Assessing Soil Properties Under Solar Microgrids in Coastal Grasslands

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Introduction

• Rises in global populations are driving increased demands for agricultural productivity and energy efficiency.

• Photovoltaic (PV) systems provide sustainable, cost-effective energy and are often deployed as solar microgrids in areas with complex terrain and fragmented power grids, such as Humboldt County.

• PV systems may displace prime agricultural lands, posing risks to local agricultural and economic productivity.

• Agrivoltaics help address this challenge by combining renewable energy production with implemented agricultural practices.

• Soil properties influence water availability, nutrient cycling, and plant composition, providing a baseline for agrivoltaics implementation.

• The impacts of solar microgrid infrastructure on soil properties in coastal grasslands remains largely unexplored, highlighting the need for research to assess specific impacts on soil properties to determine future multi-land use practices.

Figure 1. Solar microgrid array on coastal grassland located in Kneeland, California

Research Questions

• How do soil properties vary with position under a solar microgrid array?

• Do depth intervals (0–5 cm, 5–10 cm) influence soil properties under different positions within the panel array?

• How do microclimatic effects caused by shading under the panels impact soil organic matter and inorganic carbon levels?

• Are there interaction effects between position and depth on soil water content, organic carbon, and organic matter?

Results & Implications

For Airport Site General Soil Analysis:

• Bulk Density**: No significant differences** across microhabitats (p = 0.259) or depth intervals (p = 0.112) suggest that microgrid installation does not significantly contribute to soil compaction.

• Soil Moisture: **No significant differences** by microhabitat (p = 0.303) or depth (p = 0.926), indicating moisture distribution is uniform across the study area. However, late-season sampling may have influenced values.

• Root Biomass: A **near-significant effect** of depth interval (p = 0.053) suggests a possible trend of higher root biomass in the shallower depth (0–5 cm.

• Correlations & Trends: Weak correlations between variables (e.g., bulk density and soil moisture, R^2 = 0.191) indicate that root biomass may be influenced by other unmeasured factors. The p-value (p = 0.000749) suggests this relationship is statistically significant but not strongly predictive.

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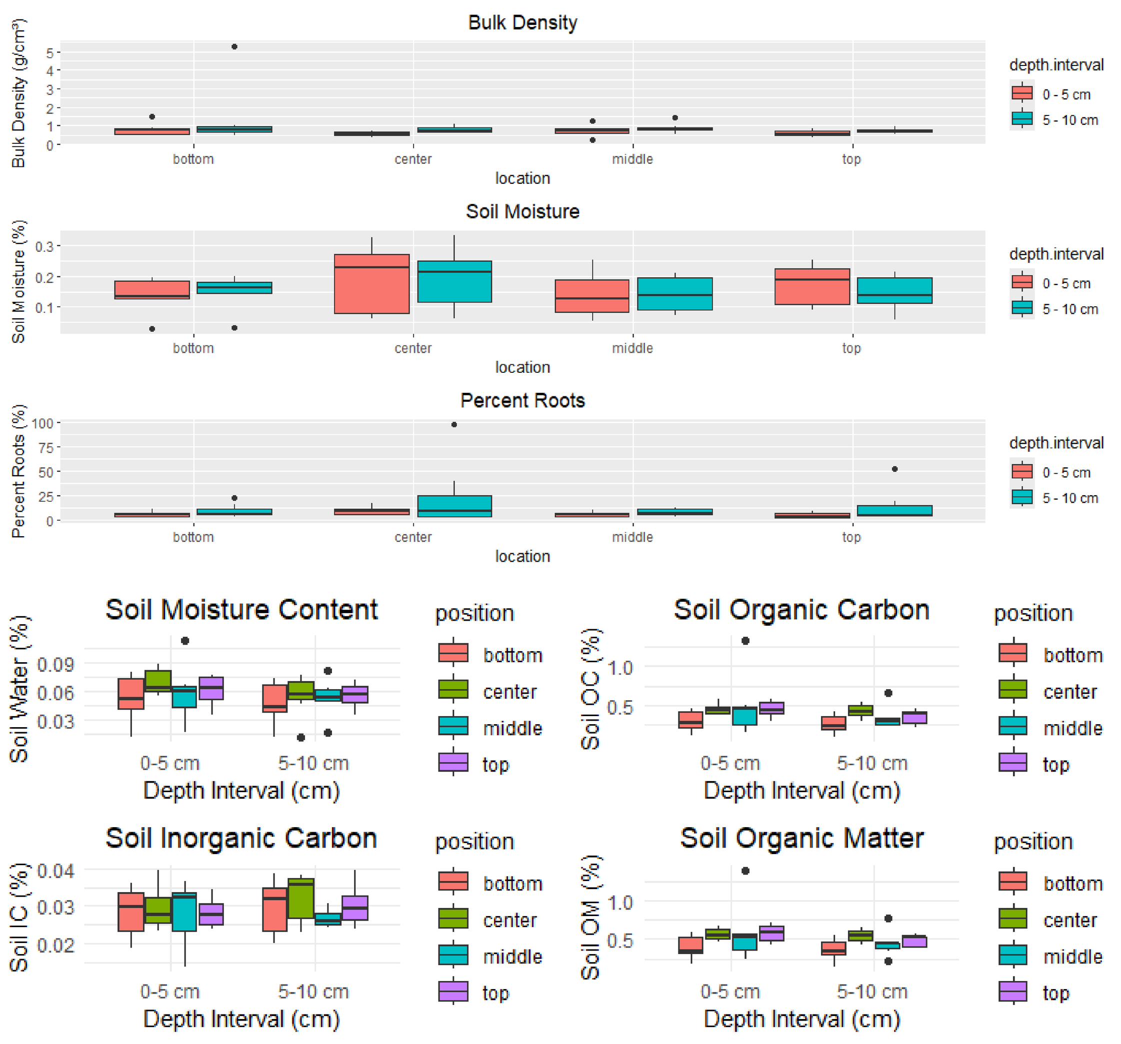
For Loss on Ignition (LOI) Analysis:

• Soil Water Content: **No significant differences** across positions or depths (p = 0.463), suggesting shading under panels does not affect soil moisture.

• Soil Organic Carbon (SOC): **Significant differences** by position (p = 0.010), with higher SOC in center positions, likely due to shading effects.

• Correlations: **Strong relationships** between SOC and soil water (rho = 0.86) and SOC and organic matter (r = 0.99) highlight correlations of soil moisture and carbon values.

• Depth Effects: **Higher** SOC and organic matter at 0–5 cm indicate surface layers respond more to shading and organic inputs.



Figures 2 & 3. Boxplots showing soil property correlations across all samples through environmental variables (above) and by microhabitats (below).

Methods

• Soil samples were obtained from three coastal grassland sites in Humboldt County along an elevation gradient.

• Samples were collected from microhabitats under solar microgrid arrays — bottom of panel (B), center of panel (C), top of panel (T), and in between panel arrays (M).

• At each panel microhabitat, soil samples were collected at 0–5 cm and 5–10 cm to analyze depth-related variation within soil characteristics.

• Each replicate included eight samples. Two study sites had four replicates per microhabitat (32 samples per site), while the largest site had seven replicates (56 samples).

• Field samples were analyzed for bulk density, root biomass, soil moisture, and carbon composition to evaluate soil structure, productivity, and water retention. Organic and inorganic carbon were measured using Loss on Ignition (LOI) to assess preliminary soil composition.

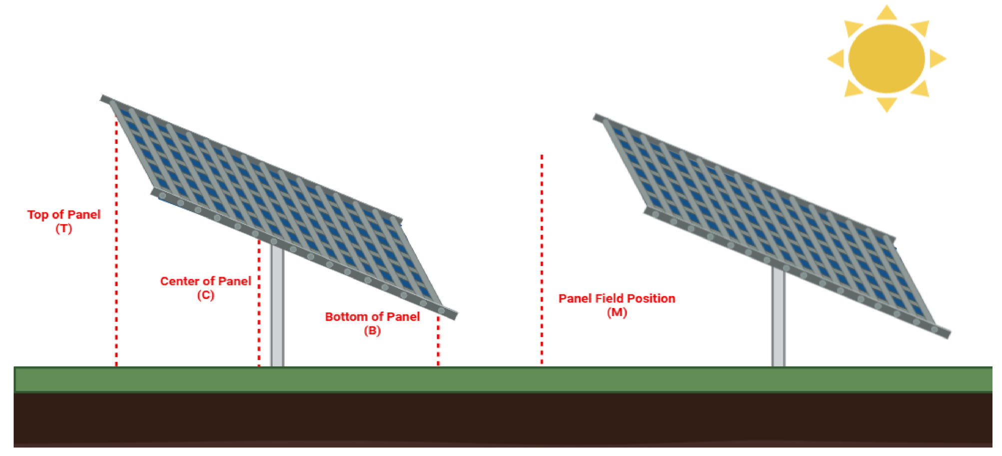


Figure 4. Example of soil sampling positions in retrospect to microgrid panel microhabitat.

General Conclusions

• Root Biomass Trends: A near-significant trend (p = 0.053) for higher root biomass in shallow depths (0–5 cm) highlights potential surface-layer influences, warranting further investigation.

• Soil Organic Carbon (SOC): Significant differences in SOC by position (p = 0.010) indicate shading effects under panels, with higher SOC and organic matter concentrations in surface layers (0–5 cm).

• Future Directions: Findings support agrivoltaics as a sustainable strategy towards multi-land use planning. Current results indicate that solar panels do not significantly alter or degrade existing soil properties. Larger sample sizes and continued monitoring could further validate these patterns

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