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Solar parks effect on soil properties: Initial results

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Abstract: Solar power generation in Greece has only been increasing since the 1980s to become the main source of renewable energy. Today, around 4.1 million m^2 of Greek land is covered by solar parks. This article starts with a literature review on how the photovoltaic panels impact their environment and on the different existing management solutions. The panels modify at some extent their environment, creating a new microclimate potentially favoring new species (Armstrong et al., 2016). To increase land use value, some solar parks are part of an agrivoltaic system, being grazed or associated with crops (Kumpanalaisatit et al., 2022). Others can be managed into a haven for pollinators (Blaydes et al., 2021). The second part of this article is about research led on three Greek solar sites from different areas, more or less recent, grazed or not. The research focuses on identifying the soil properties under and outside of the panels' zone. In some sites, differences in pH and humidity between these two parts of the park have been identified, soil being more humid and acidic under the panels.

Keywords: multiple land use, soil pH, organic matter, grazing

1. Introduction

In the aftermath of EU's decisions to invest in renewable energy, more and more PV parks are being built all over Europe (Lambert et al., 2022).

Several studies report the creation of a microclimate under a solar park, often dubbed 'cool island effect'. The panels' shadows reduce the PAR of the plants underneath, and affect soil and air temperatures, which are significantly cooler under solar panels in between panels or on a control parcel (Armstrong et al., 2016). It is worth notifying that the modification of air and soil temperature due to panels can either be an increase or a decrease, depending on the albedo difference between the PVs and the natural land surface. Evapotranspiration intensity and soil temperature tend to be positively correlated, meaning that a cooler area beneath the panels will reduce the need for plants to evapotranspirate. Furthermore, less wind was recorded under and between the solar panels, leading to air temperatures varying less during the day. The cooler temperatures lead to significantly reduced annual GDDs under the panels (Armstrong et al., 2016), which will impact the plant's growth. These conditions are suited for shade plants.

Studies also report a difference in pH under and outside the panels (Noor and Reeza, 2022), in most cases pH being higher under the panels (Moscatelli et al., 2022).

Panels also affect soil moisture. According to a 2022 modelisation, the back of the panels would be dryer than control, and the front wetter.

In an arid environment, PVs' roof effect increases water availability (Hernandez et al., 2020), which is a restrictive environmental factor for the survival of vegetation, insects, and small animals. These panels-induced properties would reportedly stabilize in time, and the microclimate under panels in a hundred years should be roughly the same as today (Wu et al., 2022).

Solutions of biodiversity management are being sought. Agrivoltaics for one is using the same area of land for both solar photovoltaic power and agriculture, providing a solution to the use of arable land competition between agricultural and electric production. They can either be systems designed for agrivoltaics, or farming set on a preexisting solar park. In the latter case, the crops would be in the direct shade of the panels in the consequent microclimate. Several crops, such as lettuce or sweet potatoes are said to be 'shade plants' and thrive in low-light environments. Another approach of agrivoltaics is letting animals graze under and between the panels. The animals enjoy the shade. Not every animal is fit to graze in a solar park, bigger ones like cattle being liable to severely damage the panels. Smaller animals like poultry or sheep are more suited.

The shade provided by the panels reduces the evapotranspiration of plants, especially in arid or Mediterranean climates like Greece. Several crops or fruit production, as well as some livestock or beekeeping, can benefit from this process, which means there is a greater overall production on the parcel than if the solar park and the farming were separated.

A solar park can also become a biodiversity haven, notably for pollinators, if managed in a good way. A broad range of management practices can be undertaken, including grazing, as livestock selectively consume vegetation, enrich the soil through faeces and compact the soil by trampling, consequently affecting the plant community and pollinator resources (Blaydes et al., 2021).

Greece has a Mediterranean climate with hot summers, making it appropriate for solar energy, which is the number one renewable energy source in Greece, making up to 4.1 million m2 of land use -the second largest total capacity in Europe (energypedia). The general purpose of this work was to investigate the effect of solar panels on certain soil parameters, more specifically on i. soil organic matter content, ii. pH, and iii. soil moisture.

2. Material and Methods

2.1. Study sites

This study is based on 3 different Greek solar parks all in Central Greece, in characteristic areas of a Mediterranean climate, with hot summers and mild winters. Greece is considered as a biodiversity hotspot, with large areas classified Natura 2000. It hosts diverse vegetation patterns of perennial herbs and bushes. However, slopes and moderate vegetation coverage make the soils very sensitive to erosion.

Table 1. Solar panel information

	Connection date	**Structure height m**	**Distance between corridors m**
SP1	2021	2,559 (0,6-4,525)	10,976
SP2	2021	2,511 (0,6-4,361)	5,476
SP3	2013	2,443 - 0,705	2,769

None of the parks are in a protected zone and all parks are mowed 3 times a year, without any use of herbicide.

Table 2. Land description

SP	**Previous land use**	**Altitude m**	**Grazing**	**Field observations**
SP 1	Agricultural land	~130	No	Dark soil, very rocky
SP 2	Agricultural land	~130	No	Dark soil, rocky
SP 3	Broad-leaved evergreen, limited & not systematic agriculture	~230	Sheep	Red soil, coming in heaps, very shallow

2.2 Methodology

On December 1st, 2022 soil samples were collected from these 3 parks. In each park 10 samples were collected, 5 under the solar panels and 5 outside, in between the rows of panels. The samples were put in closed aluminum bags to prevent soil moisture loss.

Once in the lab, the samples were weighed first in their aluminum bags, then again in a paper bag of known weight. The samples were then placed in an oven, set at 1050C to reach constant weight.

After 17 hours, the samples were taken out of the oven and weighted to evaluate soil moisture. Additionally, a soil sample of 50 grams was used to evaluate soil structure by the Bouyoucos method to collect information about the soil structure. Soil pH was measured at dissolution 1/2.5. Soil organic matter was evaluated by the Loss On Ignition (LOI) method.

3. Results & Discussion

Found properties of the soils, mean of the results of the 10 samples for each site:

Table 3. Results from the soil analyses

	pH		**Soil moisture (%)**		**OM (%)**		**Soil structure**
	O[1]	**U**[2]	**O**	**U**	**O**	**U**	
SP 1	8.44	8.32	28.0	25.7	6.46	7.50	sandy clay loam
SP 2	8.44 *	8.32 *	18.2	16.0	6.24	7.51	sandy loam
SP 3	7.83	7.95	16.0 *	28.8 *	6.96	6.99	loam

*indicates a statistical difference at 0.05 between the samples under the panels and the ones outside. The statistical analysis has been made with a Fisher test on R.

1: O indicates outside the solar panel

2: U indicates under the solar panel

The difference of soil pH under and outside the panels in SP2 is slight but statistically different. We can infer that difference in temperature and enlightenment caused by panels has favored a new biomass, which would have acidified the soil under the panels. The humidity difference on the most ancient site (9 years) seems to indicate an ability of the panels to keep the soil underneath them well moisturized even in hot and dry areas.

4. Opportunities - Recommendations

Two of the sites are very recent, therefore their ecosystems are bound to continue evolving in the years to come before they reach a point where the impact of the panels can be clearly established. The sample size of this study was rather small (5 samples per category of soil), and the samples were shallow (20 first cm of the soil). Reconducting such a study with a broader range of samples would at least solidify the statistic test and could be decisive in drawing more precise conclusions.

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