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DOES SOIL MATTER? HELPING BIODIVERSITY MANAGEMENT IN A SOLAR PARK

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Abstract: There has been a serious increase in solar energy installations in Hungary recently. The majority (98.6%) of the installations were done as greenfield investments. Due to the nature of technological intervention in the agricultural landscapes, some of the results of these investments were the disturbance of the environment (soil and water), change of landscape (and its values), and reduction in the biodiversity of these areas. Due to the increase of land use and land cover change, especially towards soil sealing or reduced availability, it should be important to maintain or improve the role of such places as habitats, besides producing the equally important renewable energy forms. Solar parks on former greenfield areas cover a significant amount of soil surface, and there are tremendous works related to soil resources, their soils are changed during the investment and thus soil properties influence their biodiversity management plan. An important step in habitat development is revegetation. While planting valuable plants for improvement of the biodiversity, it is also important to adapt the plans to the environment of the solar parks, and also, to its technical parameters. In the recent study, soil samplings were done close to the disturbed area and in a nearby natural area. Soil properties were measured by a Near Infrared device. Soil organic matter and N-content resulted in differences between the examined sites. The deviation of soil properties proved the importance of soil investigation in this case as revegetation requires knowledge on soil to find the proper plant species for the soils on-site.

Keywords: solar energy, biodiversity management plan, pedology, soil properties, comparative analyses

1. Introduction

The effects of the global energy and climate crisis have shown that the increasing energy demand of mankind can only be realized in a stable, environmentally friendly and accessible way through the increasing use renewable energy sources. Among the renewables, solar energy utilization (PV) will be the determining factor and its cumulative capacity will almost triple. The REPowerEU plan presented by the European Commission in May 2022 recommends that the EU increase the EU target for the share of renewable energy sources from 40% to 45% by 2030. The plan would increase the total renewable energy generation capacity to 1,236 GW by 2030, compared to the "Towards 55%!" with 1,067 GW planned for 2030 as part of a package of measures (European Union, 2022). The goal of the solar energy strategy created as part of the REPowerEU plan is to provide more than 320 GW of newly installed photovoltaic solar energy in the grid by 2025, and nearly 600 GW by 2030. In recent years, the domestic photovoltaic installed capacity has turned into exponential growth after a long period of stagnation. According to Hungary's Recovery and Adaptation Plan (2022), the goal set in the National Energy and

Climate Plan (2020) will be met in 2026, installed capacity of 9,000 MW can realistically be achieved by 2030. Despite the increasing importance and extent of solar parks, the environmental effects of their construction and operation have not yet been properly investigated (Zhang H. et al. 2023, Lambert 2021, Turney & Fthenakisz 2021). Research draws attention to the negative changes in soils (Choi et. al., 2020, Armstrong et. al., 2016). The preservation of soils is crucial for food production, in climate regulation and for the livelihood of the rural population and the maintenance of biodiversity (EASAC, 2018).

Hungary's most significant national asset is the conditionally renewable soil (Orosz 2018), and its protection is of increased importance (Kalocsai et al. 2022). One of the main goals of land protection, which provides quantitative protection of agricultural land, is to permanently remove as little agricultural land as possible from cultivation (Csirszki & Hornyák 2022). 2,000 hectares of agricultural land are permanently withdrawn from agricultural cultivation in Hungary every year, mainly as greenfield investments (Garaguly 2016). Following the global trend, solar parks have also appeared among greenfield investments in Hungary, increasing the pace of the final withdrawal of agricultural land. Based on research by Munkácsy (2021), large-scale solar farms in Hungary are almost exclusively installed in open fields, areas withdrawn from agricultural production. This process was also not significantly influenced by the additional scoring of the so-called Metár system for "brownfield" investments, which was developed to support solar power plants in Hungary. Based on some expert estimates (Bartek-Lesi et. al. 2019), the average land requirement for the specific capacity of domestic solar power plants is 2.4 hectares/MW, which takes into account the placement of modules without shading, the land requirement of service roads and other devices. Taking into account the ratio (2/3 to 1/3) of industrial-commercial power plants realized in the framework of the current, typically greenfield investment, and household-sized power plants typically installed on roofs (2/3 to 1/3) and the area requirement of the additional 5,000 MW installed capacity planned until 2030, we should expect an additional 8,000 ha of agricultural land to be built in the coming in 15 years.

Hungary's Recovery and Adaptation Plan (2022) also states, although only concerning residential solar investments, that they cannot reduce the biologically active surface and cannot be installed in areas under nature conservation.

During the installation of solar parks, depending on the technology used, less than 5% of the area is physically built (Takács 2022), but the installation of landscaping, cable laying, fencing, service roads and equipment may adversely affect additional surfaces. After installation, the parts of the area shaded by the panels can affect up to 25–47% of the total area of the solar park (Ong 2013). Here, the microclimatic conditions change, which affects soil moisture, surface temperature, the carbon cycle and the physical, chemical and microbiological properties of soil (Barron-Gafford et al. 2016, Lambert 2021). However, after proper planning and implementation, solar parks can offer unique opportunities for the benefit of the local environment and biological diversity (Fthenakis 2011, Hernandez et al. 2019, Blaydes et al. 2021).

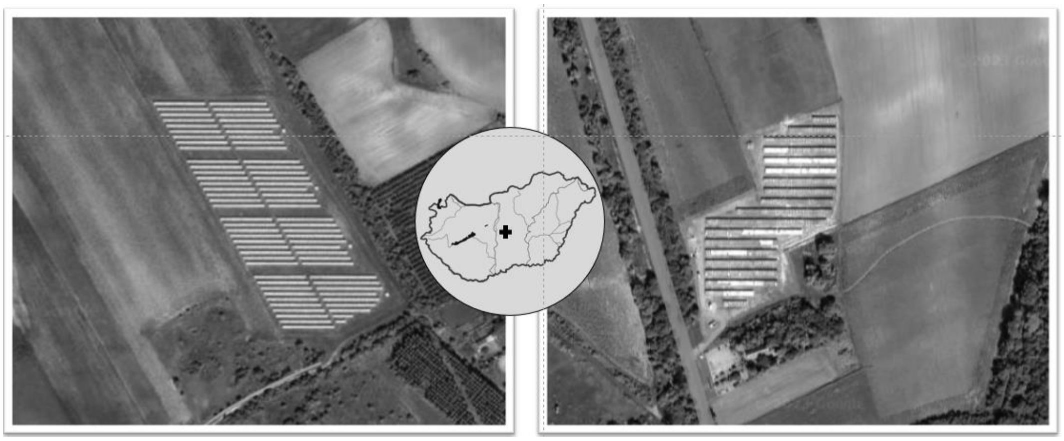
For evaluating the effect of technical installations on soil properties, such as PV, it is relatively easy the compare the soils on the construction sites with nearby agricultural or semi/natural areas (Masoudi et al. 2021). Such comparisons of agricultural land uses were done for some soil properties and various purposes, such as evaluating ecosystem services (Nel et al. 2022).

The purpose of this research was to compare the areas affected by the solar park construction with the nearby, non-affected areas. The purpose of the comparison is to provide data on the suitability of the affected soils for planting native plants, possibly those that are available in the nearby grasslands or forests.

2. Materials and methods

Sample areas have been designated for the development of a methodology aimed at improving the biodiversity of solar parks. When choosing the sample area, the investments needed to be located in a green investment garden, in the outskirts, in an agricultural environment and near valuable natural areas. Based on these, two investments (one 4.4 ha and one 1.2 ha in size) are selected, which are located 1.5 km apart in the Great Hungarian Plain (*Figure 1*).

Figure 1: Situation of the sampling sites (No. 1. on the left and No. 2. on the right) the land use of their surroundings, Szabadszállás, Hungary



(Source: Google Earth, 2022, the center of Site No. 1. is: 46°53'12.13"N, 19°12'32.41"E, the center of Site No. 2. is: 46°53'52.74"N, 19°13'7.92"E)

After the designation, habitat mapping and use analysis will be carried out in the 1 km radius surrounding the investment, taking into account international and domestic recommendations (BRE 2014, Bennun et. al 2021, Takács 2022) and field visits are done to examine the soil conditions of the study area.

Soil samples were taken from the depth of 0–10, 10–20, 20–40, 40–60 cm. Grassland species are growing in the upper 20 cm, furthermore, this layer is also important for bushes. The 20–40 cm layer is required to be analysed for bushes, while 0–40 cm is also important for tree species. The 40–60 cm layer is analysed for tree species.

We used Near-infrared spectrometry (Wavelength Range: 1300–2600 nm MEMS (micro-electromechanical systems) technology) to measure soil properties with an agro-care scanner device. Near-infrared spectroscopy is a robust method that requires little soil preparation (e.g. removing roots and stones) (Sharififar et al. 2019). In this study, an agro scanner was used to estimate soil parameters including Soil Organic Matter (SOM) (%) and organic carbon (OC) (g/kg), total N (g/kg), total P (g/kg), potentially mineralizable nitrogen (PMN), cation exchange capacity (CEC), exchangeable K (mmol/kg), clay content (%), pH (KCl).

The Shapiro-Wilk test was used to check normality. Non-normal distribution data was then analysed with Kruskal-Wallis test to prove differences and Dunn's test to show where the differences are. Normal distribution data were analysed with one-way ANOVA. Data with different variances were analysed with the Welch test.

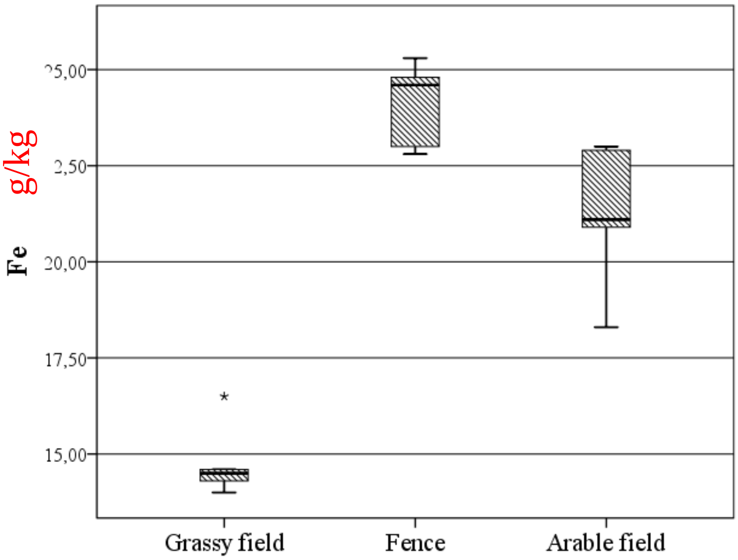
The purpose of the investigation is to provide information for planning a natural structure of the area that takes into account the ecological and technical background of the area equally.

3. Results

3.1. Results of soil sample analyses of Site No. 1.

In the 0–10 cm layer, the grassland has the lowest Fe-, Al- and clay content and the highest SOM, OC, potentially mineralizable nitrogen content. The PO_3 content is significantly lower ($p=0.003$) along the fence than on the arable field. There is significant difference in the Fe content, it is the lowest in the grassland, highest along the fence and the arable field is in between (*Figure 2*).

Figure 2: Significant difference of the Fe content of the 0–10 cm layer in Site No. 1., Szabadszállás, Hungary



In the 10–20 cm layer, the grassland has lowest Al-content than the soil along the fence. Also, the grassland has the lowest Fe content versus the arable field and the fence. No other differences were found.

In the 20–40 cm layer, SOM content is higher on the arable field than at the fence, OC content is lower along the fence than on the arable field and PMN is lower along the fence than on the arable field. The PO_3 content is lower along the fence than on the arable field (the grassland is in between).

In the 20–40 cm layer, the K-content is lower on the grassland than on the arable land. The Ca content is lower along the fence than on the arable land. The Mg content is lower on the grassland than on the arable land. OC content is lower on the grassland than along the fence. CEC and Al content are the best in the arable field.

All significance is at the level of $p<0.05$.

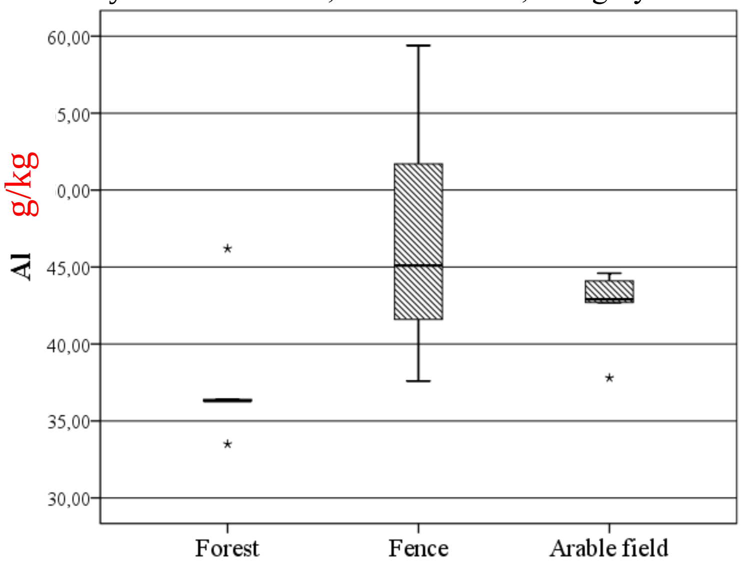
3.2. Results of soil sample analyses of Site No. 2.

In the 0–10 cm layer, the pH of the forested spot is significantly higher, while PO_3- and Al-content is lower. All other parameters do not differ.

In the 10–20 cm layer, there are no differences.

In the 20–40 cm layer, the total Al content of the soil under the forest is lower, the difference is significant (*Figure 3*). The CEC, Ca and Fe contents are lowest under the forest. The other parameters do not differ.

Figure 3: Significant difference of the total Al (g/kg) content of the 20–40 cm layer in Site No. 2., Szabadszállás, Hungary



In the 40–60 cm layer the lowest total N-, PMN-, Al-content and CEC is under the forest. The other parameters do not differ.

All significance is at the level of $p<0.05$.

4. Discussion

Malihe et al. (2021) found a connection between CEC, clay content and OC-content, and pH and clay content. In our comparative analyses these relations were not always proven, e.g. on site No1. the clay content was the lowest under grassland but grasslands had the highest SOM, OC and PMN. Nel et al. (2022) found that soil organic carbon stock was the lowest under grasslands which is against our findings. Furthermore, the OC, SOM, CEC and clay relations were different between the sites, so a direct connection between these parameters could not be found. Hudec et al. (2015) also found more (total) N in meadows compared to forest.

Abbasi et al. (2007) found that organic C content was the highest in forests, followed by grasslands and the lowest was in arable soils that is against our findings, grasslands had the highest amount of SOM and OC. Abbasi et al. (2007) also found that CEC is decreasing with depth which is again against our findings, the CEC does decrease below the upper 0–10 cm but then it increases again, sometimes in the 20–40 cm layer, sometimes in the 40–60 cm layer. These differences can be induced by the shallow soil thickness, the parent rock was sometimes close to the surface so the 40–60 cm layer was already in the parent material that was rich in minerals, thus CEC was increased again.

It is interesting that in the 10–20 cm layer, the soil characters were quite similar, more than that, on Site No. 2. there were no differences. It is of high importance because the soils along the fence were disturbed, and still, they are similar to the nearby natural areas. And, even, if they were not disturbed, the result of having such a high similarity is an extreme phenomenon. The same similarities were found in the soils of a forest and a nearby arable field (after 190 years of cultivation), the only differences found were in C/N ratio and soil organic C concentration (Zajícová & Chuman 2019).

In any case, the results show that the measurement of soil parameters provided crucial information for planning revegetation of the area of the solar park, e.g. pH is higher in the forest, so it may not be the best solution to find plants from the forest for revegetation.

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References

Abbasi M., Zafar M., Khan S.R. (2007): Influence of different land-cover types on the changes of selected soil properties in the mountain region of Rawalakot Azad Jammu and Kashmir. Nutr Cycl Agroecosyst., 78: 97-110. DOI: https://doi.org/10.1007/s10705-006-9077-z

Armstrong A., J Ostle N., Whitaker J. (2016): Solar park microclimate and vegetation management effects on grassland carbon cycling. Environmental Research Letters, 11: 7, Published 13 July 2016 • © 2016 IOP Publishing Ltd

Barron-Gafford G.A., Pavao-Zuckerman M.A., Minor R.L., Sutter L.F., Barnett-Moreno I., Blackett D.T., Thompson M., Dimond, K., Gerlak K.A., Nabhan G., Macknick J.E. (2019): Agrivoltaics provide mutual benefits across the food–energy–water nexus in drylands. Nature Sustainability, 2: 848-855. DOI: https://doi.org/10.1038/s41893-019-0364-5

Bartek-Lesi M., Dézsi B., Diallo A., Kácsor E., Kerekes L., Kotek P., Mezősi A., Mészégetőné Keszthelyi A., Rácz V., Selei A., Szajkó G., Szabó L., Vékony A. (2019): A hazai nagykereskedelmi villamosenergia-piac modellezése és ellátásbiztonsági elemzése 2030-ig különböző erőművi forgatókönyvek mellett. A tanulmány az Innovációs és Technológia Minisztérium megbízásából készült Regionális Energigazdasági Kutatóközpont, Budapest, 2019 /In Hungarian/

Bennun L., van Bochove J., Ng C., Fletcher C., Wilson D., Phair N., Carbone G. (2021): Mitigating biodiversity impacts associated with solar and wind energy development. Guidelines for project developers. Gland, Switzerland: IUCN and Cambridge, UK: The Biodiversity Consultancy.

Blaydes H., Potts S.G., Whyatt J.D., Armstrong A. (2021): Opportunities to enhance pollinator biodiversity in solar parks. Renewable and Sustainable Energy Reviews. 145, 11065 DOI: https://doi.org/10.1016/j.rser.2021.111065

BRE (2014). Biodiversity Guidance for Solar Developments. National Solar Centre, Eds. G E Parker and L Greene

Choi C.S., Cagle A.E., Macknick J., Bloom D.E., Caplan J.S., Ravi S. (2020): Effects of Revegetation on Soil Physical and Chemical Properties in Solar Photovoltaic Infrastructure. Front. Environ. Sci., 8:140. DOI: https://doi.org/10.3389/fenvs.2020.00140

Csirszki M., Hornyák, D (2022): A föld- és talajvédelem jogi rendszere. In: Raisz Anikó (ed.) (2022). Környezetjog – Különös rész. Miskolci Egyetemi Kiadó, Miskolc, 25–38 /In Hungarian/

European Academies' Science Advisory Council (EASAC) (2018): Opportunities for soil sustainability in Europe. EASAC policy report, September 2018, ISBN: 978-3-8047-3898-0

European Union (2022): REPowerEU Actions. Luxembourg: Publications Office of the European Union, 2022, ISBN 978-92-76-52654-4

Fthenakis V., Turney D. (2011): Environmental impacts from the installation and operation of large-scale solar power plants. Renewable and Sustainable Energy Reviews, 15: 3261-3270. DOI: https://doi.org/10.1016/j.rser.2011.04.023

Garaguly I. (2016): Az alapvető jogok biztosának és a jövő nemzedékek érdekeinek védelmét ellátó helyettesének közös jelentése az AJB-698/2016. számú ügyben.

Hernandez R.R., Armstrong A., Burney J., Ryan G., Moore-O'Leary K., Diédhiou I., Grodsky S.M., Saul-Gershenz L., Davis R., Macknick J., Mulvaney D., Heath G.A., Easter S.B., Hoffacker M. K., Allen M.F., Kammen D.M. (2019): Techno–ecological synergies of solar energy for global sustainability. Nature Sustainability, 2: 560-568. DOI: http://dx.doi.org/10.1038/s41893-019-0309-z

Hudec M., Tulis F., Feszterová M., Hreško J. (2015): Comparison of the andosols properties of forest and meadow ecosystems on the neovolcanic rocks of the Central Slovakia. Folia Oecologica, 42: 89-102.

Kalocsai R., Szalka É., Svétlíková A., Kukurová K., Szakál T., Giczi Zs., Vona V. (2022): The principles of sustainable agricultural cultivation and the supply of nutrients to our cultivated plants. Acta Agronomica Óváriensis, 63: 51-65.

Lambert Q., Bischoff A., Cluchier A., Cueff S., Gros R. (2021): Effects of solar parks on soil quality, CO_2 effluxes and vegetation under Mediterranean climate. Authorea, June 06, 2021. DOI: https://doi.org/10.22541/au.162300877.73953918/v1

Magyarország Helyreállítási és Alkalmazkodási Terve (2022): Magyarország Kormánya

Masoudi M., Vona V., Vona M. (2021): Assessment of the relationship between soil properties in an old tree line and its relation to tree density and tree trunk circumference. Tájökológiai Lapok/Journal of Landscape Ecology, 19(2): 81-89. DOI: https://doi.org/10.56617/tl.3431

Munkácsy B. (ed.) (2021): Csak nappal! Csak nappal? Avagy a napelemes áramtermelés jövője Magyarországon a területhasználat nézőpontjából. Energiaklub Szakpolitikai Intézet és Módszertani Központ. /In Hungarian/

Nel L., Boeni A.F., Prohászka V.J., Szilágyi A., Tormáné Kovács E., Pásztor L., Centeri Cs. (2021): InVEST Soil Carbon Stock Modelling of Agricultural Landscapes as an Ecosystem Service Indicator. Sustainability 14: 16. Paper: 9808 DOI: https://doi.org/10.3390/su14169808

Nemzeti Energia- és Klímaterv (2020): Innovációs és Technológiai Minisztérium, 2020

Ong S., Campbell C., Denholm P., Margolis R., Heath G. (2013): Land-Use Requirements for Solar Power Plants in the United States. National Renewable Energy Laboratory, Technical Report NREL/TP-6A20-56290 June 2013

Orosz F. (2018): A termőföld mint nemzeti kincs alkotmányos védelme hazai és nemzetközi vonatkozásban. Publicationes Universitatis Miskolcinensis Sectio Juridica et Politica, Tomus XXXVI/1, pp. 178–191.

Sharififar A., Singh K., Jones E., Ginting F.I., Minasny B. (2019): Evaluating a low-cost portable NIR spectrometer for the prediction of soil organic and total carbon using different calibration models. Soil Use and Management, 35 (4): 607-616. DOI: http://doi.org/10.1111/sum.12537

Takács Á. (ed.) (2022): Szakmai Iránytű az újgenerációs napelemparkok fejlesztéséhez. SolServices Kft., Budapest 2022. /In Hungarian/

Turney D., Fthenakis V. (2021): Environmental impacts from the installation and operation of large-scale solar power plants. Renewable and Sustainable Energy Reviews. 15(6): 3261-3270. DOI: https://doi.org/dx.doi.org/10.1016/j.rser.2011.04.023

Zajícová K., Chuman T. (2019): Effect of land use on soil chemical properties after 190 years of forest to agricultural land conversion. Soil & Water Res., 14: 121-131. DOI: https://doi.org/10.59258/hk.13175

Zhang H., Yu Z., Zhu C., Yang R. Yan B., Jiang G. (2023): Green or not? Environmental challenges from photovoltaic technology. Environmental Pollution, 320, 1 March 2023, 121066 DOI: https://doi.org/10.1016/j.envpol.2023.121066