Herbage availability and utilisation in small-scale patches in a bahia grass (*Paspalum notatum*) pasture under cattle grazing

M. HIRATA
Grassland and Animal Production Division, Faculty of Agriculture, Miyazaki University, Miyazaki, Japan

Abstract

Herbage availability and utilisation at a scale of small patches (approximately a feeding station scale) were investigated in a bahia grass (*Paspalum notatum*) pasture under cattle grazing. For 11 grazing periods (2–7 days) between May (late spring) and October (autumn) in 2 years, pre- and post-grazing herbage masses and rate of defoliation were non-destructively estimated with an electronic capacitance probe at 182 fixed locations (50 cm × 50 cm) along 2 permanent line transects.

Distribution of herbage mass was spatially heterogeneous both before and after grazing, exhibiting patches with different herbage masses. Spatial variation in herbage mass always increased with grazing, with the increase being greater under higher mean herbage utilisation over the transects, *i.e.* under higher grazing intensity. Herbage consumption by animals also varied spatially with rates of defoliation differing among patches. Rate of defoliation across the locations became more uniform as the mean herbage utilisation increased, *i.e.* animals consumed more uniform amounts of herbage from patches under higher grazing intensity. The correlation coefficient between the rate of defoliation and pre-grazing herbage mass increased as mean herbage utilisation increased, *i.e.* the tendency for animals to consume more herbage from patches with higher herbage mass became stronger under higher grazing intensity. Thus, higher grazing intensity resulted in more uniform utilisation of patches by reducing selectivity by animals, but resulted in more variation in vegetation across the patches.

Correspondence: Dr Masahiko Hirata, Division of Grassland Science, Faculty of Agriculture, Miyazaki University, Miyazaki 889-2192, Japan.
E-mail: m.hirata@cc.miyazaki-u.ac.jp

Introduction

Vegetation in grazing systems is spatially heterogeneous (Vallentine 1990). Even in monospecific pastures, vegetation forms a mosaic of short, heavily grazed patches with low herbage mass, tall, ungrazed or lightly grazed patches with high herbage mass and a transitional zone of intermediate height, utilisation and mass (Illius *et al.* 1987; Liu and Hirata 1995; Hirata and Fukuyama 1997; Cid and Brizuela 1998; Hirata 1998, 2000a, 2000b).

Animals respond to such heterogeneity by selectively grazing patches (Illius *et al.* 1987; Vallentine 1990; WallisDeVries and Daleboudt 1994). Past studies have reported that animals visit short patches more frequently, spend longer grazing and take more bites from these areas than they do from tall or intermediate patches, preferring higher digestibility and nitrogen concentration of herbage in short patches (Illius *et al.* 1987; WallisDeVries and Daleboudt 1994; Cid and Brizuela 1998). However, there is limited information about herbage consumption from individual patches in a pasture (WallisDeVries and Daleboudt 1994; Distel *et al.* 1995). Frequent visits, longer grazing time and increased bite numbers on short patches do not necessarily mean that herbage consumption in this patch type is greater than in other patch types, because low herbage availability in short patches may limit intake rate of animals (Black and Kenney 1984; Arias *et al.* 1990; Ungar *et al.* 1991; Laca *et al.* 1994; WallisDeVries and Daleboudt 1994; Distel *et al.* 1995).

Hirata (2000b) developed a sward-based technique for quantifying herbage mass and consumption by grazing animals at a small patch scale (50 cm × 50 cm); and used the technique for the initial 2 days of grazing in 3 to 6-day rotational grazing periods covering a grazing season of 5 months, on a bahia grass (*Paspalum notatum*) pasture grazed by cattle. This work showed that distributions of both herbage mass and consumption were spatially heterogeneous over the grazing season, confirming that cattle consumed different amounts of herbage from patches with different herbage masses. In addition, herbage consumption from individual patches was positively correlated or not correlated with herbage mass in the patches, showing that the manner of patch utilisation by cattle varied within the grazing season.

The aims of the present study were to obtain broader information on the fine-scale spatial distribution of herbage mass and consumption in a bahia grass pasture under cattle grazing and to analyse the manner of patch utilisation by cattle. For these purposes, measurements were conducted in the same pasture for another grazing season of 5 months. Since the previous study (Hirata 2000b) dealt with data only from the initial stage (2 days) of rotational grazing periods where animals are assumed to be relatively selective, the additional data were collected for the whole duration of rotational grazing periods (4–7 days). Pooling these data sets enabled the present study to deal with data from a wide range of grazing intensities.

Materials and methods

The site, pasture and animals

A 1.1-ha paddock of a Pensacola bahia grass pasture at the Sumiyoshi Livestock Farm (31°59'N, 131°28'E), Faculty of Agriculture, Miyazaki University, southern Kyushu, Japan, was used. The paddock was one of 5 paddocks (total area=6.3 ha) rotationally grazed by Japanese Black cows.

The climate of the site is humid subtropical with cool, dry winters. The long-term averages (1961–1990) for mean monthly air temperature and monthly rainfall are, respectively, 22.8–27.2°C and 288–377 mm for the summer months (June–August) and 6.8–8.7°C and 50–83 mm for the winter months (December–February). The mean annual air temperature and annual rainfall are 17.0°C and 2435 mm, respectively. Bahia grass is utilised from May (late spring) to October–November (autumn) because the grass is dormant for the rest of the year. Pastures are rarely irrigated.

During the grazing season (May–October) of 1996, the paddock was grazed 6 times by 28–32 cows for periods of 2–6 days at intervals varying between 11 and 37 days. The total duration of grazing was 23 days. In 1998, the paddock was grazed 6 times by 31–34 cows for periods of 4–7 days at intervals of 18–34 days. The total duration of grazing was 32 days.

The paddock was fertilised with compound fertiliser and urea. The fertilisation rates were 77 kg N (split application in March and August), 20 kg P (March) and 30 kg K (March) per ha in 1996 and 97 kg N (April and September), 26 kg P (April) and 40 kg K (April) per ha in 1998. The vegetation was dominated by bahia grass and virtually monospecific from summer to autumn.

Measurements

Eleven periods, 5 in 1996 and 6 in 1998, were selected from the rotational grazing program and designated Periods 1–11 (Table 1). Periods 1–5 represented the first 2 days of grazing in 5 rotational grazing periods of 3–6 days. Periods 6–11 covered the whole duration of 6 rotational grazing periods.

Table 1. Outlines of selected grazing periods for measurements.

Period	Date[1]	Duration (d)	Number of cows	Mean liveweight (kg/cow)
1	May 25–26 1996	2	28	462
2	Jun 29–30 1996	2	28	454
3	Aug 3–4 1996	2	28	446
4	Sep 14–15 1996	2	29	452
5	Oct 26–27 1996	2	32	468
6	May 21–25 1998	5	32	444
7	Jun 17–23 1998	7	32	444
8	Jul 18–24 1998	7	32	458
9	Aug 12–16 1998	5	32	455
10	Sep 20–23 1998	4	31	444
11	Oct 23–26 1998	4	34	453

[1]Initial 2 days of 3 to 6-day rotational grazing periods for 1996, and whole duration of rotational grazing periods for 1998.

Herbage mass was non-destructively estimated at both the beginning and the end of each selected period (*viz.* 22 occasions), at 182 fixed locations (50 cm × 50 cm; 1-m intervals) along 2 permanent 90-m line transects crossing the paddock, using an electronic capacitance probe (PastureProbe™, Mosaic Systems Ltd, New Zealand). The area of 50 cm × 50 cm was selected based on the approximate size of the feeding station (an area of herbage within the reach of the neck and head when the forefeet are stationary) of cattle used. Calibration equations for converting corrected meter readings (CMR) of the electronic capacitance probe into herbage mass (above a 3 cm height) were developed for the 22 individual measurement occasions.

Rate of defoliation or daily herbage consumption at each location along the transects was calculated as: apparent rate of herbage consumption (difference between pre- and post-grazing herbage masses divided by the duration (d) of the selected grazing period) plus rate of disturbed herbage accumulation during grazing. The rate of disturbed herbage accumulation was estimated from the rate of undisturbed herbage accumulation inside exclosure cages (1 m × 1 m in area and 75 cm in height) in 1996. Details of the measurements and estimation are described in Hirata (2000b).

Characteristics of the spatial distribution of pre- and post-grazing herbage masses and the rate of defoliation were expressed by the mean, minimum, maximum, standard deviation (SD) and coefficient of variation (CV) of data from the 182 locations along the transects. Mean herbage utilisation, calculated as 100×[1-(post-grazing herbage mass)/(pre-grazing herbage mass)] averaged over the 182 locations along the transects, was used as a measure of grazing intensity during the 11 periods, which differed in such aspects of grazing conditions as the duration, number and liveweight of animals (Table 1) and the mean pre-grazing herbage mass over the transects (Figures 2a, 2b).

Results and discussion

The meteorological conditions are shown in Figure 1. Compared with the long-term mean (1961–1990), the grazing season of 1996 showed similar mean air temperature (24.0 *vs* 23.3°C), slightly higher mean solar radiation (16.4 *vs* 15.5 MJ/m^2/d) and lower total rainfall (1476 *vs* 1761

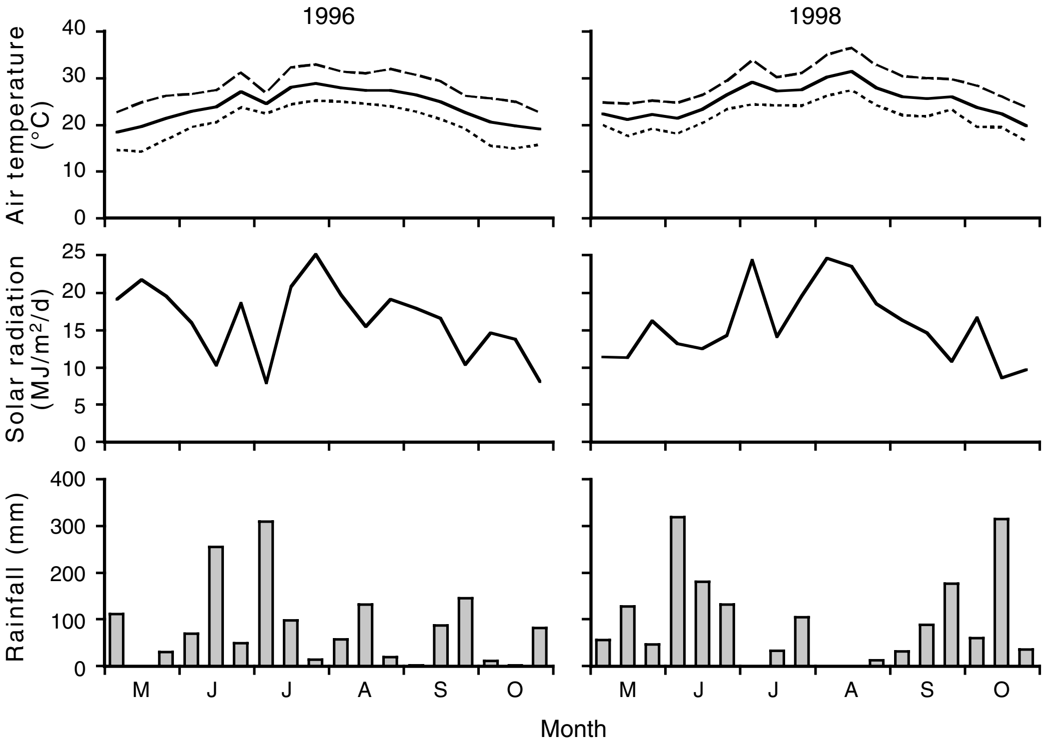

Figure 1. Meteorological conditions during the study. Ten- or 11-day means of maximum (– – –), mean (——) and minimum (-----) daily air temperatures, daily total short-wave solar radiation and 10- or 11-day totals of rainfall.

mm). The grazing season of 1998 showed higher mean air temperature (25.2°C) and similar mean solar radiation (15.6 $MJ/m^2/d$) and total rainfall (1719 mm).

Spatial distribution of herbage mass

Estimation of herbage mass with an electronic capacitance probe was relatively good: R^2=0.88–1.00. The SE of estimation was 41–914 kg/haDM, tending to be greater as the range of herbage mass broadened (*e.g.* Periods 4, 8 and 9).

Distribution of herbage mass was spatially heterogeneous both before and after grazing, exhibiting patches with different herbage masses (CV=0.226–0.972; Figures 2a, 2b). Earlier and subsequent measurements in the same pasture showed a close linear relationship between height and herbage mass of the sward across the grazing season (r=0.833–0.959, P<0.001) (Higashiyama and Hirata 1995; S. Ogura and M. Hirata, unpublished data). Therefore, patches with higher herbage mass were generally taller patches and *vice versa*.

With grazing, the CV of herbage mass always increased, whereas the mean and minimum herbage masses always decreased (Figures 2a, 2b). Furthermore, the increase in CV was positively related to the mean herbage utilisation (r=0.889, P<0.001; Figure 3a), indicating that spatial distribution of herbage mass became more heterogeneous under higher grazing intensity. This finding reinforces the argument that herbivory is a crucial factor in the development and maintenance of the spatial heterogeneity in vegetation in grazing systems (*e.g.* Bakker *et al.* 1983; Edwards *et al.* 1996).

Spatial distribution of herbage consumption

Distribution of herbage consumption by animals was also spatially heterogeneous, showing different rates of defoliation among patches (CV=0.329–0.904; Figure 4). The rate of defoliation sometimes showed negative values probably due to errors in the estimation, as discussed in detail in Hirata (2000b). Despite these negative values, trends for the spatial distribution of herbage consumption are considered reliable overall (Hirata 2000a; 2000b).

The CV of the rate of defoliation was negatively related to the mean herbage utilisation (r=–0.808, P<0.01; Figure 3b), indicating that grazing of a pasture was more uniform under higher grazing intensity, in terms of the amount of herbage consumed from patches. This resulted in a greater increase in the spatial heterogeneity in herbage mass with more intense grazing (Figure 3a), by enlarging the variation in herbage utilisation among patches (higher proportion of utilisation in patches with lower herbage mass and *vice versa*), as discussed by Hirata (2000a) as an important mechanism behind spatial heterogeneity in herbage mass.

Spatial heterogeneity in the rate of defoliation (Figure 4) was higher than that in the pre-grazing herbage mass (Figures 2a, 2b) except for Period 8. This may reflect the overmatching foraging pattern where selection and rejection responses by animals are disproportionately large to the foraging currency or reward (Senft *et al.* 1987; Senft 1989). Therefore, the spatial heterogeneity in herbage consumption may be also evaluated using a parameter calculated as: the CV of the rate of defoliation in excess of the CV of pre-grazing herbage mass. This parameter was negatively related to the mean herbage utilisation as well (r=–0.848, P<0.001; Figure 3c), showing a stronger correlation than the CV of the rate of defoliation alone (r=–0.808, P<0.01; Figure 3b). Thus, the spatial distribution of herbage consumption was more homogeneous, or animals consumed more uniform amounts of herbage from patches, under higher grazing intensity. These results support the contention that animals are less selective under higher grazing pressure (Vallentine 1990; Cid and Brizuela 1998). The regression equation in Figure 3c indicates that the rate of defoliation is as heterogeneous (or homogeneous) as pre-grazing herbage mass when the mean herbage utilisation is 65.5%.

Relationship between herbage mass and consumption

In Periods 1–3, 6–8 and 10–11, the rate of defoliation was positively correlated with pre-grazing herbage mass, indicating that cattle tended to consume more herbage from patches with higher herbage masses (Figure 5). By contrast, there were no significant correlations between the rate of defoliation and pre-grazing herbage mass in other periods, showing that pre-grazing herbage mass did not have a dominant effect on the rate of defoliation in individual patches. The correlation

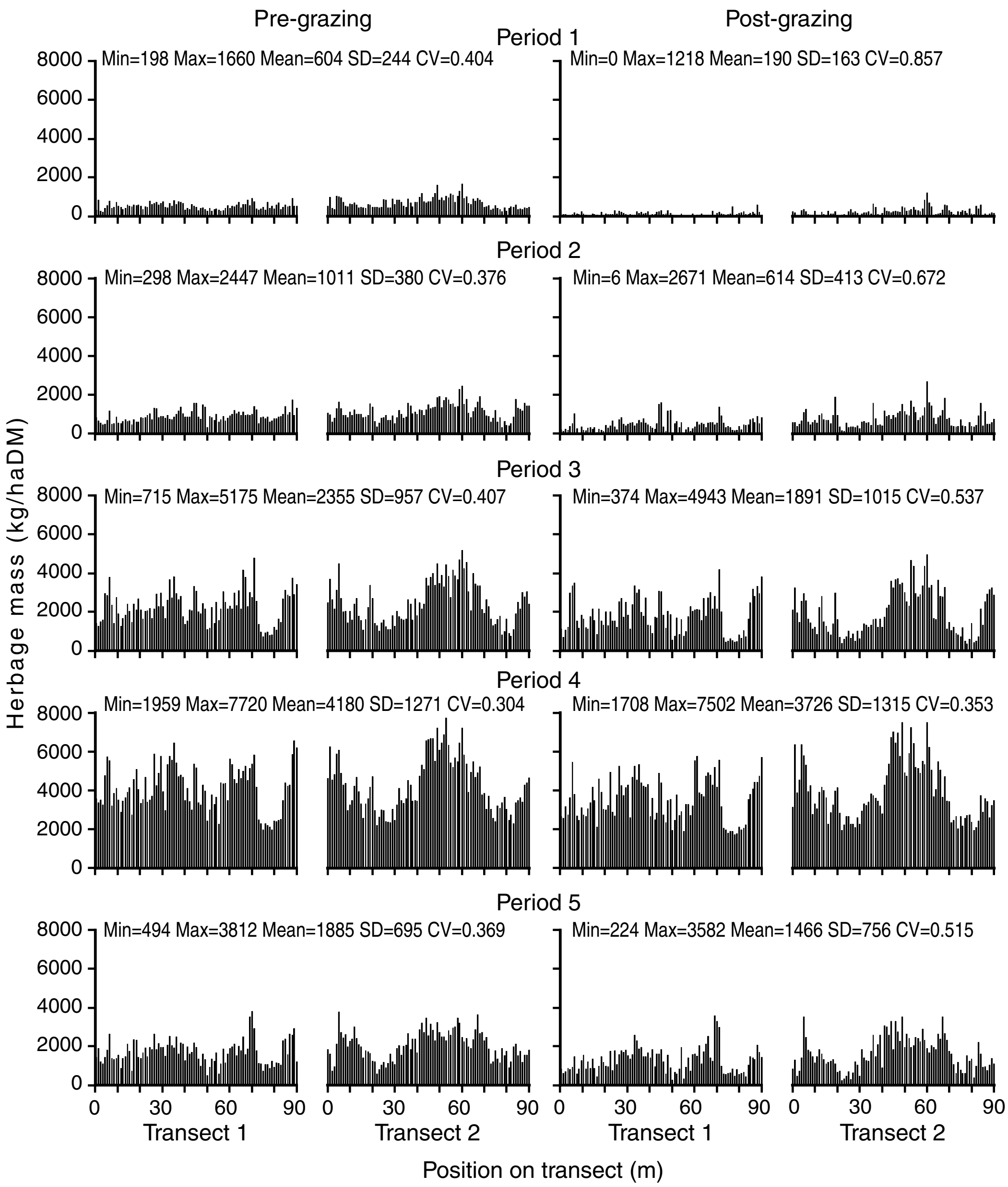

Figure 2a. Pre- and post-grazing distributions of herbage mass along the transects (Periods 1–5). The statistical parameters are minimum, maximum, mean, standard deviation (SD) and coefficient of variation (CV). CV is based on an area of 50 cm × 50 cm.

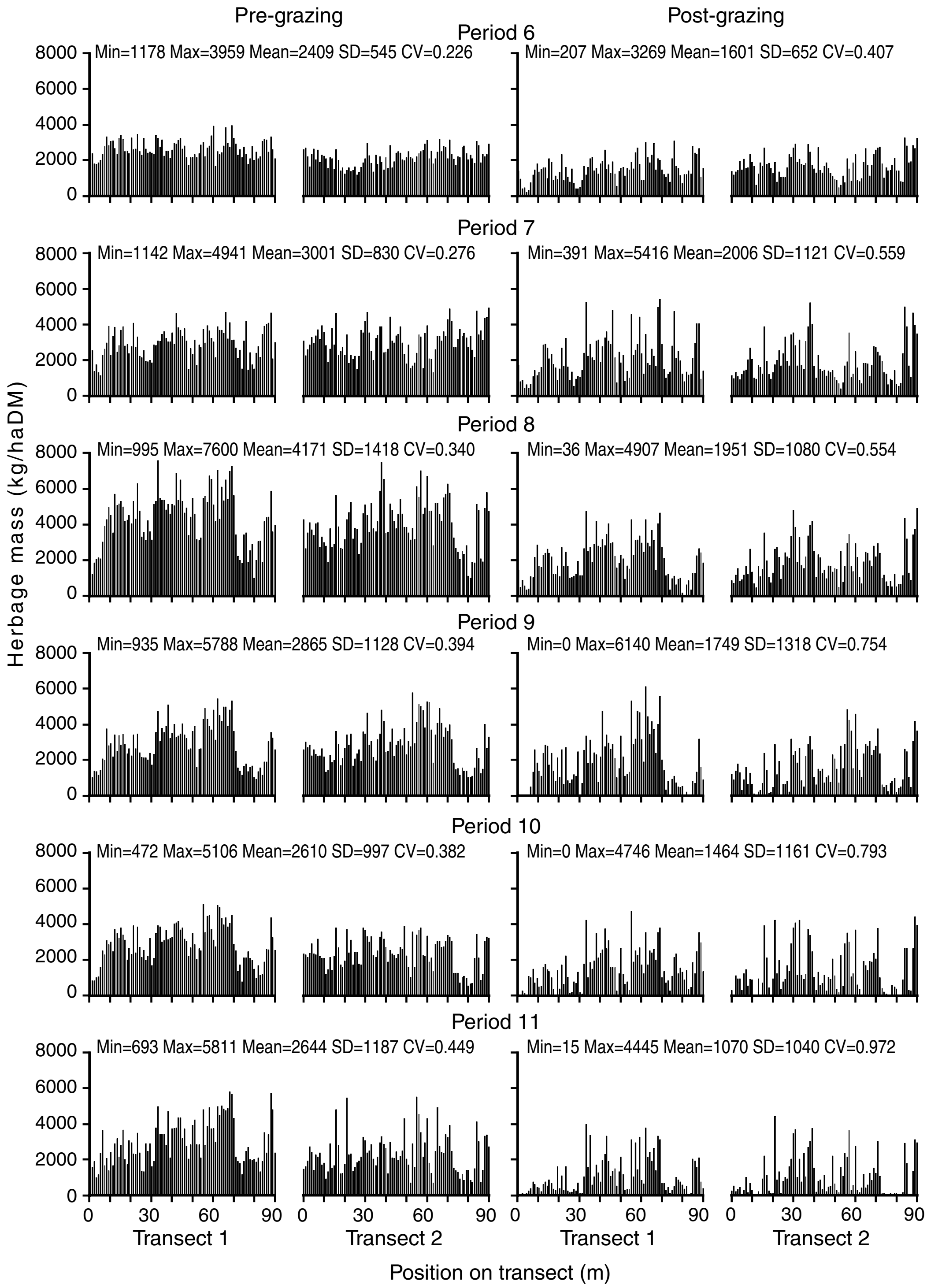

Figure 2b. Pre- and post-grazing distributions of herbage mass along the transects (Periods 6–11). The statistical parameters are minimum, maximum, mean, standard deviation (SD) and coefficient of variation (CV). CV is based on an area of 50 cm × 50 cm.

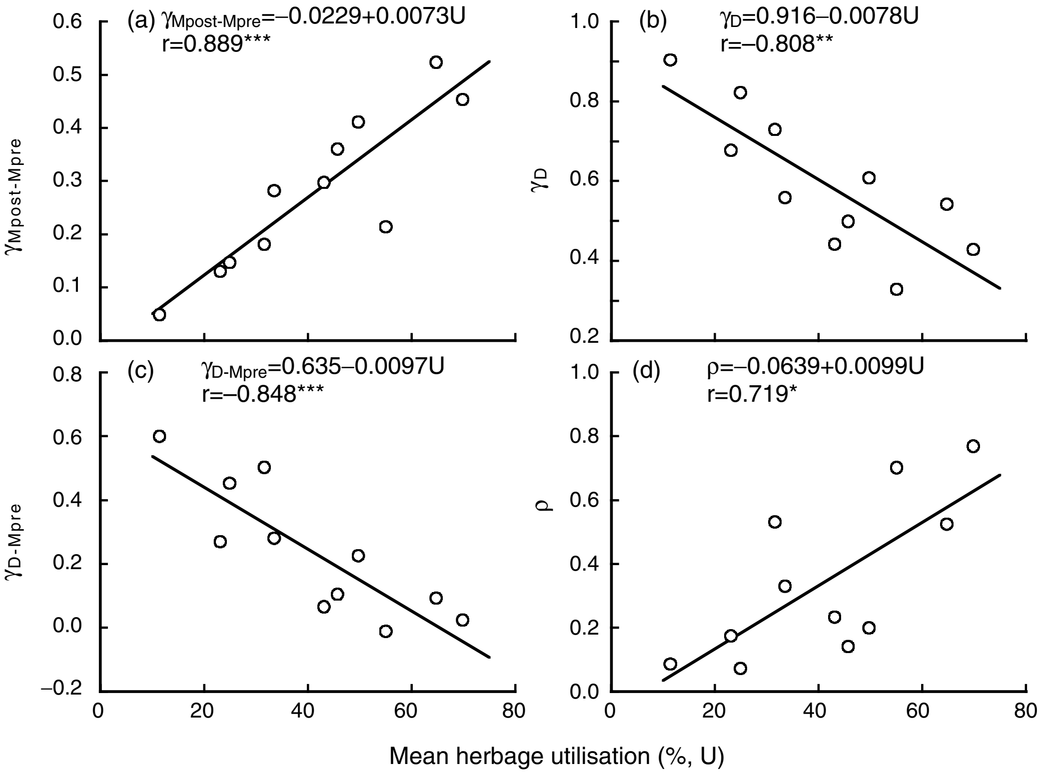

Figure 3. Relationships of (a) the increase in the coefficient of variation (CV) of herbage mass during grazing ($\gamma_{Mpost\text{-}Mpre}$), (b) the CV of the rate of defoliation (γ_D), (c) γ_D in excess of the CV of pre-grazing herbage mass ($\gamma_{D\text{-}Mpre}$) and (d) the correlation coefficient between the rate of defoliation and pre-grazing herbage mass (ρ), to the mean herbage utilisation (U) along the transects.

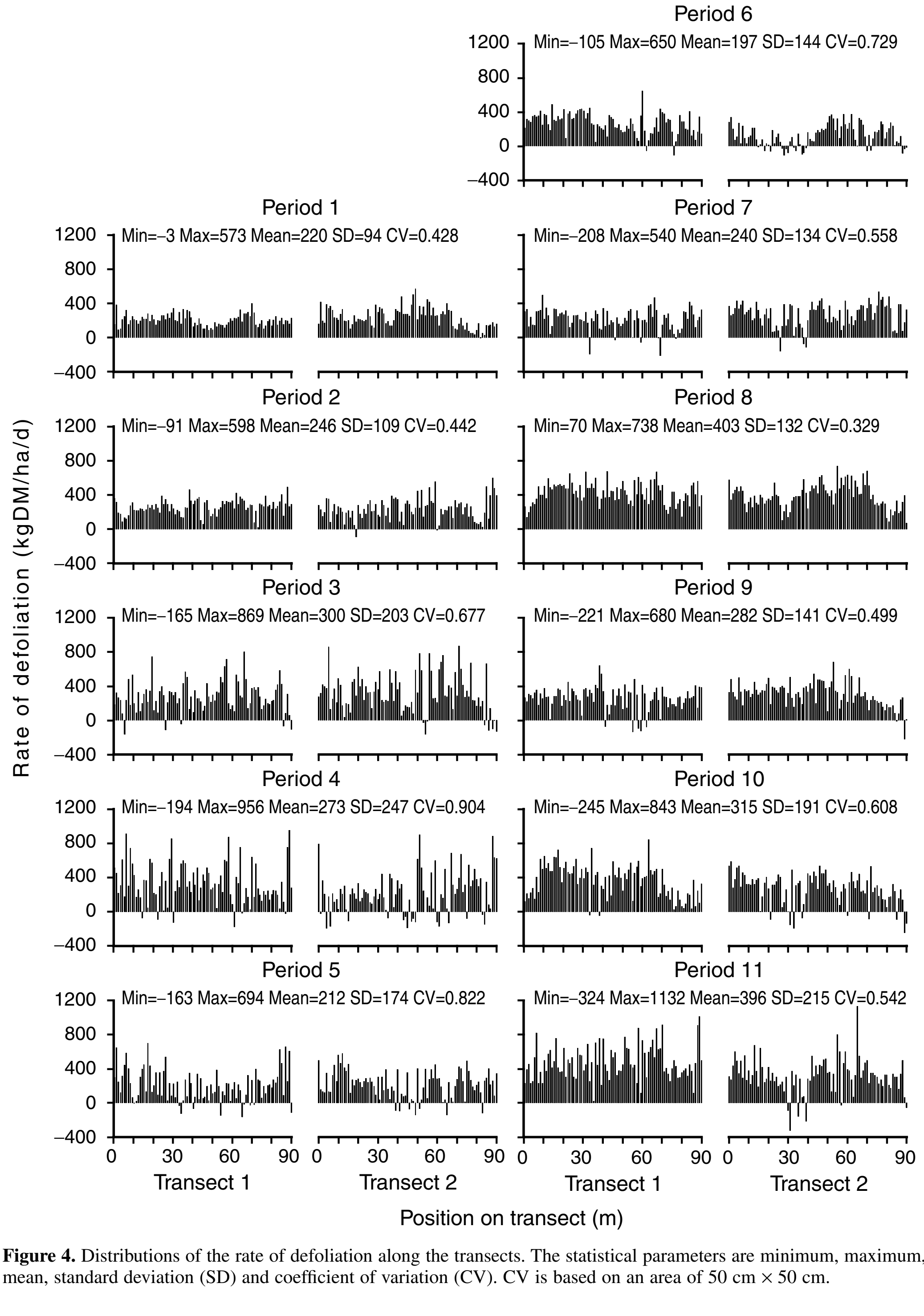

Figure 4. Distributions of the rate of defoliation along the transects. The statistical parameters are minimum, maximum, mean, standard deviation (SD) and coefficient of variation (CV). CV is based on an area of 50 cm × 50 cm.

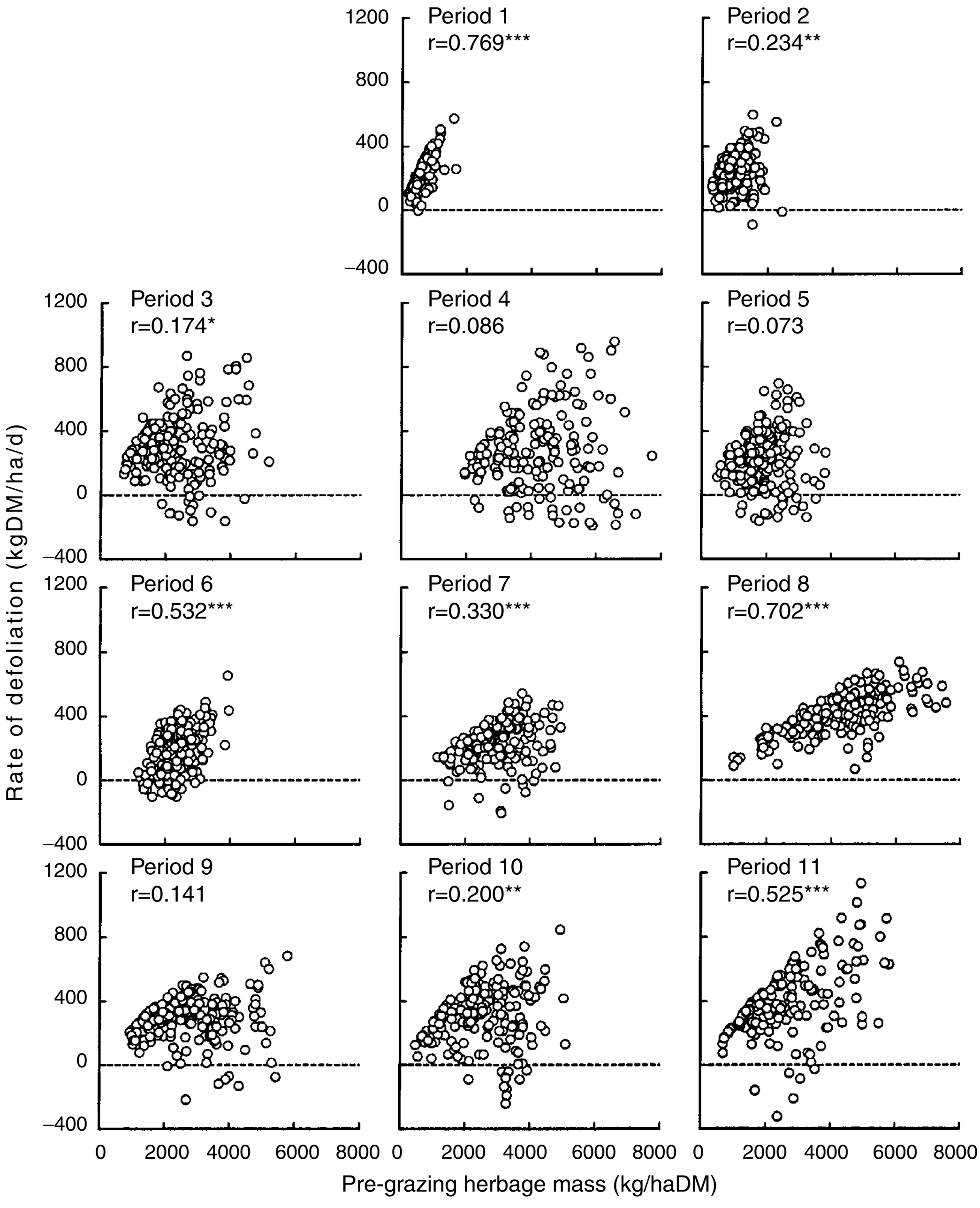

Figure 5. Relationships between the rate of defoliation and pre-grazing herbage mass along the transects.

coefficient between the rate of defoliation and pre-grazing herbage mass was positively related to the mean herbage utilisation ($r=0.719$, $P<0.05$; Figure 3d), indicating that the tendency for animals to consume more herbage from patches with higher herbage masses became stronger under higher grazing intensity. This may reflect the fact that animals are less selective under higher grazing pressure (Vallentine 1990; Cid and Brizuela 1998).

At the same time, even when there were significant positive correlations between the rate of defoliation and pre-grazing herbage mass, the data usually scattered considerably, showing many low rates of defoliation in patches with high herbage masses (Periods 2–3, 6–7 and 10–11). Consequently the r values in these periods were as low as 0.174 to 0.532, indicating that herbage mass accounted for only 3–28% of the variation in the rate of defoliation. A major explanation for this is that such patches had dung pats in them or high biomass of stems and dead material (overgrown patches). It is well known that animals avoid herbage on and near dung pats (Hirata *et al.* 1987; 1988) and that stems and dead material in a sward canopy work as a barrier against grazing by animals (Chacon and Stobbs 1976; Barthram 1981; Arias *et al.* 1990; Flores *et al.* 1993; Ginnett *et al.* 1999).

Conclusions

It is well known that grazing animals utilise a pasture in a spatially heterogeneous manner, in response to spatially heterogeneous vegetation. However, most previous studies have described pasture utilisation by animals in terms of herbage consumption, intake, botanical composition of diet and grazing behaviour, as an average over the pasture. Similarly, vegetation characteristics such as sward height, herbage mass and botanical composition have been usually described as an average. These descriptions do not reflect reality, and provide only limited information on what is happening at the pasture-animal interface. Although the spatial heterogeneity in vegetation and utilisation of pastures has received considerable research attention in recent years, available information is still limited.

Previous studies on fine-scale spatial distribution of herbage mass and consumption in a bahia grass pasture under cattle grazing (Hirata and Fukuyama 1997; Hirata 2000a, 2000b) showed that (a) distributions of both herbage mass and consumption were spatially heterogeneous, (b) spatial heterogeneity in herbage mass increased with grazing, and (c) the manner of patch utilisation by cattle, expressed by the correlation coefficient between the rate of defoliation and pre-grazing herbage mass, changed with the mean pre-grazing herbage mass of the pasture. In addition to these, the present study has provided some new information:

- The increase in the spatial heterogeneity in herbage mass with grazing was greater under higher mean herbage utilisation, *i.e.* under higher grazing intensity.
- Spatial heterogeneity in herbage consumption (rate of defoliation) decreased as the mean herbage utilisation increased, *i.e.* animals consumed more uniform amounts of herbage from patches under higher grazing intensity.
- The correlation coefficient between the rate of defoliation and pre-grazing herbage mass increased as the mean herbage utilisation increased, *i.e.* the tendency for animals to consume more herbage from patches with higher herbage mass became stronger under higher grazing intensity.
- Thus, higher grazing intensity resulted in more uniform utilisation of patches by reducing selectivity by animals, but resulted in more variation in herbage mass between patches.

It has been recognised that the spatial heterogeneity of vegetation in a grassland ecosystem has such advantages as providing a more diverse habitat for plants and animals (*i.e.* increasing biodiversity) and carrying over emergency forage into unproductive years (Willms *et al.* 1988). The information obtained in the present study is of potential value for pasture management pursuing these advantages, because it shows how spatial heterogeneity in herbage mass in a pasture can be controlled by grazing intensity.

For a deeper understanding of the dynamics in patch availability and utilisation, future studies need to incorporate measurements of both quantitative and qualitative characteristics of vegetation and grazing behaviour by animals on individual patches to link herbage consumption variables with plant and animal behaviour variables at the patch level. If labour resources allow, more locations for measurements should be established so that they cover the whole area of a pasture.

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