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Estimating the economics and adoption potential of agrivoltaics in Germany using a farm-level bottom-up approach

Feuerbacher, A., Herrmann, T., Neuenfeldt, S., Laub, M. & Gocht, A.

Open access version of this study is available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4084406

Arndt Feuerbacher and Tristan Herrmann
16.02.2023 - Fraunhofer Agrivoltaics Lecture Series

Who are we?

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- Arndt Feuerbacher
- Junior professor for Ecological-Economic Policy Modelling at Hohenheim since Sept. 2022
- Two main research areas
  - Transformation towards sustainable food systems
    - Agri-PV is one research area
    - Project BEATLE (www.project-beatle.de)
  - Economy-wide modelling of smallholder farming systems

- M.Sc. Tristan Herrmann
- PhD candidate at the institute of farm management within the DFG project:
  - „Adaptation of maize-based food-feed-energy systems to limited phosphate resources“
- Main research areas
  - Landscape modelling in GIS and GAMS
  - P emissions surface waters via erosion

Agrivoltaics

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- Global efforts to promote the adoption of agrivoltaics (AV)
- But – there are trade-offs:
  - Shade can increase or decrease agricultural production
  - Certain % of agricultural area is lost due to mounting structure
  - Higher cost for power generation
- Determinants of adoption potential
  - Farm type
  - Farm size (Economies of Scale?)
  - Production system (crop rotation, level of intensity, mechanization, etc.)
  - Region (Differences in annual solar radiation)

→ Research gap: Determinants of the economics and adoption potential of AV at the national level

- Trilemma

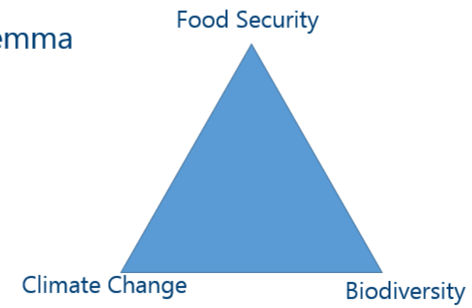

Fig. 1 Shaded winter wheat in an agrivoltaic system in Germany (Photograph by Lisa Pataczek).

Data and methods

- Method: FEADPLUS
  (see publication in Agricultural Systems)

- Data: Official farm database of the German Federal Ministry of Food and Agriculture (BMEL)

- 10% of a farmer's own land (min. 0.25 ha – max. 10 ha)


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An analytical framework to estimate the economics and adoption potential of dual land-use systems: The case of agrivoltaics

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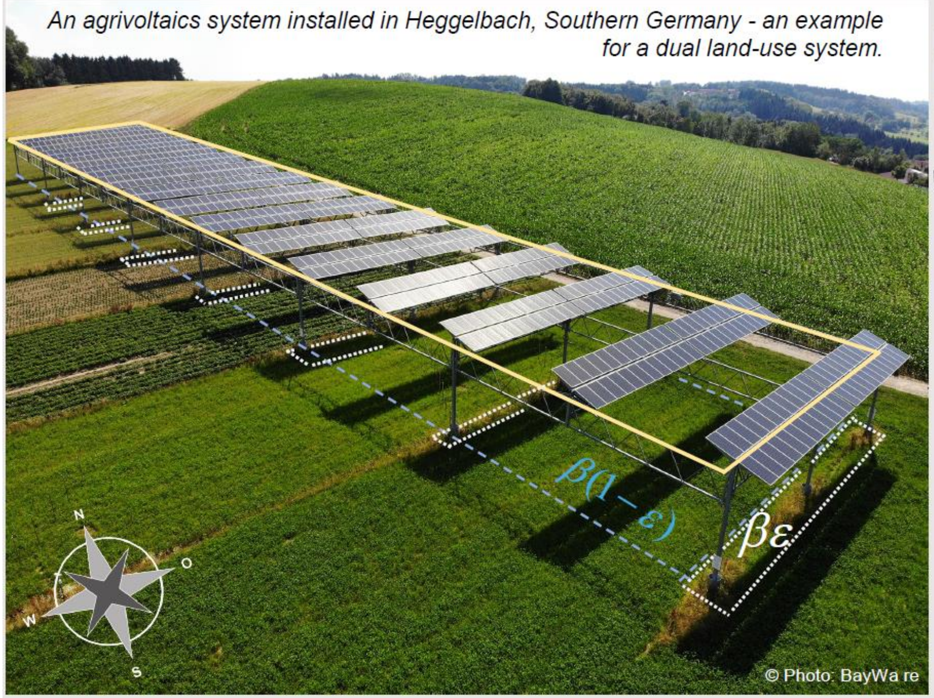
FEADPLUS: Framework to Assess the Economic Benefits and the ADoption Potential of Dual Land-Use Systems

An agrivoltaics system installed in Heggelbach, Southern Germany - an example for a dual land-use system.



$$\beta(1-\varepsilon)\sum_{i=1}^{I}\left(U_i\delta_i-\sum_{v=1}^{V}C_{i,v}\gamma_{i,v}\right)-\beta\varepsilon E_{Base}^{Agri}+cap_{AV}\left(H\ ae\ ta-CRF\ INV-M\right)>0$$

Component 1 (C1): Change in agri. contribution margin due to shading and change in input costs (under the agrivoltaics (AV) system)

C2: Change in agri. contribution margin due to loss in cultivated area (under the AV system)

C3: Change in annual profit due to AV power production

Where:

β = Area covered by dual land-use system
ε = Share of land lost (due to mounting structure area) in area β
δ_i = Change in yield of crop *I*
U_i = Revenue of crop *i*
$C_{i,v}$ = Cost of input use *v* in crop *i*
$\gamma_{i,v}$ = Change in input intensity *v* in crop *I*
E_{Base}^{Agri} = Agricultural contribution margin before adoption

cap = Installed capacity of agrivoltaics (AV) system
H = Full load hours
ae = Average lifetime efficiency (PV)
ta = Electricity tariff (€ kWh^{-1})
CRF = Capital recovery factor
INV = AV investment cost
M = AV maintenance cost

Main findings

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2. Which regions are among the early AV adopters?

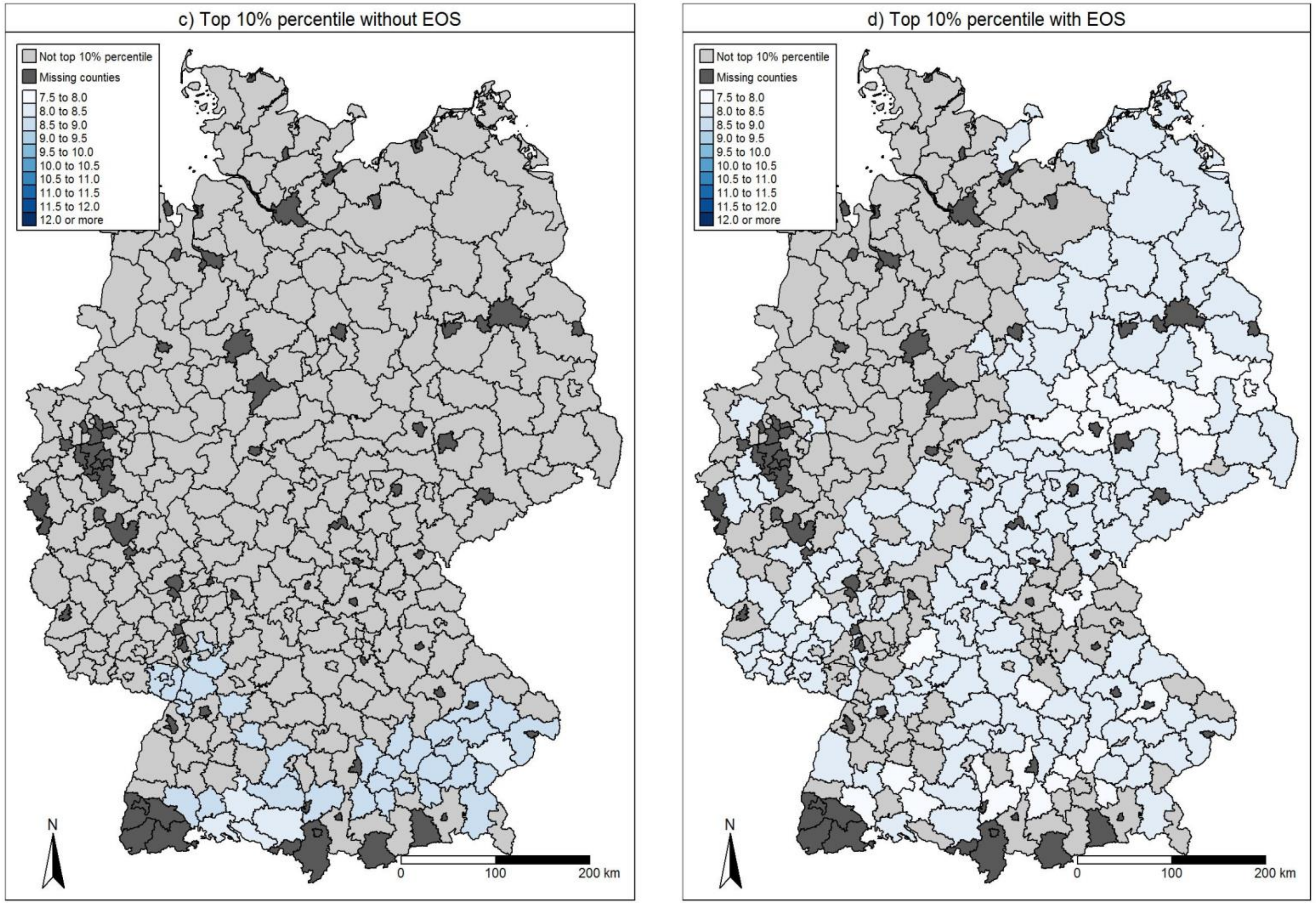

Fig.2: Average cost in ct/kWh at NUTS-3 level

Without Economies of Scale:

- Annual solar radiation is the dominant factor

With Economies of Scale:

- More variation in break-even prices
- Diseconomies of scale for smaller systems
- Regional differences in the structure of farm sizes

Main findings

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3. What about the incentive to continue to farm after adoption?

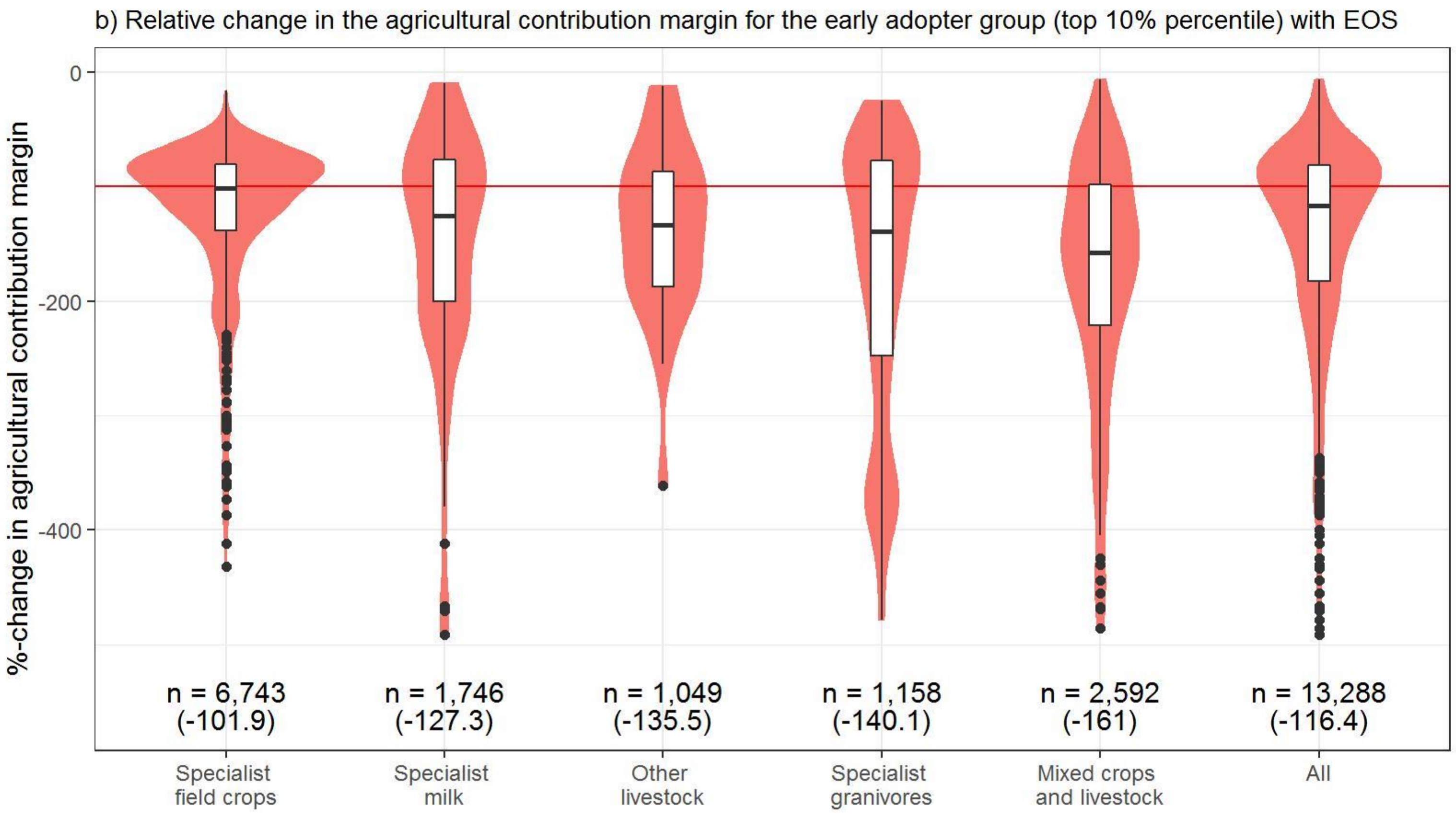

Fig.5: Relative change in the base contribution margin with EOS

- All farms beneath the red vertical line face more than a complete loss of their agricultural contribution margin
- With EOS 38% of farms still have a positive agri. contribution margin (without EOS 62%)
- Policy challenges to ensure continued farming incentives

But: Agronomic costs are still small compared to the income from energy production

Discussion & Summary

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- With EOS the 10% of early adopters could meet 8.8% of Germany's total electricity demand, on around 1% of arable land at 8.3 ct/kWh
  - ➢ Policy support is needed to ensure competitiveness with ground-mounted PV
  - ➢ Even more so for smaller system sizes (social acceptance?)
- Solar radiation and investment costs are key determinants for adoption
  - ➢ Investment costs can be highly volatile
- Agronomic costs have a small impact on adoption (but matter to ensure dual usage)

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Thank you for your attention!

… Questions?

Also, many thanks to our co-authors Moritz Laub (now ETH Zürich), Sebastian Neuenfeldt and Alexander Gocht (both Thünen Institut, Germany).

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