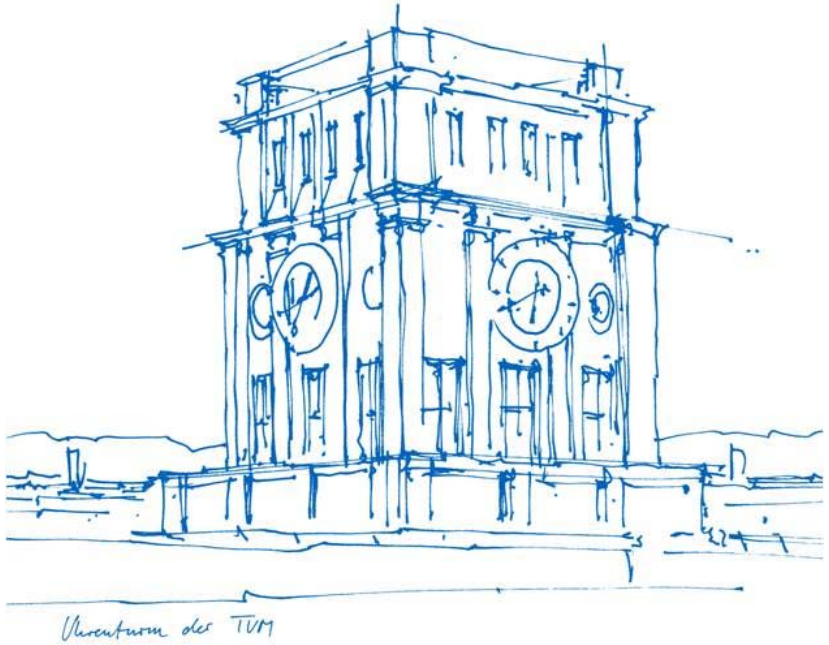
Fachgebiet für Waldinventur
und nachhaltige Nutzung

Influence of climate change on land use and multifunctionality

Sebastian Rössert

Institute of Forest Management
Center of Life and Food Sciences Weihenstephan
Technical University of Munich



Seminar "Silviculture, Ecosystem Dynamics and Forest Management"
09. January 2020
WZW Freising

Outline

- Introduction
- Methods and Material
- Results
- Discussion
- Conclusion and next steps
- References

Introduction

Why this title?

- One subtopic of the research project *BLIZ "look into the future"*
  → What could Bavaria look like at 2100?

- Extreme events like the hot and dry summer in 2018 will occur more frequently; prices fluctuate unpredictably
  → Land users have to take **risk** into account

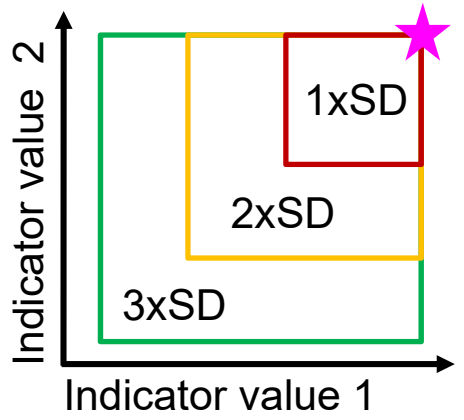
- Societal demands on agriculture and forestry increased recently
  → Land users (will) have **multiple objectives**

→ **Providing a tool to support decision making in land use planning**

Methods

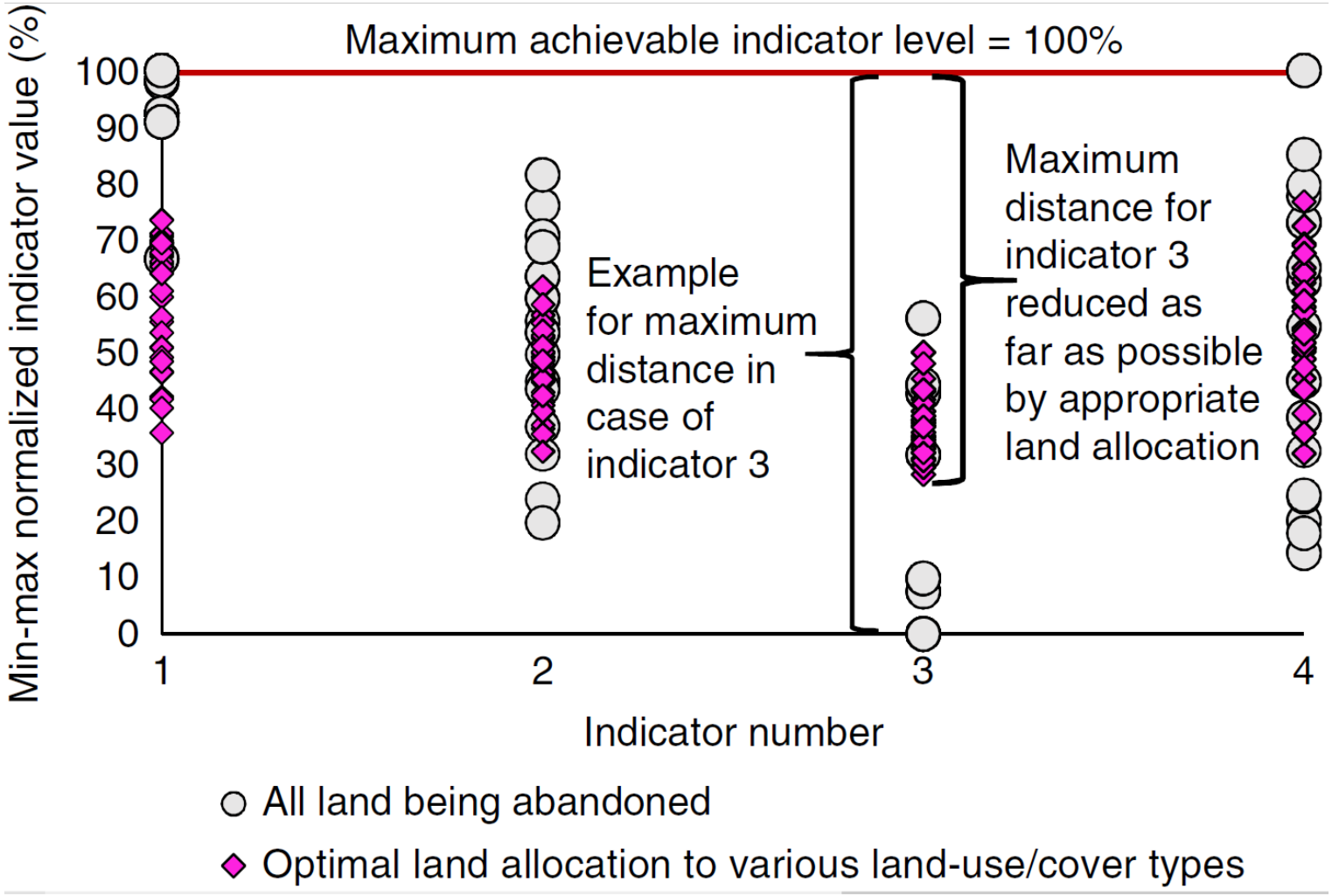
❖ **Portfolio Theory** (introduced by MARKOWITZ, 1952)
→ Well-established method in economic research
→ Considers risks and returns in asset allocations and potential benefits of diversification (cf. MATTHIES et al., 2019)

❖ **Robust Optimization** (cf. BEN-TAL et al., 2009)
→ Multidimensional uncertainty spaces
→ Best-case and worst-case scenarios as corners
→ Standard Deviation (SD) as uncertainty factor



❖ **Normalized Indicators** (cf. Knoke et al., 2014)
→ Relative position of each land-use option in the achievable range
→ Lowest value ≙ 0 %; highest value ≙ 100 %
→ Formula: $P_i = \frac{R_i - R_{min}}{R_{max} - R_{min}} * 100$ with P ≙ normalized value
R ≙ original values

Methods



KNOKE et al., 2016

Material

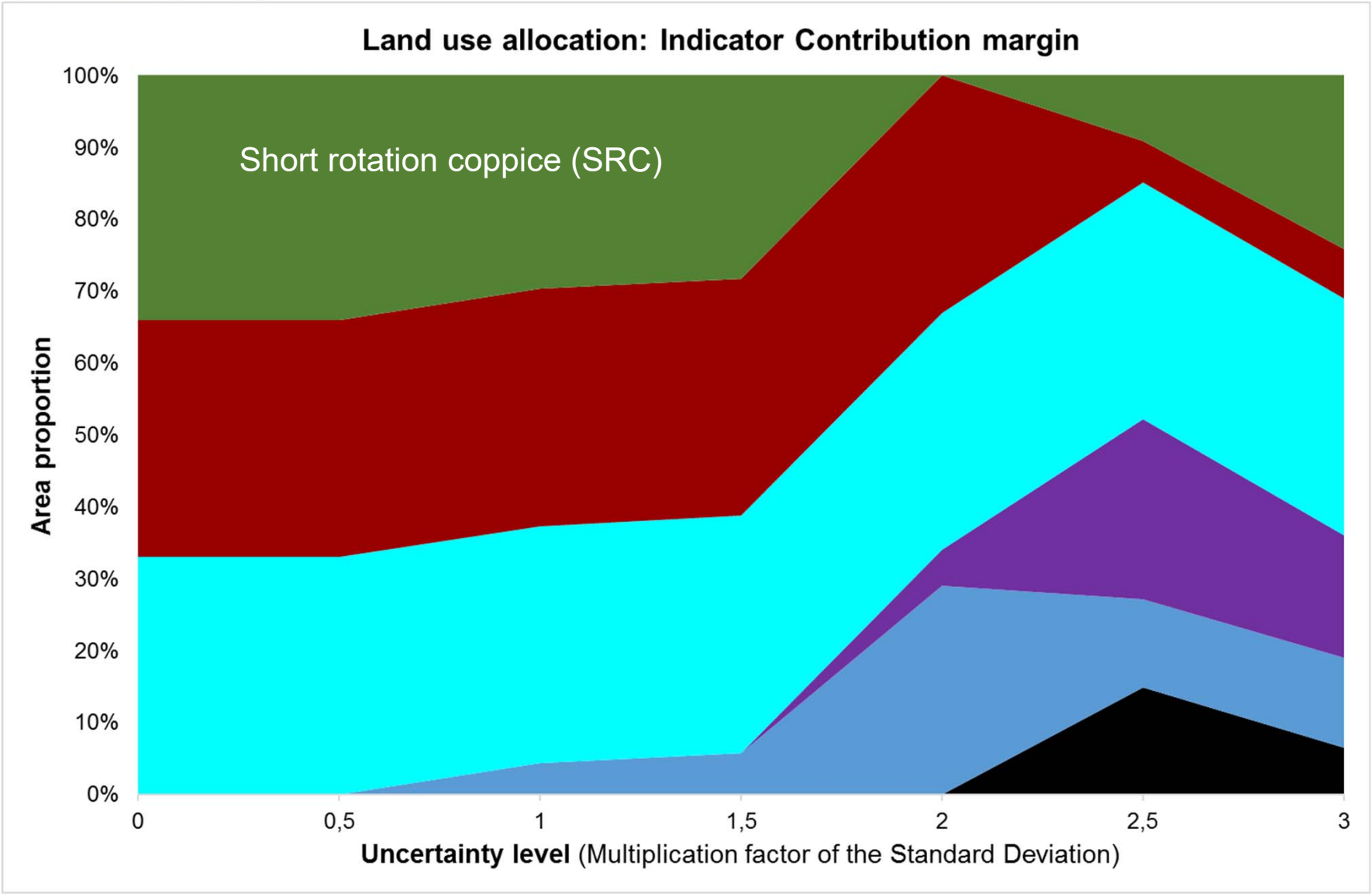
- Economic data for the administrative district Pfaffenhofen a. d. Ilm
  → Socioeconomic Indicator **Contribution margin** (CM) [€*ha^{-1}*yr^{-1}]
  (prices, costs and yields from HAUK (2015))

- Ecological Indicator **Carbon input** into the soil [t*ha^{-1}*yr^{-1}]
  (calculations based on the yield after WIESMEIER et al. (2014) and BERHONGARAY et al. (2016))

- Ecological Indicator **N fertilizer** applied to the crops [kg*ha^{-1}*yr^{-1}] ***less is better***
  (values from good practice according to SEIFFERT (2014))

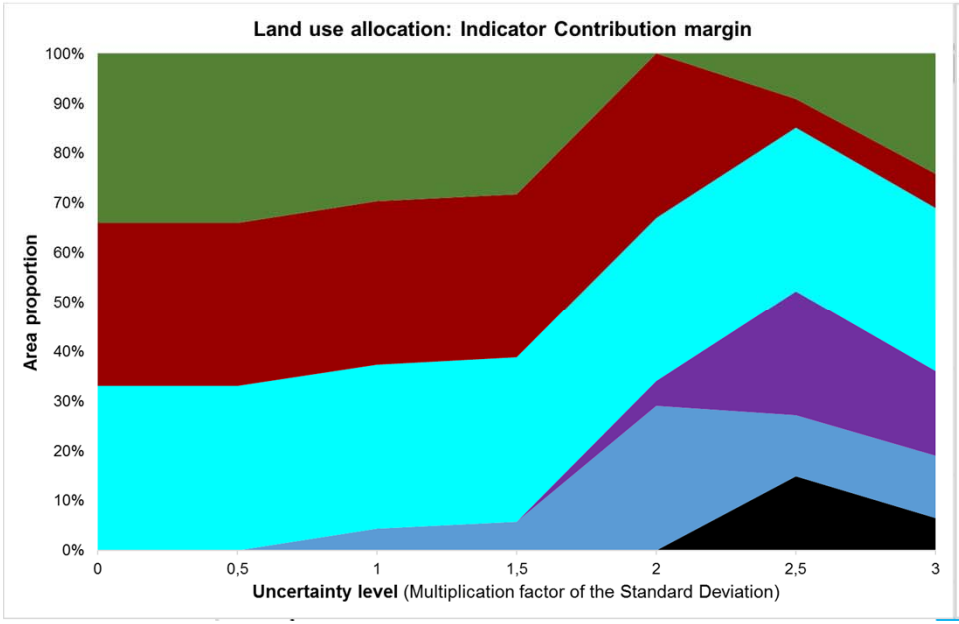
→ **Mean** and **Standard Deviation** for each indicator and land use option

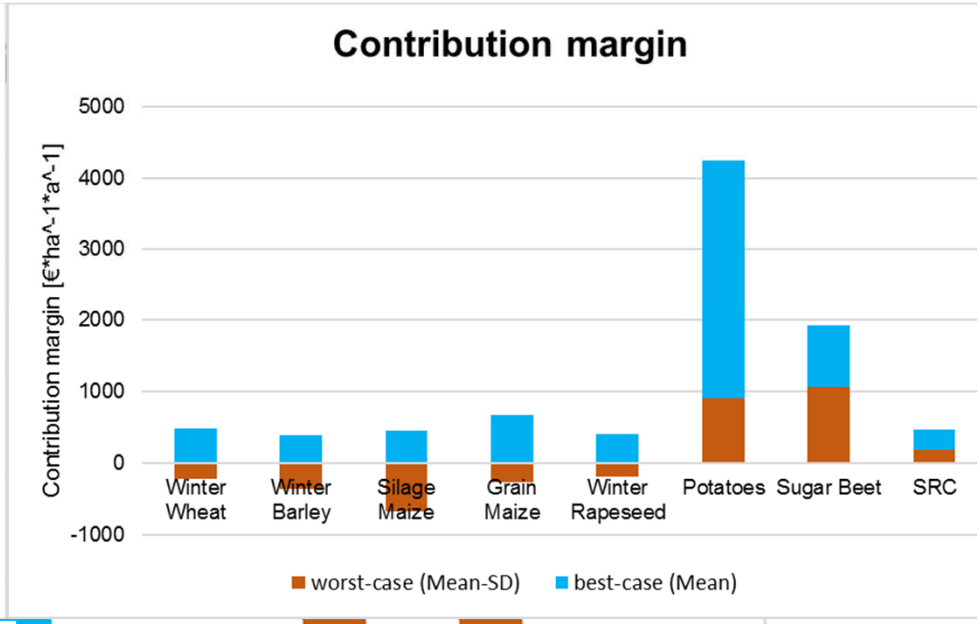
- Restrictions of the area proportion for each crop due to phytosanitary reasons and good practice according to SEIFFERT (2014)

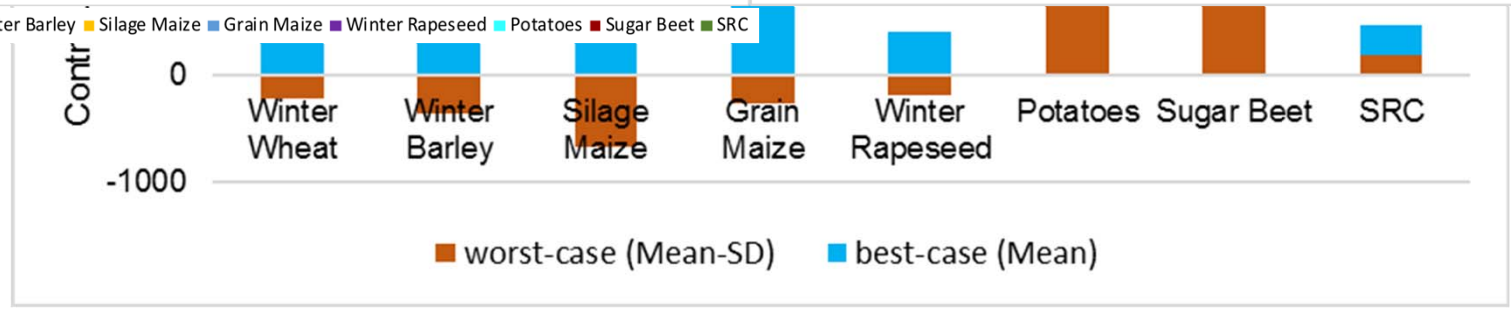

Land use allocation: Indicator Contribution margin
Short rotation coppice (SRC)
Area proportion
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
0,5
1
1,5
2
2,5
3
Uncertainty level (Multiplication factor of the Standard Deviation)
Winter Wheat
Winter Barley
Silage Maize
Grain Maize
Winter Rapeseed
Potatoes
Sugar Beet
SRC

Results

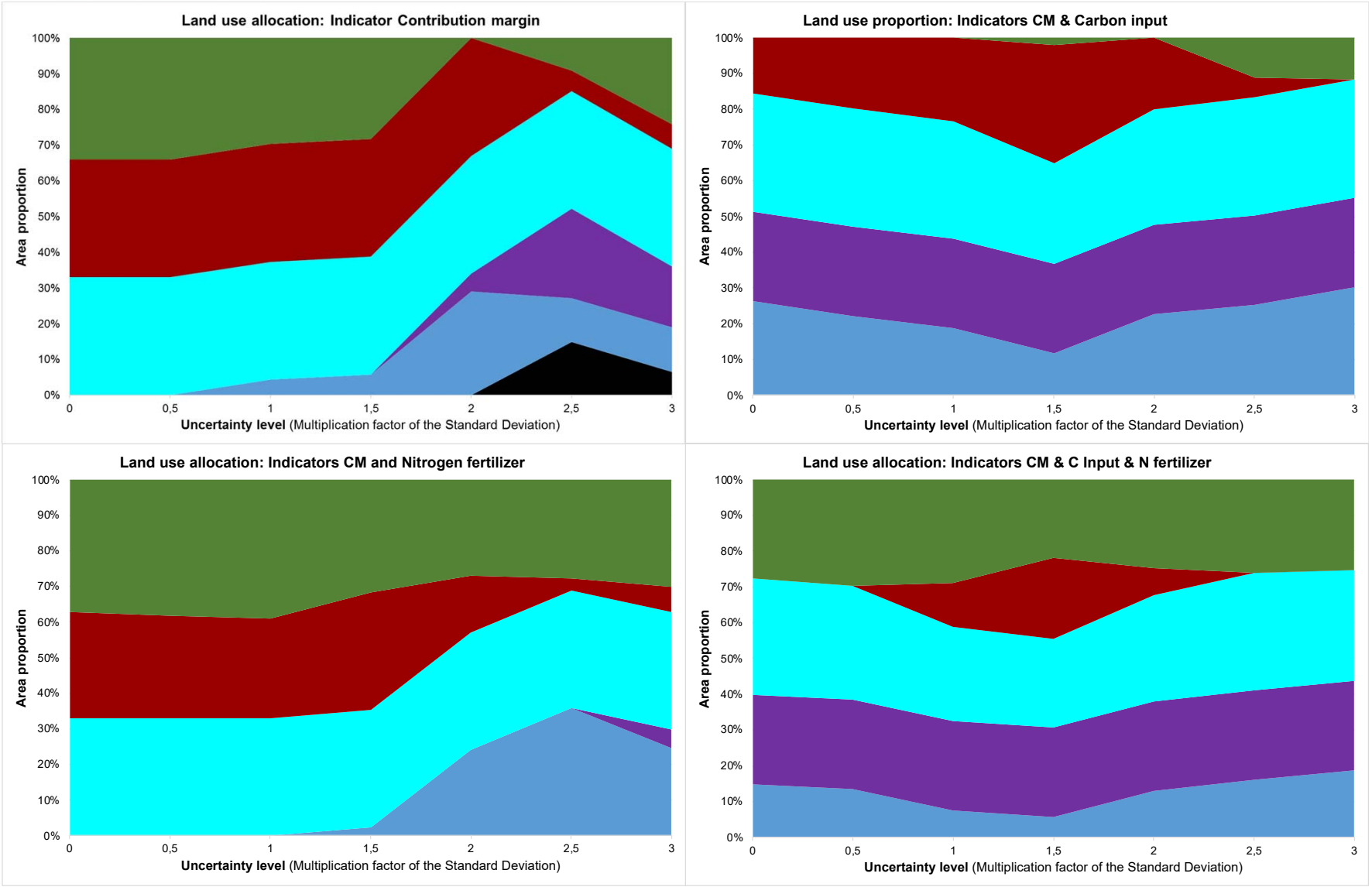
❖ The higher the accepted risk level, the less the portfolio diversity







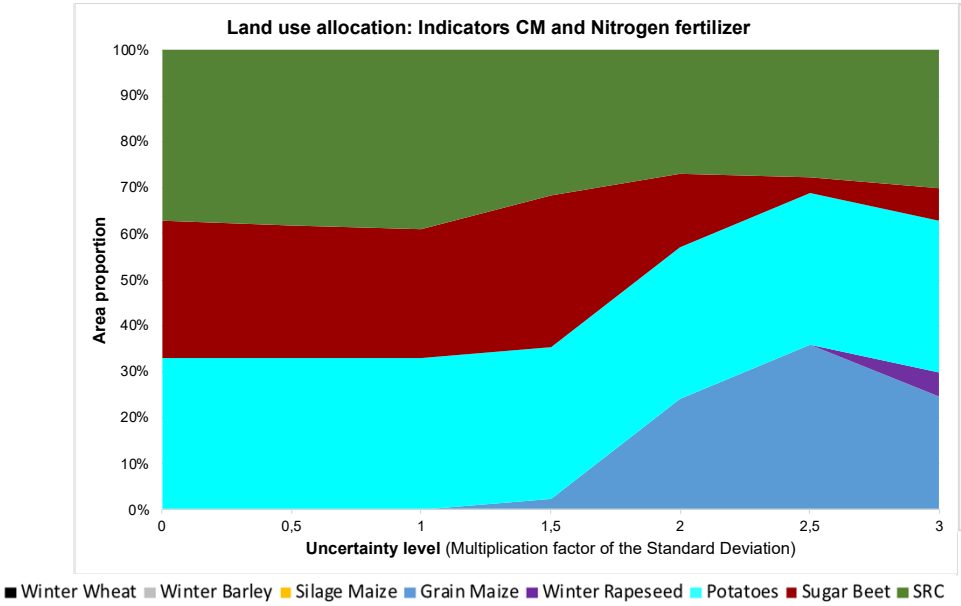
SD factor = 1

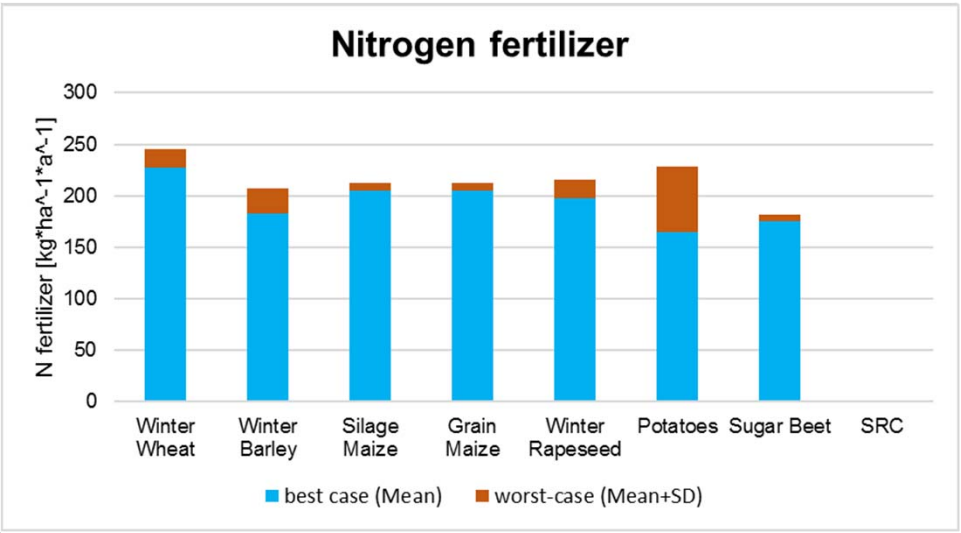

Land use allocation: Indicator Contribution margin
Land use proportion: Indicators CM & Carbon input
Land use allocation: Indicators CM and Nitrogen fertilizer
Land use allocation: Indicators CM & C Input & N fertilizer
Area proportion
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
0,5
1
1,5
2
2,5
3
Uncertainty level (Multiplication factor of the Standard Deviation)
Winter Wheat
Winter Barley
Silage Maize
Grain Maize
Winter Rapeseed
Potatoes
Sugar Beet
SRC

Results

- Including the C Input causes more stable area proportions
  → Winter Rapeseed and Grain Maize also included at higher risk levels

- Including N fertilizer causes higher SRC proportions and excludes/lowers Winter Wheat and Winter Rapeseed

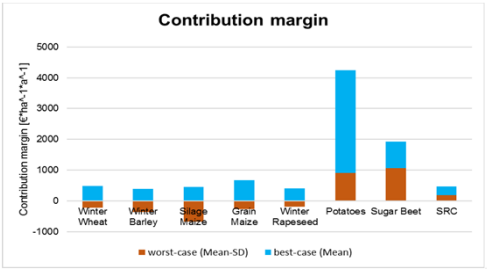


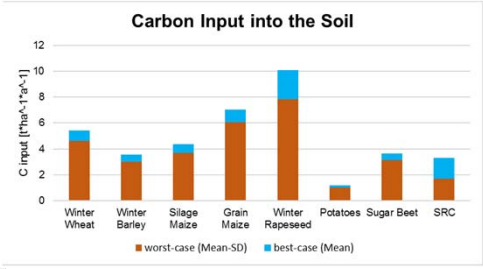


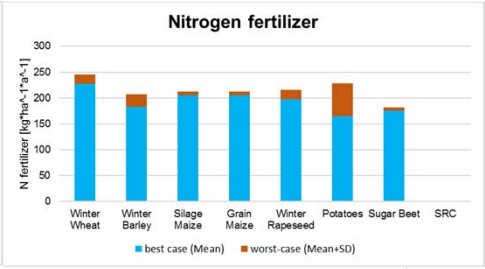
SD factor = 1

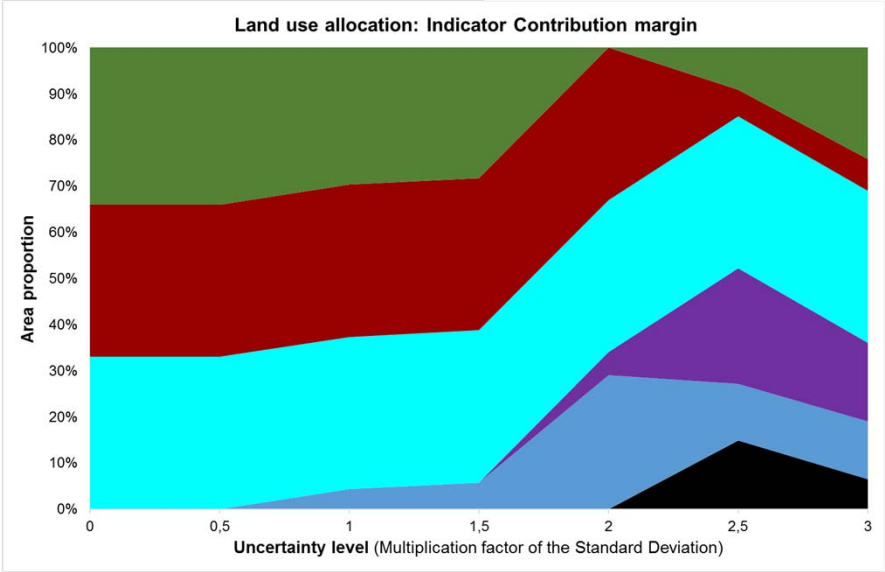
Results

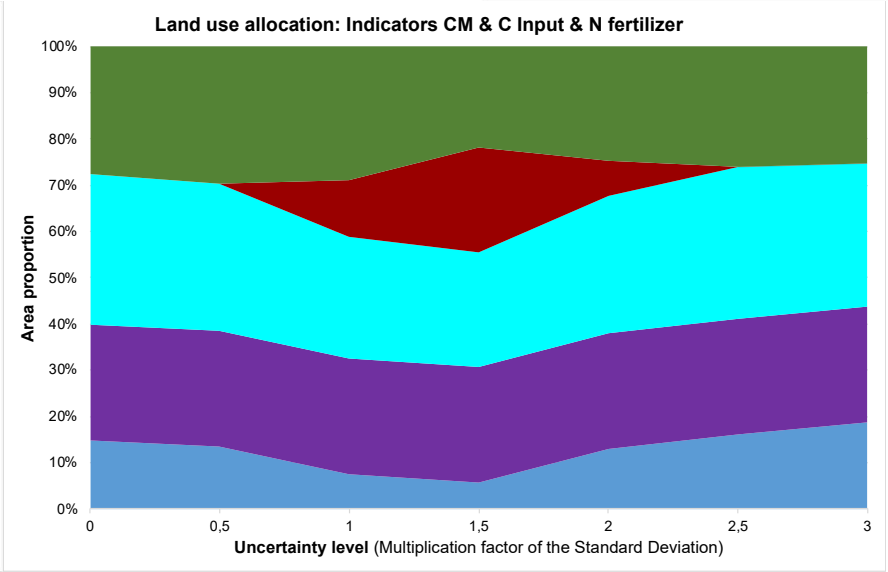
❖ Including both ecological indicators → stable portfolios over uncertainty levels









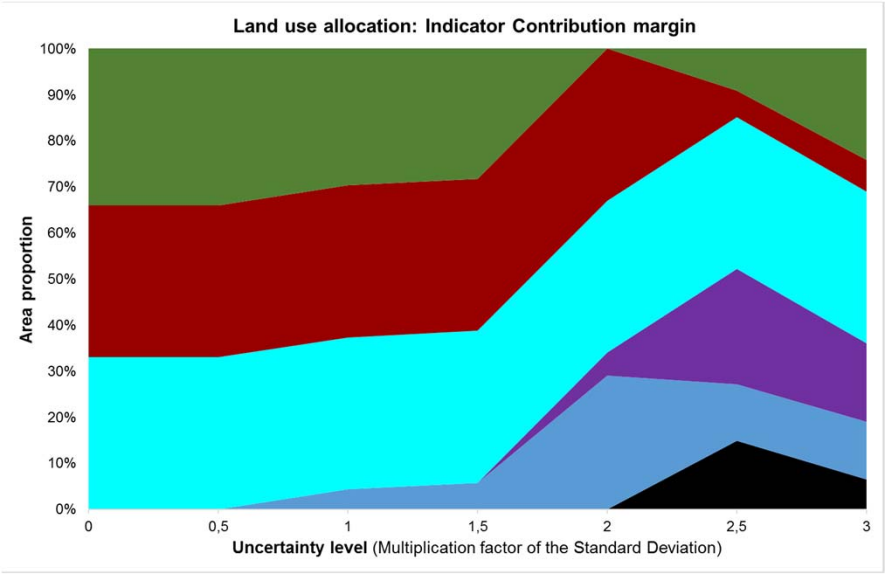


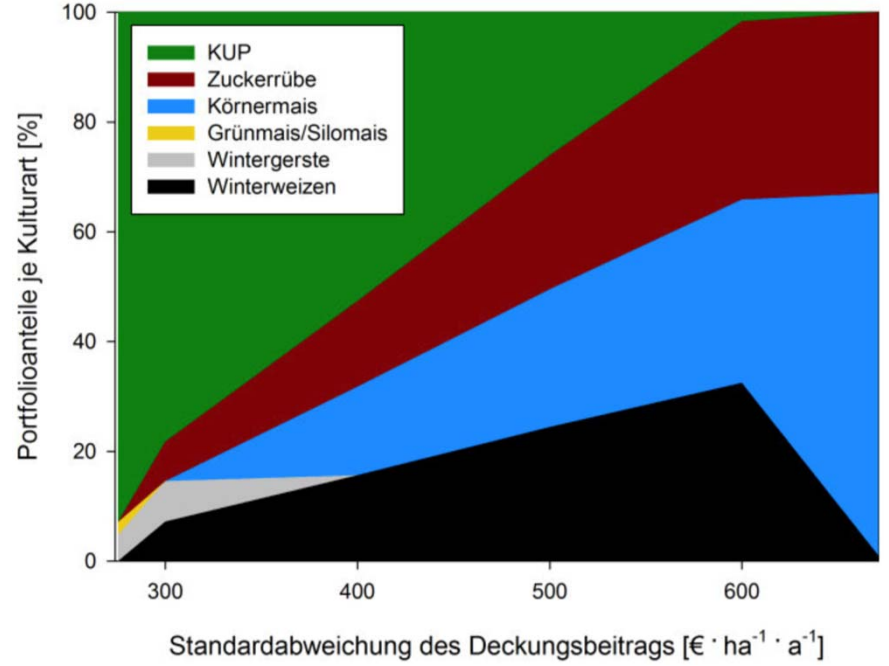
Winter Wheat Winter Barley Silage Maize Grain Maize Winter Rapeseed Potatoes Sugar Beet SRC

Discussion

- Robust model
- Less data demanding
- All types of indicators could be integrated
- Method leads to more diverse portfolios

- Stochastic model
- Covariances must be determined
- Extensive calculations e.g. Monte Carlo Simulations
- Higher SRC proportions (maybe not realistic)





Hauk (2015)

Discussion: Limitations

- ”Outdated” economical data from 2013 → prices, costs (, yield) changed
- Legal situation changed → deployable quantity of N fertilizer restricted
- Annual crops and short rotation coppice (perennial) treated equally
  → loss of flexibility; can not be part of a classical crop rotation system
- Site conditions not considered → Carbon related indicators partially sensitive to e.g. soil parameters

Conclusion

- The model produces plausible results
- It can handle different types of indicators → solutions for multiple objectives
- Risk is integrated in several levels → different risk tolerance of land users
- The optimistic scenarios are conservative estimations (could be exceeded)

Conclusion: Next Steps

- ❖ Updating the data basis (prices, costs, yields)
- ❖ Enlarging the data set to Bavaria
  and splitting into areas with similar soil and climate *(“Boden-Klima-Räume”)*
- ❖ Including another innovative land-use option (e.g. Alley cropping)
- ❖ Calculations with modelled yield and plant growth under climate change scenarios provided by project members (LPJ-Guess simulations)

→ Taking a “*look into the future*” at Bavaria from now until 2100

References

- BEN-TAL, A., EL GHAOUI, L., NEMIROVSKI, A. (2009): Robust Optimization. Princeton University Press
- BERHONGARAY, G. et al. (2016): Soil carbon and belowground carbon balance of a short-rotation coppice: assessments from three different approaches. GCB Bioenergy (2017) 9, 299-313, doi: 10.1111 / gcbb.12369
- HAUK, S. (2015): Analyse und ökonomische Optimierung von Kurzumtriebsplantagen (Dissertation), Technische Universität München
- KNOKE, T. et al. (2014): Afforestation or intense pasturing improve the ecological and economic value of abandoned tropical farmland. Nat. Commun. 5:5612
- KNOKE, T. et al. (2016): Compositional diversity of rehabilitated tropical lands supports multiple ecosystem services and buffers uncertainties. Nat. Commun. 7:11877
- MATTHIES, B. et al. (2019): Utilising portfolio theory in environmental research – New perspectives and considerations. Journal of Environmental Management 231 (2019) 926-939
- SEIFFERT, M. (2014): Landwirtschaftlicher Pflanzenbau. Grundlagen des Acker und Pflanzenbaus. 13., völlig neu bearb. u. erw. Aufl. München: BLV Buchverlag (Die Landwirtschaft).
- WIESMEIER, M. et al. (2014): Estimation of past and recent carbon input by crops into agricultural soils of southeast Germany. European Journal of Agronomy 61 (2014) 10-23