Project brief

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Solar power from agricultural areas: Efficient use of land with low land use conflicts

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- **Due to their low land use, ground-mounted photovoltaic systems currently pose little competition to agricultural land use.**
- **The high competitiveness of ground-mounted photovoltaic systems can lead to potential land use conflicts.**
- **Agri-Photovoltaics (Agri-PV) offers a solution with space-saving dual benefits, but is associated with very high costs.**

Background and Objectives

With the Federal Climate Protection Act, Germany has committed itself to net greenhouse gas neutrality by 2045. To achieve this goal, the transport and heating sectors are to be electrified and electricity generation decarbonized. The Renewable Energy Sources Act sets out expansion paths for the various renewable energies. For example, photovoltaic (PV) capacity is to be increased from 88 gigawatt peak (GWp) in 2024 to 400 GWp in 2040. Since the expansion of ground-mounted PV systems mainly takes place on agricultural land, conflicts of use with agricultural production may arise (Fig. 1). To reduce these conflicts, Agri-PV is being discussed as a possible solution.

Figure 1: Separation of ground-mounted photovoltaic systems and agricultural use (© ValentinValkov - stock.adobe.comAdobeStock_ 115120296).

Against this backdrop, we addressed the following questions in the project:

(1) How does the land use efficiency of ground-mounted PV systems compare to other renewable energies on agricultural land?
(2) What conflicts of use arise in agricultural land use?
(3) To what extent and at what cost can land use competition be reduced with the help of agri-PV concepts?

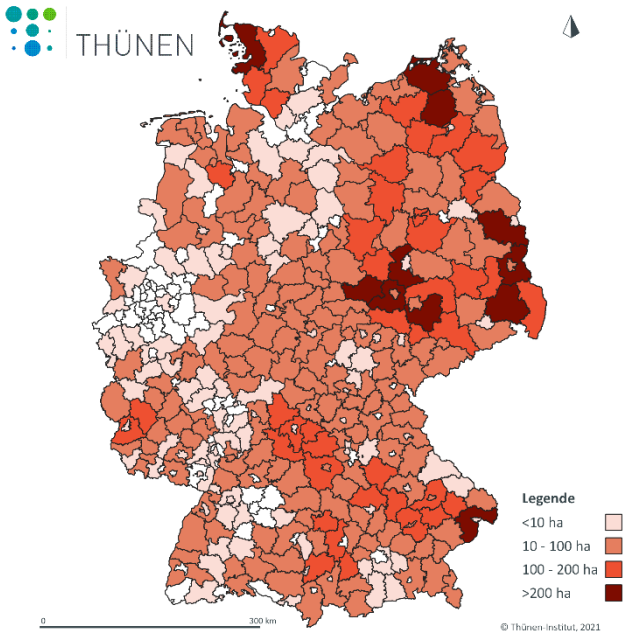

Figure 2: Distribution of land use by ground-mounted PV systems. As of 2020. (Source: from Böhm et al. 2022b).

Methods

In order to examine the current competition for land use with agricultural cultivation, we analyzed the land use of ground-mounted PV systems. The current regional distribution depends on the framework conditions and the economic efficiency of ground-mounted PV systems in the past. In order to be able to estimate future developments, we have therefore reviewed and analyzed the legal framework conditions and the factors influencing the economic efficiency of ground-mounted PV systems. The following methods were used:

a) GIS analyses to evaluate the status quo
b) Literature analyses and life cycle assessments to determine land use efficiency

c) Investment calculations for typical systems and data collection through expert surveys to calculate costs.

Results

With regard to land use to date, it can be seen that in 2018 a total of 25,500 hectares were used for ground-mounted PV systems, 52 percent of which was arable land and 15 percent grassland. This corresponds to 0.1 percent of the area used for agriculture and suggests that there have been very few conflicts with agricultural production in Germany to date. However, as the systems are distributed very heterogeneously (Fig. 2), regional conflicts cannot be ruled out.
The economic efficiency of ground-mounted PV systems is strongly influenced by the size of the system and the distance to the grid feed-in point. Under the given conditions, ground-mounted PV systems are only profitable if they are larger than approximately five hectares. Larger systems can exceed the agricultural willingness to pay for the land by more than tenfold.

Figure 3: Potential mileage with one hectare of agricultural land (Source: https://www.thuenen.de/de/newsroom/mediathek/faktencheck/energie-vom-acker-lohnt-sich-das).

In addition, we were able to show that land use efficiency in terms of land energy yields in the electricity, heat, and transportation sectors is significantly higher for ground-mounted PV systems than for biogenic renewable energies, which are already cultivated on more than ten percent of agricultural land in Germany (Fig. 3). Thus, a change in land use could increase land use efficiency. The life cycle assessment (LCA) of PV and biogas shows that ground-mounted PV systems achieve higher greenhouse gas avoidance performance and have a lower environmental impact than electricity generation in biogas plants using silage maize.

In Agri-PV concepts with dual use of land, the agricultural area can largely continue to be used (Fig. 4). However, analysis of different Agri-PV concepts shows that these advantages come at a higher cost. The higher electricity production costs result in costs for maintaining one hectare of agricultural land ranging from €8,500 to over €70,000 per hectare per year. This exceeds the agricultural added value many times over. At the same time, agricultural use has little impact on the economic viability of the overall concept.

Figure 4: Agri-PV system with tracking modules (© Thomas Rebitzer).

Conclusion

Based on the results of the project, it can be assumed that there will only be minimal competition for land use between ground-mounted PV systems and agricultural production throughout Germany. The increased use of PV instead of bioenergy can increase land use efficiency. Due to the high costs of Agri-PV concepts, broad-based subsidies should be critically examined. Future work should examine whether other concepts involving dual land use (peatland PV, biodiversity PV) can be implemented at lower costs and how the synergy effects for agricultural use can be increased.

Further Information

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https://www.thuenen.de/de/fachinstitute/betriebswirtschaft/projekte/pv-freiflaechenanlagen-in-der-landwirtschaft

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Publications

Jonas Böhm (2025)). Dissertation: Photovoltaik auf landwirtschaftlichen Flächen: Nutzungskonkurrenz, Flächennutzungseffizienz und Rentabilität verschiedener Konzepte.

Böhm et al. (2024). Life cycle assessment of electricity from wind, photovoltaic and biogas from maize in combination with area-specific energy yields – a case study for Germany. Environ. Res. Commun., 6 (10).

Jonas Böhm (2023). Vergleich der Flächenenergieerträge verschiedener erneuerbarer Energien auf landwirtschaftlichen Flächen – für Strom, Wärme und Verkehr. Berichte über Landwirtschaft – Zeitschrift für Agrarpolitik und Landwirtschaft. Band 101, Heft 1.

Böhm et al. (2022a). PV-Freiflächen-anlagen: Rahmenbedingungen und Wirtschaftlichkeit. Berichte über Landwirtschaft – Zeitschrift für Agrarpolitik und Landwirtschaft. Band 100, Heft 2.

Böhm et al. (2022b). Land use Prior to Installation of Ground-mounted Photovoltaic in Germany -GIS-analysis Based on MaStR and Basis-DLM. Z. Energiewirtsch. 46, 147–156.

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