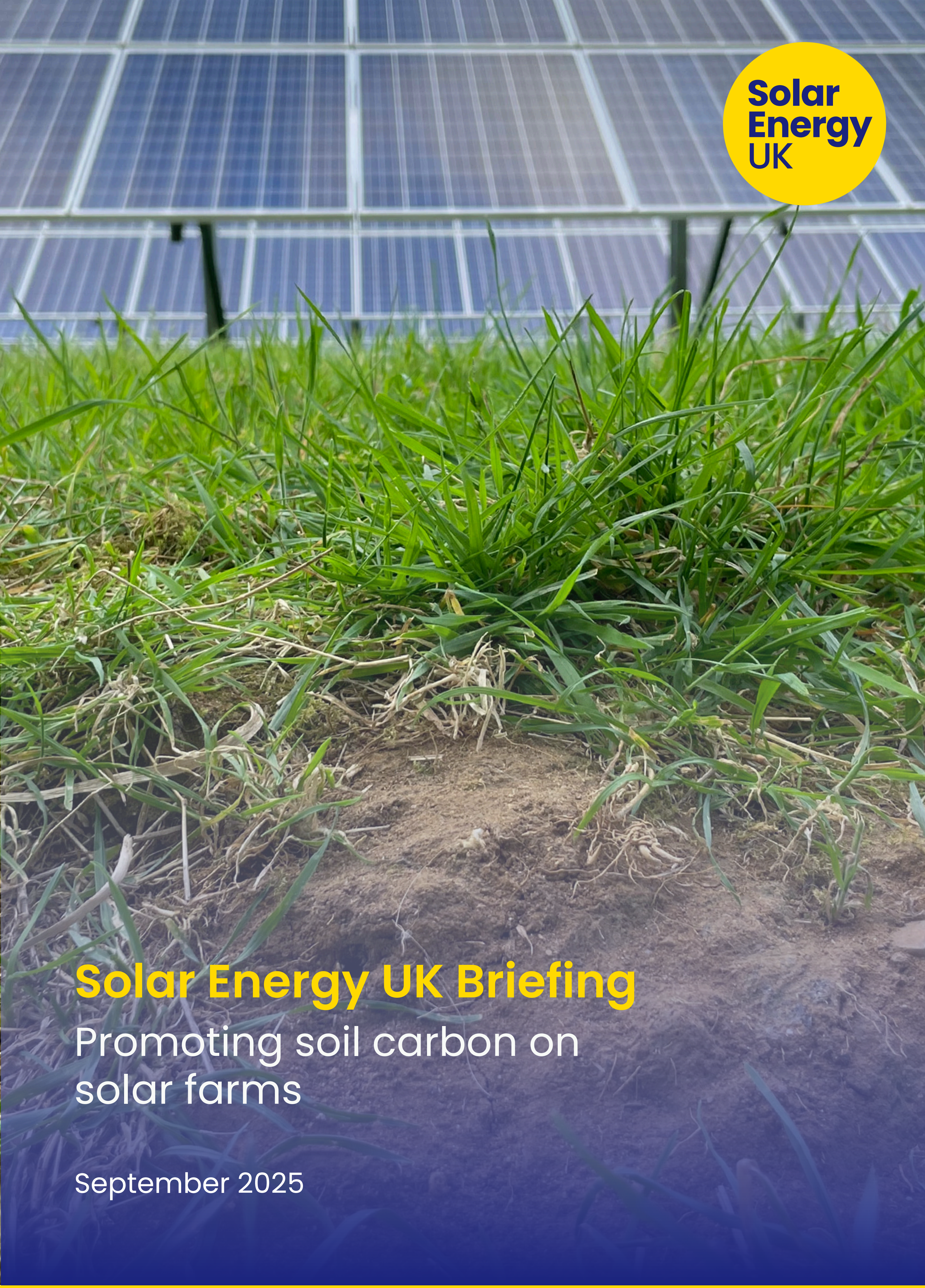

Solar Energy UK Briefing

Promoting soil carbon on solar farms

September 2025

About Us

As an established trade association working for and representing the entire solar and energy storage value chain, Solar Energy UK represents a thriving member-led community of over 430+ businesses and associates, including installers, manufacturers, distributors, large-scale developers, investors, and law firms.

Our underlying ethos has remained the same since our foundation in 1978 – to be a powerful voice for our members by catalysing their collective strengths to build a clean energy system for everyone's benefit.

Our mission is to empower the UK solar transformation. Together with our members, we are paving the way for solar to deliver 60 GW by 2030 by enabling a bigger and better solar industry.

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Glossary

Ecosystem services: the numerous benefits that humans derive from ecosystems, including material goods like food and water and non-material benefits like recreation.

Photosynthesis: the process by which plants use sunlight, water, and carbon dioxide from the atmosphere to produce oxygen and energy in the form of sugar.

Respiration: the process by which living organisms (including plants and soil organisms) take in oxygen to break down sugars and release carbon dioxide, water, and energy.

Soil decomposition: the process by which dead organic matter (including fallen leaves, twigs, roots and soil organisms) is broken down, releasing nutrients.

Soil Sampling *- photo by Hollie Blaydes*

Overview

Promoting healthy soils is central to addressing some of the most critical global issues of the 21st century related to food and water security, climate change, nature degradation, and biodiversity decline [1]. Soils are responsible for the provision of numerous ecosystem services that benefit humans, including food production, water purification, and habitat creation [2]. However, human activities are putting increased pressure on soil resources, pushing them to critical limits that may prevent soils from delivering these vital ecosystems services [3].

Solar farms can be part of the solution in addressing global soil issues by promoting healthy soils and, in particular, the storage and sequestration of soil organic carbon (SOC), which is essential to mitigate climate change, support food production, and promote biodiversity.

Solar farms can promote SOC increases through a range of design, construction, and management options that are fully compatible with solar farm development and operation. Therefore, promoting SOC on solar farms rely on best practice in three key aspects:

- Design (e.g., designing solar farms to minimise impact on plant productivity).
- Construction (e.g., minimising the use of heavy machinery).
- Land management (e.g., boosting plant species diversity).

Soil carbon

Soil holds more carbon than is contained in the atmosphere and terrestrial vegetation combined [4]. In most cases, SOC contributes to the majority of soil carbon in topsoil layers [5] and, crucially, is influenced by soil management practices.

SOC concentration is a result of several interacting ecosystem processes, including photosynthesis, respiration, and soil decomposition. The major input of organic carbon into soils is via plant uptake and fixation of carbon dioxide from the atmosphere and subsequent incorporation of plant residue carbon into the soil. Decomposition of biomass by soil microbes is one of the main sources of carbon loss from soils due to microbial respiration releasing carbon dioxide, though some loss can also occur via leaching in the form of dissolved carbon.

When inputs and losses are in balance, there is no net change in SOC concentration. However, human activities (e.g., change in natural land cover to intensive agriculture) can have detrimental consequences for soils (e.g., accelerated erosion, acidification, compaction, loss of soil organic matter) and lead to an imbalance between the two, which may result in increased carbon loss from soils [2]. In fact, approximately one-third of the total increase in atmospheric carbon dioxide stemming from human activities since the preindustrial era has been attributed to SOC loss due to land use change [4].

The goal of increased soil carbon storage to combat climate change has received much attention in recent years, partly due to its other known benefits (e.g., water quality, food security), but mostly due to the direct control human activities can exert on soil carbon processes.

Effects of land use change on soil carbon

Land use change has resulted in substantial losses of soil carbon globally [6]. Some recent estimates have projected losses of 133 billion tonnes of carbon in the top 2 m of soil due to agriculture alone (mostly cropping and grazing lands) [7], though losses of over 500 billion tonnes have been quoted in previous studies [8]. It is thought that, since the industrial revolution, the conversion of natural ecosystems to agricultural use has released 50 to 100 billion tonnes of carbon from soil into the atmosphere [9], while SOC stocks have been depleted by as much as 60% in some temperate regions [4].

The current drive to convert agricultural land to ground-mounted solar farms to meet Net Zero targets may offer risks and opportunities in enhancing soil's role in climate, food, and human security. For instance, a recent study found that solar farms have a significant impact on plant biomass production, with cascading negative effects on soil carbon storage due to reduced carbon input from plants [10]. Several studies have indeed found solar farms reduce solar radiation receipts and alter the microclimate to affect plant productivity [e.g., 11].

Yet, at the farm scale, solar farms showed slightly higher soil carbon levels than adjacent pastureland, likely due to relatively well-vegetated areas away from solar panels and low levels of disturbance [10]. These results suggest solar farms have the potential to promote soil carbon storage at scale (compared to intensive agricultural land) if appropriately designed, built, and managed, despite the negative impact of solar panels on plant carbon input to soils.

In agricultural systems, management for soil carbon may include the use of organic amendments, appropriate animal stocking densities, and revegetation of degraded lands [6], all of which are suitable for adoption as land management practices within solar farms.

Land management (and other) recommendations for solar farms

Despite intense research interest in soil carbon, there is still considerable uncertainty in establishing land management strategies to rebuild SOC stocks [12, 13]. The wide temporal and spatial variability in soil conditions in temperate agricultural systems [14], as well as the highly contextual nature of the effects of land management on soils [15], make devising general recommendations difficult.

Nevertheless, a recent review of the scientific evidence from the UK and Ireland [16] has revealed land management practices that may offer great potential to deliver net soil carbon gains within solar farms built in temperate agricultural systems and managed as grasslands. Based on these findings, land management recommendations include:

Designing solar farms to deliver positive outcomes for plants and soils.
For instance, increasing the proportion of areas not over-sailed by panels may reduce the negative effects of shading on plant productivity and favour the establishment of diverse plant communities, with positive consequences for soil carbon given increased plant carbon input. However, this would likely result in increased land take for solar farms, with overall outcomes dependent on the type of land use being converted.

Adopting construction practices that minimise impact on soils and facilitate beneficial land management during operation.
Favouring the use of low-impact vehicles during construction (and during operation for mowing and other maintenance) should help reduce soil compaction (which can be detrimental to plant establishment). In addition, power cables should be buried according to national regulations and deep enough to avoid damage by grazers and facilitate soil monitoring during operation (see below). See the good practice guidance by BRE National Solar Centre [17] for more details.

Promoting greater plant species richness and diversity.
Increasing plant species richness and the diversity of plant functional groups, including those commonly associated with increased soil carbon sequestration (e.g., legumes) and those tolerant to shading (to cope with conditions found underneath solar panels) should favour soil carbon accrual. Plant diversity can be increased through seeding and maintaining native wildflower meadows that can also benefit wider biodiversity (e.g., invertebrates, birds).

Improving grazing management.
This can be achieved through low-to-moderate intensity grazing and rotational grazing (i.e., rotating livestock to allow the land to rest). These practices can create structured habitats and enhance plant diversity and productivity and favour soil carbon stocks. This can be achieved through low-to-moderate intensity grazing and rotational grazing (i.e., rotating livestock to allow the land to rest) and by placing the leading (lower) edges of solar arrays high enough above the ground to allow grazing animals (e.g., sheep) to move freely across the site. These practices can create structured habitats and enhance plant diversity and productivity and favour soil carbon stocks'.

Applying organic fertilisation tailored to site conditions.
Moderate levels of organic nutrient addition, particularly cattle slurry and biosolids, often results in positive outcomes for grassland soil carbon storage in the long term, especially if combined with other management options (e.g., rotational grazing).

Other considerations

Design, construction, and management strategies must be optimised for each solar farm to accommodate site specific conditions. For instance, local soil and climate conditions, as well as initial soil carbon and nutrient status, must be considered given the inconsistent and highly variable effects of land management actions on soil carbon, especially when considering nutrient amendment options since practices that change soil nutrient dynamics are likely to have various implications for other greenhouse gas emissions (e.g., nitrous oxide). Positive results will most likely be realised if conversion is from degraded agricultural land or brownfield sites.

Despite the challenges in designing, building, and managing solar farms to promote soil carbon storage, solar farms offer unique opportunities for adopting and tailoring development and management options to fit site-specific conditions given they are largely undisturbed during operation. Public policy recommendations to encourage such actions have been recently formulated by Carvalho *et al*. [18] and include access to public financial incentives that encourage sustainable land use, implementation of nascent nature markets, and formulation of ecological indicators and metrics that underpin best practice. Importantly, constant monitoring will be key in evaluating the success of any intervention to support healthy soils.

Soil monitoring on solar farms

Regular soil monitoring will be essential to ensure the chosen options are delivering to the objective of enhancing soil carbon storage to help combat climate change (and delivering to other objectives such as promoting food security and benefiting nature).

Ideally, soil monitoring should adopt standardised approaches to data collection (see Resources section below) to ensure the systematic valuation of temporal and spatial changes in soil carbon storage resulting from solar farm development and operation.
In addition, the use of standardised methods across different sites and regions should contribute to generating comparable and reproducible data on ecosystem impact assessments of solar farms to inform scientific research (currently limited due to a scarcity of data), land use frameworks, policy development, and industry best practice.

Resources

Standardised protocol to assess a suite of ecosystem services (including soil carbon storage) on solar farms:
https://besjournals.onlinelibrary.wiley.com/doi/10.1002/2688-8319.12210

Solar Energy UK's best practice guidance on natural capital assessment:
https://solarenergyuk.org/resource/natural-capital-best-practice-guidance/

Solar Energy UK's guide to monitoring biodiversity:
https://solarenergyuk.org/resource/solar-energy-uk-guidance-a-standarised-approach-to-monitoring-biodiversity/

References

[1] Amundson, R. et al. (2015) Soil and human security in the 21st century. Science, 348,1261071 (https://www.science.org/doi/10.1126/science.1261071).

[2] FAO and ITPS (2015) Status of the World's Soil Resources (SWSR). Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils. Rome, Italy (https://www.fao.org/family-farming/detail/en/c/357394/).

[3] Montanarella, L. et al. (2016) World's soils are under threat. Soil, 2, 79-82 (https://doi.org/10.5194/soil-2-79-2016).

[4] Lal, R. (2004) Soil carbon sequestration impacts on global climate change and food security. Science, 304,1623-1627 (https://www.science.org/doi/full/10.1126/science.1097396).

[5] Batjes, N. H. (2014) Total carbon and nitrogen in the soils of the world. European Journal of Soil Science, 65, 10-21 (https://doi.org/10.1111/ejss.12114_2).

[6] Smith, P. et al. (2016) Global change pressures on soils from land use and management. Global Change Biology, 22, 1008-1028 (https://doi.org/10.1111/gcb.13068).

[7] Sanderman, J. et al. (2017) Soil carbon debt of 12,000 years of human land use. PNAS, 114, 9575-9580 (https://doi.org/10.1073/pnas.1706103114).

[8] Lal, R. (2001) World cropland soils as a source or sink for atmospheric carbon. Advances in Agronomy, 71, 145-191 (https://doi.org/10.1016/S0065-2113(01)71014-0).

[9] Lal, R. (2009) Sequestering atmospheric carbon dioxide. Critical Reviews in Plant Sciences, 28, 90-96 (https://doi.org/10.1080/07352680902782711).

[10] Carvalho, F. et al. (2025) Plant and soil responses to ground-mounted solar panels in temperate agricultural systems. Environmental Research Letters, 20, 024003 (https://iopscience.iop.org/article/10.1088/1748-9326/ada45b).

[11] Armstrong, A. et al. (2016) Solar park microclimate and vegetation management effects on grassland carbon cycling. Environmental Research Letters, 11, 074016 (https://iopscience.iop.org/article/10.1088/1748-9326/11/7/074016).

[12] Stockmann, U. et al. (2013) The knowns, known unknowns and unknowns of sequestration of soil organic carbon. Agriculture, Ecosystems & Environment, 164, 80-99 (https://doi.org/10.1016/j.agee.2012.10.001).

References

[13] Paustian, K. et al. (2016) Climate-smart soils. Nature, 532, 49-57 (https://doi.org/10.1038/nature17174).

[14] Soussana, J.-F. et al. (2004) Carbon cycling and sequestration opportunities in temperate grasslands. Soil Use and Management, 20, 219-230 (https://doi.org/10.1111/j.1475-2743.2004.tb00362.x).

[15] Mayel, S. et al. (2021) How does grassland management affect physical and biochemical properties of temperate grassland soils? A review study. Grass and Forage Science, 76, 215–244 (https://doi.org/10.1111/gfs.12512).

[16] Carvalho, F. et al. (2024) Enhancing soil carbon in solar farms through active land management: a systematic review of the available evidence. Environmental Research: Ecology, 3, 042001 (https://iopscience.iop.org/article/10.1088/2752-664X/ad8ce4).

[17] BRE (2014) Agricultural good practice guidance for solar farms. Ed J. Scurlock. Available at https://files.bregroup.com/solar/NSC_-Guid_Agricultural-good-practice-for-SFs_0914.pdf (accessed January 2025).

[18] Carvalho, F. et al. (2024) Integrated policymaking is needed to deliver climate and ecological benefits from solar farms. Journal of Applied Ecology (https://doi.org/10.1111/1365-2664.14745).

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