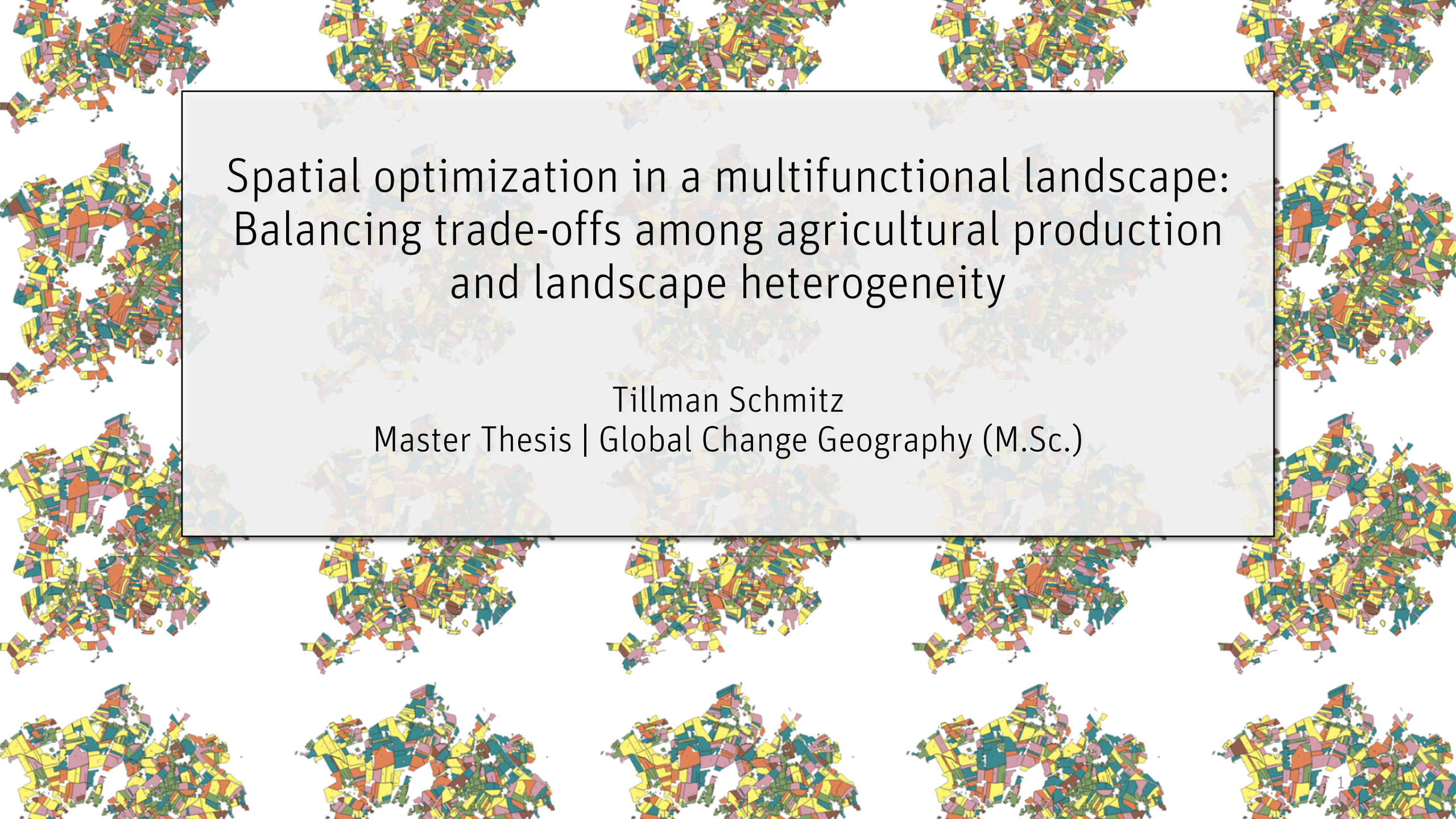


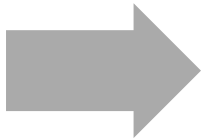
Spatial optimization in a multifunctional landscape: Balancing trade-offs among agricultural production and landscape heterogeneity

Tillman Schmitz

Master Thesis | Global Change Geography (M.Sc.)

Trade-offs in agricultural land systems

Multifunctionality of landscapes



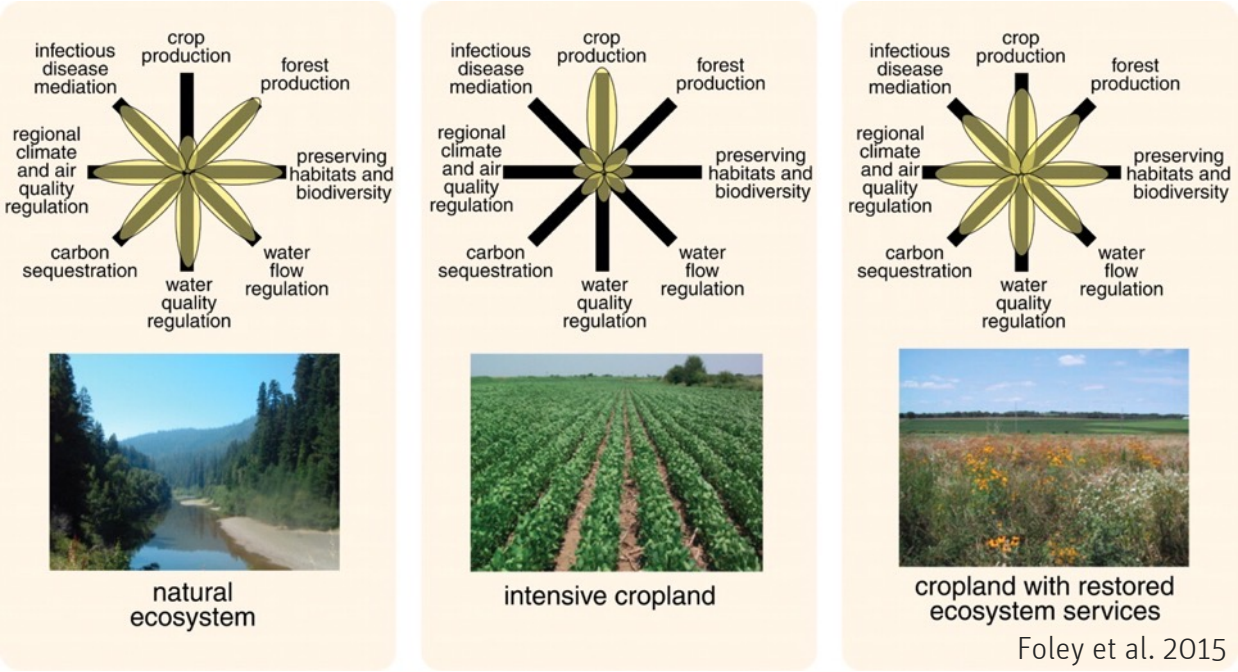
Trade-offs

Trade-off:

an antagonistic situation that involves losing one quality of something in return for gaining another

Trade-offs in agricultural land systems

Multifunctionality of landscapes → Trade-offs



Foley et al. 2015

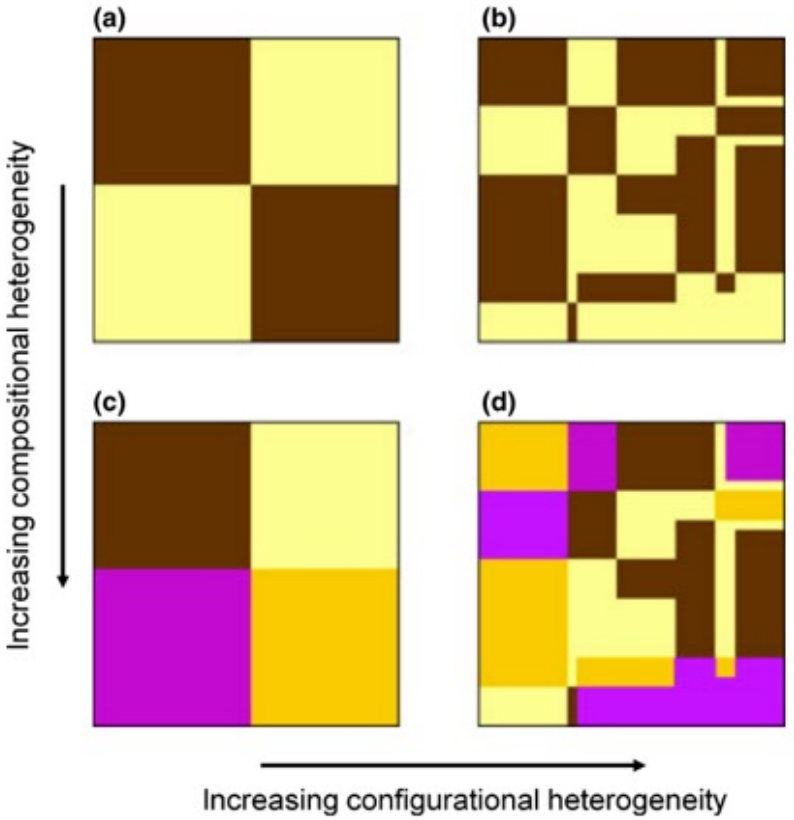
Agricultural landscapes

- often optimized for the production of food
- resulting in declines of farmland biodiversity due to the loss & fragmentation of natural land and the intensification of agricultural production

Landscape heterogeneity as a key element

- **Compositional:**
  variety and abundance of patch types irrespective of their spatial arrangement
  - proportion of habitat area
  - diversity of habitat types

- **Configurational:**
  spatial character and arrangement, position or orientation of landscape elements
  - patch shape
  - edge length
  - mean patch size

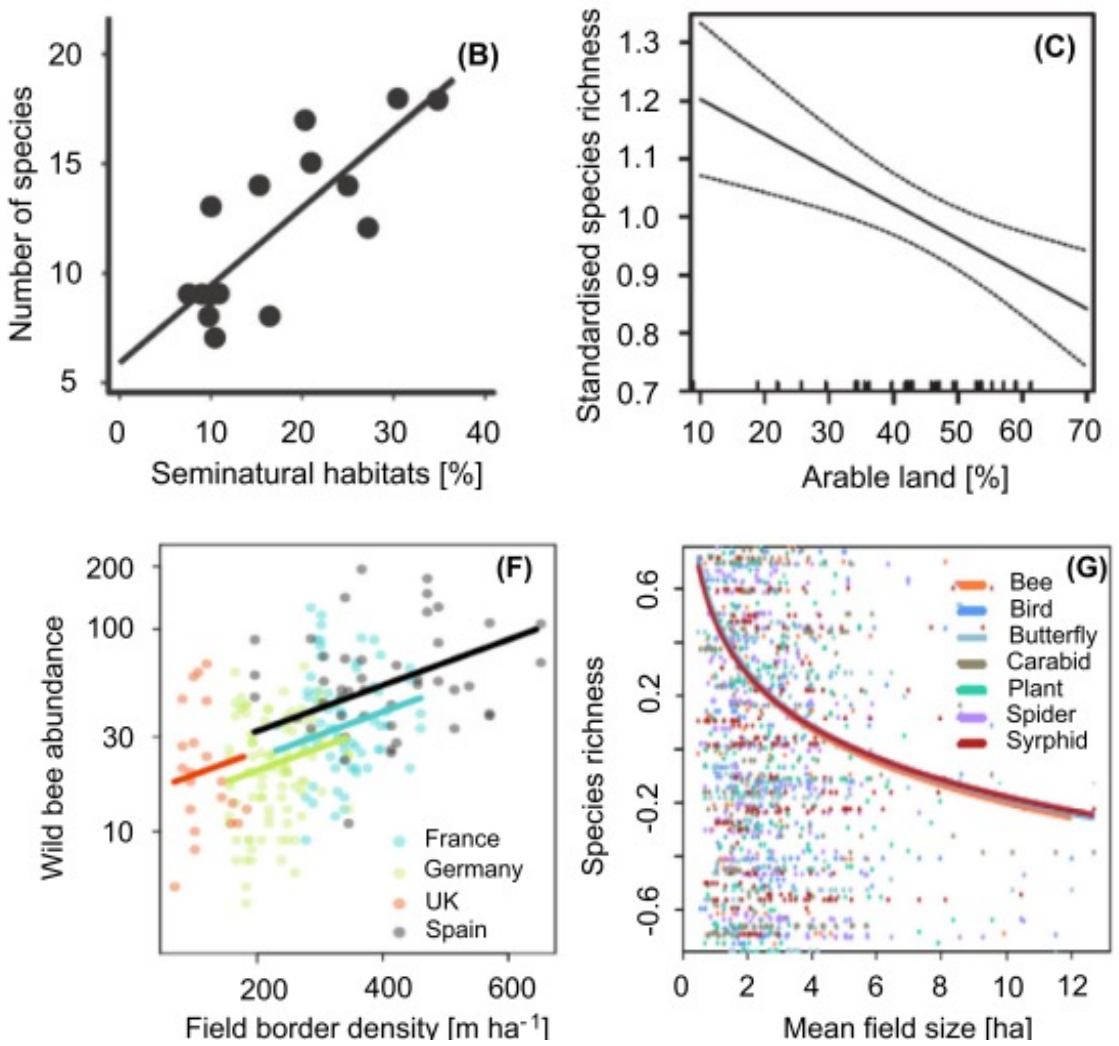


Fahrig et al. 2011

Landscape heterogeneity & farmland biodiversity

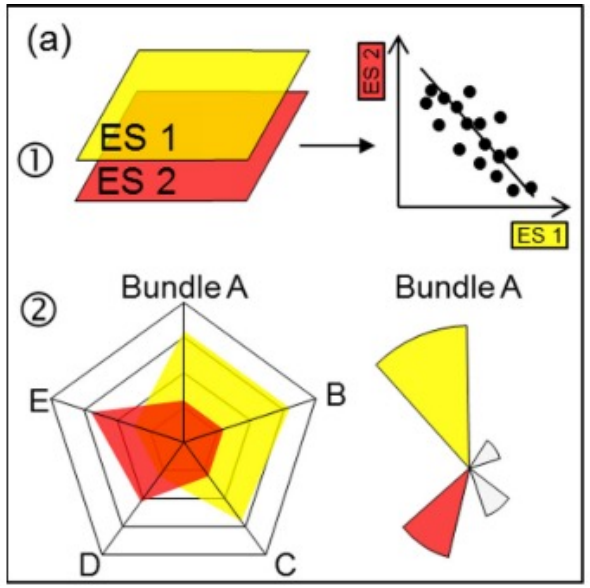
Increase of compositional & configurational heterogeneity → Increase of farmland biodiversity

-> relationships vary between species, locations and metrics used and have to be interpreted in their context



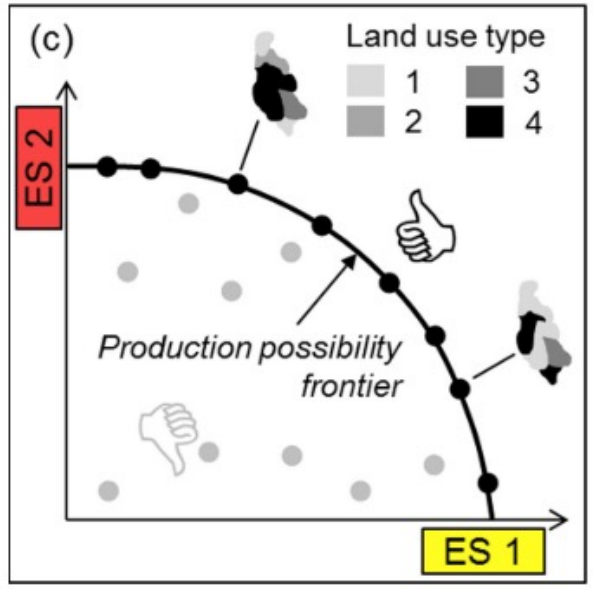
Tscharntke et al. 2021

Trade-off analysis



Cord et al. 2017

- Are ES provided or can be used simultaneously in the same location or at the same time?
- Does the presence of one ES exclude the presence of another?

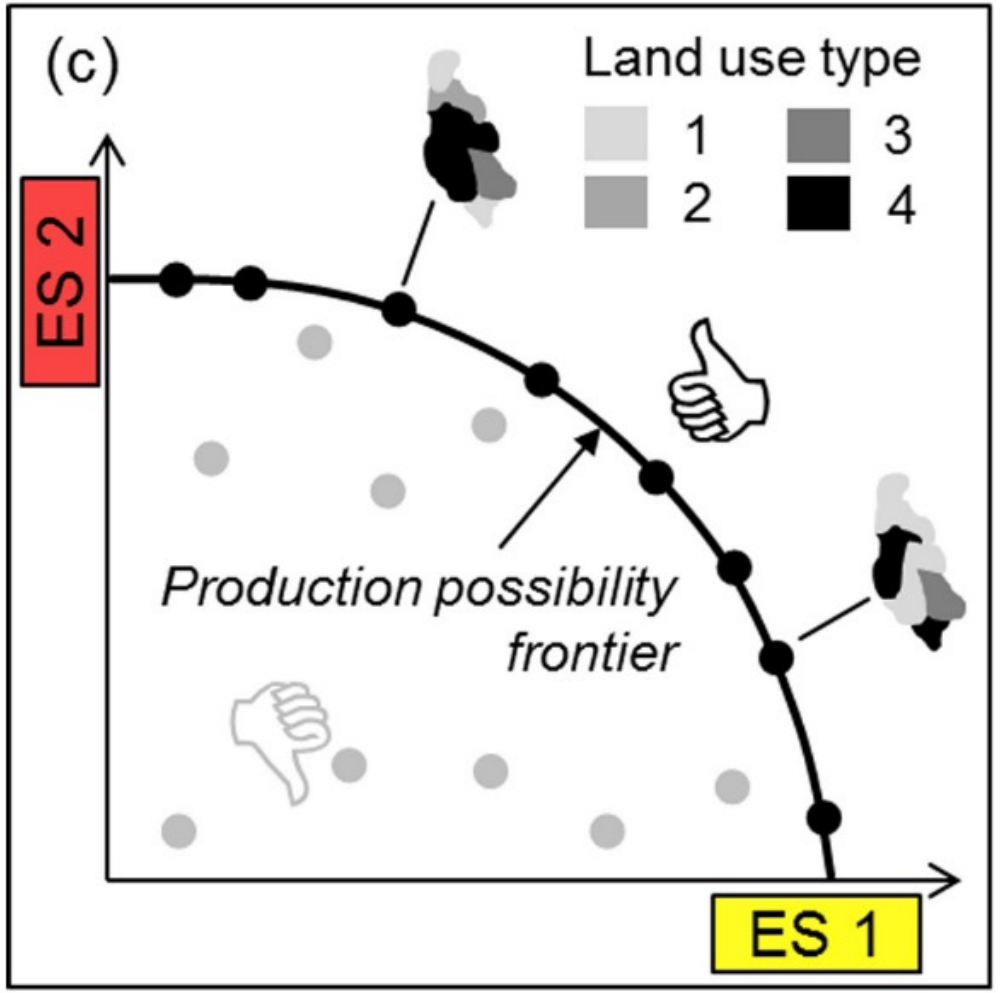


Cord et al. 2017

- What is the capacity of a landscape to provide different ES at the same time?
- How to maximize a landscape‘s ecosystem services and biodiversity?
- Where is the biophysical limit?
- How do the best achievable trade-offs look like?

Spatial optimization of land use

- provide trade-offs between functions
- but also provide a full set of alternative land use allocations where trade-offs are minimized
- Pareto-Optimality: solutions are produced where no function can be further improved without compromising at least one of the other functions
- From the set of best alternatives, decision makers can discuss and select appropriate solutions according to their preferences



Cord et al. 2017

Aim of the study/ Research questions

The aim of my study is to assess how multi-objective land-use optimization can be used to minimize trade-offs between agricultural production and landscape heterogeneity on field level in an intensively used agricultural area in Brandenburg, Germany.

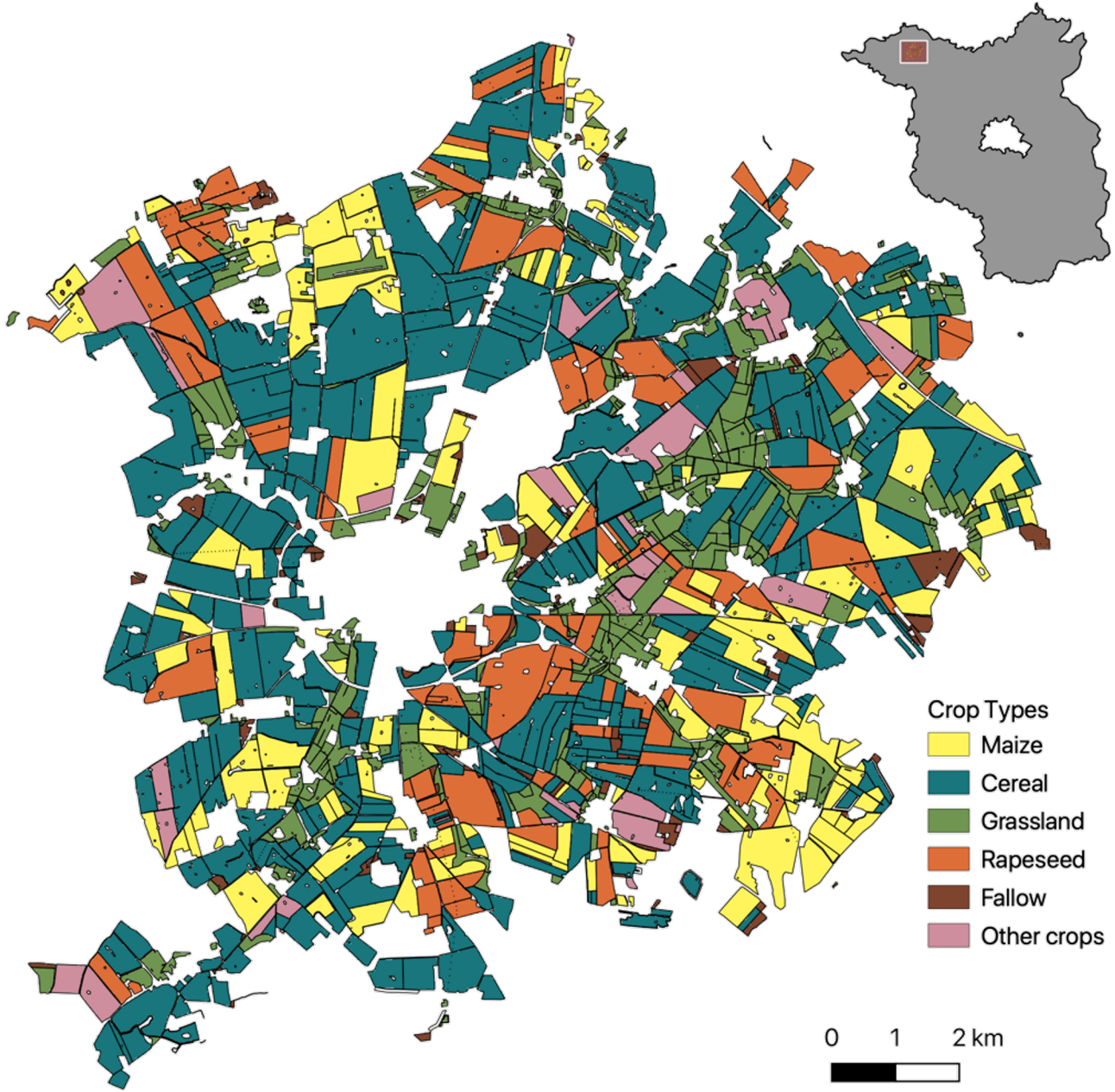
1. What is the relationship between agricultural production, compositional and configurational landscape heterogeneity in the study region?

2. What is the improvement potential of the optimized land use allocations compared to the current land-use allocation in terms of the selected objectives?

Study Area & Data

Pritzwalk, Brandenburg

- 165 km^2
- Dominated by agricultural land use
- Low quality soils and low precipitation
- Main crop types: cereal and maize

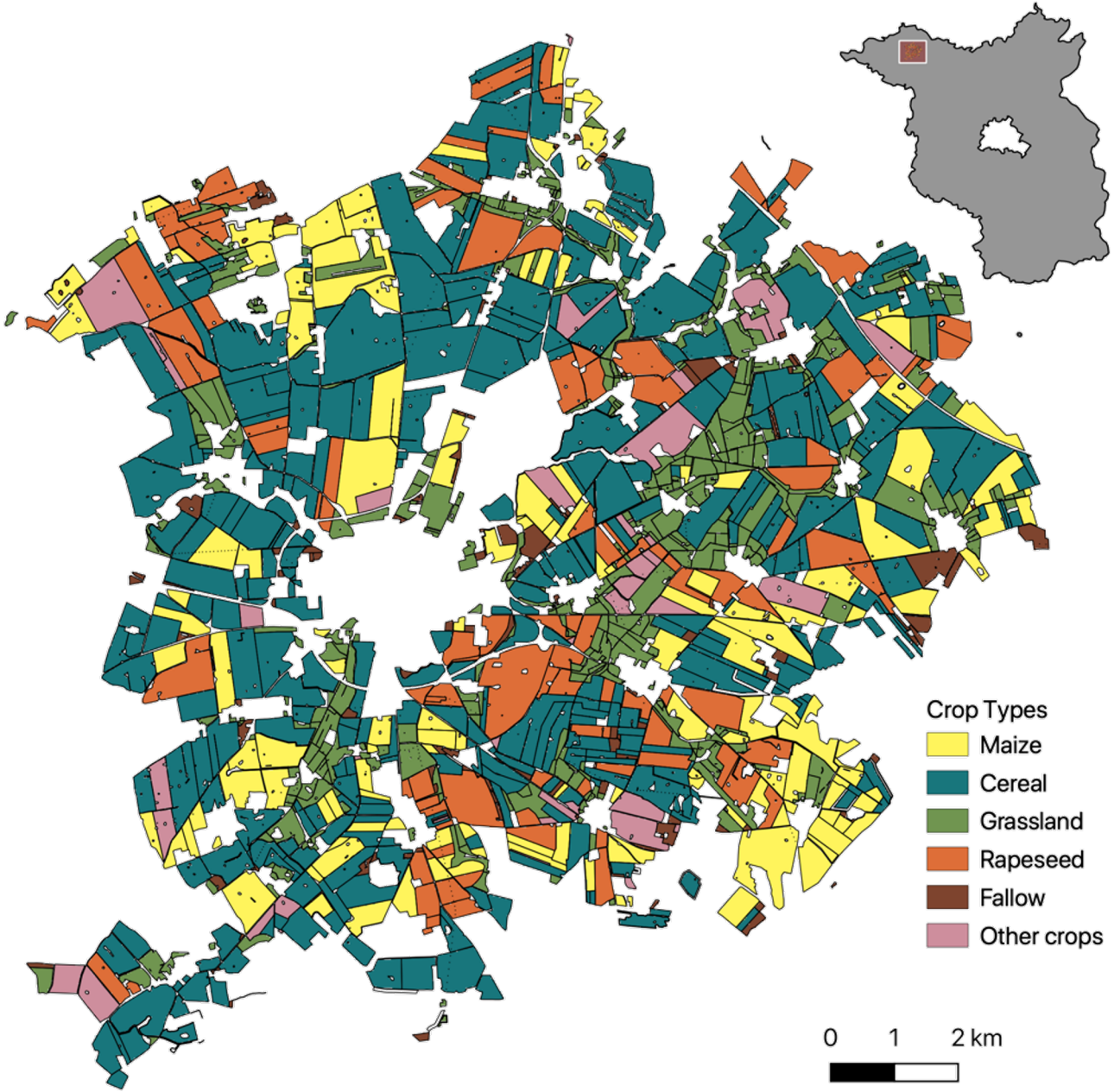


Study Area & Data

Input Data

- IACS (Integrated Administration and Control System)
  - plot-based information about crop types
  - Farmer apply for area-based payments to get income support by the European union

- Yield potential map from soil values
  - contains information about the natural productivity of all agriculture areas
  - Value range from 0 – 100
  - determined from information on soil type, geological formation of the soil, status level, and general climate and water conditions



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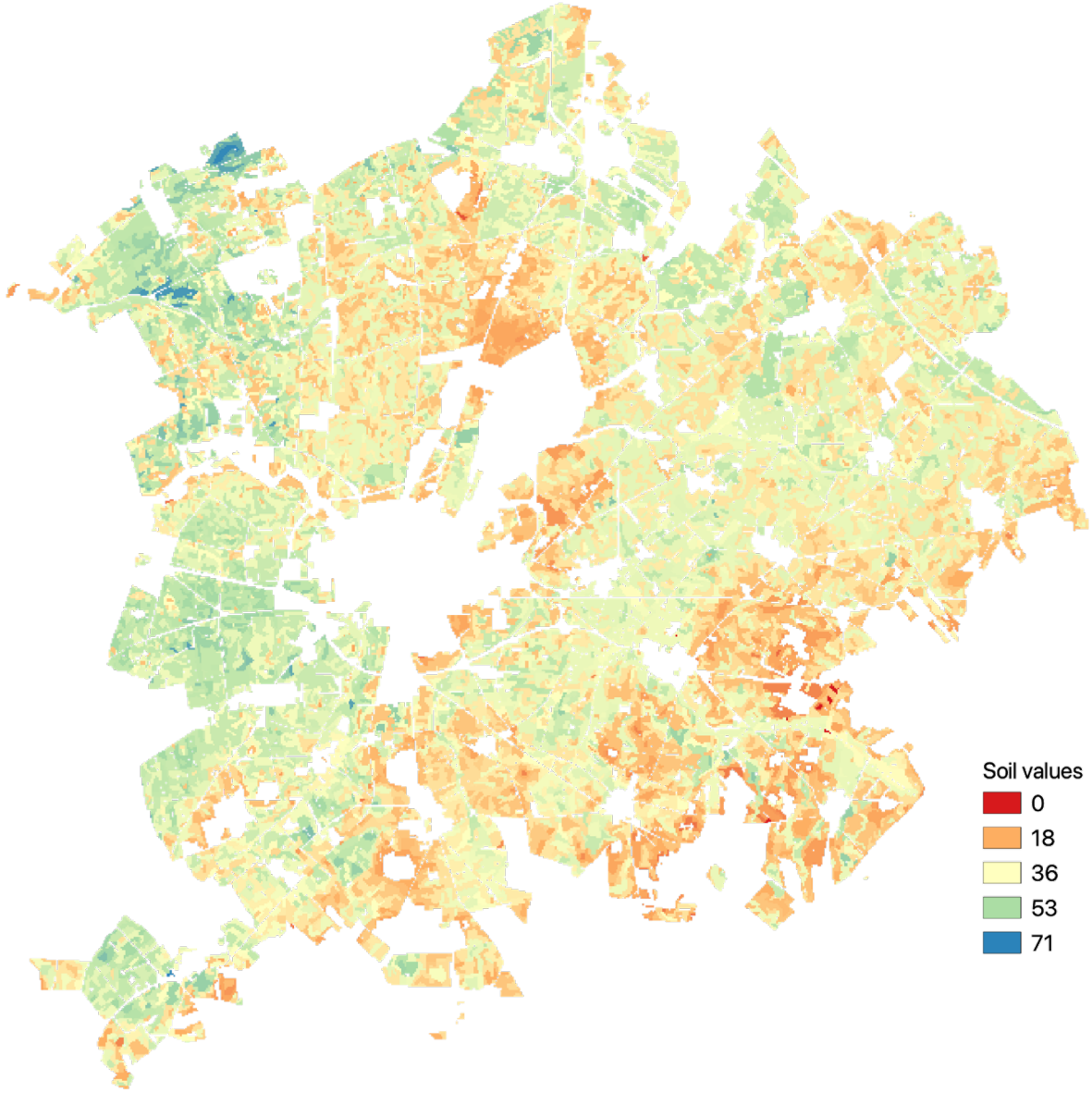
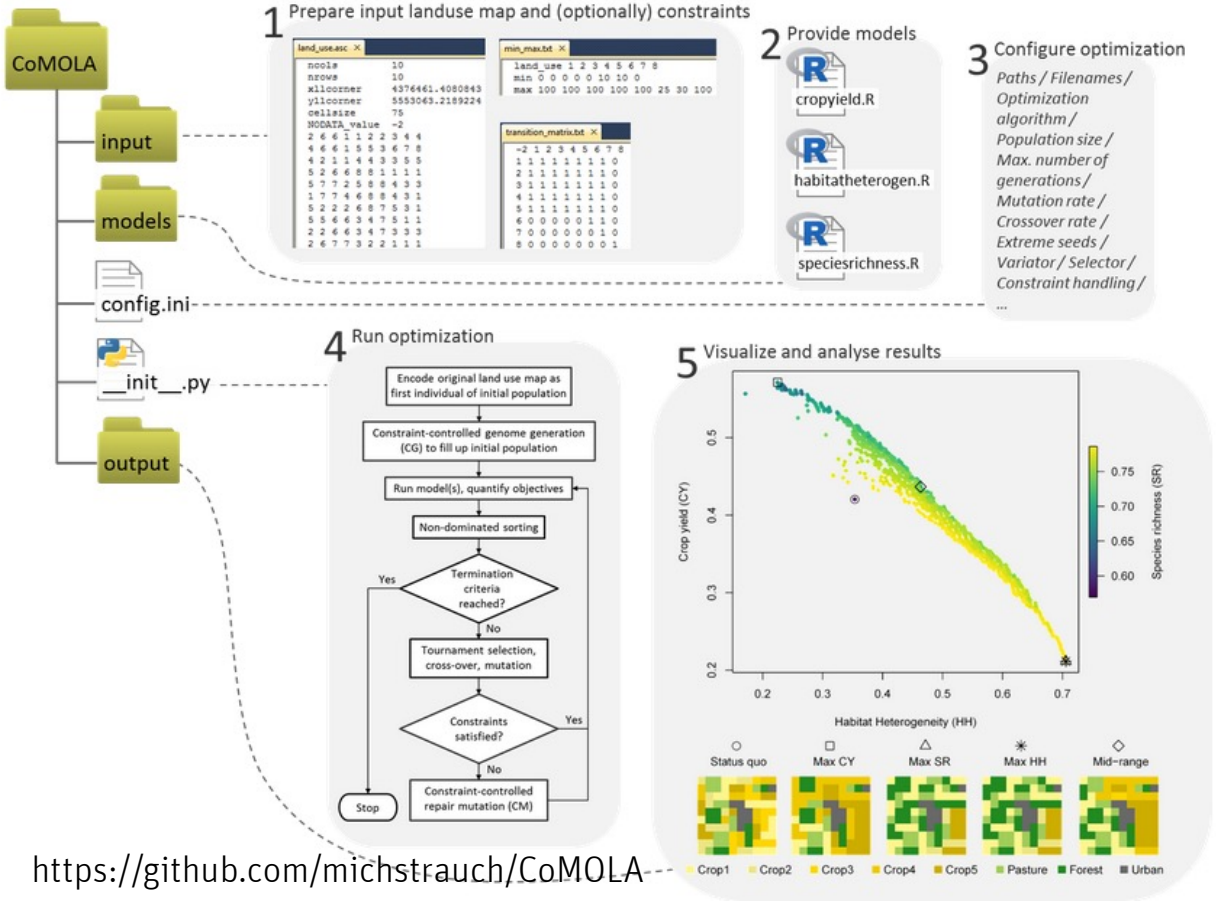


Methods: Spatial Optimization Algorithm

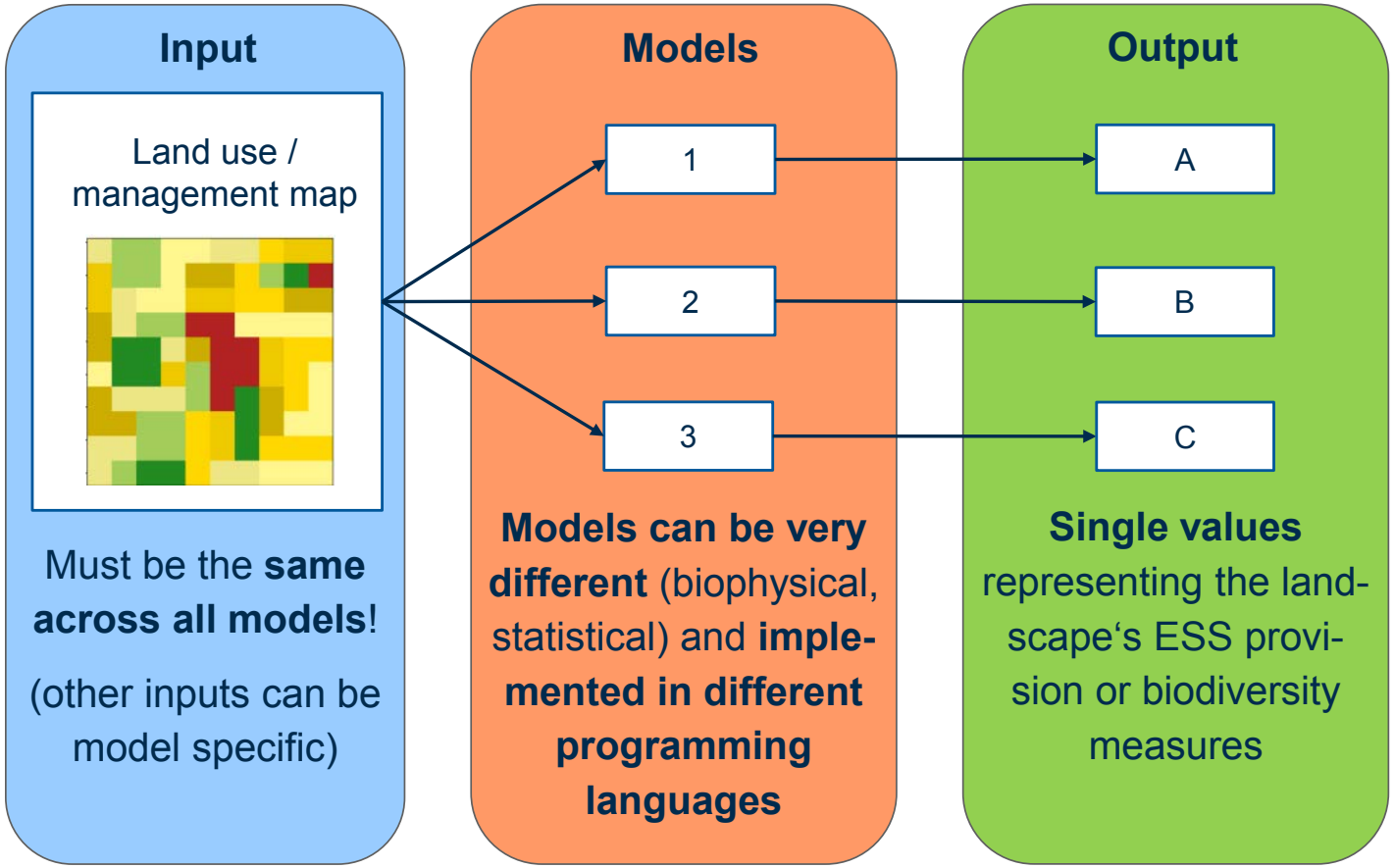


https://github.com/michstrauch/CoMOLA

CoMOLA:

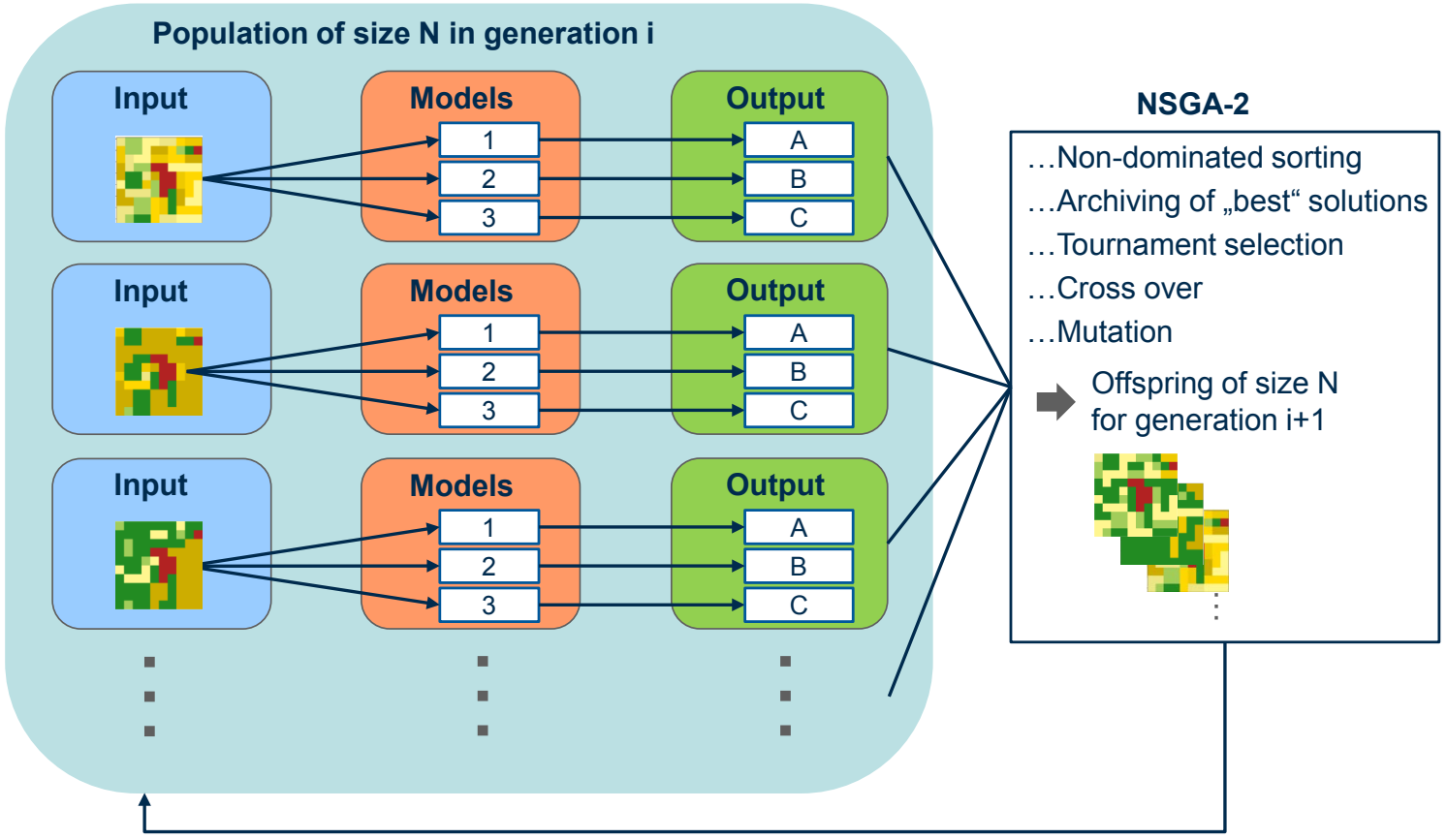
- "Constrained Multi-objective Optimization of Land use Allocation"
- landscape optimization tool that utilizes the NGSA-II algorithm to create Pareto-solutions
- The tool also allows to consider land use change constraints to include real-world constraints

Methods: Spatial Optimization Algorithm



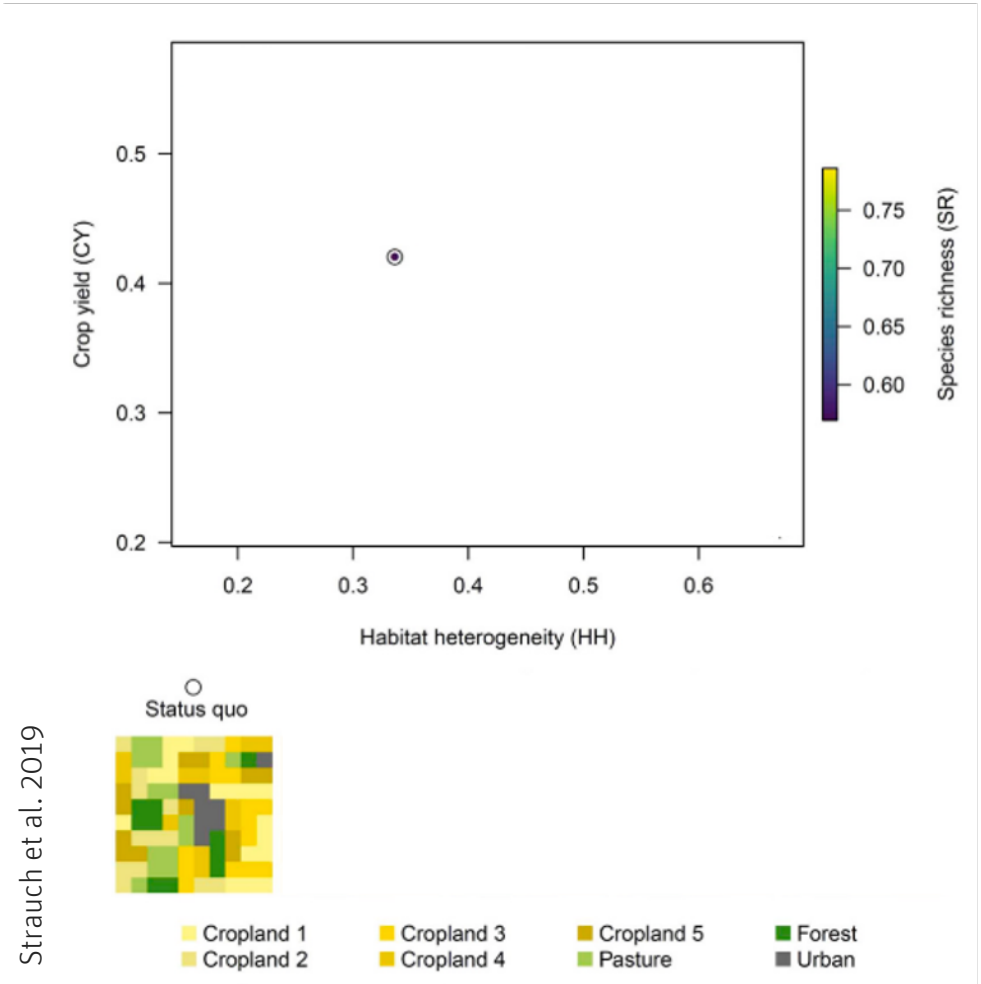
Strauch et al. 2016

Methods: Spatial Optimization Algorithm



Strauch et al. 2016

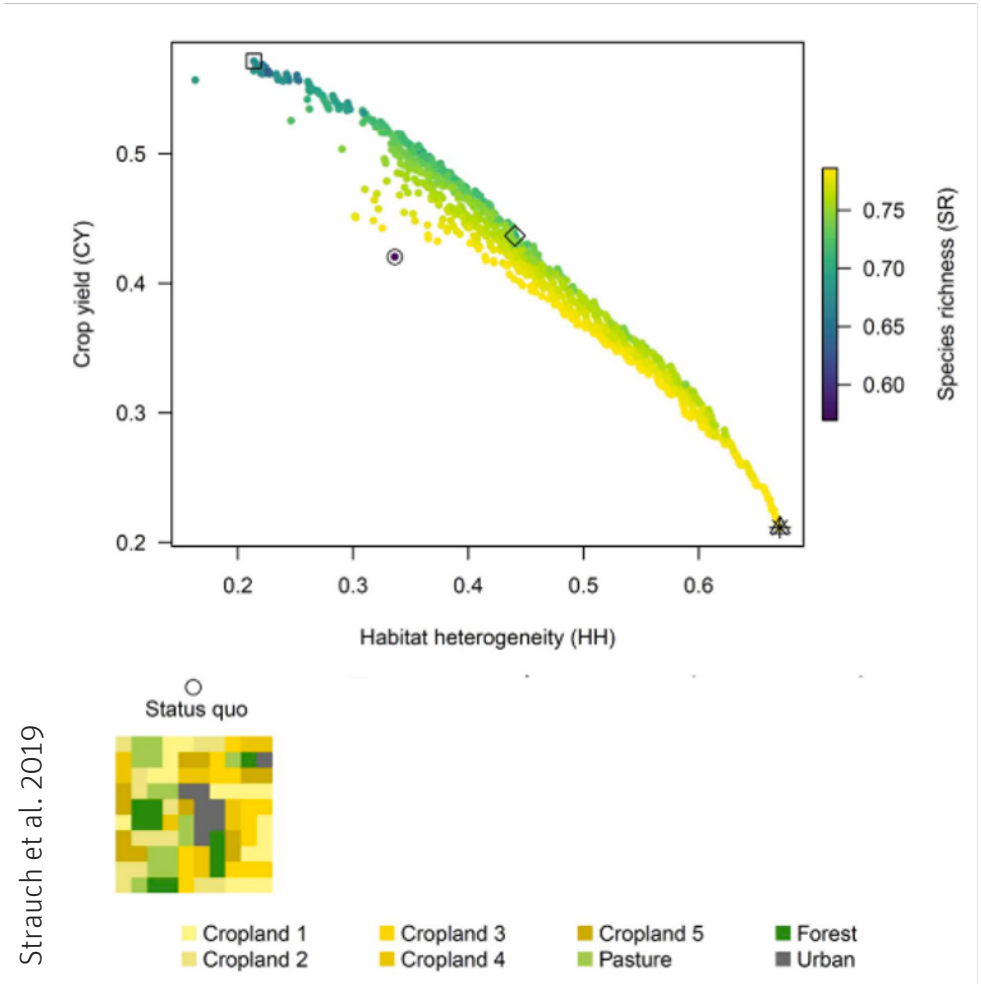
Methods: Spatial Optimization Algorithm



Strauch et al. 2019

- Status quo land use map & three objective functions to assess the values of a certain landscape

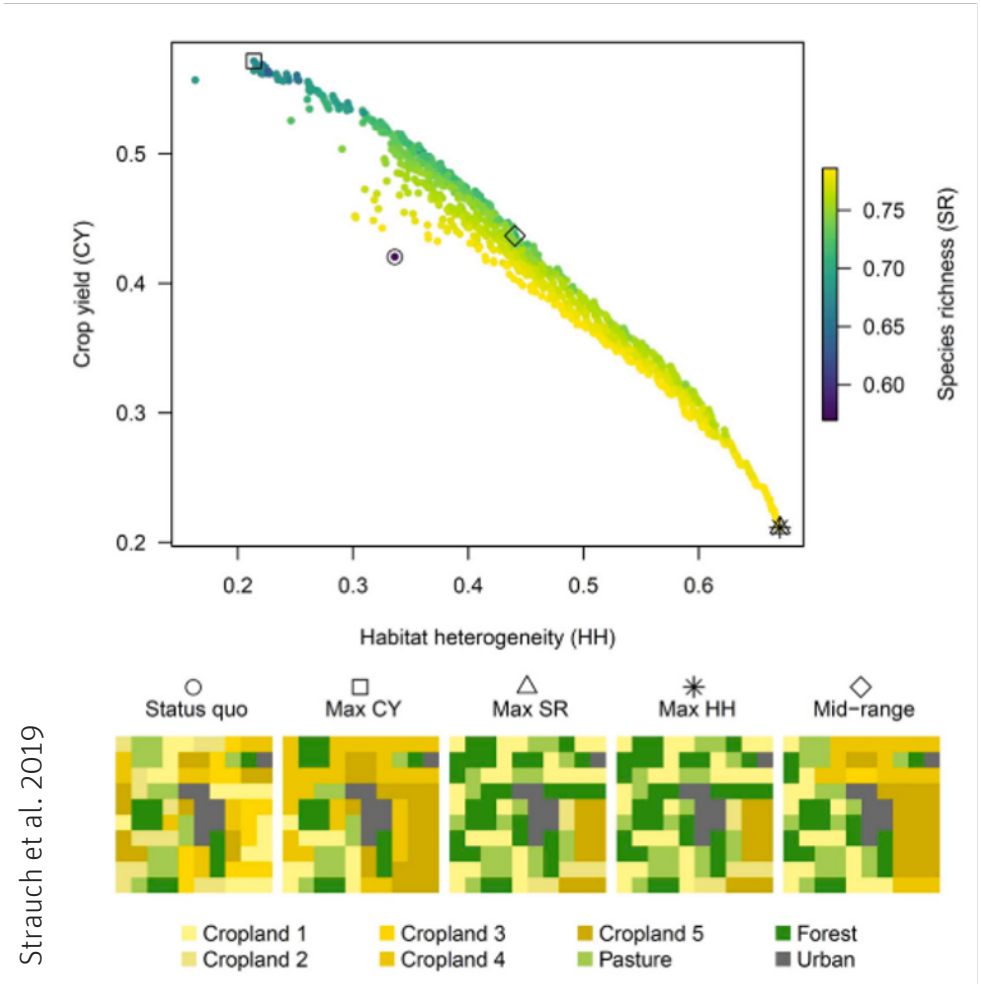
Methods: Spatial Optimization Algorithm



Strauch et al. 2019

- Status quo land use map & three objective functions to assess the values of a certain landscape
- New land use maps are generated and placed along a pareto front via the optimization algorithm

Methods: Spatial Optimization Algorithm



Strauch et al. 2019

- Status quo land use map & three objective functions to assess the values of a certain landscape
- New land use maps are generated and placed along a pareto front via the optimization algorithm
- Each point is a new land use map
- All maps were produced under the Pareto-Optimality concept

Methods: Objectives & Models

Ecosystem function

Agricultural prodcution

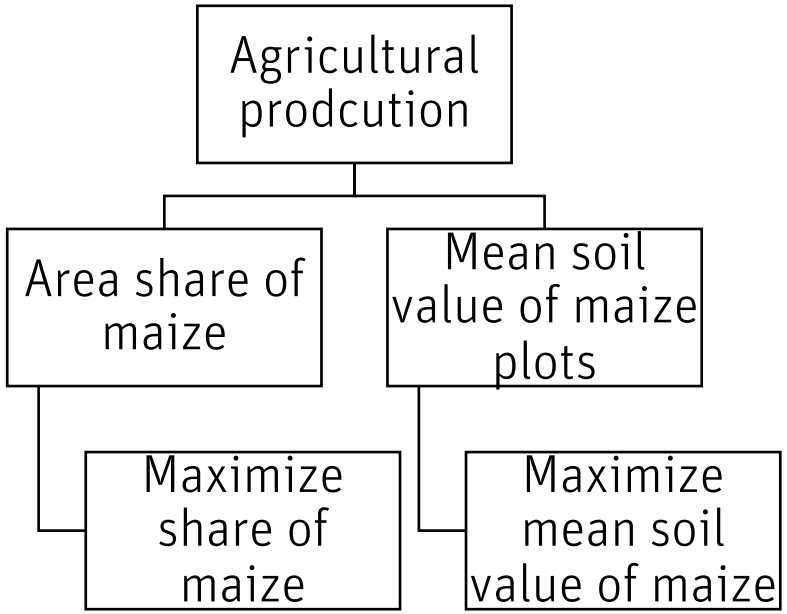
Farmland biodiversity

Methods: Objectives & Models

Ecosystem function

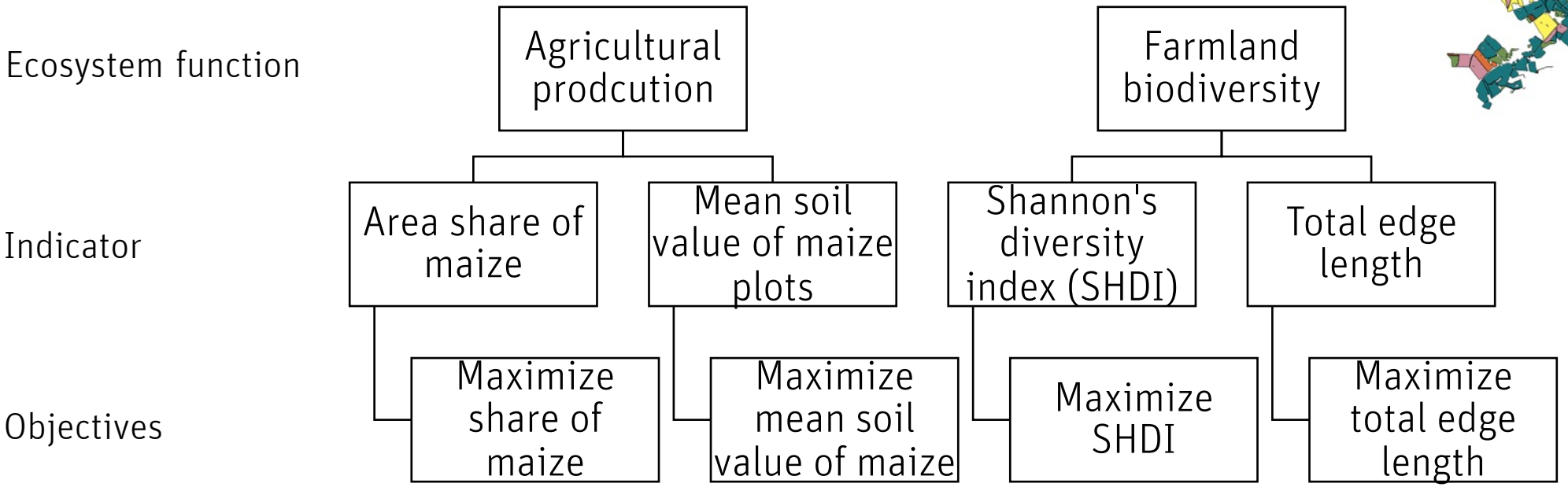
Indicator

Objectives



Farmland biodiversity

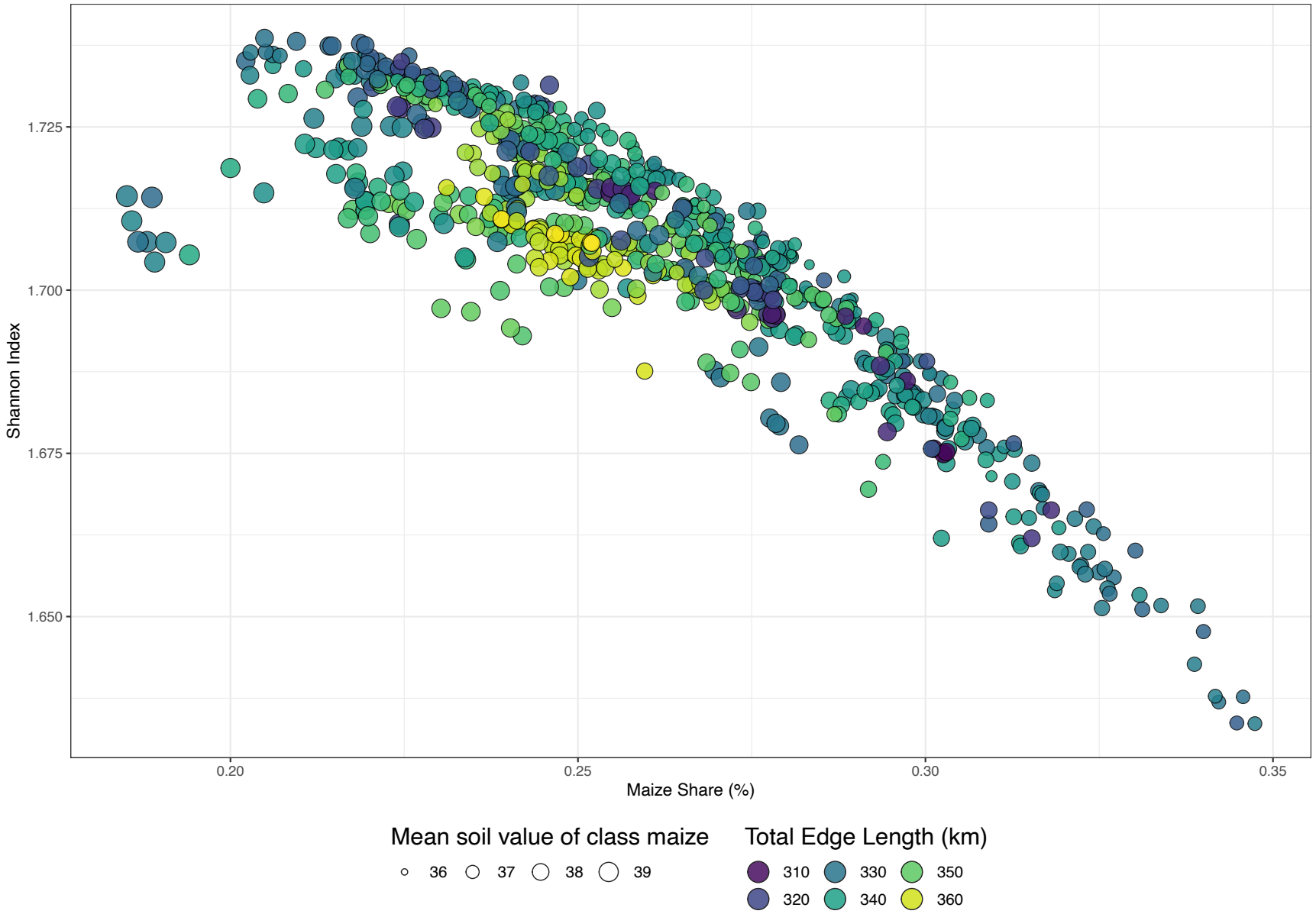
Methods: Objectives & Models



Results

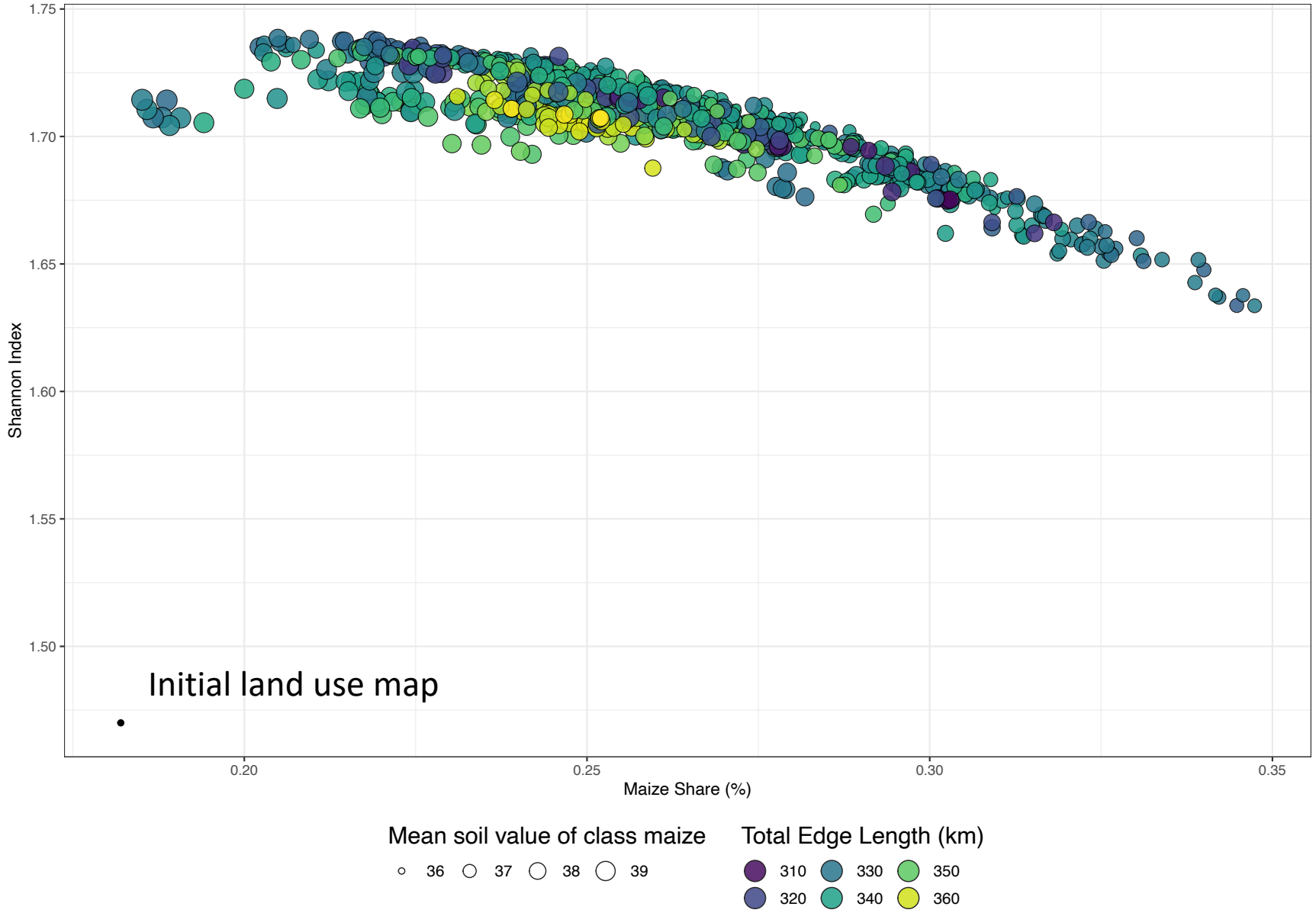
- 801 pareto-optimal solutions which are all feasible (=do not violate any constraints)

- Pareto-Optimality: solutions are produced where no function can be further improved without compromising at least one of the other functions



Results

- Comparison with initial land use map



Spatial optimization in a multifunctional landscape

X-axis variable

Maize_Share

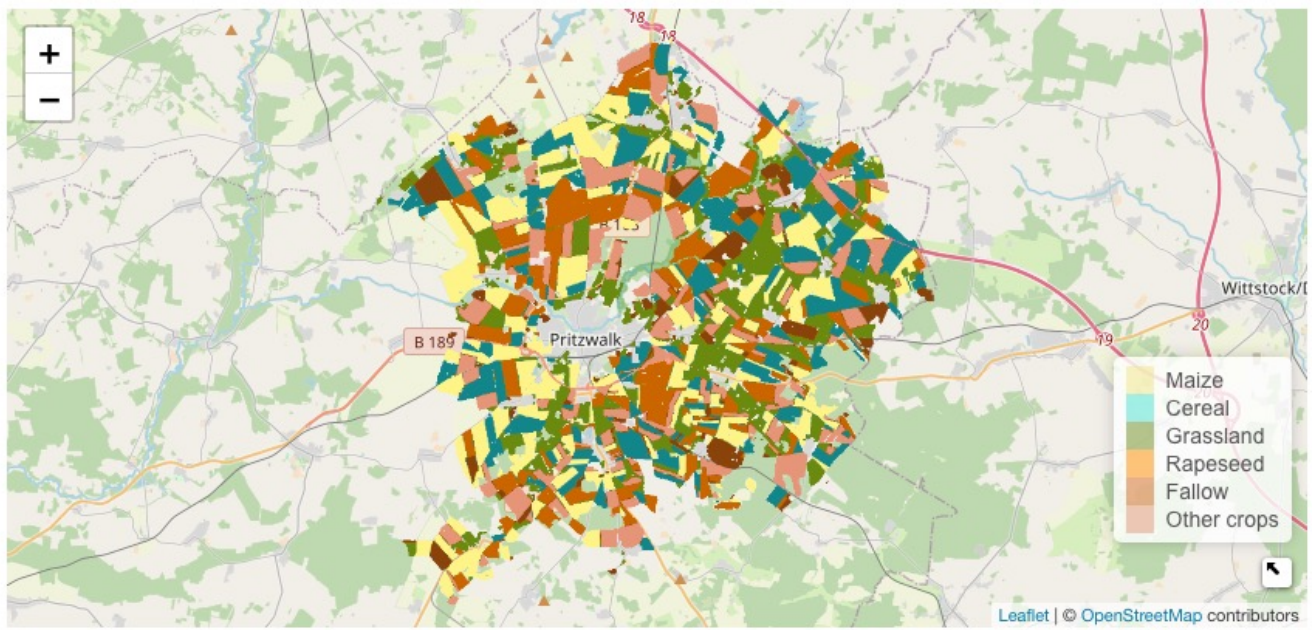
Y-axis variable

Shannon_Index

color gradient

Total_Edge_Length

Map with alternative land use config



(Preliminary) Conclusion

- Spatial optimization for multiple objectives can identify functional trade-offs between competing objectives
- Method could identify landscape configurations that would increase maize production while increasing landscape heterogeneity (= win-win situation)
- From the set of best alternatives, decision makers can discuss and select appropriate solutions according to their preferences