Studying spatial and temporal dynamics of sward structure at low stocking densities: the use of an extended rising-plate-meter method

O. Correll*, J. Isselstein* and V. Pavlu†

*Institut fuer Pflanzenbau und Pflanzenzuechtung, Universitaet Goettingen, Goettingen, Germany, and †Research Institute of Crop Production Prague–Ruzyne, Grassland Research Station, Liberec, The Czech Republic

Abstract

An extended rising-plate-meter method was used to study the spatial and temporal variability of the sward structure of extensively managed pastures over a grazing season. Two treatments of a long-term grazing experiment with heifers were investigated: extensive continuous grazing (EG) with a target sward height of 10 cm and intensive continuous grazing (IG) with a target sward height of 5 cm. Compressed sward height and related herbage mass (HM), dominant plant species and stage of development of phenology were determined at weekly or twice weekly intervals at fixed measuring points. The results demonstrated a strong variability in sward height and HM, especially on the EG treatment. The botanical composition of the standing herbage differed between treatments and between patches of different heights within the same treatment. In areas with a short sward, the herbage was predominantly composed of *Agrostis capillaris*, *Festuca rubra* and *Trifolium repens*. It was more evenly composed and also included taller growing species, such as *Alopecurus pratensis* and *Galium mollugo*, in areas with a tall sward. The area potentially available for reproductive development was high in the EG treatment and low in the IG treatment. The method employed proved suitable to provide a detailed description of the dynamics of the sward structure.

Keywords: extensive continuous grazing, sward patches, plant species composition, sward height, herbage mass, sward structure

Correspondence to: J. Isselstein, Institut fuer Pflanzenbau und Pflanzenzuechtung, Universitaet Goettingen, Von-Siebold-Str. 8, 37075 Goettingen, Germany.
E-mail: jissels@gwdg.de

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Introduction

Systems of extensive continuous grazing with beef cattle or sheep have an important role in grassland utilization in Europe and they have received considerable attention in scientific research in recent years. Such systems characteristically need little input in terms of capital and labour, which makes them a promising option for the maintenance of agricultural grassland that is otherwise at risk of being abandoned. This holds particularly for Europe's less-favoured areas (Oppermann and Luick, 1999).

In practice, swards under low stocking rates are often characterized by a strongly heterogeneous structure. Selective grazing gradually creates a mosaic of different heights (Bakker *et al.*, 1983), which is most clearly marked in periods with a large herbage surplus. Once the mosaic is established, it can remain stable for months (Cid and Brizuela, 1998). Agronomic attributes, such as herbage mass (HM) and quality, and ecological attributes, such as species abundance and diversity, are strongly influenced by this spatial pattern (Laca and Lemaire, 2000). A detailed knowledge of the relevant processes is thus essential for estimating the long-term effects on the productivity as well as the ecological value of the sward. However, under these circumstances, meaningful sward features are insufficiently described by calculating mean plot or field values, as no account is taken of the variability at a smaller scale (Gibb and Ridout, 1986). Hence, variability with a high level of data resolution should be recorded. Attention should be paid to variability in both space and time. As this requires a high number of sampling points and occasions, the methods employed have to be fast in application and affect the sward as little as possible ('t Mannetje, 2000). This favours the use of non-destructive methods.

In this paper, the methodological possibilities of an extended rising-plate-meter technique are studied. As a case study, the dynamics of the sward structure of extensively managed upland pastures in the Czech Jizerské hory uplands are documented over a growing season.

Materials and methods

An ongoing long-term grazing experiment of the Grassland Research Station Liberec was used as the framework for this study (Pavlu *et al.*, 2001). This is a site in the Jizerské hory uplands (50°50′N, 15°06′E, 420 m a.s.l.) in Northern Bohemia (The Czech Republic). The vegetation is classified as upland hay meadow (alliance *Arrhenatherion*). It was managed only occasionally by cutting or mulching before the start of the experiment in 1998. Of the current treatments, two continuously stocked treatments were studied (two replicates): extensive grazing (EG) by growing heifers (stocking rate adjusted to achieve a mean target sward surface height of 10 cm) and intensive grazing (IG) of growing heifers (stocking rate adjusted to achieve a mean target sward surface height of 5 cm). The sward surface heights were determined weekly and stocking density was adjusted accordingly by increasing or decreasing the area available for grazing by moving fences with a set number of stock per plot. Each plot was comprised of a central observation area of 0·35 ha constantly managed under the treatment and an additional area to adjust the stocking rate. All measurements were made within the 0·35 ha area.

The present study took place during the grazing season of May–October 2000. On each plot, a permanent transect line with fixed sampling points was established within the observation area. The transect diagonally crossed the plot and comprised sixty sampling points at 1-m intervals. A sampling point covered a circular area of 0·071 m^2 (rising-plate-meter, see below). The development of the sward at these points was recorded as follows. At weekly intervals early in the season and at twice weekly intervals later in the season (see Figure 1), the sward height was measured as compressed sward height (CSH), employing the rising-plate-meter according to Castle (1976). On every second sampling occasion (see Figure 3), the percentage contributions of the dominant plant species (>15%) in terms of dry weight were directly estimated at every sampling point following a method of percentage ranking (see Whalley and Hardy, 2000). The estimations were made after thorough training. A sampling point was considered to be at a reproductive stage if at least one dominant plant species was flowering or setting seeds. In addition, the reproductive growth of plant species that are typical constituents of hay meadows (according to Klapp, 1971, comprising here: *Anthriscus sylvestris*, *Campanula patula*, *Galium mollugo*, *Heracleum sphondylium*, *Lathyrus pratensis*, *Lychnis flos-cuculi*, *Ranunculus acris*, *Rumex acetosa* and *Vicia sepium*) was recorded at the sampling points, irrespective of whether these species were dominant or not.

For the calibration of the CSH readings with the standing HM, combined CSH measurements and yield cuts were taken at seven occasions during the season. On each occasion, seventy extra points throughout the

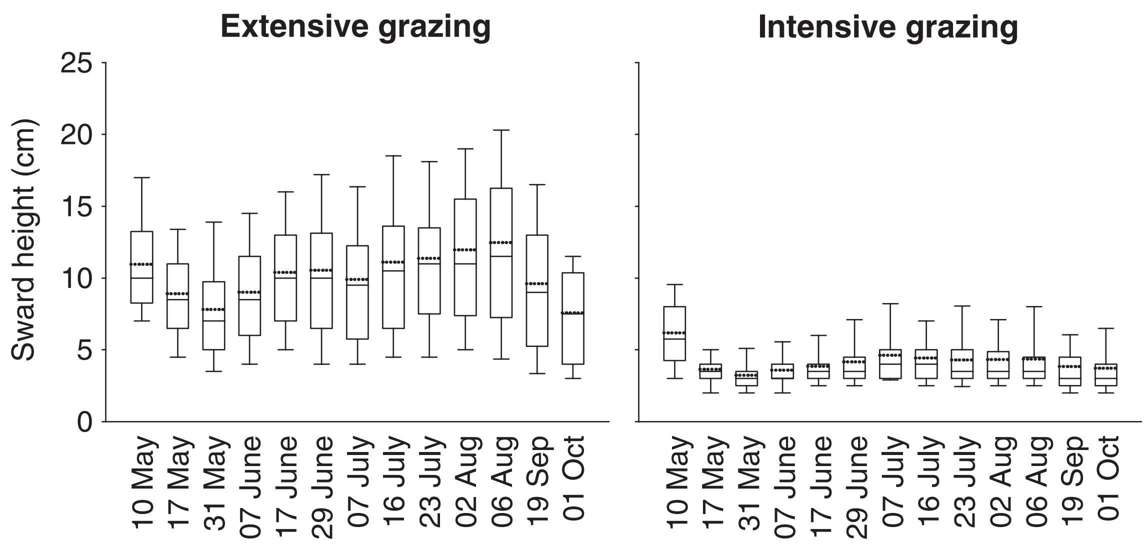

Figure 1 Frequency distribution of compressed sward heights, shown as Box-Whisker plots, in the course of the grazing season under extensive and intensive grazing. The boxes cover 75% and the whisker 90% of the data. Dotted lines are mean and solid lines, median.

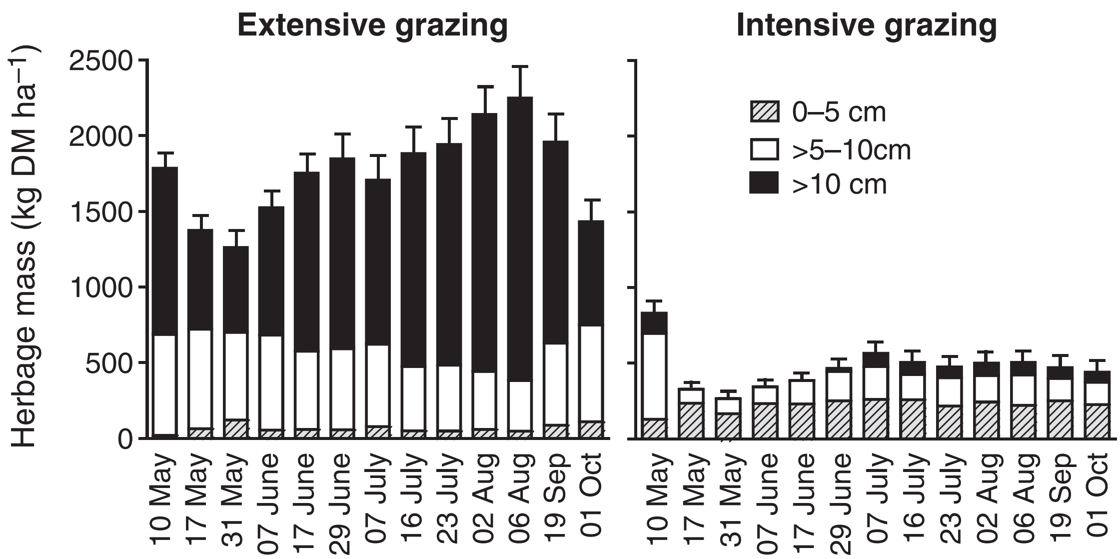

Figure 2 Herbage mass in the course of the grazing season under extensive and intensive grazing relating to the different sward height classes (compressed sward height 0–5, >5–10 and >10 cm). Error bars indicate the s.e.m. of the total herbage mass.

plots (twenty-five on EG plots and ten on IG plots), constituting a stratified sample in terms of CSH, were recorded. The HM of dry matter (DM) was related to CSH by using a linear regression equation of the type, $y = b(x - 2)$, with $y =$ HM (kg DM ha^{-1} at a cutting height of 2 cm), $x =$ CSH (cm) and $b =$ regression coefficient. The slope b varied between 199 and 256 kg DM ha^{-1} cm^{-1} CSH. The r^2-values were always above 0·90 and the coefficient of variation of the standard error varied from 0·19 to 0·32; this is considered as an acceptable range for regressions calculated in order to assign herbage masses to measured sward heights (e.g. Virkajärvi, 1999).

Results and discussion

Figure 1 shows the frequency distributions of the sward heights measured at thirteen sampling dates over the season for the EG and IG treatments. It reveals a strong spatial and temporal variability in the sward heights. Under both treatments the sward heights varied similarly (expressed by the coefficient of variation, EG: 0·34–0·58; IG: 0·36–0·54). However, the variability was clearly different with respect to absolute magnitudes. Both the range of heights (distance of percentiles, see Figure 1) and the standard deviation of the mean height (EG: 3·54–7·28 cm; IG: 1·29–2·59 cm) indicated greater heterogeneity in the EG treatment. In terms of seasonal variation, the sward showed the greatest variability in heights at the beginning of August. This was true for both EG and IG treatments (Figure 1). This was probably due to the changes in herbage growth rates at the site, with comparatively high growth rates from May to August and declining growth rates thereafter (see Pavlu *et al.*, 2001). Vigorous herbage growth is reported to promote selective grazing of parts of a pasture under extensive stocking conditions (Strodthoff and Isselstein, 2001), which leads to an increase of sward heterogeneity in exactly these periods.

The dynamics of the corresponding HM is shown in Figure 2. The total HM is classified according to the CSH. Therefore, three sward height classes were established representing different patches within the investigated pastures, i.e. frequently (0–5 cm), intermediately (>5–10 cm) and infrequently (>10 cm) grazed patches. In the EG treatment the total HM varied between 1260 kg DM ha^{-1} at the end of May to 2250 kg DM ha^{-1} in August. Only small amounts of herbage (20–120 kg DM ha^{-1}) were present in areas with a low sward height (0–5 cm) and, therefore, young and highly digestible herbage; considerably more (330–670 kg ha^{-1}) was available in intermediate zones (>5–10 cm). Tall areas (>10 cm) with older and more mature herbage contained high amounts of herbage in late summer, but the amount of herbage in these areas was highly variable over the whole season (560–1870 kg DM ha^{-1}). Some of the variability could perhaps be attributed to senescence or to the use of taller areas as a forage buffer.

The HM of DM in the IG treatment was consistently low, even when grazing started in early May. It fluctuated between 270 kg DM ha^{-1} (May) and 560 kg DM ha^{-1} (July) over the season. Throughout

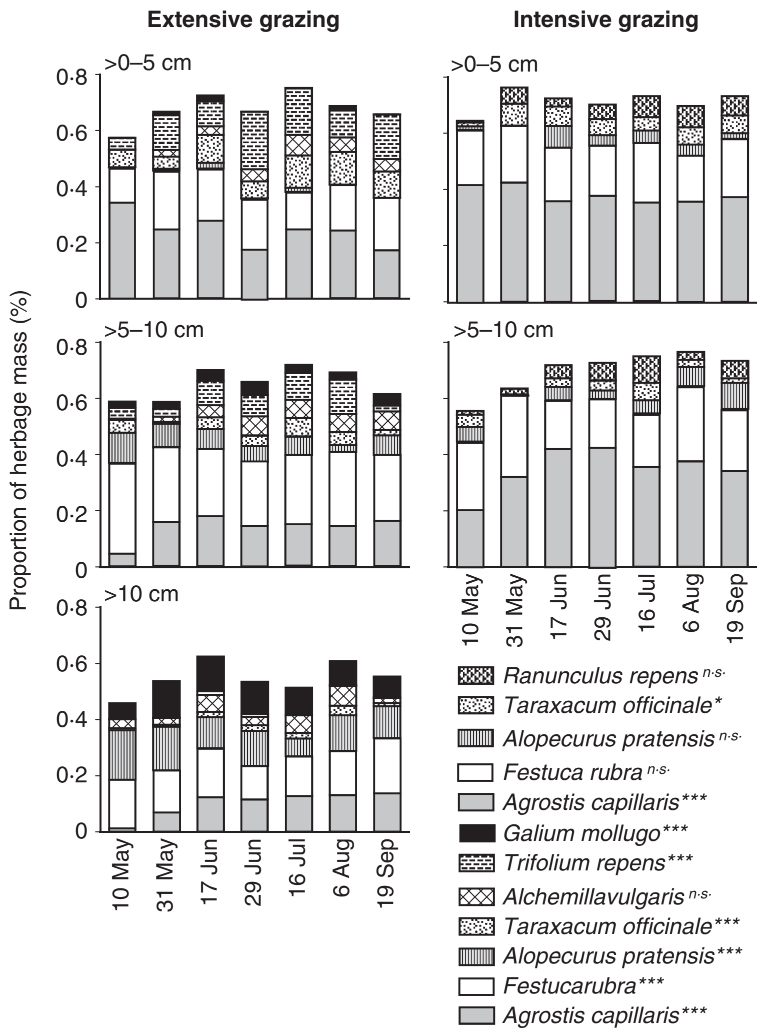

Figure 3 Proportion of dominant plant species of the total herbage mass in different sward height classes (compressed sward height 0–5, >5–10 and >10 cm) under extensive (first five species in list) and intensive grazing. Species characterized by superscripts show a significant difference in the proportion between different sward height classes for either extensive or intensive grazing; $^{***}P < 0{\cdot}001$, $^{**}P < 0{\cdot}01$, $^{*}P < 0{\cdot}05$, n.s., non-significant, Kruskal–Wallis test.

the season most of the herbage was available as a short sward of up to 5 cm (170–260 kg DM ha^{-1}). Areas intermediate in height (>5–10 cm) were less frequent and had herbage masses of 90–220 kg DM ha^{-1}, while tall areas >10 cm were rare (0–90 kg DM ha^{-1}).

Altogether thirty-seven and forty-three species were found to occur as locally dominant plant species at sampling points in treatments IG and EG respectively. The contribution of the species that were most frequently dominant in standing HM is shown in Figure 3. The contribution of the species to HM varied between different sward height classes within the grazing system; this effect was particularly the case in treatment EG. The species composition of the herbage in the short grass areas (<5 cm) was predominantly composed of a few species tolerant to heavy grazing (*Agrostis capillaris*, *Festuca rubra*, *Trifolium repens*, together 51–59%) and therefore resembled to some extent the herbage of the short IG sward. In contrast, the lightly or ungrazed areas >10 cm in treatment EG were more evenly composed. The percentage of the seven most dominant species was lower (46–62%) than in the other areas (0–5 cm: 58–76%; >5–10 cm: 59–72%), and taller growing species, such as *Alopecurus pratensis* or *G. mollugo*, formed higher percentages.

With regard to species conservation issues, the area potentially available for reproductive development within the pastures was quantitatively assessed. Many endangered species, for example typical hay meadow species that are not adapted to frequent defoliation and that are dependent on a regular regeneration from seeds, can only be conserved in grazing systems if suitable niches exist. During the grazing season an average of 0·60 of sampling points showed reproductive growth in treatment EG when compared with 0·23 in treatment IG. Focusing on the typical hay meadow species, 0·24 of the sampling points showed reproductive growth of these species in treatment EG, compared with only 0·02 in treatment IG. The extent of reproductive growth was obviously related to the different patch height of the pastures. Reproductive growth of hay meadow species was hardly recorded within patches <0–5 cm in height in both EG and IG treatments (seasonal mean 0·01 for both treatments), and to an intermediate extent within patches of >5–10 cm in height in treatments EG (0·20) and IG (0·12). The highest frequency of reproductive species was in the tall patches >10 cm in height and occurred almost exclusively in the EG treatment (0·47). Thus, extensive, rather than intensive, grazing appears to better provide niches for these species to flower and to set seeds. Whether seedling emergence and establishment was also increased by extensive grazing was not investigated in this study. Recent research on de-intensified grassland has shown that a switch from infrequent to frequent defoliation increases the opportunity for seedling establishment. Infrequent defoliation gives an open sward and improved conditions for germination, and establishment, whereas a frequent defoliation afterwards increases seedling growth as more light reaches the soil (Hofmann and Isselstein, 2002).

Conclusion

The extended rising-plate-meter method used proved suitable in describing a detailed picture of the sward structure under different grazing treatments. It is simple in application, does not require expensive instruments and provides relevant information to allow an estimation of effects on the agronomic output and the ecological benefits. Further research is needed on other sward characteristics, such as herbage quality and herbage growth rates in relation to sward height, in order to explain the importance of the different patches and species dominances for the nutrition of grazing cattle and sheep.

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