Current Knowledge on Low-Impact Ground-Mounted Solar Siting, Construction, and Installation Practices

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Abstract

Solar energy represents an increasingly large proportion of total energy generation in the United States and worldwide and is projected to continue to grow rapidly in the future. Like any landscape modification, solar development can have unintended negative consequences on the environment. This document provides a comprehensive yet non-exhaustive overview of the current literature on low-impact ground-mounted solar development practices and how they alter hydrological (water quality and availability), ecological (vegetation and wildlife), and pedological (soil health and structure) functioning. We discuss low-impact ground-mounted solar siting, construction, and installation practices, reporting current best practices to minimize land disturbance and mitigate negative environmental impacts while identifying knowledge gaps that require future research. Low-impact practices include appropriately targeting locations in the site selection process, prioritizing retention of existing vegetation where possible, designing around site geomorphology to minimize grading and topsoil disturbance, and adopting soil health management best practices to maintain water on the landscape. We observe that most existing literature has focused on minimizing impacts during the operational phase of solar development, and there is a major knowledge gap in understanding best practices during the construction and installation phase.

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Background

Unintended negative impacts of solar array site selection, preparation, and construction have long been a concern of the public and scientific community (Lovich and Ennen, 2011; Hernandez et al., 2014; Grippo et al., 2015; Moore-O'Leary et al., 2017). In response to these concerns, best management practices have emerged to minimize negative hydrological, ecological, and pedological impacts of solar development. Here, we use ***low-impact solar development*** to refer to an active effort to minimize the water, soil, and ecology impacts during ground-mounted solar siting, construction, and initial site establishment to mimic or even regenerate natural landscape processes of an undeveloped system (modified from McCall et al., 2023 and Davis, 2005). This is in contrast to the colloquially defined ***conventional solar development***, where natural processes (water, soils, and ecology) are near absent from ground-mounted solar siting, construction, and site establishment considerations that focus on installation and management cost reduction and electricity generation optimization.

In this report, we make a distinction between low-impact practices during the construction and installation phase as opposed to during the operational phase (e.g., dual-use, agrisolar, ecovoltaic, and agrivoltaic management) of the solar facility lifecycle, on which there is an expansive and growing body of well-validated best practices (e.g., NREL, 2018; Macknick et al., 2022; Choi et al., 2023; McCall et al., 2023; SolarPower Europe, 2023). Best-practices in low-impact site construction and installation are far less studied than effects of varying land management practices during the operational phase (post-installation), and there is not yet a single authority or legally binding set of regulations in any public jurisdiction in the United States requiring or incentivizing low-impact solar development (McCall et al., 2023). Only recently did the Protecting Future Farmland Act of 2023 set out a goal for the USDA Natural Resources Conservation Service (NRCS) to: (excerpted) "develop both national and regionally relevant guidance on best practices for protection of soil health and productivity during the siting, construction, operation, and decommissioning of solar energy systems on agricultural land, which shall include guidance for: soil carbon and soil health, water management, vegetation management, including types of plants best suited for pollinators; and other practices, as determined appropriate by the Secretary of Agriculture…" (§4(a)(1) Part A from Baldwin and Grassley, 2023).

Following this call, the NRCS came out with a fact sheet and report on Conservation Considerations for Utility-Scale Solar Farms that highlight the importance of natural resource considerations in the design and operation of successful solar farms (USDA NRCS, 2024a; USDA NRCS, 2024b). These considerations are centered on protecting soil health, water quality, and wildlife while mitigating erosion and wildfire potential. Several independent groups also have produced robust primers, reports, or factsheets on low-impact solar development, specifically the National Renewable Energy Laboratory (NREL) (Doyle et al., 2015; NREL, 2024), The Nature Conservancy (TNC) (TNC, 2023), American Farmland Trust (AFT) (Beck et al., 2022; Hunter et al., 2022; Levy et al., 2022; Sorenson et al., 2022), Great Plains Institute (GPI) (GPI, 2023), and the Environmental Protection Agency (EPA) (EPA and NREL, 2022). These are comprehensive resources, and the authors of this document strongly suggest reviewing these in addition to the content of this report. A collection of relevant peer-reviewed articles and reviews on topics regarding effective siting, stormwater management, and construction practices also exist and are discussed in the following sections. Here, we compile existing knowledge on key areas of concern and current best practices and elucidate gaps in understanding on low-impact solar development.

Key Areas of Concern and Current Best Practices

Solar energy installations are land-use intensive, and as a result concerns about solar energy development are often centered on (1) ecosystem opportunity costs and (2) newly created hazards. Ecosystem opportunity costs refer to potential alternate uses for the land being developed and typically depend on the historical land use of the selected solar development site (e.g., differential impacts of converting landfill vs. forested areas to solar), potential future land use under a changing climate (e.g., potential benefits of annual monoculture cropland or perennial specialty cropland vs. solar), and developmental and management practices at the site (e.g., whether solar facilities have bare soil or native grass establishment). In contrast, newly created hazards refer to emerging concerns that develop as a result of the solar energy construction, which tend to be more dependent on system design and management practices but can also be driven by historical land use (e.g., tilled cropland vs. forested areas may cause different amounts of stormwater runoff) and local landscape characteristics (e.g., slope, soil drainage status, etc. can all affect post-installation runoff).

Specific areas of concern commonly include loss of prime natural, migratory, and agricultural habitats (e.g., Levin et al., 2023; Daniels et al., 2024); habitat fragmentation and biodiversity loss (e.g., Cameron et al., 2012; Grodsky et al., 2021); surface and groundwater contamination, land grading, soil compaction, and loss of organic matter (e.g., Hernandez et al., 2014; Daniels et al., 2024); erosion, flooding, and soil stability (e.g., Lambert et al., 2021; Liu et al., 2023); and wildfires (e.g., Hernandez et al., 2014; Wu et al., 2020). Here, we review and discuss potential ways to address these concerns through four low-impact development solutions: effective siting and design, retention or establishment of relevant vegetative ground cover, preservation methods for topsoil and its structure during construction, and effective hydrological management. These are detailed in the following sections.

Low-impact siting and design

Solar site selection (siting) creates the antecedent conditions that underlie the impacts of all other decisions made during the design, construction, and operation of solar energy development. The location will inherently impose constraints on which impacts can and need to be addressed through site engineering and design decisions. Reducing the negative impacts of land use means selecting the solar land footprint with the lowest opportunity costs and designing the system to enhance possibly degraded site conditions (TNC, 2023). Of six key principles that TNC (2023) identified for low-impact solar development, three are focused on siting: 1) avoid high native biodiversity and high-quality natural areas, 2) allow for wildlife connectivity, and 3) use disturbed or degraded lands. The remaining three involve system design and establishing ground cover management: 4) protect water quality and avoid erosion, 5) restore native vegetation and grasslands, and 6) provide wildlife habitat (TNC, 2023).).

Land with low(er) opportunity costs (low-impact siting; Table 1) can thus be defined as land that is not critical for insect and animal (biotic) habitat, nesting, and migration pathways (Cameron et al., 2012; Hernandez et al., 2015; Hoffacker et al., 2017; Grodsky et al., 2021; Hise et al., 2022; Levin et al., 2023; Ashraf et al., 2024); land in which disturbance will not result in contamination or altered ecosystem functioning (e.g., avoiding wetlands, floodplains, acid sulfate soils) (TNC, 2023; Daniels et al., 2024); land with low-quality or anthropogenically depleted resources (marginal) (Milbrandt et al., 2014; Katkar et al., 2021; Lambert et al., 2021; Hunter et al., 2022; Levy et al., 2022; Sorenson et al., 2022); and land in close proximity to existing electrical infrastructure to reduce the need for new access roads and transmission lines (Hoffacker and Hernandez, 2020). Each of these conditions can change with time, making it essential to consider the future biotic and abiotic functioning of the land within a changing climate (Ashraf et al., 2024).

Building a solar energy system on top of a landfill is a real-world example of low-impact siting and also inherently requires other forms of low-impact development (topsoil and structure preservation, vegetation retention/establishment, and effective hydrological management), albeit to prevent disturbance of the landfill cap rather than to preserve the natural ecosystem and resources. Currently, 621 solar photovoltaic (PV) projects are associated with landfills according to the EPA RE-Powering America's Land data portal (EPA, 2024). Despite its prominence, only a few examples of applied best practices for solar installation on landfills have been documented (e.g., EPA and NREL, 2022; MI EGLE, 2024).

Table 1. Low-impact siting considerations.

Concern	**Low-impact siting best practices**
Organismal ecological impacts	• Avoid locations with important habitat, nesting, and migration value • Incorporate wildlife-friendly fencing or unfenced passageways
Altered ecosystem function	• Target marginal land or already modified land • Avoid locations with important ecological functions, such as wetlands and floodplains • Include buffer areas around streams and wetlands
Access road and transmission line creation	• Target locations close to existing electrical infrastructure
Enhanced runoff and erosion	• Design with natural ecosystem function in mind • Incorporate natural geomorphological variability to minimize grading needs

A range of existing resources are available to help identify low-impact sites for solar deployment. For example, TNC's Site Renewables Right map synthesizes more than 100 layers of engineering, land-use, and wildlife data to identify "no-go" areas for renewable energy deployment based on key regions for wildlife preservation (TNC, 2022; TNC, 2024). The DOE Renewable Energy Siting through Technical Engagement and Planning (R-STEP™) program is an additional resource for navigating local zoning ordinances, fire and safety codes, community engagement strategies, and environmental impacts across 17 states (DOE, 2024a). Regarding solar siting on farmland, AFT has developed the Smart Solar program, which aims to maximize renewable energy generation while supporting farm viability and protecting the nation's most productive farmland (Hunter et al., 2022; Levy et al., 2022; Sorenson et al., 2022). The USDA and DOE also recently announced the Solar Energy and Farming Initiatives website, which compiles additional information about initiatives to help farmers site renewable energy on their land (DOE, 2024b). Although varying in scope and region, most of these articles and resources report that the United States has more than enough low-impact land to meet net-zero electricity needs.

Once a site is selected, several other low-impact design considerations can help mitigate impacts of developing solar arrays. For example, from the start of the project, the natural contours of the land should be surveyed and worked into project design (racking, spacing, tilt), thus reducing the need to grade the land and meet conventional (non-site specific) design requirements (NREL, 2024). Additionally, even when avoiding key migratory and connectivity areas, designing solar arrays with wildlife-friendly fencing or even unfenced passageways as well as buffers around streams and wetlands promotes and may even regenerate connectivity and migratory potential for potentially affected species (TNC, 2023). Evidence also suggests that solar arrays can be designed to reduce the risk of electrical faults (e.g., installing multiple smaller inverters rather than fewer larger inverters, allowing for better detection of ground faults) (Falvo and Capparella, 2015) and can undergo regular preventative maintenance to prevent fires (e.g., hot spot analysis, blind spot analysis, electrical wire insulation monitoring, residual current monitoring, and ground-fault protection) throughout their lifetime (Falvo and Capparella, 2015; Wu et al., 2020). These low-impact designs are in addition to effective ground cover and stormwater management discussed in the following sections.

Vegetation retention, revegetation, and vegetation establishment

Ground cover conditions are a major control of the impacts of solar arrays on the physical landscape. Again, most studies have focused on the operational phase impacts of effective ground cover management (e.g., NREL, 2018; Macknick et al., 2022; Choi et al., 2023; McCall et al., 2023; SolarPower Europe, 2023), and little research has been published regarding construction and installation impacts and best practices. However, given the importance of vegetation for topsoil retention, habitat functioning, and hydrological processes, ground cover design best practices in the installation and construction phase are critical to low-impact solar development.

Ground cover vegetation decisions depend on the antecedent land use (e.g., tilled cropland vs. perennial prairie vs. contaminated land) and post-installation management intentions (e.g., native vegetation or newly established pollinator habitat, grasses, crops, etc.). If available, and if the topsoil is well-developed with an existing productive ground cover, the best practice is to make every effort to retain existing ground cover and topsoil structure (see *Preserving topsoil and soil structure* in this report) and remediate unavoidable damages, which may include revegetation (Daniels et al., 2024) and post-construction soil decompaction (GPI, 2023). In general, revegetation, establishing new productive ground cover when the original ground cover was productive and locally appropriate, should be avoided unless the desired ecosystem service for that ground cover changes with the installation of a solar array (e.g., a conversion from prairie to combined solar energy and crop production in an agrivoltaic system). Even with effective ground cover management, such as native grasses replacing well-developed tallgrass prairie, existing evidence suggests that intensive grading and revegetation did not achieve previous soil nutrient or texture profiles after nearly a decade of effective ground cover management (Choi et al., 2020) compared to locations where land grading and intensive construction practices were avoided (Figure 1; Choi et al., 2023). This highlights the critical importance of retaining existing ground cover as the preferred approach over revegetation for low-impact development in locations where the pre-development land cover is to be maintained.

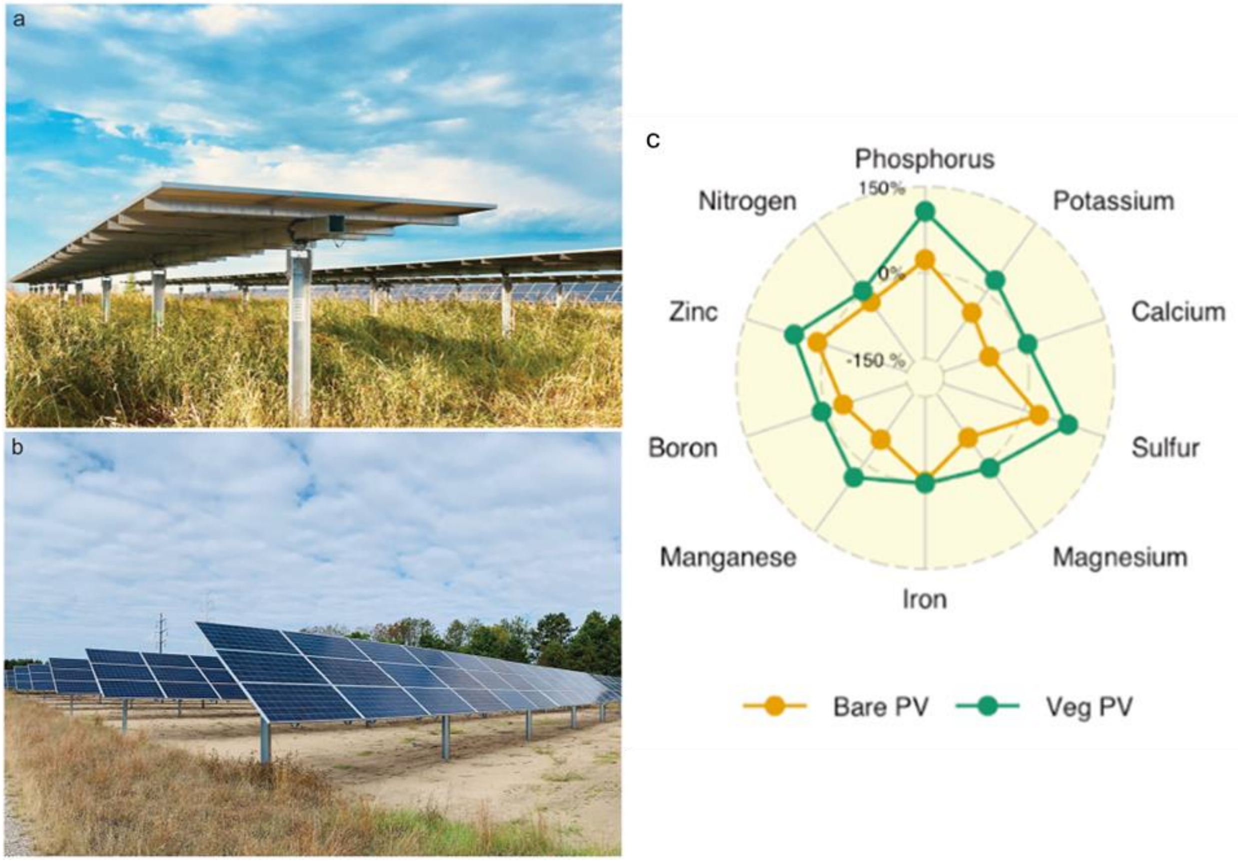

Figure 1. Example and data regarding Chisago Solar Development, modified from Choi et al. (2023). (a) Vegetated and (b) bare photovoltaic plots. (c) Changes in soil nutrients in each treatment plot relative to an undisturbed control plot. Positive values indicate an increase in that nutrient.

Low-impact solar ground cover selection should consider the needs of the land owner and the region. For example, if the prior land use was low-productivity pollinator-dependent cropland in a flood-prone area, low-impact solar development could include deep-rooting pollinator habitat, providing both pollination services and water management.

In some heavily managed landscapes, solar arrays can provide an opportunity to restore native vegetation and grasslands and provide new habitat and migration pathways with appropriate revegetation strategies (TNC, 2023). Overall, incorporating locally appropriate vegetation ground cover (in regions where vegetation can establish) results in better biotic and abiotic outcomes over barren, gravel, or other ground covers (Choi et al., 2023; McCall et al., 2023; Choi et al., 2024).

We are not aware of a comprehensive source for guidance on ground cover revegetation or vegetation establishment selection that considers varying landowner and regional needs. However, for pollinator habitat, 18 U.S. states actively maintain or are preparing solar pollinator scorecards (EPRI, 2021) and other groups, such as Fresh Energy (2020) and Right-of-Way as Habitat Working Group (ROWHWG, 2024), have developed several state-neutral scorecards that provide guidance on how to effectively establish locally important pollinator habitat at solar sites.

A growing number of agrivoltaic and ecovoltaic design tools (e.g., Warmann et al., 2024; Jamil et al., 2024; Williams et al., 2025) also are available, although these tools have not yet been broadly applied and tested. ***Agrivoltaic*** design is defined as "...a system under which solar energy production and agricultural production, including crop or animal production, occurs in an integrated manner on the same piece of land through the duration of a solar project" (Baldwin and Grassley, 2023), and ***ecovoltaic*** design is defined as systems that "co-prioritize energy production and ecosystem services during both the design and management phases of PV arrays" (Sturchio and Knapp, 2023).

Available literature provides early guidance on managing wildfire risk with ground cover management, with suggestions involving installing single-axis tracking mounted solar modules and regular removal of biomass by mowing or grazing (Vaverková et al., 2022), although establishing new vegetation can act either as a barrier or fuel to spreading fire and requires further study (Salmerón-Manzano et al., 2024). Revegetation of solar arrays on landfills using engineered turf (e.g., ClosureTurf®) has been shown to enhance soil retention, stability, stormwater runoff quality, and reduction of post-closure maintenance (Zhu et al., 2023), although this highly specialized turf ground cover may not be ideal for non-landfill land uses.

Preserving topsoil and soil structure

Soil formation is a slow process, taking decades to centuries. It is likely that intense topsoil removal (grading), disturbance, and compaction during solar array construction result in degraded soil functioning for the lifetime of the solar array and beyond (Choi et al., 2020; Daniels et al., 2024). Thus, the guiding principle should be to maintain and enhance existing soil resources rather than to rehabilitate the soil after construction. Retaining existing topsoil supports native vegetation growth, improves stormwater management, reduces the risk of erosion, and maintains soil health post-construction. Some states, for instance Virginia, have included soil structure preservation requirements for solar development in their Erosion and Sediment Control (ESC) guidance, although these practices are not yet required by Virginia state law (Morris, 2022).

Pathways for preserving topsoil and its structure in low-impact solar development are generally analogous to agricultural soil health principles, which include (1) minimizing disturbances; maximizing the presence of (2) living roots and (3) ground cover; and (4) maximizing biodiversity (Figure 2; USDA NRCS, 2024c). Again, maximizing soil cover and minimizing roots can be accomplished by leaving existing vegetation in the ground during installation and avoiding large grading operations (Daniels et al., 2024). Compacted soils limit infiltration and are the greatest control of stormwater runoff on solar sites (GPI, 2023). Soil compaction can be reduced by lowering tire pressure on construction equipment, designing the installation to minimize grading, trenching, and temporary access roads, and reducing heavy machinery traffic, especially on wet soils (NREL, 2024; Daniels et al., 2024). Low-impact racking options—including helical piles and I-beams, or more broadly "rammed posts" or "driven piles" (NREL, 2024)—also reduce the required land grading and land footprint as compared to concrete sleepers or ballasts. Intensive land grading is known to result in a strong degradation of soil quality, structure, and stability (Lambert et al., 2021). Topsoil retention practices during the construction phase can include ground covering such as applying weed-free erosion control mulches, mats, socks, or geotextile fabrics where existing vegetation cannot be maintained, placing windbreaks perpendicular to the prevailing wind direction, and installing protective berms, silt fences, and sandbags to prevent excessive stormwater runoff events (NREL, 2024; USDA NRCS, 2024a; Beyea et al., 2025).

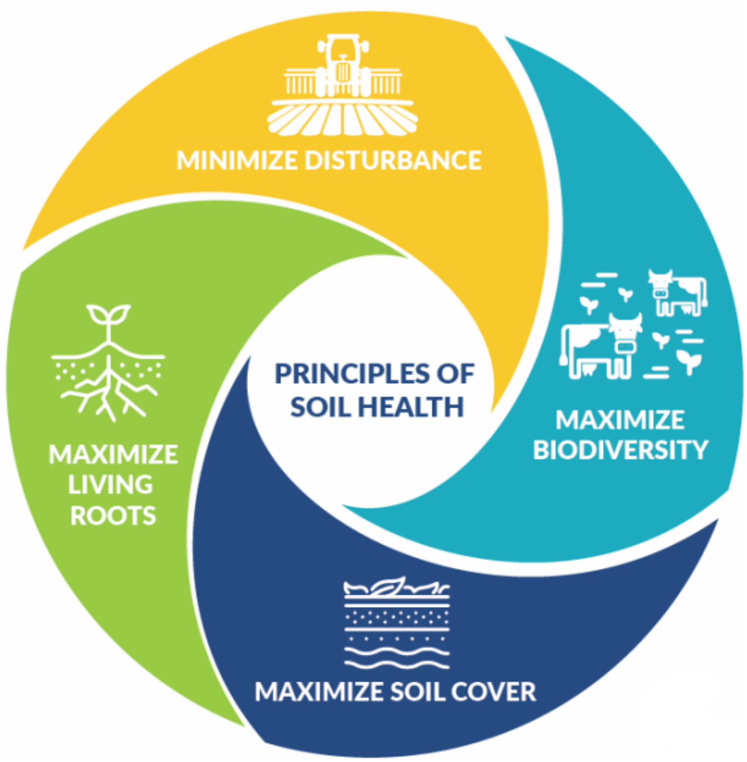

Figure 2. Agricultural soil health management principles, which provide a useful analog for topsoil and soil structure maintenance during low-impact solar installation and construction. Source: USDA NRCS, 2024c.

Effective hydrological management

Stormwater runoff quantity and quality are directly influenced by construction and installation landscape disturbance and the design of the stormwater management plan. Yavari et al. (2022) provide an informative review of existing solar and hydrology literature stormwater management guidance. Stormwater Pollution Prevention Plans (SWPPP) are typically required federally under the EPA National Pollution Discharge Elimination System (NPDES) during construction (EPA, 2015), with similar plans independently required by many U.S. states during operation (Yavari et al., 2022). Storm Water Prevention Permits (SWPP) are generally required when the natural runoff and erosion coefficients at a site will be changed (NREL, 2024). Changes in runoff and erosion coefficients as a result of solar array construction have been postulated and documented in several studies (e.g., Pisinaras et al., 2014; Barnard et al., 2017; Jahanfar et al., 2020; Walston et al., 2021). Despite this, most permitting practices do not include requirements for measuring compaction, soil depth (rooting depth), and specific ground cover and disconnection approaches (GPI, 2023).

Solar arrays change the hydrological budget in two primary ways that have to be considered when developing a stormwater management plan: 1) by altering the physical landscape during construction and due to disturbed and established ground cover and 2) by redistributing water and energy during operation (Figure 3; e.g., Jahanfar et al., 2020; Sturchio et al., 2024). Solar arrays with poorly managed stormwater can lead to greater hydrological connectivity and thus erosion, flooding, sedimentation in adjacent water bodies, and contamination of surface and groundwater (e.g., Baiamonte et al., 2023; GPI, 2023; Liu et al., 2023). Low-impact hydrological management thus requires a site-specific understanding of antecedent local hydrology, soil characteristics, and topography, how construction will alter those antecedent conditions, and how the water and energy redistribution will alter runoff-generating processes (Baiamonte et al., 2023; Liu et al., 2023; Yavari Bajehbaj et al., 2024). These aspects will be strongly influenced by the site location and should be characterized as part of the low-impact siting process.

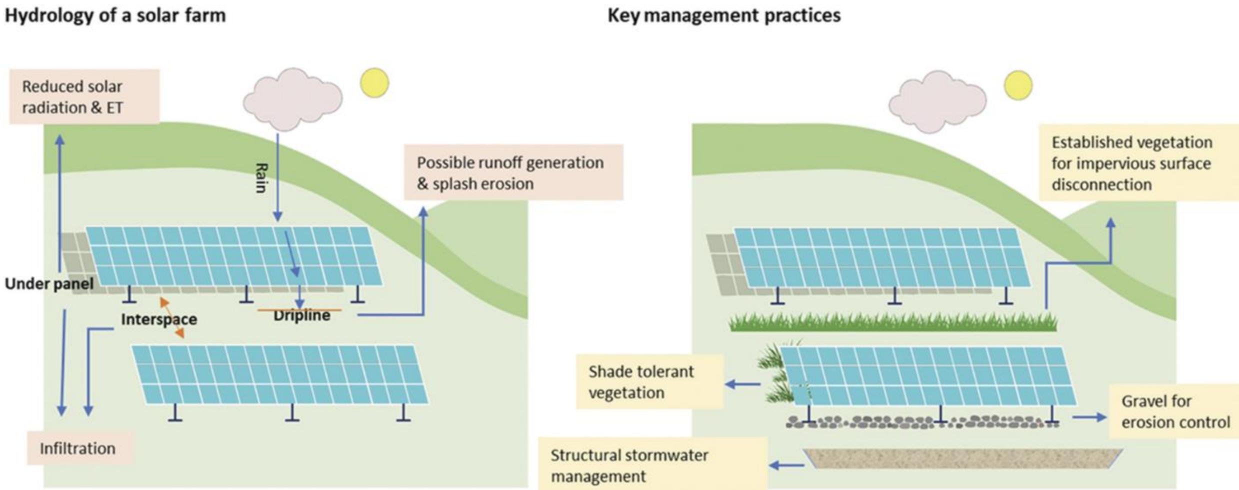

Figure 3. Hydrological processes (left) and associated best-management practices (right) for water management in solar array design. Source: Yavari et al. (2022).

GPI and partners have provided a robust best practices guidance document with their Photovoltaic Stormwater Management Research and Testing (PV-SMaRT) initiative (GPI, 2023). This guidance identifies four key elements (in order of importance) that affect stormwater quantity and quality at solar sites: 1) compaction/bulk density, 2) soil depth, 3) ground cover, and 4) disconnection, referring to the between-panel spacing that allows infiltration to occur. The first recommendation from this guidance report is that measurements of antecedent bulk density and infiltration capacities at the site are an important tool to better understand the original site conditions. This data can guide low-impact best practices (such as those discussed in preceding sections) to maintain existing flow and infiltration patterns, which can thus reduce the amount of new stormwater management necessary. Best practices most commonly used to reduce runoff would include retaining natural contours, topsoil, and soil structure (reduced grading and compaction) and either retaining existing vegetation or revegetating with appropriate ground cover as needed (GPI, 2023; Daniels et al., 2024). Vegetated inter-row spaces between panels and creation of down-gradient buffer strips also can reduce erosion and peak stormwater discharge (Cook and McCuen, 2013; GPI, 2023; Yavari Bajehbaj et al., 2024). Vegetation selection (plant height and rooting depth) and array design (panel height and spacing) should thus incorporate the needs of a given site, for example by prioritizing deep rooting diverse plant species to promote infiltration when runoff is a concern (Walston et al., 2021; GPI, 2023). Incorporating surface water flow direction into site design is critical, as erosion and stormwater runoff can be intensified when panel orientation is in the same direction as runoff flow direction (Edalat, 2017; Baiamonte et al., 2023) if no disconnection methods are incorporated (GPI, 2023). Designing and constructing retention basins can help mitigate large erosional events during and after site construction (NREL, 2024) but also can transform land and thus alter the way the natural ecosystem functions similar to other forms of disconnection (increasing panel-row spacing).

Several efforts aim to develop and maintain comprehensive tools to help solar developers and landowners design effective and informed stormwater management plans (e.g., GPI, 2023; Gullotta et al., 2023; Nair et al., 2023; McCall et al., 2023; Mulla et al., 2024; Galzki and Mulla, 2024). Similar to the agrivoltaic design tools, these efforts have largely not yet been tested at scale beyond individual case studies. Given that solar arrays are often installed in degraded landscapes (a low-impact siting best practice; Table 1), there is a potential to go beyond low-impact development and venture into regenerative solar development that enhances and restores landscape-scale ecosystem services. These include efforts such as rainwater collection (Şevik and Aktaş, 2022), ecovoltaic design (Knapp and Sturchio, 2024), irrigation water use offset (Biggs et al., 2022; Stid et al., 2025), and enhancing groundwater recharge to depleted aquifers–spearheaded by the Kansas Geological Survey, The University of Kansas, and Michigan State University (Nelson, 2024; Pierson, 2024; Siomades, 2024).

Key Knowledge Gaps in Low-Impact Solar Development

Solar energy deployment in the United States is projected to increase more than 10-fold relative to existing infrastructure to meet the net-zero energy needs of 2050. This will correspond to converting between 0.5 and 2% of the contiguous U.S. land area to solar energy installations over the next 25 years (Larson et al., 2021). Despite advancements in low-impact ground-mounted solar siting, construction, and hydrological management practices, several knowledge gaps that limit outcome validation and widespread adoption of existing methods remain. Most critically, the vast majority of the literature on low-impact solar development has focused on post-construction practices that can remediate undesirable impacts of solar farm installation, and relatively little work has investigated approaches to avoid disturbance at sites during the construction process. Lessons from agricultural soil health management, such as retaining soil cover, minimizing soil disturbance, maximizing living roots, and maximizing biodiversity, provide a valuable template for low-impact solar construction practices (Figure 2). In some cases, the translation of agricultural soil health practices to solar farms is straightforward; retaining living ground cover and minimizing operations that disturb soil structure, such as grading, will decrease the risk of soil erosion, runoff, and other related processes. However, some soil disturbance is inherent in the construction and racking process.

Despite the growing body of guidance on many of these practices, implementation remains mostly voluntary with few binding or incentivized requirements that promote adoption (e.g., for low-impact operational development; McCall et al., 2023). This limited uptake is likely due to both the lack of consensus on best practices and the lack of evidence helping to delineate how best practices compare across regions, soils, land uses, and other factors. There are, however, critical examples of trusted institutions coming together to provide guidance documents for local governments and zoning bodies (e.g., GPI, 2023; Beyea et al., 2025). Given appropriate evidence, a potential approach could involve a model similar to pollinator scorecards, where low-impact development is assessed and scored using standardized methods, thus permitting tax- or cost-offset incentives (EPRI, 2021). However, developing a standardized approach requires a robust evaluation of the diverse practices discussed here and the measured impact on the physical landscape—a comprehensive assessment that is currently lacking.

To our knowledge, no field trials quantifying the effects of these different low-impact construction practices have been published. However, field trials are essential to evaluate the effectiveness, costs, and benefits of potential approaches. Ideally, trials would be carried out via a replicated factorial design, allowing an assessment of the impacts of practices in isolation and combined, as soil health interventions often have compounding (rather than linearly additive) benefits in agricultural systems. Specific research needs include the following:

1. Investigation of field-scale siting impacts within agricultural and natural landscapes. A vast majority of solar energy arrays in the United States are installed on agricultural land (Kruitwagen et al., 2021; Stid et al., 2022) and although the scale of existing federal and NGO initiatives are semi-local to national, field-scale siting suggestions are largely absent from available siting resources.
2. Investigation of the long-term effects of low-impact construction approaches (e.g., mulches, mats, socks, fabrics, windbreaks, berms, silt fences, and sandbags) on topsoil preservation, soil structure and health, and water quantity and quality compared to conventional practices. Although practiced and recommended in various guidance reports, robust peer-reviewed sources to quantify and compare these approaches do not exist.
3. Investigation of the effect of low-impact ground cover management approaches (e.g., native vegetation, pollinator habitat) on long-term ecosystem services such as soil carbon storage, nutrient profile, textural profile, and deep percolation (recharge) potential. Although Choi et al. (2020) and Choi et al. (2023) (among others; e.g., Kanneberg et al., 2023) have begun to elucidate this gap and several others have begun developing design tools (e.g., Warmann et al., 2024; Jamil et al., 2024; Williams et al., 2025), a set of replicate-designed field trials is needed to better understand these effects.

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