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GRAZING MANAGEMENT TO MAINTAIN SOIL HEALTH AND PASTURE PRODUCTIVITY IN GRAZED TROPICAL SAVANNAS

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ABSTRACT

Whilst the importance of good soil condition in grazed systems has long been recognised, grazing management in tropical savannas has historically focussed on the maintenance of perennial grasses and scant attention has been paid to the soil. In this paper we briefly discuss the role of perennial grasses and soil macroinvertebrates in maintaining ecological function and soil health and the effects of grazing on these elements. However, our understanding of these relationships remains poor. For example, the respective roles of, and interactions between, perennial plants and soil macroinvertebrates in promoting soil health and ecological function, and how grazing affects these processes, are all poorly understood. The potential complexity of soil macroinvertebrate responses to grazing suggests that current best-practice management focussed on the maintenance of perennial grasses may be inadequate for maintaining soil health This points to a need for a better understanding of these processes to develop improved grazing management practices to maintain land condition.

INTRODUCTION

Extensive cattle grazing is the dominant land use across northern Australia's tropical savannas. Managing land used for grazing involves achieving a balance between acceptable levels of livestock production and maintaining land condition, and minimising effects on other land use values such as biodiversity. Grazing management has historically focussed on the palatable perennial grasses, aimed at ensuring the persistence of the grass layer. The importance of good soil condition in maintaining pasture productivity has long been appreciated, but seldom receives specific management attention. However, the need for understanding and managing the effects of livestock on landscape function and soil health (i.e. the ability to capture and retain nutrients and water and support plant growth), is increasingly being recognised (e.g. Tongway and Ludwig 1997). Consequently recent efforts have been directed at improving our understanding of soil health and how it is affected by grazing.

Having an improved understanding of soil health will prompt questions concerning the respective roles of, and interactions between, perennial grasses and soil macroinvertebrates in maintaining ecological function, and what grazing management practices are needed to optimise pastures, soil health and livestock production. In this paper we briefly discuss the importance and respective roles of perennial grasses and soil macroinvertebrates in maintaining ecological function, the effects of grazing on these elements, and the implications for grazing management. We consider these issues in the context of (a) maintaining productive pastures under grazing and (b) restoration of degraded pastures. In particular, we question the implicit assumption that management focussed on the perennial grasses is adequate for maintaining soil health.

ROLE OF PERENNIAL GRASSES AND SOIL MACROINVERTEBRATES

Perennial grasses

Palatable perennial grasses continue to be the primary focus of grazing management in tropical savannas because of their value as livestock forage and their key role in ecosystem function. These grasses provide a valuable source of forage that persists for longer than annual herbaceous species. Patches of perennial grasses also function to trap soil particles, nutrients and water, thus helping to retain these materials within the ecosystem (Tongway and Ludwig 1997). Patches of perennial vegetation can thus be focal sites of biological activity and primary production. Fine roots of perennial grasses and other plants also help to aggregate soil particles and improve soil structure (Lavelle *et al*. 2006), and when decomposed may leave pores that improve infiltration. The perenniality of the grasses is important in providing stability to the system by protecting and stabilising the soil, especially during seasons with poor rainfall.

Soil macroinvertebrates

Soil macrofauna including earthworms and termites play a vital role in maintaining soil health in tropical soils. Through their burrowing, nesting and feeding activities, these macroinvertebrates contribute to the maintenance of soil structure and mediate essential soil processes such as water infiltration and nutrient cycling (Lal 1988). For example, termite feeding galleries created in the soil increase water infiltration and provide space for root growth. Earthworms play a fundamental role in bioturbation of soils, and their burrowing chambers increase soil macroporosity and infiltration.

The effect of termites on soil properties may depend on the species of termite and type of vegetation (Lal 1988). Termites can be classified into functional groups defined by their primary food resources. In Australia these include (1) soil-feeders (2) wood/soil interface feeders (3) wood-feeders (4) litter-feeders; (5) grass-harvesters; and (6) polyphagous-feeders (opportunists on a range of woody and herbaceous material). Knowledge of local functional group diversity is a pre-requisite to understanding which groups of species may be responsible for different pedological and ecological effects. However, it is not yet clear which groups are most important to soil health in Australia's grazed savannas.

PASTURE MANAGEMENT

Grazing management guidelines for Australia's tropical savannas are primarily concerned with ensuring the persistence of palatable perennial grasses by keeping the defoliation of tussocks to a 'safe' level. Setting stock numbers according to safe annual pasture utilisation rates is the primary way recommended for managing the severity of defoliation. Providing occasional periods of rest from grazing during the summer growing season is also accepted as a vital part of grazing management. Spelling early in the growing period is aimed at protecting perennial grasses as they regrow following dry season dormancy, when they are particularly sensitive to defoliation. Spelling later in the season is intended to facilitate flowering and seed production and hence promote seedling recruitment. Specific recommendations in relation to managing soil health have not featured in best-practice grazing management guidelines, and it would appear there has been an assumption that management that maintains the pasture is adequate to maintain soil condition. The only concession to maintaining soil condition is encompassed in a recommendation to maintain a minimum vegetative ground cover of 40% and biomass of 1000 kg/ha going into the wet season to minimise the risk of erosion in early wet season storms. The need to maintain soil surface conditions conducive to grass seed germination and establishment is also important but rarely considered.

MANAGEMENT OF SOIL HEALTH

Grazing generally reduces the abundance of earthworms and termites, although an increase or no change in termite abundance is sometimes observed (Lal 1988, Dawes-Gromadzki 2005). Infiltration rates decline due to a drop in the density of soil macropores under grazing (Dawes-Gromadzki *et al*. unpublished), and nutrient cycling is also expected to decrease. Few specific management guidelines have yet been developed for maintaining soil health under grazing. However, research is currently underway to provide a better understanding of the role of soil macroinvertebrates in soil health in northern Australia, and the potential effects of grazing on macroinvertebrates and associated soil processes (Dawes-Gromadzki 2005). This should provide a basis for developing some key principles for maintaining soil health. We will now briefly review what is currently known about the mechanisms through which grazing might affect soil macroinvertebrates.

Not surprisingly, soil macroinvertebrates require an adequate food resource to thrive. Heavy grazing that reduces plant biomass (and thus food availability) can be expected to reduce macroinvertebrate abundance. However, soil macroinvertebrates also have other requirements or can be affected in ways other than via changes in food availability and diversity. Earthworm activity is also influenced by soil temperature and moisture (Lal 1988). Soil vegetative cover plays a major role in regulating soil temperature and moisture, with higher levels of vegetative cover being associated with increased earthworm activity, particularly where the plant residue has a slower rate of decomposition (Lal 1988). Earthworm populations are therefore likely to be affected adversely by high stocking rates that reduce vegetative ground cover. Compaction of the soil by livestock trampling also reduces earthworm

abundance (Lal 1988, Cluzeau *et al.* 1992). On the positive side, animal manure may increase earthworm activity.

As with earthworms, termites benefit from higher vegetative ground cover (Barros *et al*. 2004). This is presumably a response to the availability of food, but may also reflect the moderation of soil temperature and moisture under higher cover. There are no specific reports concerning the effect of trampling of soils by livestock on termite communities, although it is likely that some termite species may be adversely affected by trampling. Other termites are capable of burrowing through compacted surface soil (Barros *et al*. 2004) and so may be less affected by trampling and compaction. Overall, termite responses to grazing appear to be variable in terms of their abundance and their sensitivity to factors such as trampling and changes in food availability. The implications of grazing for termites would appear to depend on the species and functional role of termites and the nature and severity of vegetation and soil changes wrought by grazing activity. For example, shifts in plant species composition may lead to changes in the termite assemblage, although if the replacement plants are similar to the lost species there may be little effect on termites (Brown *et al*. 2004).

Heavy grazing reduced termite species diversity in north-east Queensland due to the loss of grass-feeding termites (Holt *et al*. 1996). Such changes in the termite community might be expected to have flow-on effects to soil health, depending on the role in soil health played by the termites most affected. It is possible there will be different effects on soil biology and health depending on the nature of change in the plant community.

IMPLICATIONS FOR GRAZING MANAGEMENT

Little is known about the mechanisms by which grazing affects soil macroinvertebrates and soil health and the implications for management in Australia's tropical savannas. Given the importance of plant biomass as food and a moderator of soil conditions for soil macroinvertebrates, it might be expected that changes in soil macroinvertebrates and soil health might lag behind degradation of the plant community. It might also be expected that restoring soil health will depend on first re-establishing a vigorous herbaceous community. However, we suggest the possibility that changes to soil health and health-sustaining process may occur before substantial changes to the pasture layer, and that restoration efforts should emphasise the importance of reinstating soil health. If this is the case grazing management practices may need revision.

Research in tropical systems overseas suggests that soil macroinvertebrates (especially earthworms) may respond more rapidly to grazing than the plant community due to the effects of livestock trampling or subtle changes in the cover, structure and composition of the pasture. Simply disturbing the natural vegetation can reduce earthworm abundance (Lal 1988), and termite activity can decline within a year following the depletion of a food source (Léonard *et al*. 2004). In addition, the persistence of established perennial grasses may mask early changes in soil health. Monitoring of the perennial pasture component may therefore not provide useful insights into soil health if the latter is responding more rapidly than the plant community. Similarly, it is not known whether the current management target of maintaining a minimum of 40% vegetative cover will be effective in protecting soil macroinvertebrates, particularly if they are sensitive to changes in plant species composition.

While soil macroinvertebrates may respond rapidly to the effects of grazing, Lavelle *et al*. (2006) suggested that the combined effects of soil invertebrates and plant roots on soil physical properties confers high resistance to soils that allows the persistence of favourable hydraulic properties well after key processes have been compromised by poor management. This suggests the need for a good understanding of the circumstances and rates at which soil health attributes and processes are impaired by grazing, since this resistance may create a false perception of the well-being of soil health.

Frequently land restoration activities have concentrated on introducing seed of desirable perennial species to accelerate recovery, but this often meets with limited success. Poor soil conditions likely contribute to the slowness of recovery and low success rate of recovery activities. Greater success might be achieved if actions to improve soil health are implemented as an early part of the restoration

process. Possible options include creating conditions that promote soil macroinvertebrate activity, such as by the distribution of plant litter (e.g. straw) at strategic locations as a food source for macroinvertebrates and to moderate soil temperature and moisture. Alternatively, placing timber (e.g. fallen trees and branches) across degraded areas may act to trap soil particles, plant litter and moisture, thus creating conditions that favour soil invertebrates. Improvements in plant cover and growth can be expected as soil macroinvertebrate assemblages recover (Barros *et al*. 2004).

CONCLUSIONS

This paper presents evidence that soil macroinvertebrates can be affected by changes to the cover, structure and composition of the understorey vegetation, and trampling and soil compaction. The complexity of responses to grazing suggests that current best-practice management focussed on the perennial grasses may be inadequate for maintaining soil health in Australia's tropical savannas. However, numerous aspects of soil health and how it is affected by grazing remain poorly understood. Key issues to be addressed include: what are the mechanisms by which grazing affects functionally important soil macroinvertebrates and soil health, how do these effects relate to changes in the plant layer, and what are the relative rates of change to perennial plant communities and soil health attributes (Hunt and Dawes-Gromadzki 2005).

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