Optimizing land-use portfolios on farm-level: Case study for a South African forestry and agricultural enterprise

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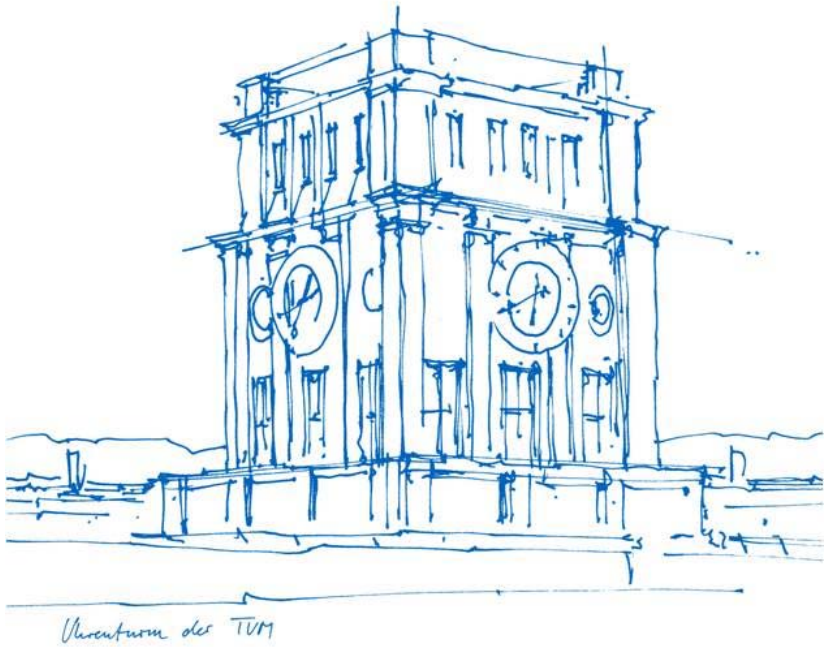


Research objectives

1) Defining **land-use types** (LUT), which are suitable for the specific sites and typical for the enterprise

2) Financial assessment of the chosen LUTs

3) Recommendations for an **optimized land-use composition f**or several levels of **risk acceptance** based on **stochastic and robust** optimization

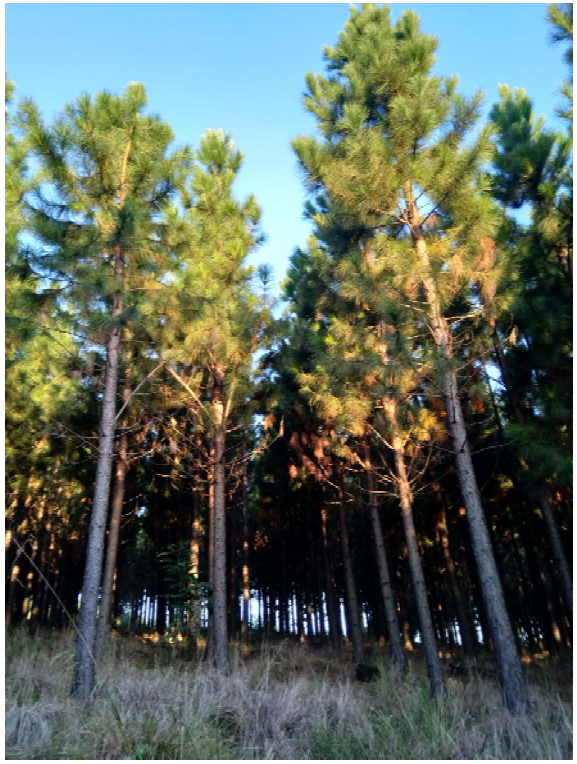
4) Multi-criteria evaluation of the LUT

5) Comparing pure financial and multi-criteria optimized land-use portfolios under the **assumption of substitutability** and **non-substitutability**

1) Definition of appropriate land-use types

Pinus patula ***Ppat***

Pinus elliottii ***Pell***



Eucaluytus grandis ***Egra***

Eucalyptus grandis x urophylla ***Egxu***

Persea americana
cultivar Hass;
Irrigated (**Hass40**) and dryland management (**Hass40_dry**)

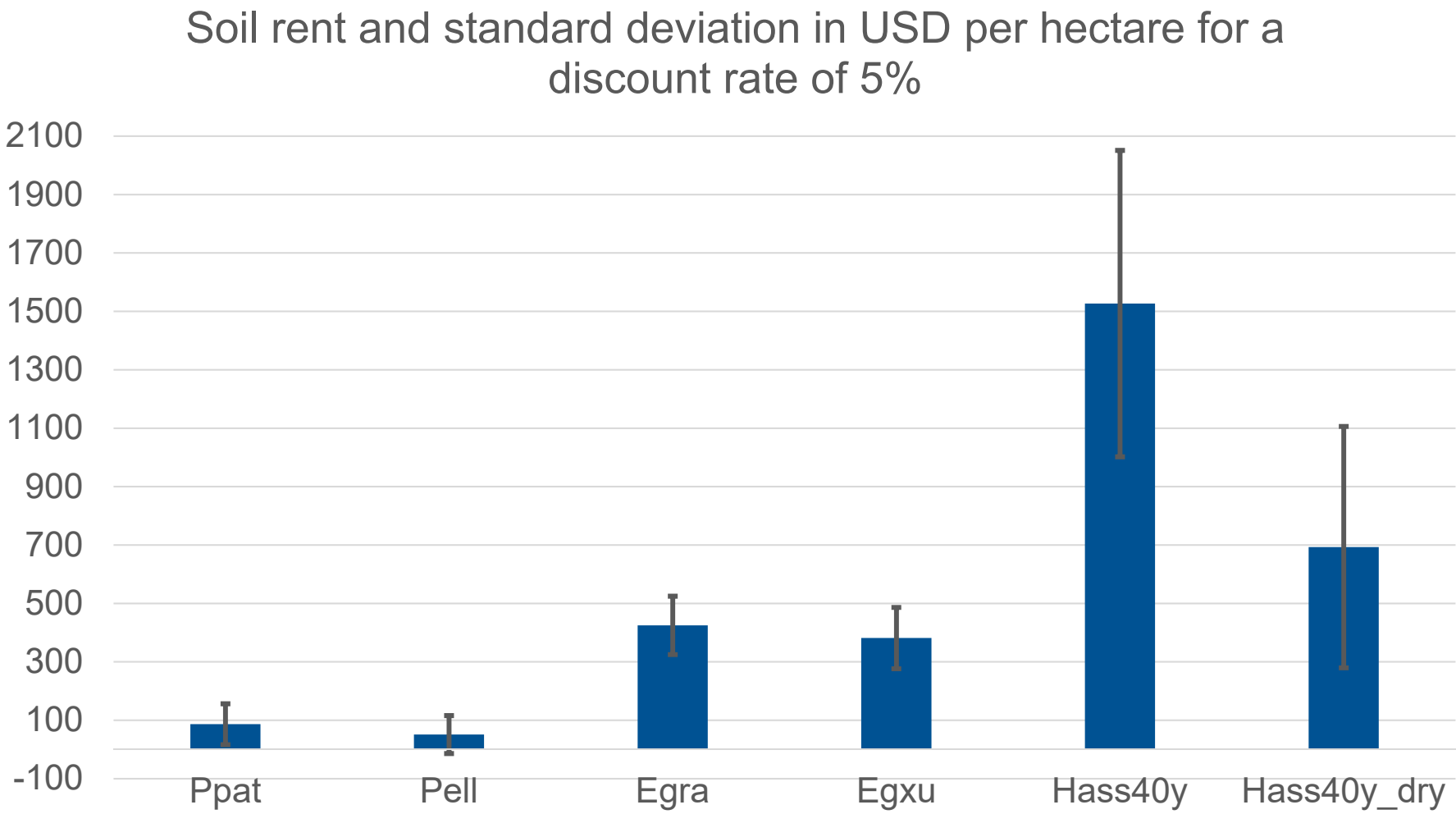
2) Financial assessment

a) **Financial performance** of every LUT: soil rent

b) **Financial risk** of every LUT: standard deviation

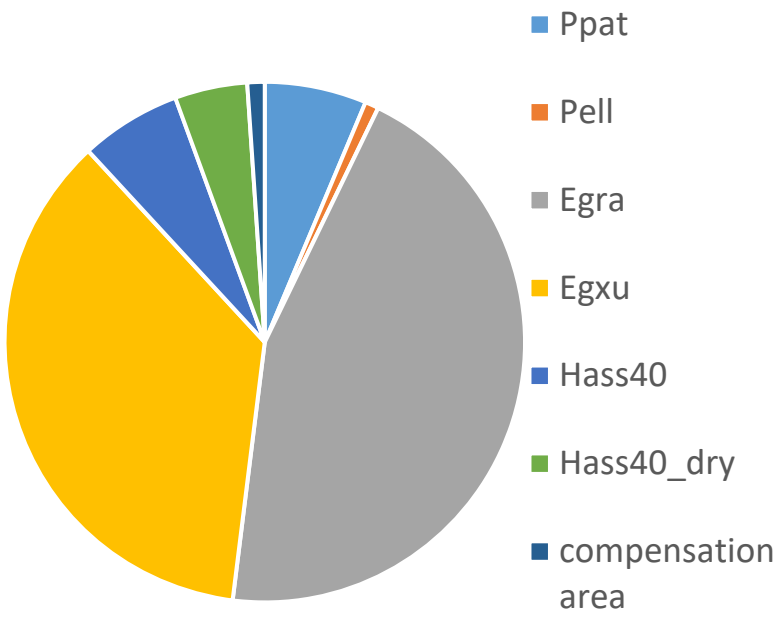
c) **Correlations** (just necessary for the stochastic approach)

2) Results: Financial performance and risk



3) Recommendations for an optimized Portfolio

Portfolio theory:
Investments with different riks are combined such that the expected return is maximized for a given level of risk. The risk is defined as standard deviation of the mean return of the single asset. (Harry Markowitz,1952)



3) Recommendations for an optimized Portfolio

Stochastic optimization following Markowitz (1952,2010)

Robust optimization following Messerer et al. (2017) and Knoke et al. (2015)

Objective Function of both approaches:
Maximizing the expected returns of the land-use portfolio,
but different constraints and theorethical background

$$\boldsymbol{max\ E(Y_L) = \sum_{i \in L} E(y_i) \times f_i}$$

$$\boldsymbol{y_i = soil\ rent\ of\ option\ i}$$
$$\boldsymbol{f_i = share\ of\ option\ i}$$

Markowitz (1952): *J Finance* 7 (1):77–91; Markowitz (2010): *Annu Rev Financ Econ* 2 (1): 1–23.
Messerer et al. (2017): *Ann For Sci* 74 (2): 45; Knoke et al. (2015): *Ecol Econ* 120: 250–259

Comparing the optimization approaches

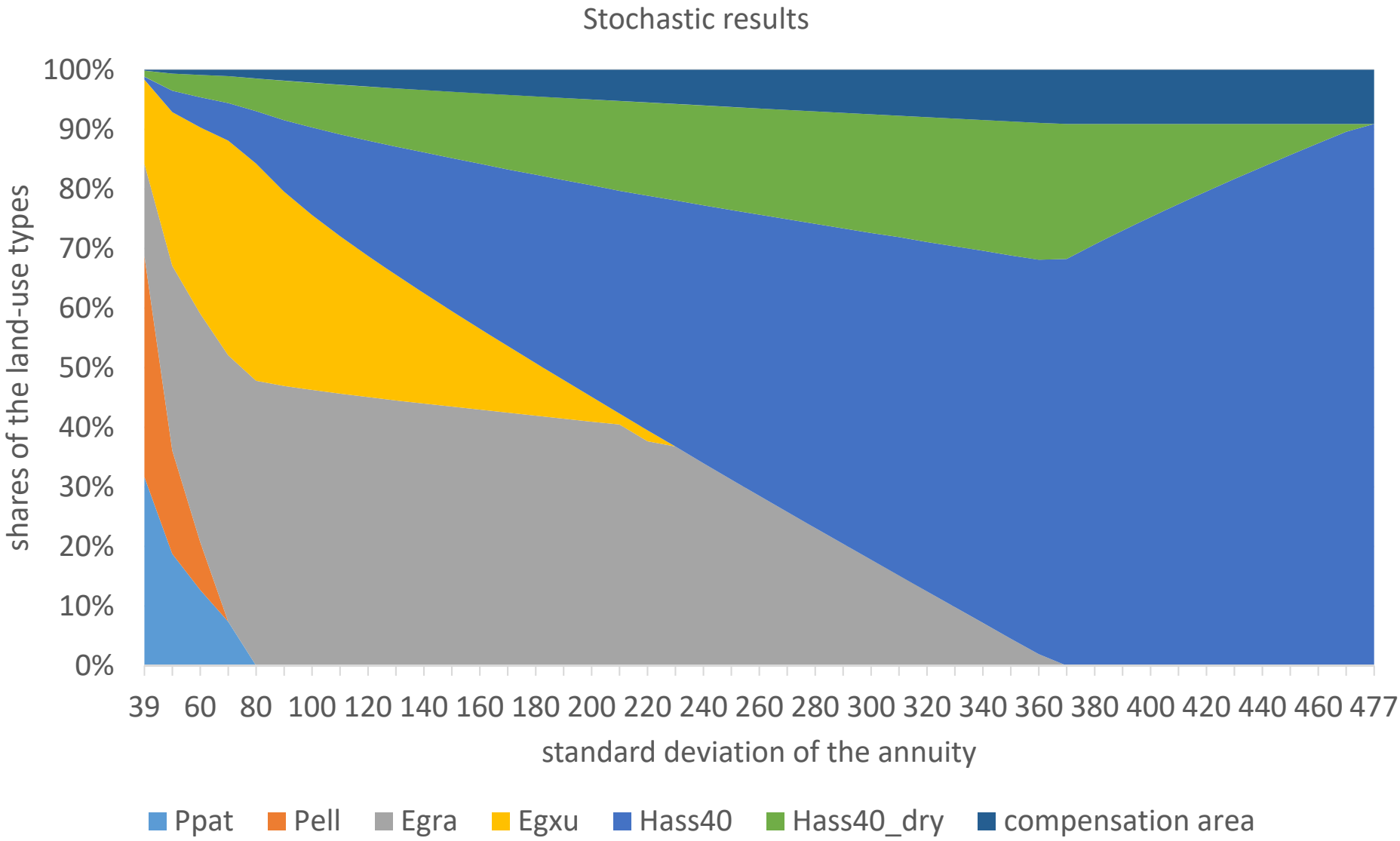
Stochastic Optimization

- **Non-linear** programming
- **High amount** of input data necessary
- required: **normally distributed** financial returns
- Even just small changes in the input data can cause **strong reactions on the results**, sometimes **extrem results**
- Uncertainty is included as **probability distribution**

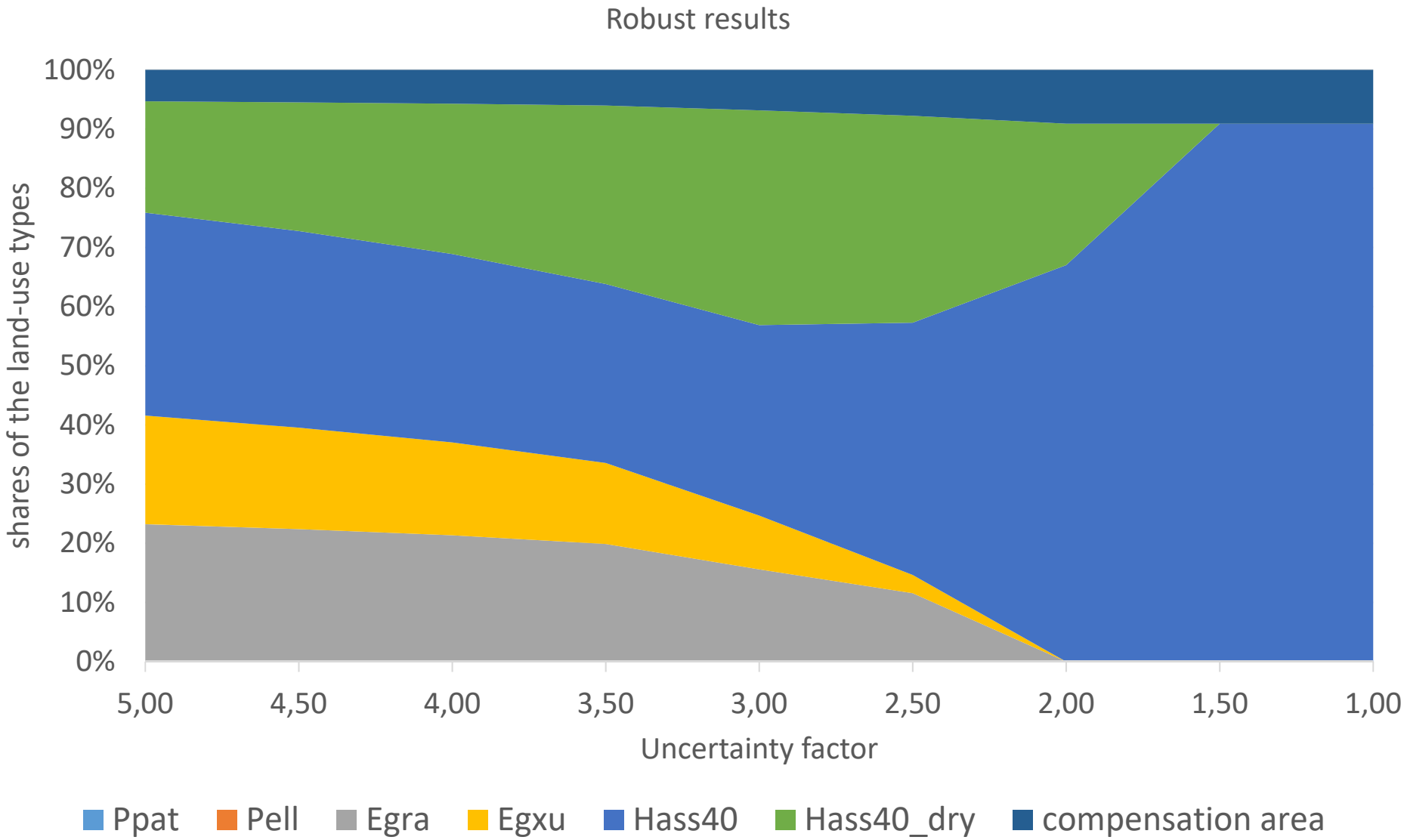
Robust Optimization

- **Linear** programming
- Works with **scarce data**
- No information about result distribution required as we use uncertainty boxes
- **More robust** results
- Considering **large uncertainty boxes** (= borders of the parameter fluctuations), therefore including higher risks than at stochastic optimization

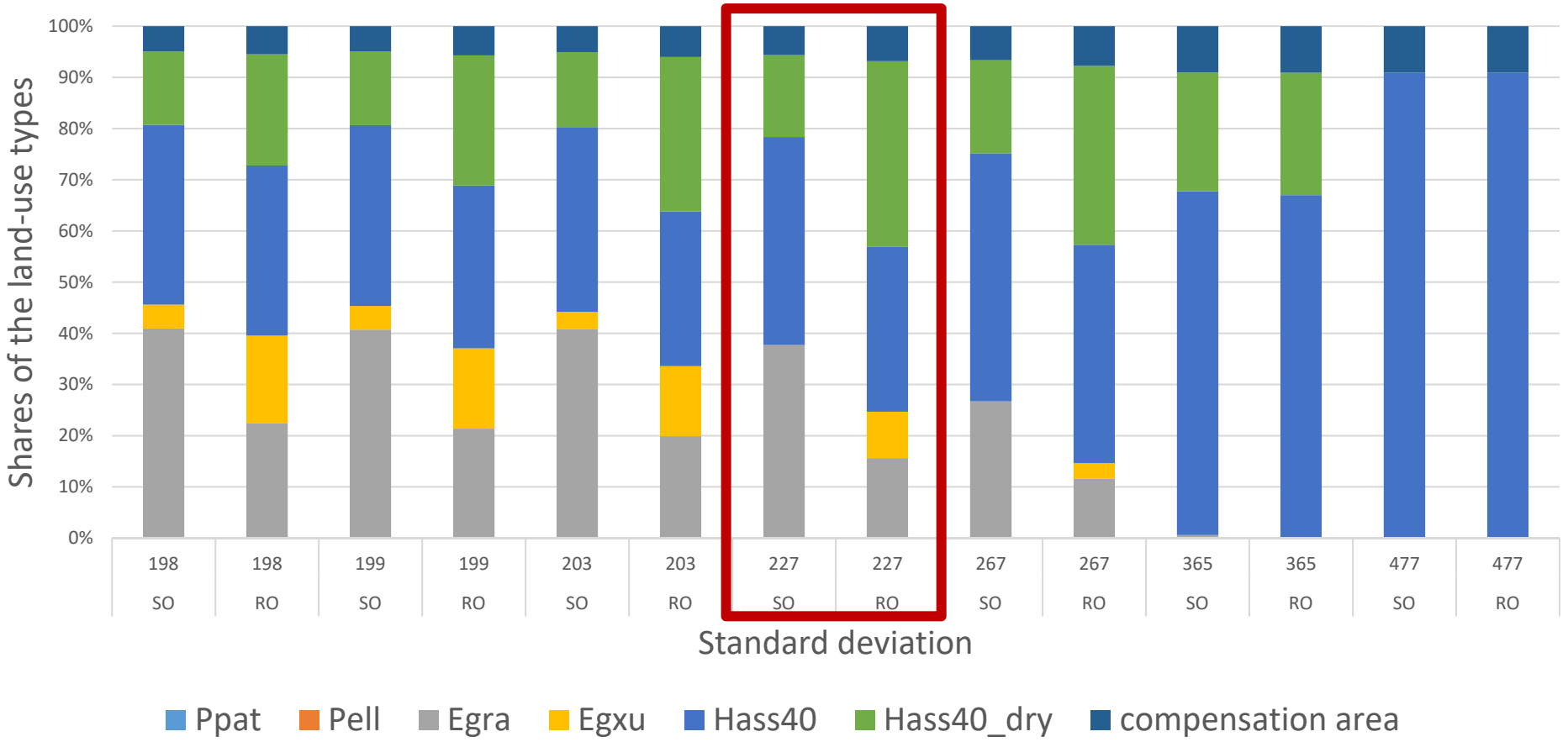
3) Recommendations for an optimized portfolio



3) Recommendations for an optimized portfolio

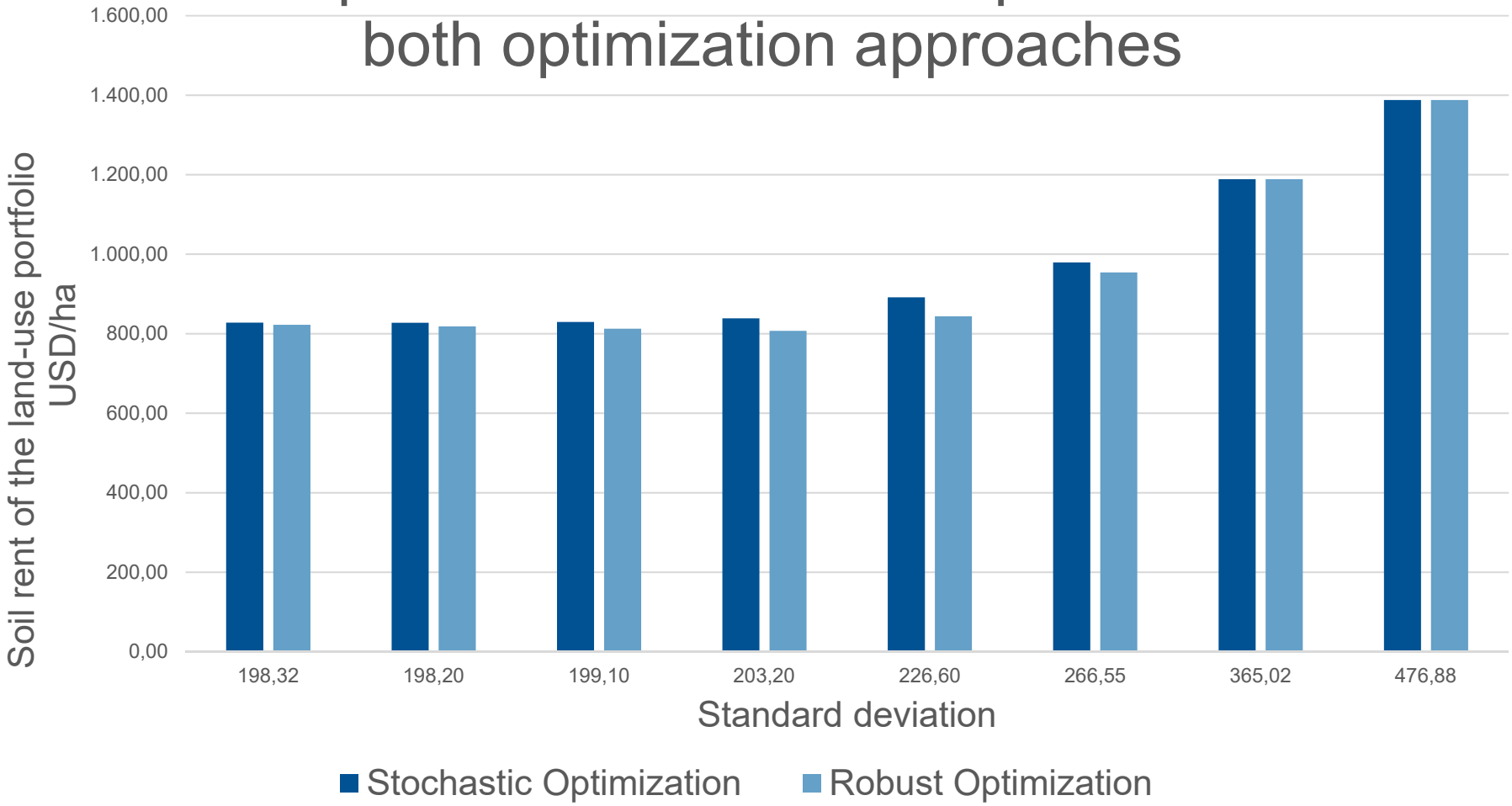


Comparison of portfolios with identical Standard Deviation for both aproaches



Comparison of the respective land-use shares for the stochastic (SO) and robust (RO) optimized Portfolios for selected standard deviations

Comparison of the land-use portfolios for both optimization approaches



Comparison of the annuities in USD/ha for the stochastic (SO) and the robust (RO) optimized land-use Portfolio FOR_AVO_5%

3) Recommendations for an optimized portfolio

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4) Multi-criteria evaluation

Socio-economic indicators

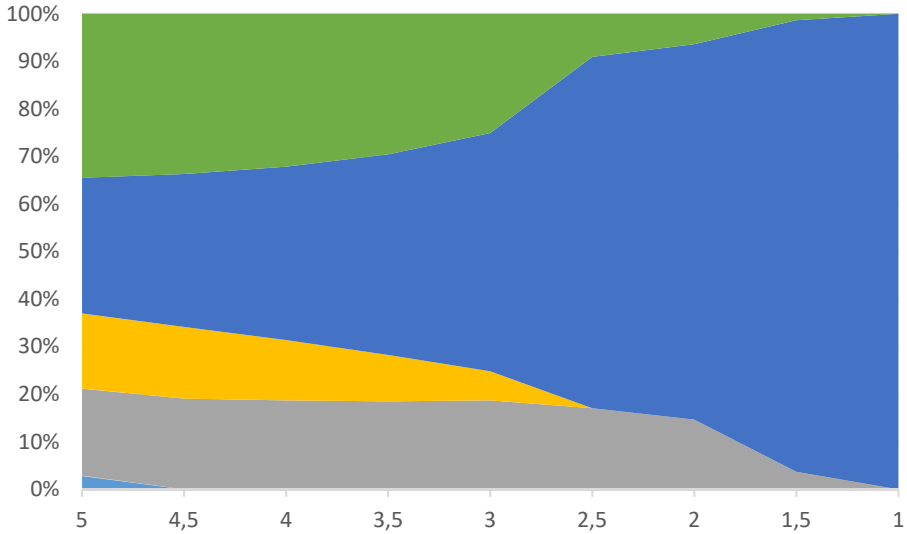
- Financial return: Net Present Value for 3 different discount rates
- Access to money: Payback periods for 3 different discount rates

Ecological indicators

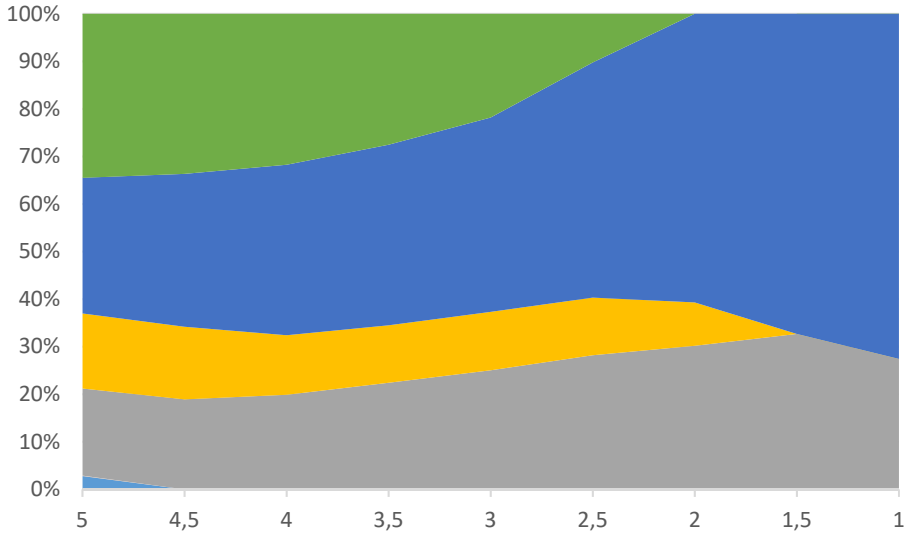
- Carbon sequestration: above-ground biomass
- Life Cycle Assessment: impact of transport
- Fertilizer application
- ….

Substitutability: Instead of optimizing the performance of the worst scenario (highest distance to best case), we optimize the overall **sum of all scenario performances**. Therefore, the performances of different indicators can compensate for each other.

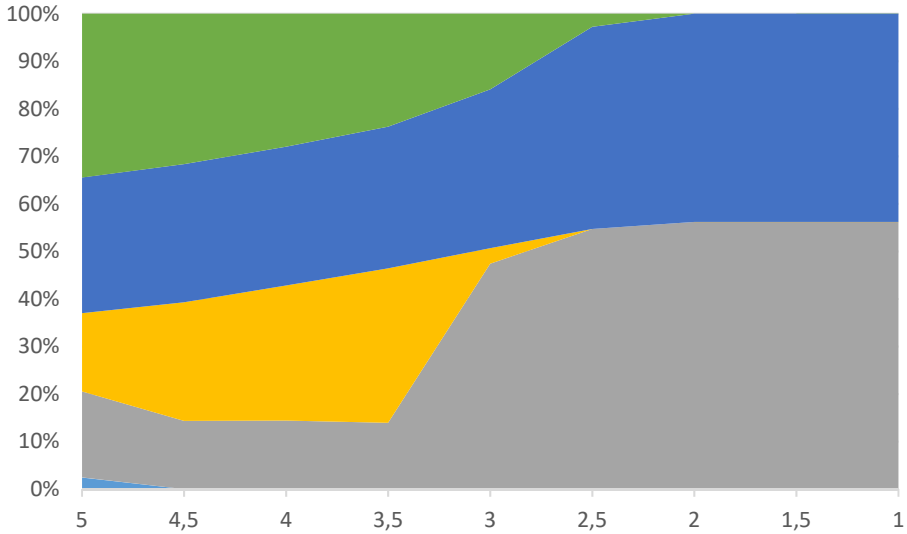
Indicator: NPV



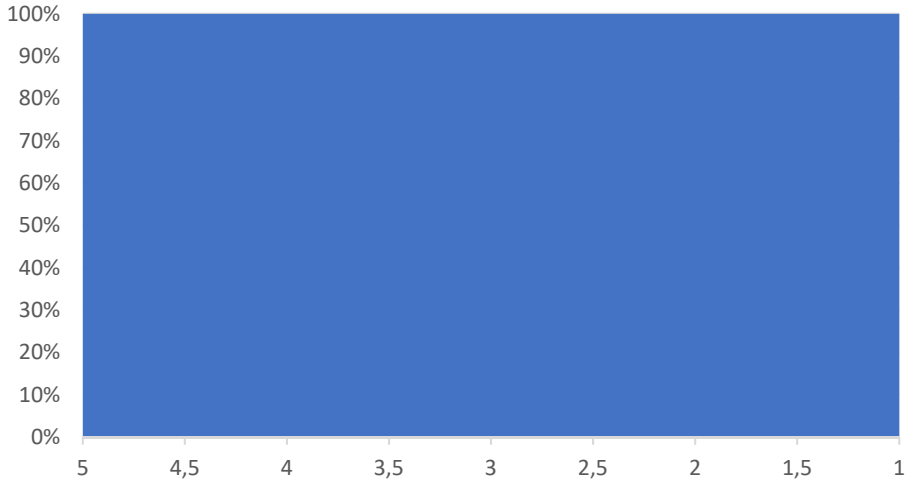
Indicators: NPV,PP



Indicators: NPV, PP, Carbon sequestration



Aggregated approach
Indicators: NPV, PP, Carbon sequestration



Ppat Pell Egra Egxu Hass Hass_dry

Thank you! Baie Dankie!

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