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Why grasslands?

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Microclimate, grass growth and herbage quality of peat grassland under free field photovoltaic modules

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Abstract

Exploring the compatibility of solar energy and grass production on peat soil grasslands is needed to identify suitable solutions for energy provision and agricultural land use. In this context, a field experiment was established with permanent grassland on peat soil in North Germany. A free field photovoltaic system had been installed two years before. Results of the first full growing season are shown. To analyse the impact of the photovoltaic modules, measurements were done in three different sections: (i) an adjacent free grassland not affected by modules, (ii) under the solar modules (SM), (iii) in between SM. Eight sensors in each section collected data on soil moisture and surface temperature. Grass samples in a three-cut system were taken to measure herbage mass and quality. Results indicate changes in grassland microclimate due to SM and showed slightly lower herbage production underneath the modules and altered forage nutrition, with higher protein and lower sugar concentration. The ongoing research will assess herbage production variability with climate and solar module impacts on peat soil water retention and grass-water use. The obtained results are promising to combine energy production and livestock nutrition in the future.

Keywords: photovoltaic, herbage, sensors, peat, microclimate

Introduction

The use of photovoltaic systems on agricultural lands is of growing interest and could lead to a beneficial combination of sustainable energy and agricultural production (Weselek *et al.*, 2019). This raises questions regarding the impact of solar modules (SM) on microclimatic conditions and the quantity and quality of forage production. This study aimed to analyse surface temperature, soil moisture, biomass, crude protein and crude sugar on a free-field photovoltaic system on peatland using transects in a free area, under SM, and in the aisle between SM as treatments.

Materials and methods

The study was conducted at the Solarpark Lottorf (54°44′55.5″ N, 9°56′78.1″ E), Schleswig-Holstein, Germany. SM rotate on a single-axis and are 2000 mm long, with a maximum edge height of 640 mm, respectively, 2170 mm above the surface and a distance of 4000 mm to the next row of SM. From April 2023 on, 48 TMS-4 sensors (TOMST, Prague, Czech Republic) were put into the ground to measure soil moisture and temperature at -6cm, +2cm and +15cm. For the experimental design, three different treatments were selected: (i) an adjacent free area without SM, (ii) beneath the SM, and (iii) the aisle between a group of SM (Figure 1). A transect of 4 m×10 m was established for each treatment.

Within these transects, sensors were inserted into the ground at the midpoint, with approximately one-metre spacing. Beneath SM (ii), a transect extended precisely under two rows of SM, with two sensors each placed between the solar cells, directly beneath the solar cells, and at the left and right edges of the solar cells. This design was replicated at a second location within the solar park. Two of the 48 sensors did not record data correctly. Sensors operated with a 15-minute measurement interval. Concurrently with the sensor measurements, to simulate a three-cut system, grass samples were cut at ca. 7 cm above

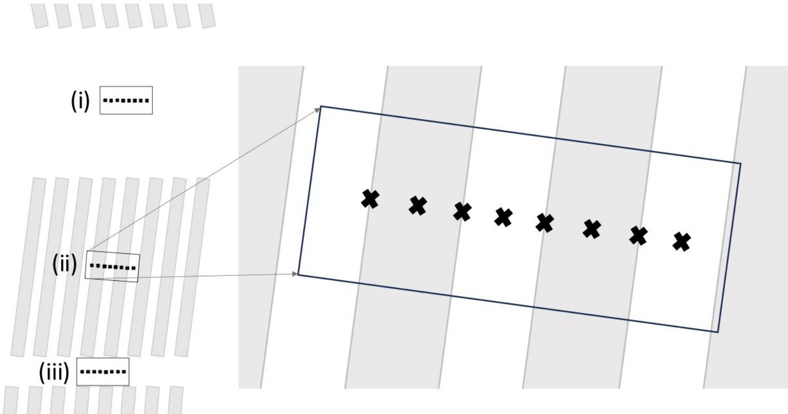

Figure 1. Schematic view of one experimental block with (i) free, (ii) under SM, (iii) aisle; expanded picture of sensor placement under SM.

ground on three different dates (24 May, 26 July and 28 September) within a 30 cm×60 cm frame east of each sensor in each transect (48 grass samples each day). The sensor data were aggregated and averaged for each cutting date. After drying, the grass samples were subjected to Near-Infrared Spectroscopy (NIRS) for forage analysis. To compare the median and variability among treatments we applied boxplots and calculated the coefficient of variation (CV).

Results and discussion

The surface temperature (surface T) was visibly lower at the first cutting date (Figure 2). Fluctuations within a treatment, especially towards the third cutting date, were minimal. Direct exposure to sunlight in the free area could contribute to a higher temperature range (Vervloesem *et al.* 2022). Accordingly, the surface temperature was lower under SM at all three cutting dates. The coefficient of variation (CV) is consistently lower or equal to 0.05 (Table 1). An accompanying study by Hamidi *et al.* (these proceedings) explores how this influence of covered or uncovered grassland affects sheep behaviour in lying and active time. In June and July (second cut), soil moisture (vol. moisture) was lower across all three treatments. Although the measured range shows a wide span, moisture values are slightly higher in the free area on all three dates. The change in soil moisture across cutting dates is similar; however, the second experimental block was noticeably wetter in comparison to the first, which could account for the wide range of soil moisture. Within the SM treatment, soil moisture directly under, at the edges and in the gap between SM had quite different values (data not shown). CV of the free area is particularly smaller on the second date (0.332) compared to the other treatments (aisle 0.549, modules 0.488). Biomass production (dry matter, DM) was slightly reduced under SM. Related CV in the free area is higher at all three cutting dates (1: 0.625, 2: 0.519, 3: 0,441). Armstrong *et al.* (2016) showed that plant biomass is up to four times higher in uncovered areas. Under SM crude protein (XP) shows higher values and reaches a median of 20% on the third cutting date. CV for XP in the free area is approximately 0.05 for the first two dates, with all other measurements below 0.15. Crude sugar (XZ) content is lower under SM with medians at 5-6% on all three cutting dates. The highest CV is observed for the first cut in the aisle (0.308) and, the lowest CV for the second cut in the free area (0.144). Further research should consider the differences within each treatment and the possible change in biodiversity, especially grass species.

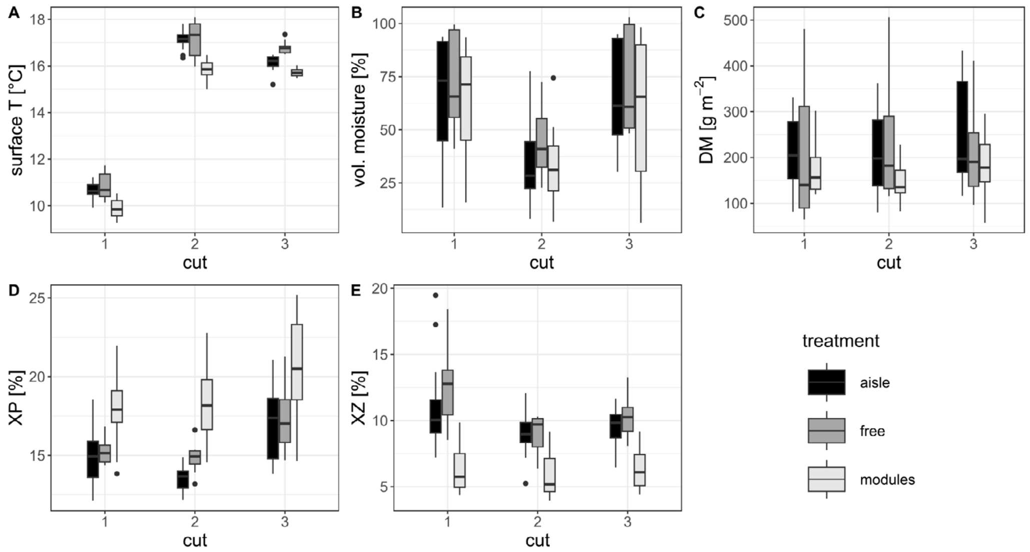

Figure 2. Boxplots of treatments (aisle, free, modules) for A: average surface temperature (surface T), B: average volumetric moisture (vol. moisture), C: dry matter (DM), D: crude protein (XP), E: crude sugar (XZ) on each cutting day (1: 24 May, 2: 26 July, 3: 28 September).

Table 1. Coefficient of variation for surface temperature (T), vol. moisture (vM), dry matter (DM), crude protein (XP) and crude sugar (XZ) for each treatment on each cutting day (1: 24 May, 2: 26 July, 3: 28 September).

	aisle 1	free 1	modules 1	aisle 2	free 2	modules 2	aisle 3	free 3	modules 3
T	0.031	0.051	0.041	0.022	0.043	0.025	0.021	0.014	0.011
vM	0.411	0.309	0.407	0.549	0.332	0.488	0.373	0.328	0.526
DM	0.373	0.625	0.328	0.485	0.519	0.299	0.425	0.441	0.359
XP	0.121	0.046	0.122	0.055	0.058	0.138	0.143	0.112	0.154
XZ	0.308	0.210	0.271	0.178	0.144	0.275	0.157	0.150	0.236

Conclusion

We found influences on surface temperature, soil moisture, biomass production, crude protein and crude sugar levels by solar modules (SM), calling for further research to understand the underlying mechanisms for the impact of SM on grassland microclimate and vegetation.

Acknowledgement

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