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EFFECT OF LONG-TERM EXCLUSION OF CATTLE ON SOIL PROPERTIES IN THE UPPER BURDEKIN CATCHMENT

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ABSTRACT

There is growing evidence of long term degradation of soil resources as a result of grazing pressures in many parts of the upper Burdekin catchment, north Queensland. To assess pathways to recovery of grazed land, sites were selected where small parts of a paddock had been fenced off to completely exclude cattle for the last 15 years. Generally, exclusion improved cover and soil surface condition but had little effect on nutrient stocks. However, in grazed areas, some nutrients were in greater concentrations close to the surface and therefore more vulnerable to loss through run-off from rainfall events.

INTRODUCTION

The upper catchment of the Burdekin River in north Queensland has been used for beef production for many decades and there is growing evidence that grazing pressures have resulted in degradation of this resource (Ash *et al.* 1997). Amongst the evidence for this decline are results of long-term exclosure experiments assessing impacts of grazing intensity since the mid 1980's on a range of factors including grass productivity and sediment generation from hillslopes (Scanlan *et al.* 1996a,b).

In this paper we present the preliminary results of a study using these long-term exclosure sites to evaluate the extent and rate of 'recovery' in soil physical and chemical properties where cattle have been excluded.

METHODS

Six sites, representing two major soil types, were chosen from the ten exclosures originally established by Pressland and Scanlan (Scanlan *et al.* 1996a,b) some 15 years prior to our study. In addition to the 4 ha 'exclosed' treatment which excluded domestic stock, these researchers also set up 0.25 ha exclosures which excluded kangaroos and other large native animals. At each site we compared selected soil properties in these 0.25 ha 'complete exclosures' with those in adjacent areas outside which were subject to normal grazing pressures. Unfortunately we could not use the original 4 ha 'stock only' exclosures as some were no longer intact.

Three of the sites were on red duplex soils derived from granodiorite (MV, KR, and LV) and three on neutral yellow duplex soils derived from sedimentary parent material (KHE, KHW, and BR). At each of these sites, the exclosures (ungrazed) and grazed areas close by were assessed for soil surface condition (Tongway and Hindley 1995), above ground biomass (standing and litter), and soil physical and chemical properties. Soil surface condition, above ground biomass (0.25 m^2 plots), near-saturated hydraulic conductivity using a mini disc-permeameter and soil bulk density were measured at the same five randomly selected locations. Soil chemical properties were measured on two replicates of seven bulked cores. The cores were separated into 0-5 cm and 5-15 cm depth. An additional 0-1 cm sample was collected at the same seven locations as the core samples. Bulk surface soil from some sites was returned to the laboratory for nutrient status analysis by bioassay. Results for the three sites on granodiorite parent material were similar in nature, as were two of the sites on sedimentary parent material (KHE, KHW). The other sedimentary site (BR), showed atypical results; this was the only site at which the sampling locations of grazed and ungrazed areas were some distance apart. The data presented here in tables and figures are for the MV (granodiorite) and KHE (sedimentary) sites only, however, the text in the results and discussion refers, in general, to the other sites on the same parent material. (ie KR, LV on granodiorite; KHW on sedimentary).

RESULTS

Excluding cattle had a substantial effect on pasture species composition. In the granodiorite landscapes, marked differences in pasture condition were evident between the exclosure and the adjacent grazed area with areas outside being almost totally dominated by the introduced, stoloniferous grass Indian couch *(Bothriochloa pertusa)* and having a markedly lower ground cover. In contrast, although *B. pertusa* was present within the exclosures, these areas had a high ground cover and contained a high proportion of palatable, perennial species like *Heteropogon contortus, Dicanthium secriceum, Bothriochloa ewartiana* and *Chrysopogon fallax* as well as a wide diversity of native legumes. On the sedimentary landscapes, differences in pasture composition were less evident inside and outside the exclosures with both areas containing a relatively high proportion of species like *H. contortus*, *B. ewartiana* and, in some cases, *Themeda triandra*. Nevertheless, the grazed areas tended to have a lower proportion of these species as well as a higher proportion of the increaser grass *Bothriochloa decipiens* and a relatively lower ground cover.

Excluding cattle also markedly affected standing biomass and cover (Table 1) with the grandiorite landscapes being more responsive than the sedimentary landscapes. At all sites, except BR (data not shown), standing biomass and percentage cover were significantly greater when cattle were excluded.

Table 1. Effect of excluding cattle on above ground biomass, cover and soil surface condition. Within each soil parent material, cattle and no cattle treatments are significantly different (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$). Data are for the MV and KHE sites only.

	Granodiorite (MV)		Sedimentary (KHE)	
Parameter	Cattle	No cattle	Cattle	No cattle
Standing Biomass (kg/ha)	766	7208**	1898	2509***
Soil Surface Condition Assessment				
Cover (%)	1-15	>50**	15-30	>50**
Stability (%)	60	72**	70	75**
Infiltration (%)	23	50**	36	43*
Nutrient Cycling (%)	16	35**	26	35**

Soil surface condition was also affected by excluding cattle with significant increases the Tongway and Hindley indices of stability, infiltration and nutrient cycling (Table 1). Generally, the indices were similar across all sites when cattle were excluded. However, when grazed, the granodiorite landscapes tended to have lower indices.

Soil physical properties such as bulk density and hydraulic conductivity were generally improved by excluding cattle (Table 2). In another experiment, infiltration rate was increased more than 10-fold, from approximately 6 mm/hr to greater than 75 mm/hr (MV site; Roth, in review) by excluding cattle.

In spite of the large differences in biomass, cover and soil surface condition, 15 years of excluding cattle had little effect on soil nutrients. Data from two selected sites show that while there are some differences between cattle treatments, these differences are often small and not consistent between sites (Table 2, Soil depth 0-5 cm). Results from other sites show similar trends. For example, excluding cattle increased exchangeable Ca and CEC at MV, but decreased these parameters at KHE. These results also suggest that the sedimentary site (KHE) has a greater natural fertility than the granodiorite site (MV).

The small difference in nutrient status between exclosed and grazed sites was confirmed by bioassay in soil from MV (Figure 1). Thus when no nutrients ('nil') were added (as is the case in the field), there was no difference in growth of buffel grass (*Cenchrus ciliaris*) on soil which had been excluded from cattle compared to that which had been continually grazed, indicating little change in effective nutrient status. These results also demonstrate the general low fertility status ('nil' compared to 'complete') and the most limiting nutrients that are responsible for this low fertility (P>N>S>K). Closer inspection of these results indicates that in many treatments which exclude these most limiting nutrients, growth is better in soil which has been grazed compared to ungrazed, especially in the 'minus N' treatment.

Table 2. Effect of excluding cattle on selected soil properties. The numbers in the smaller font represent the standard error of the means. Data are for the MV and KHE sites only.

	Granodiorite (MV)				Sedimentary (KHE)			
Parameter	Cattle		No cattle		Cattle		No cattle	
Soil Depth 0-5cm								
Bulk Density (g/cm^3)	1.60	0.02	1.41	0.02	1.64	0.03	1.51	0.03
Hydr. Cond.^{a} (mm/h)	4.9	1.3	5.6	1.2	3.0	0.8	6.0	1.4
pH (water)	6.45	0.02	6.87	0.04	6.33	0.08	6.35	0.15
CEC (cmol+/kg)	3.1	0.4	8.2	0.1	11.7	2.2	9.0	1.9
Total C (%)	0.84	0.04	1.05	0.01	2.23	0.35	1.58	0.04
Total N (%)	0.065	0.005	0.075	0.000	0.135	0.025	0.100	0.000
Exch Ca (cmol$^+$/kg)	1.5	0.3	2.8	0.3	5.3	1.4	4.1	0.2
Exch K (cmol+/kg)	0.5	0.0	0.6	0.1	1.0	0.1	1.0	0.0
Exch Mg (cmol+/kg)	1.2	0.1	1.6	0.0	2.7	0.4	2.4	0.0
Bicarb. P (mg/kg)	4.9	0.4	4.4	0.8	6.0	0.9	4.8	0.3
Soil Depth 0-1cm								
Total C (%)	1.68	0.37	1.50	0.37	5.01	0.90	2.78	0.41
Total N (%)	0.113	0.018	0.098	0.023	0.28	0.06	0.17	0.02
Total P (%)	90	21	64	4	250	40	205	25

^{a} Hydraulic conductivity determined at -2 cm suction

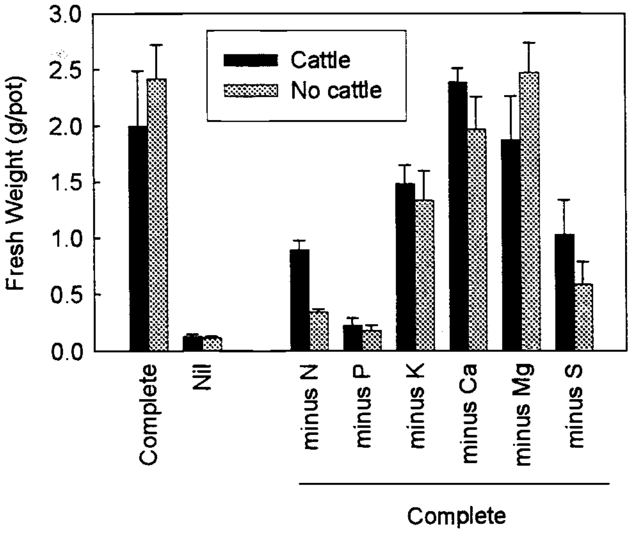

Figure 1. Bioassay to determine natural fertility and limiting nutrients in MV soil.

As the soils used in the above experiment were collected from the surface, a separate analysis of a 0-1 cm fraction was done (Table 2). At the MV and KHE sites, this revealed that in the very surface of these soils, there is tendency for nutrients to be higher under grazed compared to ungrazed soils. Further, the higher ratios of carbon and nitrogen in the 0-1 fraction to that in the 0-5 fraction in grazed areas would suggest less mixing of these nutrients though the soil.

DISCUSSION

Recovery

While the biomass recovery observed may have occurred within the first five years (see Ash *et al.*, 2001; Scanlan *et al.*, 1996b), it is less clear what length of time was required for the recovery of soil hydrological properties. Scanlan *et al.* (1996a) showed reduced runoff during the first five years of excluding cattle but the response was generally small compared with that found by Roth (in review) after a further 10 years at the same site. Although not quantified, there was clear visual evidence of greater soil fauna activity (castings) in the exclosed areas, and the more even distribution of nutrients through the upper soil layers of the ungrazed sites would support this conclusion. It is likely that increased biological activity may have contributed to the reduced bulk density and increased infiltration rate in ungrazed areas, as has been reported for a range of sites in the Burdekin by Roth (in review).

It appears that the improvements in soil condition were not generally associated with any marked increase in soil or site nutrient status over the 15 year exclosure period, possibly due to differences in turnover rates. While efficient nutrient turnover will be an important part of the recovery process, the results of the bioassay clearly indicate that soil fertility may be one of the factors limiting primary productivity and therefore potential rates of recovery. This suggests that improving soil nutrient status, in addition to grazing management, may be necessary to increase recovery rates to timescales that are manageable.

Potential for Nutrient Loss

Under grazed conditions, there is some evidence that the nutrients retained on site have accumulated in the surface to a greater concentration than under ungrazed conditions because of assumed lower rates of bioturbation. Thus under grazed conditions these nutrients would be more vulnerable to loss because of both their position within the profile and the greater likelihood of rainfall events causing runoff containing suspended sediments (Scanlan *et al.* 1996a).

In these already eroded sites, it is unclear what the implications of these potential nutrient losses will be on primary productivity in the long term as the nutrients being lost at the greatest rate may not necessarily be the ones currently limiting growth.

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