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Effects of time-controlled and continuous grazing on total herbage mass and ground cover

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Abstract

Grazing practices in rangelands are increasingly recognized as a management tool for environmental protection in addition to livestock production. Long term continuous grazing has been largely documented to reduce pasture productivity and decline the protective layer of soil surface affecting environmental protection. Time-controlled rotational grazing (TC grazing) as an alternative to continuous grazing is considered to reduce such negative effects and provides pasture with a higher amount of vegetation securing food for animals and conserving environment. To research on how the grazing system affects herbage and above ground organic materials compared with continuous grazing, the study was conducted in a sub-tropical region of Australia from 2001 to 2006.
The overall results showed that herbage mass under TC grazing increased to 140 % in 2006 compared with the first records taken in 2001. The outcomes were even higher (150 %) when the soil is deeper and the slope is gentle. In line with the results of herbage mass, ground cover under TC grazing achieved significant higher percentages than continuous grazing in all the years of the study. Ground cover under TC grazing increased from 54 % in 2003 to 73 %, 82 %, and 89 % in 2004, 2005, and 2006, respectively, despite the fact that after the high yielding year of 2004 herbage mass declined to around 2.5 ton ha^{-1} in 2005 and 2006. Under continuous grazing however there was no significant increase over time comparable to TC grazing neither in herbage mass nor in ground cover. The successful outcome is largely attributed to the flexible nature of the management in which grazing frequency, durations and the rest periods were efficiently controlled. Such flexibility of animal presence on pastures could result in higher water retention and soil moisture condition promoting above ground organic material.

Keywords: Currajong, herbage mass, ground cover, time-controlled grazing, continuous grazing

1 Introduction

It is well accepted that continuous grazing largely exposes desirable species to repeated defoliations of differing intensities, compared with the less desirable and undesirable (Dyksterhuis, 1949; Holechek *et al.*, 1998). For this reason, even when stocking rates are low in relation to the pasture carrying capacity, the most palatable and nutritious plants are subject to higher grazing pressures (Wilson & Harrington, 1984). Depending on the pastoral ecosystem characteristics such a continual selective grazing over time results in a decrease in the quantity of desirable species and in turn reduces pasture productivity.

Rotational grazing which includes some periods of grazing exclusion, helps to minimize this repeated defoliation of the species. To include rest periods, at least two paddocks are needed; however a higher number of paddocks, as many as 50 or more, could be involved. The more paddocks in the rotation, the greater is the flexibility in management such as the option of skipping

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one paddock during a rotation cycle without imposing significant stress on the remaining paddocks (Norton, 2003). Time-controlled (TC) grazing as a new variant of rotational grazing involves short periods of intensive grazing followed by long rest durations. Grazing intensity is much higher than that of the normal carrying capacity usually estimated for continues grazing, therefore selective grazing is greatly reduced. The grazing system was put forward by Savory & Parsons (1980). The terms "The Savory Grazing System", "Short Duration Grazing" and "Cell Grazing" are the various names given to the grazing practice.

Field trials by graziers under commercial livestock production in the USA, South Africa and Australia have shown quite significant improvements in some pasture attributes under TC grazing (Alsemgeest & Alchin, 2002; Detterling, 1999; Johnson, 1998; Joyce, 2000; Sayre, 2001; Sparke, 2000; Suther, 1991), however, uncertainty in relation to the ability of TC grazing to increase desirable species, livestock production, labour costs and herbage mass still exist (Gammon, 1978; Holechek *et al.*, 1998; Valentine, 2000; Wilson, 1986).

The successful outcomes from commercial trials in grazing lands reported earlier have resulted in an increasing adoption of the new grazing practice in Australia as well as throughout the world. However, due to the periods of intensive grazing, balance between pasture utilisation and environmental conservation is of great concern. Such a balance is more emphasised in areas where soil depth and available moisture are limiting factors of herbage growth.

To investigate how the grazing system of TC grazing affects above ground organic matter and land surface protection, the current study was conducted using research paddocks of the commercial property of Currajong in southeast Queensland Australia over the period of 2001 to 2006. In this study, the focus is only on pasture attributes that affect above ground organic materials and land surface protection. The paper is then aimed to report on the general impacts of the grazing treatments (TC, Continuous grazing) on total herbage mass and ground cover.

2 Materials and methods

2.1 Study sites

The study area is located 40 km West of Stanthorpe in the semi-arid region of southeast Queensland Australia (28º 33′ S, 151º 33′ E, altitude 675 m). Long term average rainfall (119 years) is 645 mm of which 70 % is falling in summer within the months of October to March. The rain in summer (grass growth season) is characterised by relatively high frequency of medium to large events of short (thunderstorms) and long (cyclonic depressions) duration. Mean temperature is 17.3°C with July being the coldest (10°C) and January the warmest months (24°C).

Natural vegetation in the study area is an Eucalypt open woodland that has been extensively cleared over the past century for agricultural and grazing activities. Understory vegetation is dominated mostly by Queensland blue grass [*Dichanthium sericeum* (R. Br.) A. Camus]. The remaining desirable species include but are not limited to Silky browntop [*Eulalia aurea* (Bory) Kunth], Wallaby grass [*Danthonia tenuior* (Steud.) Conert] and Hairy Panic [*Panicum effusum* R.Br.]. The next grouping of plants, in the order of dominance, comprises native species of Wiregrass (*Aristida* sp.) known as less desirable. There is also another group of species that has a medium palatability in the area such as Pitted blue grass [*Bothriochloa decipiens* (Hack.) C.E. Hubb.] and Digitaria [*Digitaria breviglumis* (Domin) Henrard]. Coolati grass [*Hyparrhenia hirta* (L.) Stapf] along with African lovegrass [*Eragrostis curvula* (Schrad.) Nees] are less desirable to sheep than to cattle, while both species are invasive to the area.

The study area has shallow to moderately deep soils with a brown to dark clay loam underlaid by a bleached A2 horizon. The soil analysis showed for the surface soil (0–10 cm) a pH and EC of 5.6 and 0.06 mS respectively; soil organic carbon of 26 ton ha^{-1}; NO_3 of 0.6 kg ha^{-1} and extractable P of 17 kg ha^{-1} (Sanjari *et al.*, 2008). The area is the headwater for a number of streams and visibly eroded by sheet erosion due to the lack of vegetative cover, channel incisions and re-incision of alluvial deposits in valley floors (Sanjari, 2008).

2.2 Treatments

This research was conducted on a commercial grazing property, which was in the process of converting from long term continuous grazing into TC grazing. The application of TC grazing required the existing large paddocks to be sub-divided into 21 smaller paddocks using electric fences. One of the paddocks under TC grazing was assigned to this research for data collection. There was also another research paddock with similar geomorphology and soils as the TC paddock to represent the continuous grazing system. Following the assignment of the paddocks to the grazing treatments, they were each subdivided into two sub-treatments that based on the differences in slope and soil depth are hence forth called “deep flat” and “shallow sloppy” (Table 1). Under this arrangement, the sub-treatments T.deep flat and T.shallow sloppy belong to time-controlled and the sub-treatments C.deep flat and C.shallow sloppy belong to continuous grazing. The combined results of the sub-treatments are reported as the grazing treatment effects. The similarities (in terms of slope and soil depth) between sub-treatments T.deep flat and C.deep flat on the one hand and between T.shallow sloppy and C.shallow sloppy on the other hand, provided the experiment with a chance of reducing *between treatment errors* when comparing the two grazing treatments.

Under TC grazing, a large herd of livestock is moved between a number of paddocks for short periods of time. These periods of grazing are considerably shorter than the rest durations. A general recommendation suggests 30–90 days for the rest durations, which shortens during rapid plant growth and lengthens as plant growth slows (Gillen *et al.*, 1991). Such flexibility in rest duration is also the case for grazing periods and stocking rates, therefore a different numbers of stocks could be moved between paddocks at any time depending on grass growth rate and feed on offer (Fig 1). In our study a sheep herd of merinos with different sizes in different grazing events (1750 – 4577 DSE) were moved between the 21 paddocks over the study period. The grazing details for our research paddocks (one per grazing system) are summarized in Figure 1 and Table 2.

The stocking rate (SR) for the two grazing treatments is expressed as dry sheep equivalent (dse) per hectare. Dry sheep equivalent is defined as the nutritional or metabolisable energy needed to maintain a 50 kg dry sheep (non-lactating). A 50 kg wether has a dry sheep equivalent of 1, animals requiring more feed have a higher rating and animals with less feed requirements have a lower rating. The history of stocking rate summarised in Table 2 shows that the paddock with TC grazing was heavily stocked with an average number of 12.3 dse ha^{-1} over a mean grazing period of 14 days and then rested for various time (101 ± 60 days). In the continuous grazing, the pasture was stocked with a constant stocking rate of around 1.6 dse/ha throughout the years of the study that is considered normal in the region and exerts a light to moderate pressure on the pasture.

Maximum efforts were made to keep the same overall grazing pressure in both grazing treatments. This was achieved by the similar total number of dse.day ha^{-1} (DDH) reported in Table 2 despite the fact that the grazing systems had major differences in stocking rates, grazing durations and rest periods. The similar DDH between the paddocks indicates that the stocking management by the grazier kept the overall stocking pressure equal between the treatments.

2.3 *Sampling*

To undertake field data collection, 44 permanent sampling location sites were selected across the research paddocks that were distributed equally between the two grazing treatments and sub-treatments in catenary sequences to include all landform components. Sampling with 10 replications was performed randomly at each permanent location using a quadrate of 0.25 m^2 to measure main components of vegetation and residue cover (i.e. herbage mass and ground cover). The area in which quadrates were placed was a circle with 25 meter radius centred at each permanent location. The quadrate was thrown to fall at random within the site area. Cautious was taken to avoid any overlap between the new and the previous sampling locations.

Table 1: *Summary of soil characteristics assigned to the grazing treatments*

Sub treatments	*Depth* (cm)	*Area* (ha)	*Slope* %	*Size fraction* (%)			*pH*	*EC* (mS)
				sand	*silt*	*clay*		
TC grazing								
T.deep flat	40	50	10.2	34.6	28.7	36.7	5.9	0.07
T.shallow sloppy	28	42	15.3	28.1	34.0	38.0	5.4	0.03
Continuous grazing								
C.deep flat	42	128	10.0	31.6	31.0	37.4	5.9	0.08
C.shallow sloppy	27	110	14.8	45.6	25.3	29.1	5.1	0.06

T: time-controlled grazing; C: continuous grazing

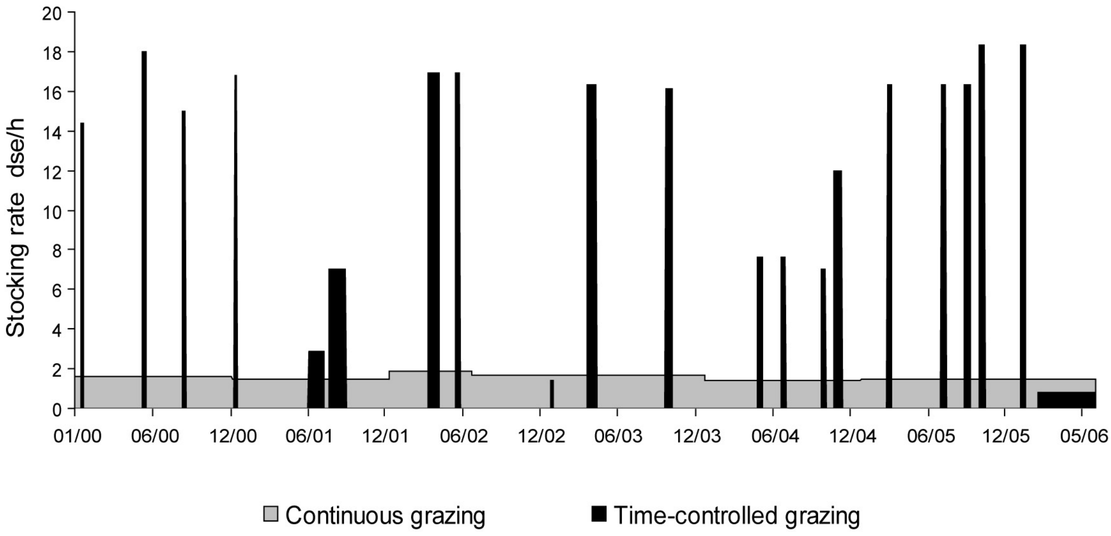

Fig. 1: *Stock density, grazing durations and rest periods under time-controlled (dark bars) and continuous grazing (grey area) systems*

Table 2: *Mean stocking details for the two grazing treatments (2000–2006)*

Grazing treatments	*Grazing periods* (days)	*Rest periods* (days)	*SR* (dse/ha)	*DDH* dse.day/ha
Time-controlled	14 ± 9 ‡	(101 ± 60) ‡	12.6 ± 6 ‡	3608
Continuous	365	0	1.6 ± 0.2	3529

DDH- Number of dse days per hectare over the whole study period; dse = dry sheep equivalent
‡ Means ± SD; *SR*: Stocking rate

Herbage was sampled each year at the end of growth season (Mid February to first May) in both grazing treatments. These times were set based on the coincidence of rest periods with end of grass growth season so that there have been always 10 to 30 days before the commencement of the next grazing period in TC grazing. Herbage harvested at ground level comprised both green and dead materials of all existing plant species. The harvested material refers only to the total (green + dead) mass of standing plant materials and excludes individual measurements of the species in the quadrat. The samples were oven dried at 40°C and reported as unit weight of dry matter per hectare (kg DM ha^{-1}).

Ground cover in this paper refers to any non-soil materials remained on or near ground surface that protect the soil surface against erosive forces of raindrops and overland flow (McIvor *et al.*, 1995). It includes any form of living and dead plant material as well as dung and stones. Ground cover in soil erosion studies has some advantages over canopy cover. While both the ground and canopy covers protect the soil against raindrop impact, only ground cover effectively interrupts overland flow and bears a fraction of its flow shear stress thus reducing soil erosion (Proffitt & Rose, 1991).

The definition of ground cover is originally based on the commonly used method of aerial plant cover (Greig-Smith, 1983) measuring the proportion of the ground occupied by perpendicular projection of the aerial parts of plants plus other non-soil components. To estimate ground cover from the randomly laid quadrates, the results of two methods of Visual estimation (Zhou *et al.*, 1998) and digital image analysis (Abramoff *et al.*, 2004) were averaged. For ground cover estimation at any permanent site, 5 out of 10 replications were assessed by visual estimation and the remaining 5 replications by digital image analysis. Visual estimation gives a relatively quick and reliable estimate of ground cover compared with those obtained by more objective and time consuming methods (Murphy & Lodge, 2002; Vanha-Majamaa *et al.*, 2000).

For image analysis, a digital camera with focal length of 35 mm was used. The photographs were taken vertically from 160 cm above the centre of the quadrates and analysed by ImageJ, a Java image processing program. The process is based on grayscale image where white pixels correspond mostly to bare ground and as the colour turns to grey and black, it includes stone, litter and standing vegetation. For ground cover to be measured by digital ImageJ analysis, the most appropriate cut-off value distinguishing the bare and non-bare ground areas needs to be determined. This threshold could be obtained by crosschecking the binary images produced under a range of different cut-off values of grey colour intensity. While ImageJ has been widely used for digital image analysis in biology, no records of such application on rangeland monitoring were found in literature.

2.4 Data analysis

A two tails T-test analysis of variance was used to compare the paired values of herbage mass and ground cover taken at the beginning and at the end of the study period. This analysis simply examines the differences between the means of the two groups of samples. The second test employs regression lines analysis of variance (Tsutakawa & Hewett, 1978) that compares the overall changes in herbage mass over time using the slopes and intercepts of two lines corresponding to the grazing treatments. All the data analyses were carried out using Statistix9 and SPSS 15.

3 Results

3.1 Herbage mass

The records of herbage mass sampled at the beginning of the study in 2001 (Fig 2a) showed an almost equal herbage mass (1.9–2.0 ton DM ha^{-1}) for the two grazing treatments. This was expected as before the start of this research both paddocks had been grazed continuously for a very long period of time. Herbage yield is in perfect relation with rain received between any two consecutive harvest times in both grazing treatments but with higher values achieved with TC grazing than continuous grazing. It should be noted that the total rainfall in 2004 was 23 % above the long term average and lead to a production of 3.25 ton herbage DM ha^{-1} under TC grazing but only 2.2 ton herbage DM ha^{-1} under continuous grazing.

Herbage mass under TC grazing (Fig 2a) fluctuated over the years, peaked on March 2004 and then sustained at 2.7 ton DM ha^{-1} in 2006 which was significantly higher ($p \leq 0.01$, Table 3) than the initial mass in May 2001. Under continuous grazing the same pattern of herbage fluctuations as under TC grazing was found. However, under continuous grazing the herbage mass in May 2006 only reached to 2.2 ton DM ha^{-1} and was not significantly different from the initial herbage mass in May 2001. When the soil condition is favourable, as it is relatively the case under deep flat, the response to the grazing treatments is more pronounced than under shallow sloppy soil conditions. As it is shown in Fig 2b and Table 3, the increased herbage mass in T.deep flat from 2001 to 2006 accounts for 966 kg DM ha^{-1} while it reached to 314 kg DM ha^{-1} in C.deep flat. Under less favourable soil conditions (shallow sloppy), TC grazing again displayed a higher gain in herbage mass (560 kg DM ha^{-1}) than continuous grazing (106 kg DM ha^{-1}) by the final year.

Table 3 also shows the mean herbage mass and the trends of herbage accumulation along with the regression line parameters for the grazing treatments. The table illustrates the mean herbage accumulation of 2.45 ton DM ha^{-1} with gradient 0.43 for TC grazing and 2.1 ton DM ha^{-1} with gradient 0.17.

The results of regression line analysis (table 4) is in line with the outcomes of the T test ANOVA presented earlier and show that TC grazing produced a higher level of herbage mass than continuous grazing in the study area.

3.2 Ground cover

Ground cover showed a general decrease from 2001 to the end of 2003 (period 1) followed by an increase from 2004 to 2006 (period 2) under both grazing systems. In the first period, ground cover declined 10 % under TC grazing and 17 % under continuous grazing (Fig 4a). During the second period however, the ground cover under TC grazing increased to 75 % in 2004 to reach 90 % by 2006. Under continuous grazing it reached 62 % in 2004 ending up at 68 % in 2006. Ground cover in the sub-treatments (Fig 4b) relatively demonstrated the same decrease trends during period 1 with a lower rate of decrease in T.deep flat than the others. However over the second period a significant higher increase in ground cover was observed under TC grazing than under continuous grazing.

The results of a T test analysis of variance displayed in table 5 show details of the comparisons made on the ground cover achieved by the grazing treatments over the first and the last halves of the study period. For any comparison in the matrix, two values are given with the associated *p* values underneath. The table shows that ground cover in T.deep flat was significantly

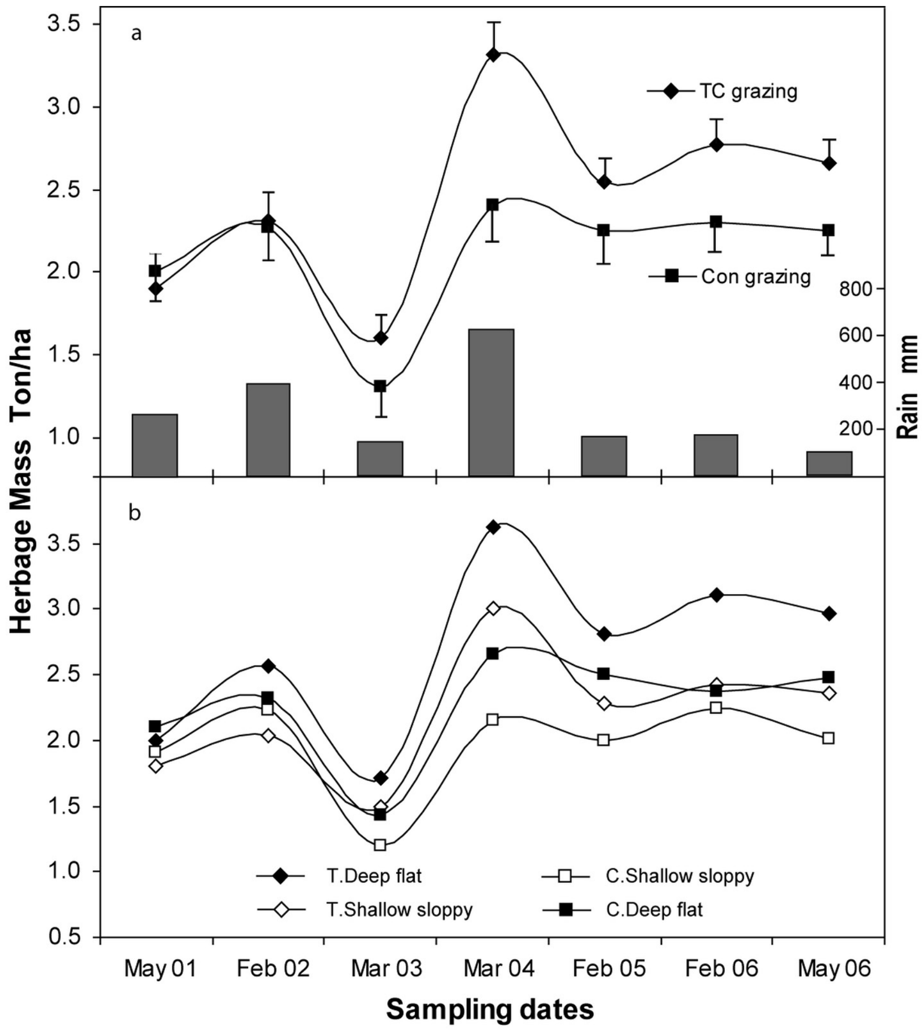

Fig. 2: *Herbage mass and the total rain received from the previous sampling date for the grazing treatments (a) and the sub-treatments (b); error bars show SDs*

Table 3: *Summary of herbage mass analysis for the period of May 2001 to May 2006*

Treatments	*Herbage* (kg DM ha^{-1})[†]	*Herbage* (kg DM ha^{-1})[‡]	*r*	*slope*[§]	*intercept*[§]
T.deep flat	+966 ***	2671 ± 615	0.75 **	0.51	2165
T.shallow sloppy	+560 **	2231 ± 438	0.63 *	0.35	1885
TC grazing (overall)	+764 ***	2451 ± 525	0.69 **	0.43	2025
C.deep flat	+314 ns	2279 ± 371	0.45 ns	0.24	2043
C.shallow sloppy	+106 ns	1918 ± 325	0.23 ns	0.11	1812
Con. grazing (overall)	+240 ns	2098 ± 318	0.38 ns	0.17	1928

[†] Results of T test ANOVA and the values are the products of the mean herbage harvested in May 2006 minus the mean herbage in May 2001;
[‡] Mean ± SD, is the mean of herbage harvested per sampling ± SD
r: Correlation coefficient; [§] Regression line identities; *: $p \leq 0.10$; **: $p \leq 0.05$; ***: $p \leq 0.01$; ns: not significant
T: time-controlled grazing; C: continuous grazing

Table 4: *The results of regression line analysis between treatments and sub-treatments*

Grazing Treatments	*T.deep* flat	*T.shallow* sloppy	*C.shallow* sloppy	*TC grazing* (overall)
T.shallow sloppy	6.22* ; 4.32*			
C.shallow sloppy	16.32*** ; 10.35**	5.44* ; 3.22*		
C.deep flat	7.42* ; 3.62*	1.31ns ; 1.06ns	0.47ns ; 3.92*	
Continuous grazing (overall)	—	—	—	7.69* ; 3.79*

The paired values in the table represent F_{slope}; $F_{intercept}$, respectively. T: time-controlled grazing; C: continuous grazing; * p ≤ 0.10; ** p ≤ 0.05; *** p ≤ 0.01; ns: not significant

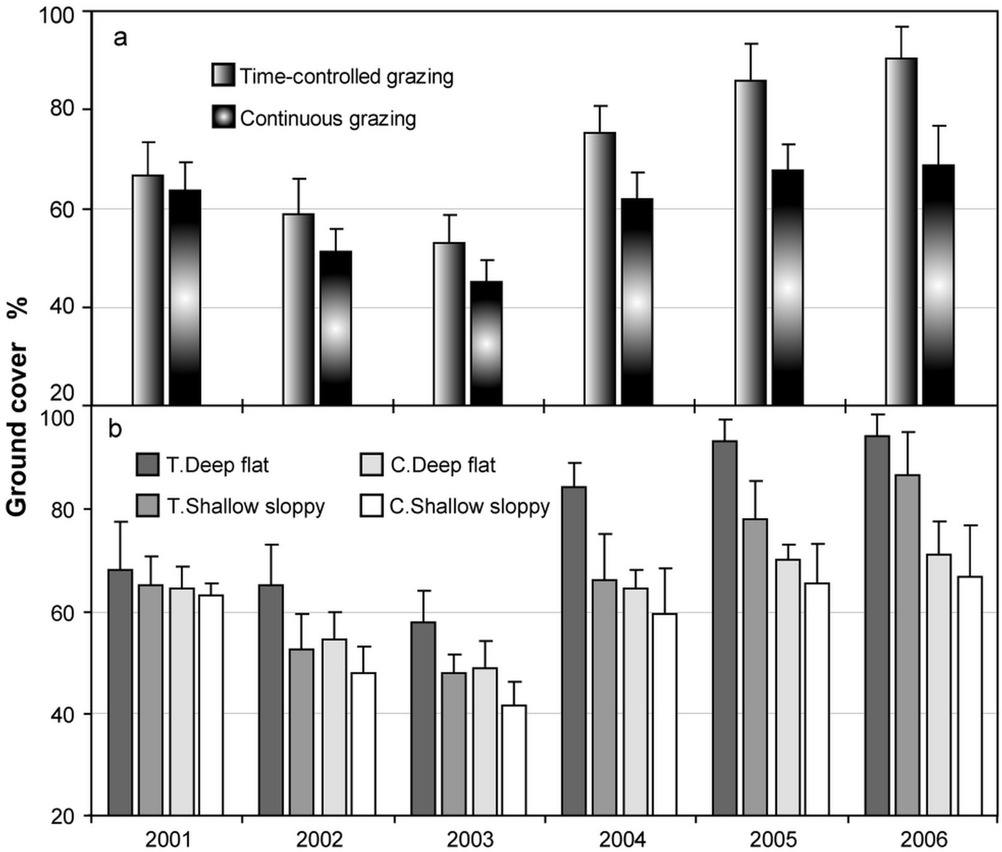

Fig. 3: *The percentage of ground cover achieved under time-controlled and continuous grazing in the study area*

Table 5: *Ground cover analysis of variance between sub-treatments for the first (2001–2003) and the second (2004–2006) periods of the study*

Sub-treatments	*T.deep flat*		*T.shallow sloppy*		*C.deep flat*	
	1st	2nd	1st	2nd	1st	2nd
T.shallow sloppy	%9 ***	%16 ***				
C.deep flat	%8 ***	%22 ***	%1 ns	%6 ***		
C.shallow sloppy	%14 ***	%27 ***	%5 ns	%11 ***	%6 *	%5 **

Values in the table indicate differences between the sub-treatments;
p < 0.1; ** p ≤ 0.05; *** p < 0.01; ns: non significant; T: time-controlled grazing; C: continuous grazing

higher than the other sub-treatments including T.shallow sloppy, both in the first and in the second periods of the study. The T.shallow sloppy received higher significant cover than the two continuous grazing sub-treatments only over the second period.

The significant increase in ground cover in 2004 as compared with 2003 for both treatments (Fig 3a) is most likely associated with the high rainfall in 2004. Although the annual rainfall declined to somewhat below the long term average in 2005 and 2006 (Fig 2a), the ground cover under TC grazing continued to increase leading to significant different levels compared to continuous grazing over the last two years of the study (Fig 3).

4 Discussion

Herbage mass, as the primary source of above ground organic materials, provides grazing animals and soil micro-organisms with nutrient and energy and protects soil by increasing litter and ground cover. The improvement in herbage mass and ground cover under TC grazing could be mainly attributed to the adequate long rest periods, appropriate grazing durations and stocking rates. The periods of animal exclusion from paddocks, are necessary for maintaining plant vigour, seeding, seedling establishment and plant recovery after defoliations (Wilson *et al.*, 1984; Lodge, 1995). In order for plant recovery to be fully implemented, the length of rest periods under TC grazing should be long enough to decrease and control the negative effects of intensive defoliations on soil conservation. The length of rest period or defoliation interval has a direct positive effect on herbage mass (Hill, 1989; Binnie & Chestnutt, 1991). In our experiment, the periods of grazing exclusion differed with time and on average lasted around 3 months. While the applied rest periods in the research paddocks seem to be adequate, a scientifically based threshold has yet to be developed for this region.

Stocking rates and grazing durations are also critical factors to manage a successful outcome by TC grazing. The physiological research on plants under intensive single defoliation (common under TC grazing) of about 50 % of shoot volume, showed that the root growth was retarded for 6–18 days in 7 out of the 8 perennial grasses investigated (Crider, 1955). Richards (1993), who reviewed a large number of studies in relation to plant physiological responses to defoliation, believes that following an intensive defoliation, the plants go through a temporal phase of rapid changes in available carbon and nitrogen ultimately resulting in partial root mortality. This mechanism restores the shoot:root ratio of the plant required to begin a recovery process with a fast photosynthesis rate.

Apart from the physiological processes involved in plant recovery, the roots pruned and decayed this way are added to soil profile as the main source of organic matter. Depending on the intensity of defoliations under TC grazing, the amounts of root pruned could be substantial, leaving a large amount of soil pores after dying off facilitating infiltration.

Over the processes of fast photosynthesis rates, if the defoliated plants have access to adequate water and nutrients, the recovery would be fully implemented. In the southeast Queensland including the study area, there is a high chance of having a number of consecutive rainfall events in summer during the long rest periods. This provides the pasture with the maximum transpiration and nutrient uptake during the fast recovery period. Over the growth season of 2003–2004, our paddock of TC grazing was rested for the longest duration of 156 days, during which it received a total rainfall of 480 mm. Although such an excessively long duration of grazing exclusion is somewhat exceptional, the coincidence of the rest period with the favourable wet condition resulted in the highest level of herbage mass in 2004 (Fig 2a). Following this period, the grazier applied more frequent but shorter grazing durations which sustained herbage mass and ground cover until the end of the study period resulting in a far better outcome than under continuous grazing.

The increase in ground cover over 2005–2006 under TC grazing shows the incremental additive effect of herbage mass on ground cover implemented either by physical action of grazing animals or by natural decay. McIvor (2002) who found a logarithmic relationship between ground cover and herbage mass showed that herbage growth can occur even when ground cover is 100 %. Such cumulative effect of herbage mass on ground cover under TC grazing practice can build up an adequate layer of surface organic materials during periods of favourable growth conditions providing soil protection in subsequent years. The results on ground cover in this study are supported by the earlier results on ground litters (Sanjari *et al.*, 2008) and soil erosion control (Sanjari *et al.*, 2009) under TC grazing.

In contrast to TC, under continuous grazing a lower herbage mass was found as well as a lower ground cover leaving the soil surface with less organic protective layer against water erosion. Continuous grazing even at light stocking rate exert high pressure on desirable species (Beattie, 1993; Tainton & Walker, 1993; Lodge, 1995; Parsons, 1995) and leave the rest of the plants un-grazed.

The results of this study have shown that under prevailing condition of the study area, time-controlled grazing has a potential to significantly increase total herbage mass compared with yearlong continuous grazing despite the fact that the total DDH (dse.days/ha) numbers for the two grazing practices were similar. Time-controlled grazing also achieved a high significant level of ground cover, providing a reliable layer of organic material to protect the soil surface against water erosion. The improvement in total herbage mass and ground cover under TC grazing is largely attributed to the proper inclusion of grazing frequency and duration, as well as the provision of adequate rest periods in the study area.

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