

Analyzing competing land use policy objectives under climate change – a regional case study from Austria

Katrin Karner, Hermine Mitter, Erwin Schmid

Institute for Sustainable Economic Development
Department of Economics and Social Sciences
University of Natural Resources and Life Sciences, Vienna

Link to published article

Karner et al. 2021, Ecological Economics, doi: [10.1016/j.ecolecon.2021.107044](https://doi.org/10.1016/j.ecolecon.2021.107044)

Ecological Economics 185 (2021) 107044



Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon



Analysis

Computing stochastic Pareto frontiers between economic and environmental goals for a semi-arid agricultural production region in Austria



Katrin Karner^{a,*}, Erwin Schmid^a, Uwe A. Schneider^b, Hermine Mitter^a

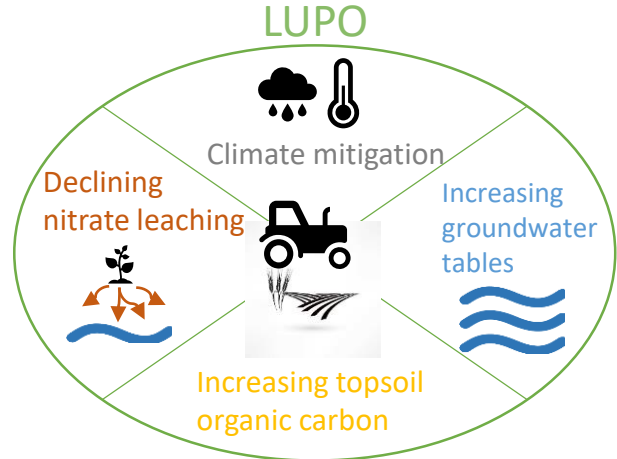
^a Institute for Sustainable Economic Development, BOKU University of Natural Resources and Life Sciences, Feistmantelstraße 4, 1180 Vienna, Austria

^b Research Unit Sustainability and Global Change, Departments of Geosciences, Center for Earth System Research and Sustainability, University of Hamburg, Hamburg, Germany

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Introduction

- Agricultural production has led to conflicts between **economic** and **environmental** land use policy objectives (LUPO) since decades. → **trade-offs**
- Improving one **environmental** LUPO might lead to **co-benefits** with other LUPO.
- **Climate change** may reinforce or alleviate **trade-offs** & **co-benefits**.



Research aims

- Quantify **trade-offs** between **economic** and **environmental** LUPO under stochastic climate scenarios
- Quantify **co-benefits** between **environmental** LUPO under stochastic climate scenarios
- Identify the influence of the **stochastic climate scenarios** on computed trade-offs and co-benefits
- Identify required changes in **land use and land management** to improve environmental LUPO under stochastic climate scenarios

...for the semi-arid case study region Seewinkel in Austria

Case study region - Seewinkel

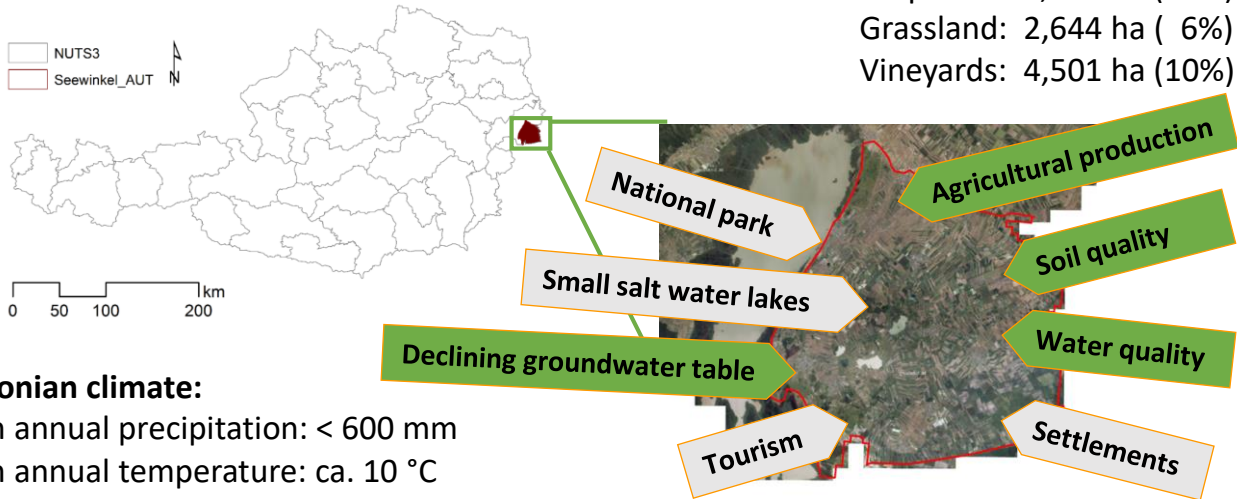
Competing interests

Area: ca. 45,100 ha

Cropland: 25,194 ha (56%)

Grassland: 2,644 ha (6%)

Vineyards: 4,501 ha (10%)



Pannonian climate:

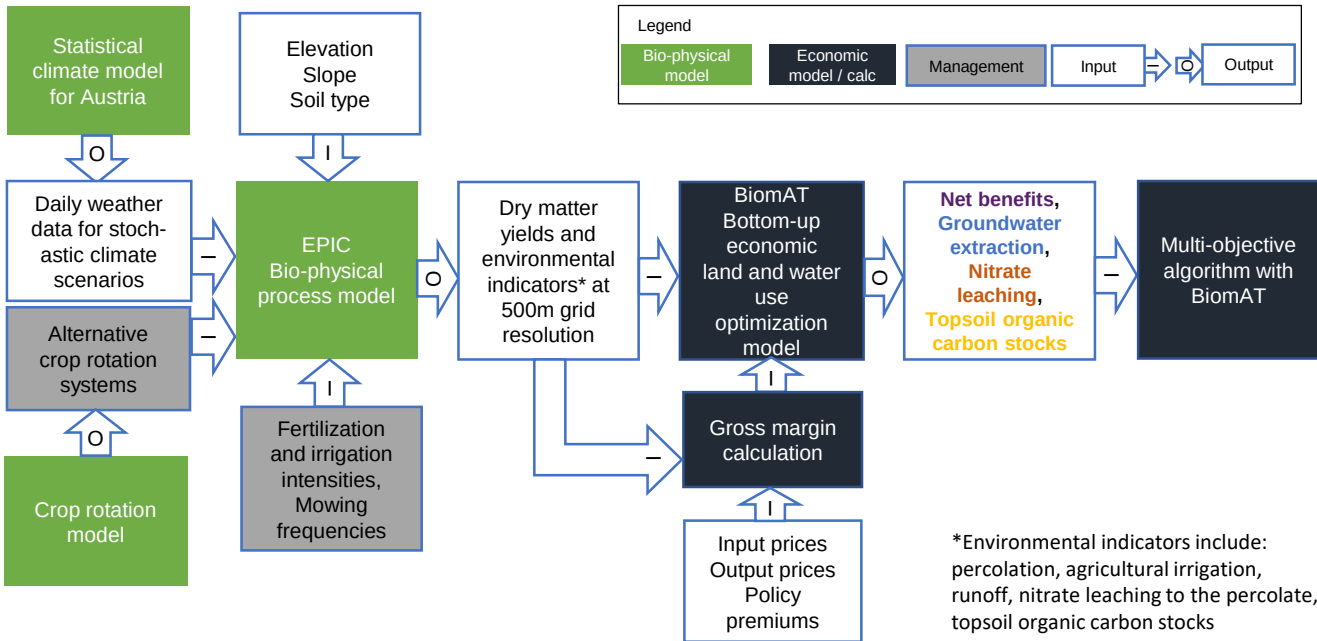
Mean annual precipitation: < 600 mm

Mean annual temperature: ca. 10 °C

Methods – Integrated Modelling Framework

- Three stochastic **climate scenarios** until 2040 assessed. They differ regarding annual precipitation volumes:
 -  SIMILAR (similar to past)
 -  DRY (-20% compared to past, on average)
 -  WET (+25% compared to past, on average)
- Four **land use policy objectives (LUPO)**:
 - Maximizing **net benefits** of agricultural production (NB)
 - Minimizing **groundwater extraction** for agricultural irrigation (GWEX)
 - Minimizing **nitrate leaching** in the percolate (NO3)
 - Maximizing **topsoil organic carbon stocks** (SOC)

Methods – Integrated Modelling Framework II



Methods – Multi-Objective Optimization I

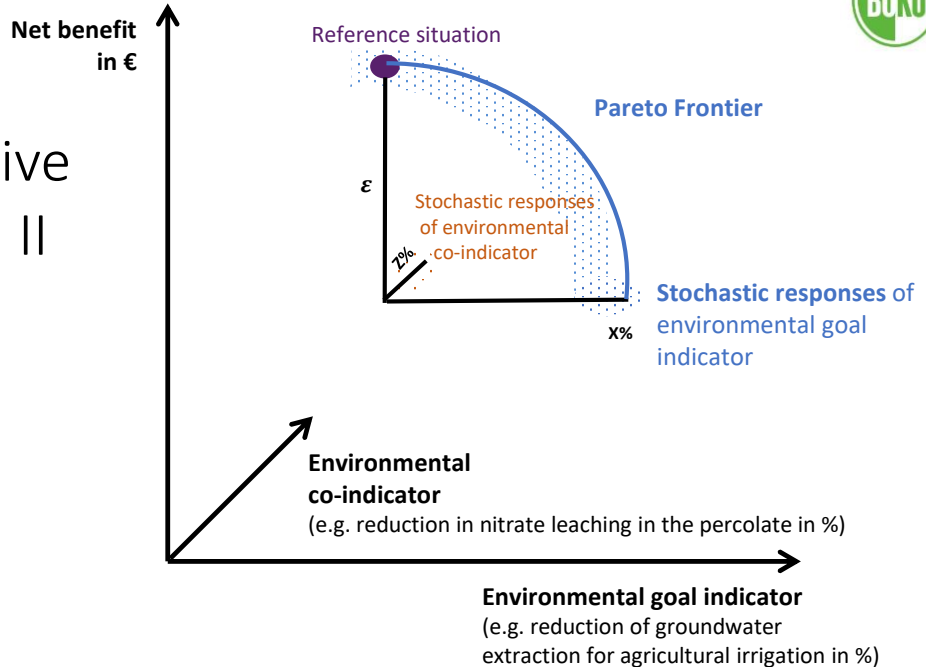
Step (1) **Calibrate** BiomAT to statistical reports of past land use using a **non-linear PMP cost function**

Step (2) **Maximize regional NB** of agricultural production for each stochastic climate scenario & save regional values for the three environmental LUPO

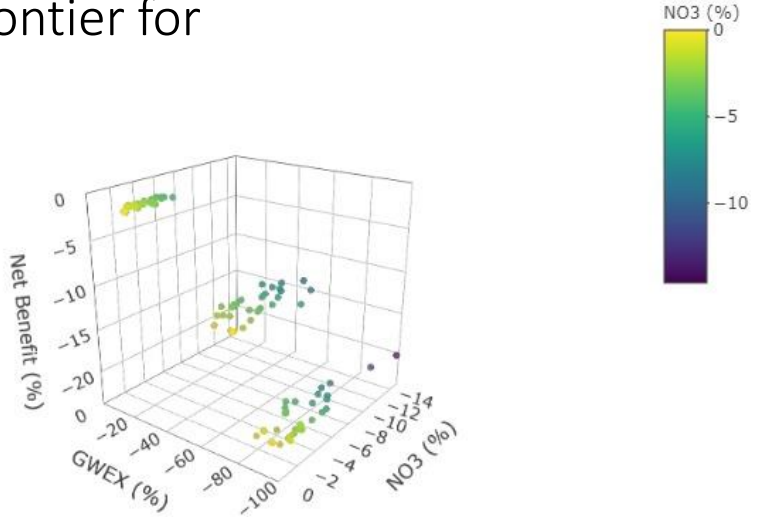
Step (3) Minimize/Maximize each **environmental LUPO** (GWEX, NO₃, SOC) while **NB can decline** by ϵ (varies between 1% and 50%) and other environmental LUPO cannot worsen compared to values from step (2)

Methods – Multi-Objective Optimization II

Computation of Pareto Frontiers



Results – Stochastic Pareto Frontier for minimizing GWEX



Video animation at: <https://youtu.be/0LtwYaZ8Wok>

Interactive version at: https://rpubs.com/katkar/frontier_fig3_3D

Results – Stochastic Pareto Frontiers



NB reductions of 1-15%
lead to 50% of maximum
modelled improvements
of **environmental** LUPO.



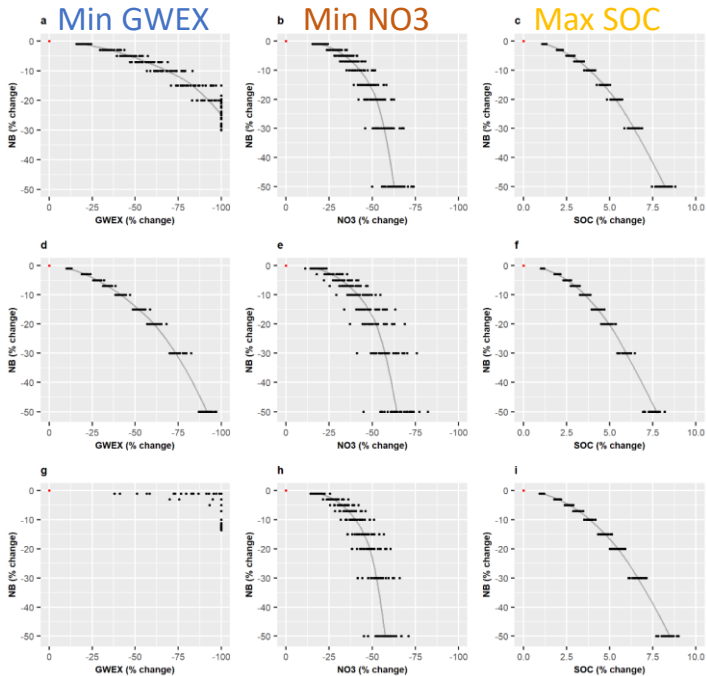
DRY

Declining **NB** by 1% leads to

- declines of **GWEX** by 11-76%
 - declines of **NO3** by 17-19%
 - increases of **SOC** by 1%
- ... depending on the
stochastic climate scenario.



WET



Results – Changes in land use

- Changes in land use due to climate change:
 - Permanent grassland increases most in WET.
 - Other land (i.e. abandoned land) increases most in DRY.
- To min **GWEX**:
Cropland declines (from 66-70% under max NB, to 52-56% with NB reductions of 50%) & other land increases (from 2-16% under max NB, to 28-34% with NB-50%)
- To min **NO3**:
Cropland declines (to 49-50% at NB-50%) & grassland increases (to 21-37% at NB-50%)
- To max **SOC**:
Cropland declines (to 25-34% at NB-50%) & grassland increases (to 15-46% at NB-50%) and other land increases (to 18-39% at NB-50%)

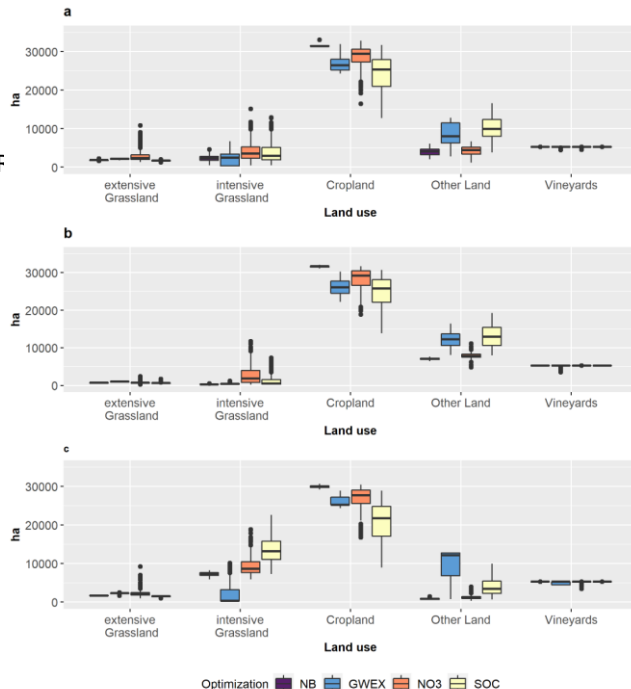
... depending on the stochastic climate scenario



DRY



WET

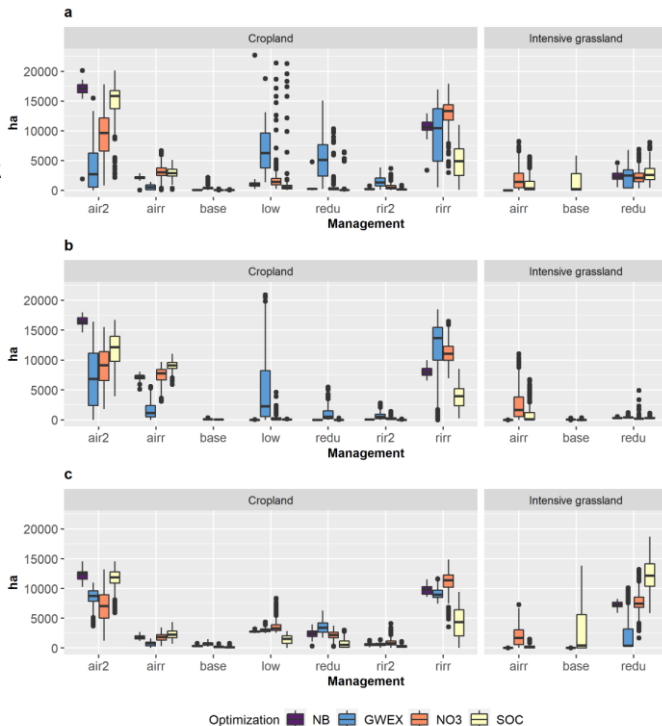


Results – Changes in land management

In terms of land management changes to improve LUPO:

- To min **GWEX**: share of irrigated cropland (sum of air2, airr, rir2, rirr) declines from 87-99% at NB reductions of 1%, and to 11-25% at NB reductions of 50% in SIMILAR and DRY
- To min **NO3**: The share of highly fertilized cropland (sum of airr, air2, base) declines from 43-69% at NB-1% to 25-43% at NB-50%, depending on the climate scenario
- To max **SOC**: fertilization intensities increase (from 53-78% at NB-1% to 94-98% at NB-50%) and irrigation intensities remain high (0-17% rainfed) → but area of irrigated or highly fertilized cropland declines

airr = high fertilization and high irrigation, air2 = high fertilization and medium irrigation, base = high fertilization and no irrigation, rirr = medium fertilization and high irrigation, rir2 = medium fertilization and medium irrigation, redu = medium fertilization and no irrigation, low = low fertilization and no irrigation.



Discussion & Conclusion I

- Adaptation of **land use** and land management **significantly improves** performance of **environmental LUPO** for fairly **small reductions** in **net benefits** of agricultural production (NB) → low costs to improve environmental LUPO in the Seewinkel
- **Trade-offs** are **smallest** between **NB** and **groundwater extraction** for agricultural irrigation (**GWEX**) and **highest** between **NB** and **topsoil organic carbon stocks (SOC)** → water management policies less costly than climate mitigation, at least in the Seewinkel region

Discussion & Conclusion II

- **Co-benefits largest** between **SOC** and **nitrate leaching** in the percolate (**NO₃**) due to modelled increases of grassland
- Overall **increasing grassland** and **reduced** irrigation and fertilization **intensities** on cropland **increases co-benefits** among environmental LUPO but high trade-offs with NB
- **Stochastic climate scenarios** influence computed trade-offs and co-benefits & performance of environmental LUPO → in WET, trade-offs decline between NB and GWEX and SOC but increase between NB and NO₃

Acknowledgements

This research was supported by

- the ERA4CS JPI Climate project “Climate Services for the Water-Energy-Land-Food Nexus (CLISWELN)” funded by the Austrian Federal Ministry of Education, Science and Research and administered by the Austrian Research Promotion Agency (FFG)
- the research project “Variability of Groundwater Recharge and its Implication for Sustainable Land Use in Austria (RechAUT)” funded by the Austrian Academy of Sciences (ÖAW)
- the research project “Uncertainty propagation in integrated modelling approaches for global change and impacts on the bio-economy” funded within the Austrian Climate Research Program (ACRP) of the Climate and Energy Fund

Contact details

Katrin Karner

Institute for Sustainable Economic Development
Department of Economics and Social Sciences
University of Natural Resources and Life Sciences, Vienna

katrin.karner@boku.ac.at

+43 1 47654-73125

[ResearchGate](#) | [Institute Website](#) | [Personal Website](#)