.024	0.820	43.7

clear division between patches (p) and non-patches (v). The species ordination (Figure 2) suggests that species can be grouped into Decreaser, Increaser I and Increaser II categories, *i.e.* the species are grouped according to their response to defoliation. Axis 1 was interpreted as representing a gradient of grazing pressure, *i.e.* a gradient characterised by species which are abundant in leniently or ungrazed non-patches at one end to species which are abundant in severely grazed patches at the other.

A comparison of individual species in patches and non-patches clearly shows that patches and non-patches were characterised by different species (Figure 3). Patches were characterised by *Microchloa caffra* (Mca) ($P<0.01$) (Increaser II), *Heteropogon contortus* (Hco) (Decreaser) ($P<0.01$) and, to a lesser extent, by a high percentage of *Eragrostis curvula* (Ecu) ($P<0.05$), *Sporobolus africanus* (Saf) ($P<0.05$) (both Increaser II) and *Digitaria tricholaenoides* (Dtr) ($P<0.05$) (Increaser I). The non-patches were characterised by a high proportion of *Trachypogon spicatus* (Tsp) ($P<0.01$), *Alloteropsis semialata* (Ase) ($P<0.01$), *Eulalia villosa* (Evi) ($P<0.01$) and sedge ($P<0.01$) and forb ($P<0.05$) species (all Increaser I species) and *Diheteropogon amplectens* (Dam) ($P<0.05$) (Decreaser). Patches could, therefore, be characterised by Increaser II species and non-patches by Increaser I species (Figure 3), indicating that patches are heavily grazed and non-patches underutilised.

Total basal cover (dead plus live) ($P<0.05$) and rooted dead material ($P<0.01$) were higher in patches than in non-patches (Table 1). Rooted live material did not differ between the two areas ($P>0.05$) (Table 1).

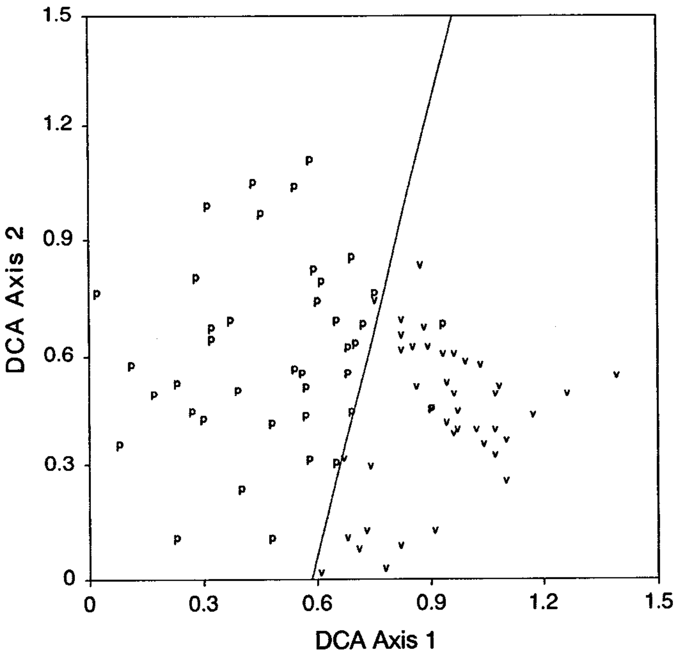

Figure 1. Ordination of sample sites along DCA Axes 1 and 2 indicating samples located in patches (p) and non-patches (v).

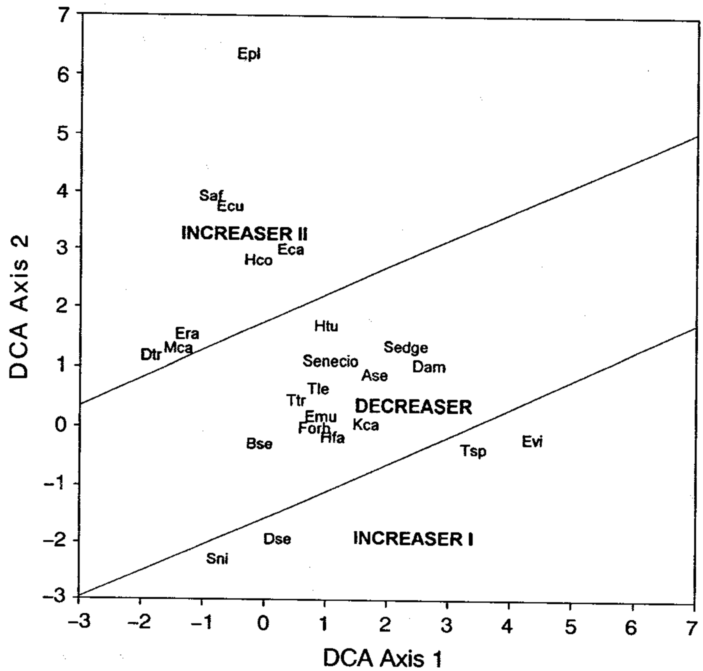

Figure 2. Ordination of species along DCA Axes 1 and 2 indicating broad groupings of Decreaser, Increaser I and Increaser II species.

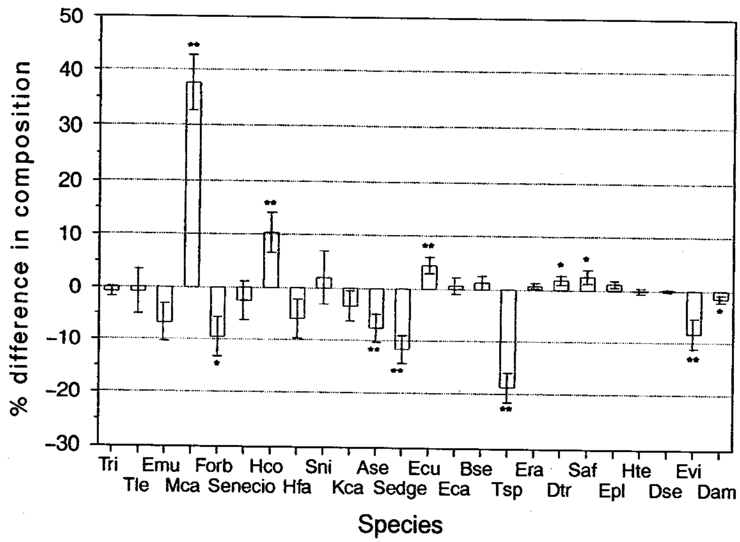

Figure 3. Difference in the percentage frequency of species, with s.e., indicating species prominent in patches (%>0) and those prominent in non-patches (%<0). Species are arranged in decreasing order of abundance.

Discussion

Patches and non-patches could be distinguished in terms of soil moisture, soil depth, certain soil nutrients, hydraulic conductivity, species composition and basal cover. It was, however, not possible to establish if these differences were a cause or effect of patch grazing. Patches had significantly shallower soil, lower hydraulic conductivity and lower soil moisture than non-patches. Similar degraded soil characteristics were observed by Mott *et al.* (1979) and Bridge *et al.* (1983) in the Northern Territory of Australia, MacDonald (1978) in the Redsoil range of Zimbabwe, Hatch and Tainton (1990) in the Southern Tall Grassveld (Acocks 1988) of South Africa, and Wandera (1993) in the *Heteropogon* grasslands of central Queensland. Decreased infiltration and increased soil compaction in patches were also observed by MacDonald (1978) and Hatch and Tainton (1990). The lower hydraulic conductivity in patches may also indicate a smaller proportion of large pores (macropores), which in turn may reduce water uptake, increase run-off rates and reduce subsequent soil water potential (Wandera 1993). These factors could, at least in part, explain the higher proportion of *Microchloa caffra* in the patches, as it is adapted to shallow soils and extreme water shortages (Tainton *et al.* 1985).

The higher soil nutrient status of the soil in patches contrasts with the findings of Hatch and Tainton (1990). They observed higher, but not significantly so, nutrient concentrations in soils of non-patches when compared with patches in the Southern Tall Grassveld of KwaZulu-Natal. Wandera (1993) recorded similar results to those of Hatch and Tainton (1990). The differences we recorded may be a function of the treatments applied prior to the start of the present trial. While the experimental area was rested (with occasional burning) for 3 years prior to the start of the existing trial to allow the sward to regain vigour from past grazing impact (Peddie *et al.* 1995; Lütge *et al.* 1996), it was grazed by cattle for a number of years before the rest period (Hardy 1994). The higher nutrient status of soils in the patches may indicate remnant urine and dung deposits (Lütge *et al.* 1995) and these previously fouled areas may now be the focus of the animals' grazing. Selection would be focused on the nutritional value of the sward, *i.e.* remnant urine and dung patches, and not on sward structure, as this would have been evened out by the rest. If grazing of these patches continues, differences in soil nutrient status may decline, as less nutrient cycling occurs due to less plant material in the patches than in the non-patches. The patches studied by Hatch and Tainton (1990) and Wandera (1993) may have been grazed for a longer period, resulting in a lower nutrient status of the soil due to continued patch grazing. Continued grazing of the patches in our study may lead eventually to patches with a lower soil nutrient status than non-patches, as observed by Hatch and Tainton (1990) and Wandera (1993).

These soil conditions may have been present prior to the start of the trial and may be responsible, in part, for the differences in species composition (*e.g. M. caffra*) between patches and non-patches. It does not, however, exclude the possibility that soil condition in the patches is a result of patch grazing, as there is less plant material available for nutrient cycling, to protect the soil from raindrop impact and to prevent the soil from drying out.

Patches are more frequently and more intensively grazed than non-patches (Ring *et al.* 1985). This may result in a shift in species composition within patches to an Increaser II-dominated stage which indicates overgrazing. Conversely, plants in non-patches are leniently defoliated or left ungrazed, resulting in a potential shift in species composition to a sward dominated by Increaser I species (underutilisation). Both scenarios indicate a shift from what is considered to be good range condition.

Hatch and Tainton (1990) recorded similar results in a similar range type and observed a gradient from newly initiated to permanent patches. Permanent patches were characterised by Increaser II species, while the other patches (newly initiated to permanent) represented an increase in Increaser II species as the patch developed. It may be slightly misleading that the non-patches were characterised by Increaser I species because, essentially, a non-patch is the remainder of the sward not classified as a patch. For the purpose of data collection, non-patches were taken as being taller that 10 cm and may therefore represent more the ungrazed than the leniently grazed remainder of the sward, so non-patches showed an abundance of Increaser I species. Studies in the semi-arid grasslands of

South Africa (Fuls 1991, 1992a, 1992b; Fuls and Bosch 1991; Kellner and Bosch 1992) also found that patches became increasingly dominated by species indicating degradation and that, eventually, xeric karroid shrub invasion occurred in the heavily overgrazed patches (Fuls 1992a). Willms *et al.* (1988) in the Rough *Fescue* grasslands of Canada, and Wandera (1993) in the *Heteropogon* grasslands of central Queensland, observed that patches were dominated increasingly by species of lower forage value. These studies indicate a degraded state in the patches, and that patch grazing is, at least in part, responsible for the shift in species composition to one which contains species which can tolerate heavy grazing (Increaser II species).

The basal cover results also indicate a certain degree of degradation. Total basal cover was significantly higher in patches than non-patches, which may be attributed to patches containing more smaller species, while non-patches contained fewer larger species. In contrast to these results, Fuls (1992a) indicated that patches in the semi-arid grasslands of South Africa had significantly lower basal cover than non-patches. Up to 90% reduction in basal cover was reported. This decrease resulted from plant death, which is indicated in this study by a higher dead basal cover, indicating a higher mortality of tussocks in the patches than in the non-patches. The humid grasslands are more stable than the semi-arid grasslands with a change in species composition rather than basal cover resulting from high grazing pressures. However, prolonged severe grazing in patches in the humid grasslands could lead eventually to the patches having a lower basal cover. Peddie *et al.* (1995) found a higher mortality of tussocks in intensively grazed plants. This may lead to range degradation, as it provides a niche for other species, especially Increaser II species, to invade these areas.

Although differences in species composition and soil characteristics may occur naturally, patch grazing may have been responsible, at least in part, for the sward and soil degradation observed in this and other studies. Patch grazing, due to the increased grazing frequency and intensity in the patches, may directly affect species composition in the patches and, due to decreased vegetation cover, may lead to soil degradation. Patch grazing may, therefore, as Tainton (1972) argued, be the focus from which range degradation proceeds.

References

ACOCKS, J.P.H. (1988) *Veld Types of South Africa.* (Botanical Research Institute, Department of Agriculture and Water Supply: South Africa).

ARNOLD, G.W. (1981) Grazing behaviour. In: Morley, F.H.W. (ed.) *Grazing Animals.* World Animal Science, B1. (Elsevier: Amsterdam).

ARNOLD, G.W. and DUBZINSKI, M.L. (1978) *Ethology of Free-ranging Domestic Animals.* (Elsevier: North Holland and New York).

BAKKER, J.P., DE LEEUW, J. and VAN WIEREN, S.E. (1983) Micro-patterns in grassland created and sustained by sheep-grazing. *Vegetatio*, **55**, 153–161.

BRIDGE, B.J., MOTT, J.J. and HARTIGAN, R.J. (1983) The formation of degraded areas in dry savanna woodlands of northern Australia. *Australian Journal of Soil Research*, **21**, 91–104.

EDWARDS, D. (1983) A broad-scale structural classification of vegetation for practical purposes. *Bothalia*, **14**, 705–712.

FULS, E.R. (1991) The effect of nutrient rich sediment deposits on the vegetational traits of a patch-grazed semi-arid grassland. *Vegetatio*, **96**, 177–183.

FULS, E.R. (1992a) Ecosystem modification created by patch-overgrazing in semi-arid grassland. *Journal of Arid Environments*, **23**, 59–69.

FULS, E.R. (1992b) Semi-arid and arid rangelands: a resource under siege due to patch-selective grazing. *Journal of Arid Environments*, **22**, 191–193.

FULS, E.R. and BOSCH, O.J.H. (1991) The influence of below average rainfall on the vegetational traits of a patch-grazed semi-arid rangeland. *Journal of Arid Environments*, **21**, 13–20.

HARDY, M.B. (1994) *Short-term effects of mixed grazing by cattle and sheep in Highland Sourveld.* Ph.D. Thesis. University of Natal, Pietermaritzburg.

HARDY, M.B. and HURT, C.R. (1989) An evaluation of veld condition assessment techniques in Highland Sourveld. *Journal of the Grassland Society of Southern Africa*, **6**, 51–58.

HATCH, G.P. and TAINTON, N.M. (1990) A preliminary investigation of area-selective grazing in the Southern Tall Grassveld of Natal. *Journal of the Grassland Society of Southern Africa*, **7**, 238–242.

HILL, M.O. (1979) *DECORANA — a FORTRAN program for detrended correspondence analysis and reciprocal averaging.* (Ecology and Systematics, Cornell University: Ithaca, New York).

KELLNER, K. and BOSCH, O.J.H. (1992) Influence of patch formation in determining the stocking rate for southern African grasslands. *Journal of Arid Environments*, **22**, 99–105.

LÜTGE, B.U., HATCH, G.P. and HARDY, M.B. (1995) The influence of urine and dung deposition on patch grazing patterns of cattle and sheep in the Southern Tall Grassveld. *African Journal of Range and Forage Science*, **12** (3), 104–110.

LÜTGE, B.U., HARDY, M.B. and HATCH, G.P. (1996) Plant and sward response to patch grazing in the Highland Sourveld. *African Journal of Range and Forage Science*, **13** (3), 94–99.

MACDONALD, I.A.W. (1978) Pattern and process in a semi-arid grassveld in Rhodesia. *Proceedings of the Grassland Society of Southern Africa*, **13**, 103–109.

MARSHALL, T.J. and HOLMES, J.W. (1988) *Soil Physics.* p. 48. (Cambridge University Press: Cambridge).

MOTT, J.J. (1985) Mosaic grazing — Animal selectivity in tropical savannas of northern Australia. *Proceedings of the XV International Grassland Congress, Kyoto, Japan, 1985.* pp. 1129–1130.

MOTT, J.J. (1987) Patch grazing and degradation in native pastures of the tropical savannas in northern Australia. In: Horn, F.P., Hodgson, J., Mott, J.J. and Brougham, R.W. (eds) *Grazing-lands Research at the Plant-Animal Interface.* pp. 153–162. (Winrock International: Arkansas).

MOTT, J.J., BRIDGE, B.J. and ARNDT, W. (1979) Soil seals in tropical tall grass pastures in northern Australia. *Australian Journal of Soil Research*, **30**, 483–494.

PEDDIE, G.M, TAINTON, N.M. and HARDY, M.B. (1995) The effect of past grazing intensity on the vigour of *Themeda triandra* and *Tristachya leucothrix*. *African Journal of Range and Forage Science*, **12** (3), 111–115.

PERROUX, K.M. and WHITE, I. (1988) Designs for disc permeameters. *Soil Science Society of America Journal*, **52**, 1205–1215.

RING, C.B., NICHOLSON, R.A. and LAUNCHBAUGH, J.L. (1985) Vegetational traits of patch grazed rangelands in west-central Kansas. *Journal of Range Management*, **38**, 51–55.

SCHOLES, R.J. (1990) The influence of soil fertility on the ecology of southern Africas dry Savannas. *Journal of Biogeography*, **17**, 415–419.

SCHOLES, R.J. (1993) Nutrient cycling in semi-arid grasslands and savannas: its influence on pattern, productivity and stability. *Proceedings of the XVII International Grassland Congress, Palmerston North/Rockhampton, 1993.* pp. 1331–1334.

STEEL, R.G.D. and TORRIE, J.H. (1980) *Principles and Procedures of Statistics — a Biometrical Approach.* (McGraw-Hill: Singapore).

TAINTON, N.M. (1972) The relative contribution of overstocking and selective grazing to the degeneration of tall grassveld in Natal. *Proceedings of the Grassland Society of Southern Africa*, **7**, 39–43.

TAINTON, N.M. (1988) Natural grazing lands and their ecology: The ecology of the main grazing lands of South Africa. In: Tainton, N.M. (ed.) *Veld and Pasture Management in South Africa*. pp. 1–55. (Shuter and Shooter: Pietermaritzburg).

TAINTON, N.M., BRANSBY, D.I. and BOOYSEN, P.deV. (1985) *Common Veld and Pasture Grasses of Natal.* (Shuter and Shooter: Pietermaritzburg).

TROLLOPE, W.S.W., TROLLOPE, L.A. and BOSCH, O.J.H. (1990) Veld and pasture management terminology in southern Africa. *Journal of the Grassland Society of Southern Africa*, **7**, 52–61.

WANDERA, F.P. (1993) *Patches in a* Heteropogon contortus *dominated grassland in southeast Queensland — their characteristics, probable causes, implications and potential for rehabilitation.* Ph.D. Thesis. University of Queensland.

WILLIAMS, J., HELYAR, K.R., GREEN, R.S.B. and HOOK, R.A. (1993) Soil characteristics and processes critical to the sustainable use of grasslands in arid, semi-arid and seasonally dry environments. *Proceedings of the XVII International Grassland Congress, Palmerston North/Rockhampton, 1993.* pp. 1335–1350.

WILLMS, W.D., DORMAAR, J.F. and SCHAALJE, G.B. (1988) Stability of grazed patches on rough fescue grasslands. *Journal of Range Management*, **41**, 503–508.

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