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Short Communication

# Management and sustainability of ground-mounted solar parks requires consideration of vegetation succession as an omnipresent process

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## Abstract

In addition to the aspects of power generation, land use, aesthetics, nature conservation, and multifunctionality considered so far, there are still overlooked issues in the relatively new topic of solar landscapes. I reveal a connection with a supposedly not equally contemporary theme: ecological succession. Understanding succession provides the background for interrelationships, and explains why, in large solar parks, the occurrence of large operational disruptors, such as trees, cannot be sustainably countered with the usual maintenance measures. Woody plants benefit from the thousands of safe sites amongst the modular panel constructions, and softwoods often avoid being cut due to their flexibility, or grow back from their stumps. Stronger and stronger over time. Instead of relying exclusively on labour-intensive and costly mowing, managers can make use of grazing animals. In this way, simply anticipating the ecological succession process and taking it into account when planning and managing a solar park can boost overall sustainability. The recommendation makes connections with social dimensions and can result in ethically produced meat.

## Keywords

food-energy-water nexus, land use, multifunctionality, photovoltaics, pluralism, sector coupling, vegetation dynamics

## Introduction

A great future lies ahead for renewable electricity production via solar parks (Victoria et al. 2021). Several authors have conceptualised how functions other than electricity generation can be integrated into the new energy landscapes. Multifunctionality is key (Selman 2009, Oudes et al. 2022). However, an essential natural process that unites many aspects of landscape development has been disregarded so far: ecological succession. Succession is an omnipresent process in landscapes (Bazzaz 1979), which can start with a vegetation-free substrate and proceed via grass- and herb-rich vegetation communities, eventually, given sufficient moisture, to woody vegetation communities, i.e. forests.

## Woody plants emerge in solar parks due to succession

The desired grass and herbaceous plant stands in ground-mounted solar parks (Meyer et al. 2023), where most of the electricity from photovoltaic systems is generated (Sturchio and Knapp 2023), are merely a temporary phenomenon within ecological succession (Zaplata et al. 2013, Zaplata and Dullau 2022). Vegetation succession as a progressive-dynamic development does not stop at this developmental state (Pickett and McDonnell 1989), in which the solar park is green, but not overgrown and shaded. Mowing is a common measure undertaken by solar park managers to maintain the physical performance of the panels by preventing shading, optimise the visual appearance, and keep the vegetation in a suitable condition for inspection by operators, service partners and owners.

However, mowing around the structures in solar parks is difficult and fails to utilise the multifunctional potential (Zaplata 2023). Mowing machines need at least lubricating oil, and most, especially those for use on large areas, require the use of unsustainable fossil fuel. In practice, some of these substances are spilled and contaminate the soil.

In principle, mown grass can be removed and used elsewhere. So far, however, it has been treated more like waste (Fig. 1) or it is left in the solar park as a mulch layer, where it reduces evaporation and increases the humus content of the soil in the medium term. This is disadvantageous for plant species that are adapted to poor soil sites (Tilman 1985) and cannot compete in intensively fertilised landscapes.

Data on the installation locations of ground-mounted PV systems in Germany are available from the end of 2021: at 36% (11,460 ha), the highest proportion is on conversion areas (e.g. former military areas or landfills), 30% (9,600 ha) on arable land

(Umweltbundesamt 2023). The latter in particular are also predestined for grassland species with high fodder value.

Figure 1.

In the case documented here, the entire biomass – hundreds of rolls of fertiliser and pesticide-free hay from two mowing operations in 2024 alone – went to a composting plant. The company (not based in the region) that had carried out the mowing and removal had tried to find users to whom the hay could have been given and even delivered free of charge. However, the nearest zoological garden was not interested either. Given spatial integration, i.e. if the companies carrying out the mowing know or own local farms with hay requirements, it is easier to utilise the biomass as fodder hay or bedding.

In ecological succession, woody plants follow herbs and grasses (Bornkamm 2007). However, woody vegetation is highly undesirable in ground-mounted solar parks, because it can shade solar panels (Fig. 3) and, thus, reduce power yields. Even slight shading of panels can lead to disproportionately high losses in electricity (Pannebakker et al. 2017).

## Unwanted and previously largely overlooked effort that increases over time

The efficiency of mowing is at odds with phenomena typical of woody plants:

1. **Survival due to bending.** The pliability of softwoods makes them difficult to mow. Softwoods, such as willows (*Salix* spp.) and poplars (*Populus* spp.) (Schnitzler 1995), are common pioneer plants (Fig. 2). In many cases, saplings are simply

pushed to the ground by mowing machines, and spring up again after mowing (Fig. 4).

2. **Survival due to re-growth after coppicing.** Many woody plants regenerate naturally via coppice shoots. If woody plants are cut by mowers, a stump remains on and in the ground (Fig. 5), which acts as a storage reservoir and from which stump shoot regrowth is possible (Shackleton 2000). Woody stumps of astonishing width can develop quickly, which enable more extensive shoots with each subsequent mowing.
3. **Survival due to growth in safe sites where mowing is not possible.** The many artificial structures in solar parks benefit woody plants. Typically, around 500 vertical metal posts are used per hectare to provide support for the panels in ground-mounted solar parks. This is a rough estimate for a two-post fixed array system with current solar panels; the exact number of posts depends on the system design, structure of the panel supports, and the loads at the site. Especially if the posts are implemented as metal U-profiles – as is often the case – each post provides a safe site for woody plants to grow. In succession research ( Meiners et al. 2015), the term ‘safe site’ is applied pragmatically: woody plants can grow in the U-profile, out of reach of mowing tools. The higher the pressure of the diaspora on an area, the more or faster these protective, safe locations are found and occupied by woody plants.

Figure 2.

Woody plants (goat willow *Salix caprea* and common aspen *Populus tremula*) that survived mechanical mowing while growing under solar panels (in the foreground and background of the photo). Photo taken on 09 June 2023 in a solar park in Brandenburg, Germany, two and a half years after it was commissioned. Please note how many woody plants are growing in the background.

Figure 3.

Elder (*Sambucus nigra*) begins to grow between solar panels (photos of the same solar park on 28 July and 11 September 2023; note the growth). For the operators, the maintenance status of a solar park is measured partly by how much of this unwanted shade exists.

Figure 4.

Taken after a mowing on 12 September 2024, this picture provides an indication of the enormous flexibility of some woody plants. This willow can immediately start to sprout again and continue to grow.

All three phenomena result in the need to increase maintenance efforts to remove woody plants from solar parks over time. Today, mowing systems with swivel arms are often used to mow around obstacles such as poles. Brush-cutter teams are being used less and less frequently and preferably in small solar parks. Currently, solar park operators are tackling the problem of growing woody plants by manually removing them, as far as I know, which of course often just means tearing off the above-ground parts. In Germany,

the nature conservation authorities have a clear say in the frequency of these measures. They do so in a particularly stringent and prescriptive manner when it comes to good professional practice for the development of appropriate and floristically high-quality meadow communities or the protection of breeding birds, including neighbouring protected breeding bird species.

Figure 5.

Situation found after mowing on 12 September 2024. A willow that has grown to an impressive size remains in the ground; resprouting is, therefore, easily possible.

## Lower maintenance effort with grazing and extension of sustainability in more directions

The topic is still young. Not least because of the following fact: there are currently no standards for this topic in the German body of standards (Keinath et al. 2024). Nevertheless, there is already some experience with grazing animals in solar parks, both of a practical nature and as reading material (Gabler et al. 2019). The relevant regulations and laws on the minimum height of the elevation and, in particular, the current animal welfare regulations for livestock farming apply. Animal husbandry-specific requirements appear to be increasingly being compiled and defined in the direction of standardisation (Keinath et al. 2024). Key aspects that have now been formulated are that the ‘farm animals’ must be able to move upright under the system in order to avoid the risk of injury. With a minimum clear height of 1.5 metres, there must be a spatial connection with stables (Keinath et al. 2024).

The situation is different - especially with regard to maintenance measures to remove woody plants - if grazing is used instead of mowing. Unlike mowers, grazers (such as

goats) using their teeth do not always cut woody plants at the same height (Elias and Tischew 2016), but also sometimes pull woody plants up by the roots. This may be easier to do near the posts, as the woody plants may be hindered in their root development by the underground part of the U-profile. Compared to mowing, the grazing of solar parks should be more sustainable according to good professional practice (i.e. extensively utilised grassland or ecological farming that does not lead to water pollution and eutrophication; D'Odorico et al. (2018)), due to lower energy use, lower and more consistent maintenance effort, provision of regular shade areas for the grazing livestock (Maia et al. 2020), and other considerations, ranging from counteracting climate change phenomena to creating positive effects in social dimensions. Regarding the former, a surface temperature cool island effect beyond the limits of ground-mounted solar parks has been demonstrated for large parks and arid ecosystems (Guoqing et al. 2021), especially due to solar radiation removed by the panels. Effects on the social dimensions include the ability to reunite an increasingly irreconcilable drifting apart society on the new territory of energy landscapes (Zaplata 2023). In a multifunctional, grazed solar park, different lifestyles are likely to come together. For example, a critical consumer (Heise and Theuvsen 2017) who disapproves any meat production in the commercial economy, and a livestock farmer who feels driven to produce high quantities in the agricultural domain despite the negative consequences for animal welfare. The need to produce so much is amended when grazing animals are kept in solar parks and meat raised in this way is likely to be considered more ethical by even highly critical consumers (Verbeke and Viaene 2000).

Grazing in solar parks is a great opportunity, in which contextual factors need to be explored (Loos et al. 2023) so that holistic perspectives and plurality can succeed. This could provide a tangible example of changing norms and incentives that are facilitated through complementarities and result in society shifting towards a vision of sustaining natural and social capital (Chapin et al. 2022). In solar parks, the main motive is efficient maintenance of energy landscapes alongside biodiversity aspects, which are understood as a service and for which money is spent. Such an ethic, catalysed in the new energy landscapes, will also help bring the important profession of shepherding out of general marginalisation.

The scientifically sound starting point for this is ecological succession, a constant, omnipresent and elemental force (Pickett and McDonnell 1989) that cannot be ignored. Using livestock grazing in the design and maintenance of ground-mounted solar parks allows the management of solar parks to take place alongside natural ecological processes, and to benefit from them. There is great potential for ground-mounted solar parks maintained with a mowing regime to be replaced by with those designed for, and maintained by, grazing management.

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## Conflicts of interest

The authors have declared that no competing interests exist.

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