Why grasslands?

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Solar grazing – spatial distribution of sheep in free-field-photovoltaic systems on grassland

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Abstract

In the context of climate change, the development and use of renewable energy is becoming increasingly important. However, with regard to free-field-photovoltaic (FFPV) systems the effective use of the land underneath the solar-modules (SM) remains an open question. When agricultural use and FFPV are combined, there is usually a trade-off between agricultural and energy production. Especially the required height and the smaller number of SM required for an effective arable land-management are obstacles. Grazing with small ruminants appears as a management option for an improved combination of agricultural and energy production. The aim of the present study was to analyse the spatio-temporal pattern of grazing behaviour of sheep and the grass sward response as affected by SM. We conducted a grazing experiment in a FFPV on peatland in Germany with GPS-collared sheep. The paddock was divided into two connected sectors, either with or without SM. Sheep behaviour was affected by SM: sheep had more lying time beneath SM with more trampling and more faeces deposition but preferred the section without SM for grazing. This is expected to lead to an increased heterogeneity of the grass sward in the longer-term. SM provided shade to the livestock which could improve animal welfare.

Keywords: photovoltaic, sheep, GPS, grazing, spatial distribution

Introduction

For free-field-photovoltaic (FFPV) systems the efficient use of the land beneath the solar modules (SM) remains an open question. Economic, social and environmental benefits can be provided by combining energy and agricultural production on the same site (Al Mamun *et al*. 2023). Grazing with small ruminants is an option that may yield reasonable livestock products without compromising the energy efficiency of the FFPV. In addition, sheep can seek shade under the SM which then improve the welfare of the livestock under heat conditions (Kampherbeek *et al*. 2023). So far, there has been little research on the grassland status underneath SM and how sheep may respond with their behaviour at a temporal and spatial scale. The main objective of this study was thus to analyse the spatial behaviour of GPS-collared sheep grazing a FFPV-system on peatland in Germany with two sectors within paddock, i.e. either with or without SM. The target variables measured were the time and location sheep spent for lying and active behaviour, the spatial distribution of faecal spots, the compressed grass sward height (CSH), and the extent of trampling of the sward.

Materials and methods

The present study was conducted in June and July 2023 at the 'Solarpark Lottorf' (54°44′55.5″ N, 9°56′78.1″ E), Schleswig-Holstein, Germany. Ten GPS collared sheep aged 3.5 ± 0.7 years (mean ± SD) were grazed on a 40 x 50 m trial site divided in two equally distributed sectors within paddock (with and without SM) (Figure 1). The trial site was divided in 80 5x5m grid cells (Fig. 1) resulting in 40 grid cells for each sector. Grid cells served as spatial replications for the analyses of vegetation (CSH pre- and post-grazing), trampling and distribution of faeces deposits. At pre- and post-grazing, five randomly distributed CSH measurements per grid cell were carried out using a rising plate meter. Post-grazing,

trampling (visual estimated percent of trampled grass sward per grid cell) and total number of faecal spots per grid cell were taken. According to Hamidi *et al*. (2023) GPS data for spatial analyses during active time and lying time (reciprocal of active time) were minute-wise retrieved from virtual fencing collars (® Nofence, AS, Batnfjordsøra Norway) with the virtual ncing function not being activated. Three GPS collars did not work properly. Consequently, daily aggregated active time per sector within paddock of seven animals (replicates) was used for analyses. The software environment R was used for statistical analyses. Generalised linear mixed effect models (R package 'glmmTMB') with the fixed effect SM (two levels) and the random term grid cell (80 levels) were used for the analyses of the target variables vegetation, trampling and number of faeces. For the analysis of active time the random term was changed to animal ID (seven levels). All data were log-transformed to improve the normality of residuals. Multiple contrast tests according to Tukey's HSD test with Sidak's method of confidence level adjustment (R package 'emmeans') were conducted to analyse the main influencing factors.

Results and discussion

Pre-grazing CSH measurements of the grass sward revealed a higher grass stand (P<0.0001) in the SM sector than in the sector without SM (Table 1); the coefficient of variation (CV) was higher in the SM sector (36.6%) than in the sector without SM (24.4%). The sheep spent active time (associated with grazing) mainly in the sector without SM (P<0.0024). Consequently, lying time occurred mainly in the SM sector. The main grass species per grid cell in both treatments were *Holcus lanatus* and *Festuca rubra;* more *H. lanatus* in the SM sector and more *F. rubra* in the sector without SM (both sectors were mown equally during last years). *Rumex acetosa* was mainly found in the SM sector. Although grazing occurred mainly in the sector without SM, post-grazing CSH measurements revealed no significant differences; however, there was an increase of heterogeneity in the SM sector (CV of 41.5% and 30.5% for the sector

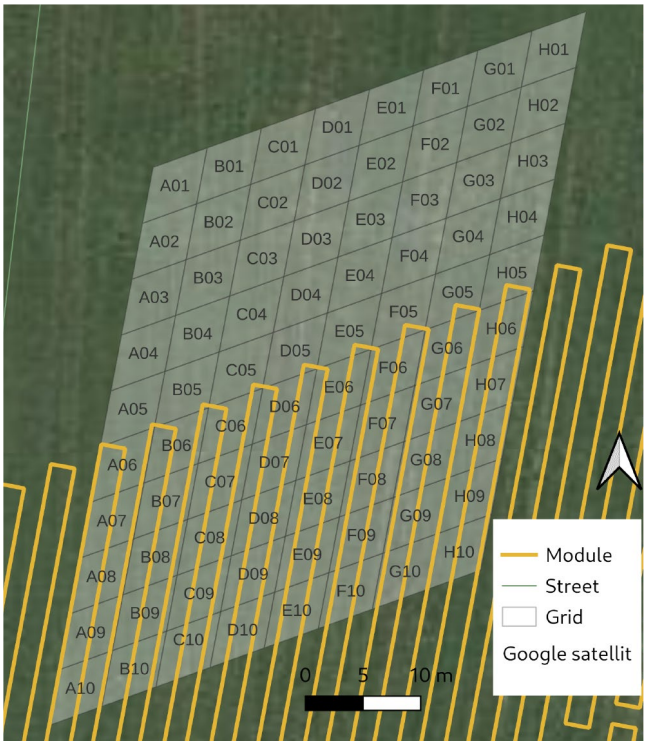

Figure 1. Representation of the study site ('Solarpark Lottorf').

without SM). Significantly more trampling occurred in the SM sector (P<0.0001; Table 1). Lying and grazing are known to be the main behaviours of sheep on pasture (Arnold, 1984). SM can be seen as anthropogenic structural landscape elements which affect the microclimate (Armstrong *et al*., 2016) and provide shade for grazing animals (Kampherbeek *et al*., 2023). An accompanying study by Zinken *et al*. (2024; these proceedings) marked differences of the microclimate between grasslands either covered by SM or not. Solar modules provide a preferred environment for lying of the sheep; this led to more trampling and defaecation (Table 1). This can lead to more uneven nutrient distribution in the field. As the study presented here was a short term one, no conclusions on long-term effects of grazing grasslands in FFPV on the vegetation and growth rates can be drawn. Yet, clear SM modulated short term effects on the grass sward and the grazing behaviour suggest a heterogenization of the grass sward in the longer term. The floristic and faunistic diversity may profit from this increased number of microhabitats within the grassland.

Table 1. Estimated means±SE (standard error) for CSH, trampling, active time and faeces.

	CSH Pre-grazing (cm per grid cell)	CSH post-grazing (cm per grid cell)	Trampling (% per grid cell)	Active time (hours per treatment)	Faeces (deposits per grid cell)
With solar modules	21.3±0.5 b	7.5±0.2 a	60.5±2.2 b	5.8±0.3 a	13.7±1.0 b
Without solar modules	15.0±0.4 a	7.4±0.2 a	32.8±2.2 a	6.7±0.3 b	10.4±0.78 a

Lowercase letters indicate significant differences between means within row (P<0.05).

Conclusions

In our study, sheep preferred to lie under solar modules, while grazing mainly occurred where no solar modules were installed. Our study highlights the complex dynamics between solar modules and sheep grazing. It is concluded that the behaviour of the sheep can induce a greater heterogeneity of the grass sward within the field which may positively influence biodiversity in the longer term.

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