Quantifying the financial value of seasonal forecasts for rainfed agriculture using discrete stochastic programming

Samuel Elias Kayamo, Christian Troost, Livia Rasche, Thomas Berger

University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

Introduction

- Seasonal rainfall forecasts (SRF) have the potential to improve productivity and profitability in rainfed agriculture by enabling farmers to reduce losses during poor years and increase profits during favourable years[1,2].
- However, smallholder farmers in developing countries rarely use SRF for crucial agricultural decisions
- This may be due to lack of trust, inadequate dissemination, and uncertain and unclear economic benefits of SRF[2,3].

Research question

What is the value of Seasonal Rainfall Forecasts (SRFs) for decision-making in rainfed agricultural production for smallholders in the central Rift Valley of Ethiopia?

Study area

- The study was conducted in Bilate district in the Central and Southern Rift Valley of Ethiopia, Sidama region (Fig. 1).
- Main production in the area is cereal crops such as tef, maize, sorghum, and barley are the major crops alongside pulse crops like common beans

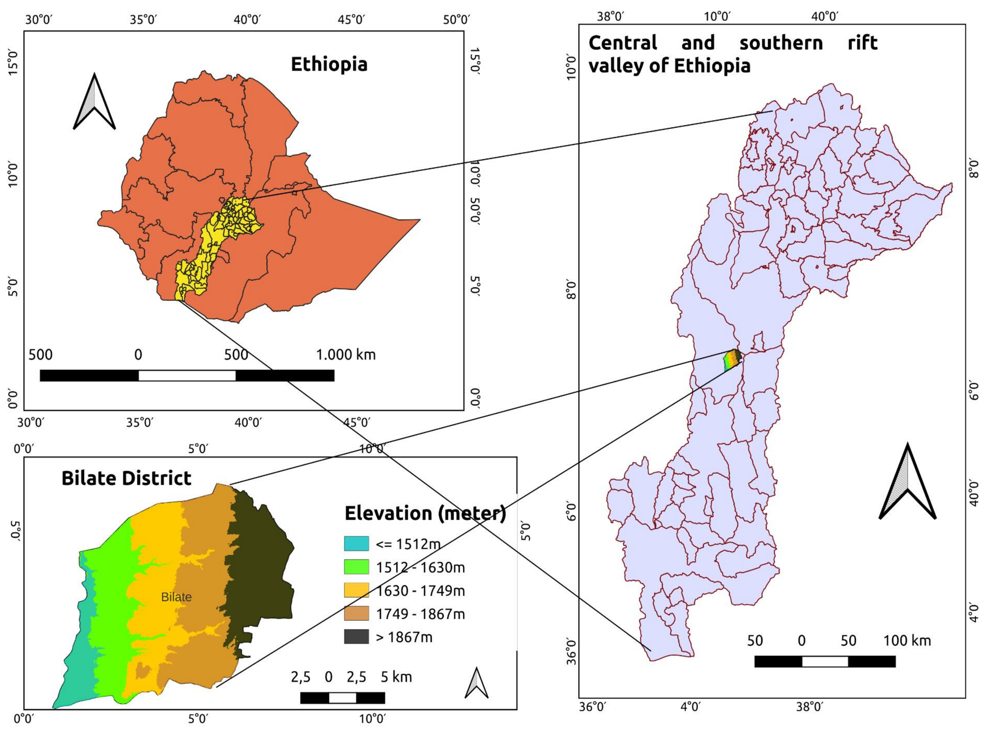

Fig. 1. Map of the study area[9]

- The rainfall follows a bimodal pattern in Bilate: the short rainy season (Belg) occurs from March to May, with rainfall averaging between 180-360 mm.
- The long rainy season (Meher) takes place from June to September, with rainfall ranging from 420-680 mm[4].

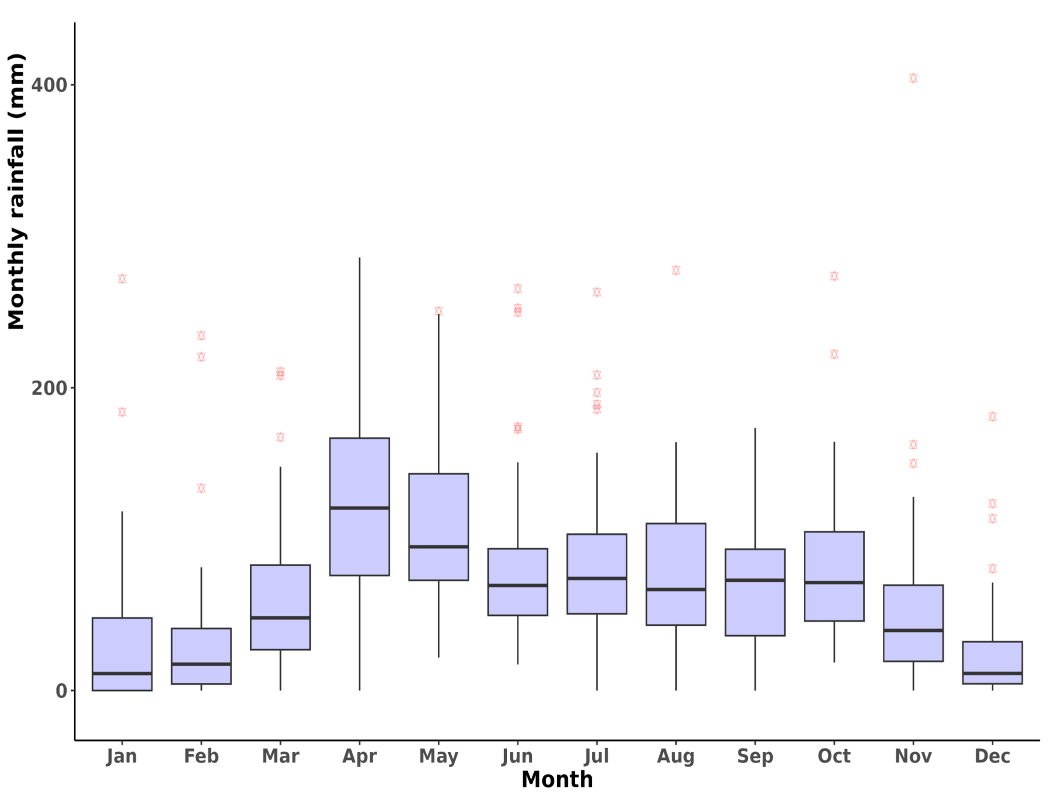

Fig. 2. Monthly rainfall distribution for the period 1980–2022 at Bilate station in the South-central Rift Valley.

- Seasonal forecasts are available for Belg and Meher, expected tercile (above, around, or below average) of total rainfall in the upcoming season.
- These forecasts are provided about one month before the season starts.

Methods

We used value of information (VoI) analysis:

- To quantify the financial benefits of SRF with different levels of forecast accuracy.
- *Expected value of information (EVI)* is the difference in optimal expected monetary value (EMV) with and without SRF.

$$EVI_{SF} = EMV_{SF} - EMV_{noSF}$$

To calculate the best possible production outcome (EMV):

- Implemented *discrete stochastic programming model (DSP)* in MPMAS[5,6] to model the sequence and timing of decisions throughout the season.
- The modelled decision sequence is based on interviews with farmers and experts.

To represent weather uncertainty:

- We generated 2400 daily weather series by resampling data from the Ethiopian Meteorology Institute (EMI).
- We used tercile classification to determine the state of nature for each season and used the resampled data to simulate crop yield using AquaCrop[7].

Results

Gross margin analysis

- As an example, figure 4 displays gross margins for various agronomic management strategies for maize in the Bilate district, based on simulated crop yields.
- According to simulations, late sowing with tied-ridge yields a higher gross margin than early sowing
- Expected gross-margins increase with fertilization, but also variance (risk) increases

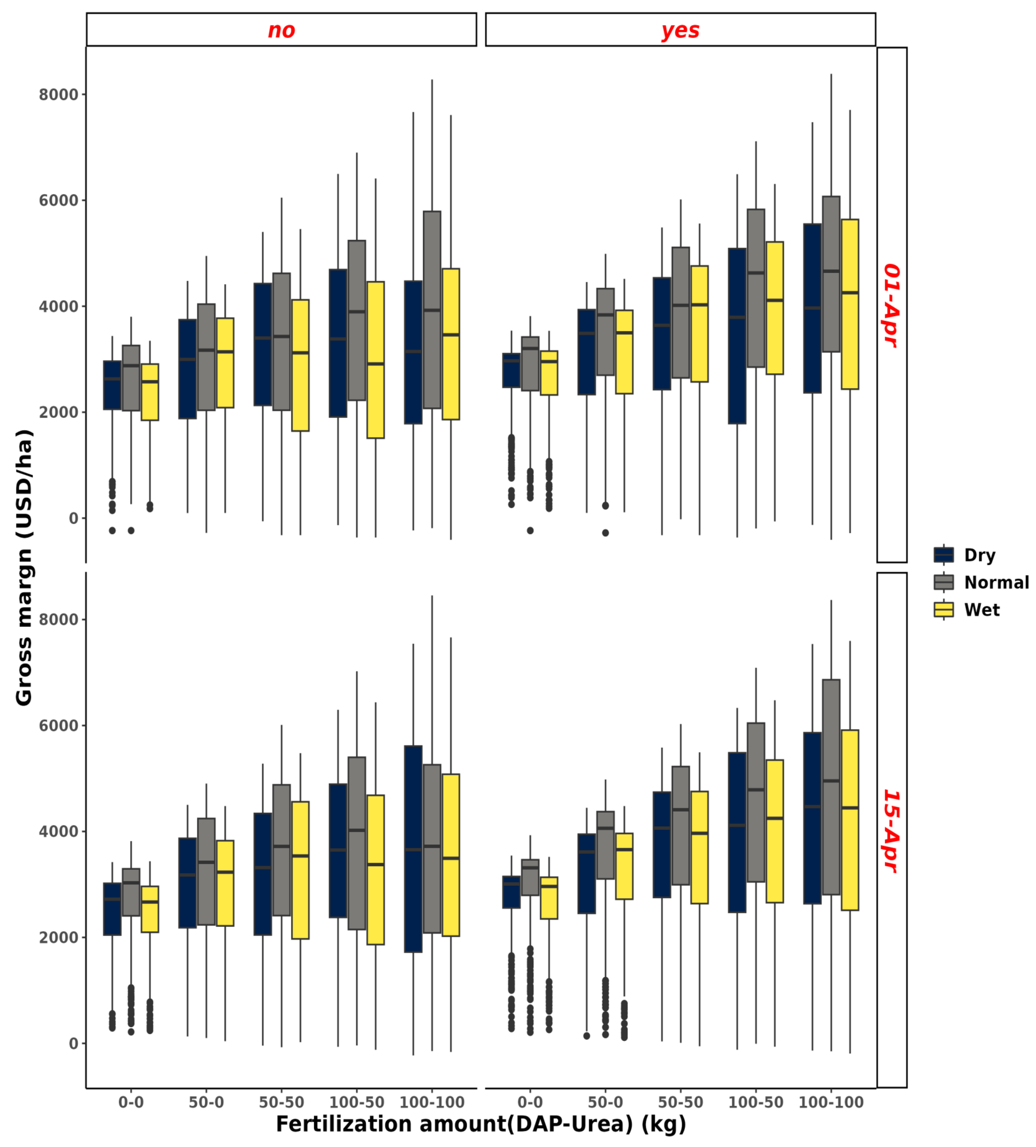

Fig. 4. Gross margin distribution across different management options of maize crop

Optimal cropping strategies

- In the without-forecast scenario, relay cropping (maize followed by beans) is frequently selected with full fertilization and tied-ridge practices regardless of the observed unfolding weather.
- In the with-forecast scenario, for dry forecast, maize is primarily selected and sown in the second week of April, using 50 DAP, without urea, and with tied-ridge practices (no beans).
- In the with-forecast scenario, for both normal and dry forecast, relay cropping is chosen and sown in the second week of March, using 50 DAP, 50 Urea, and tied-ridge practices.

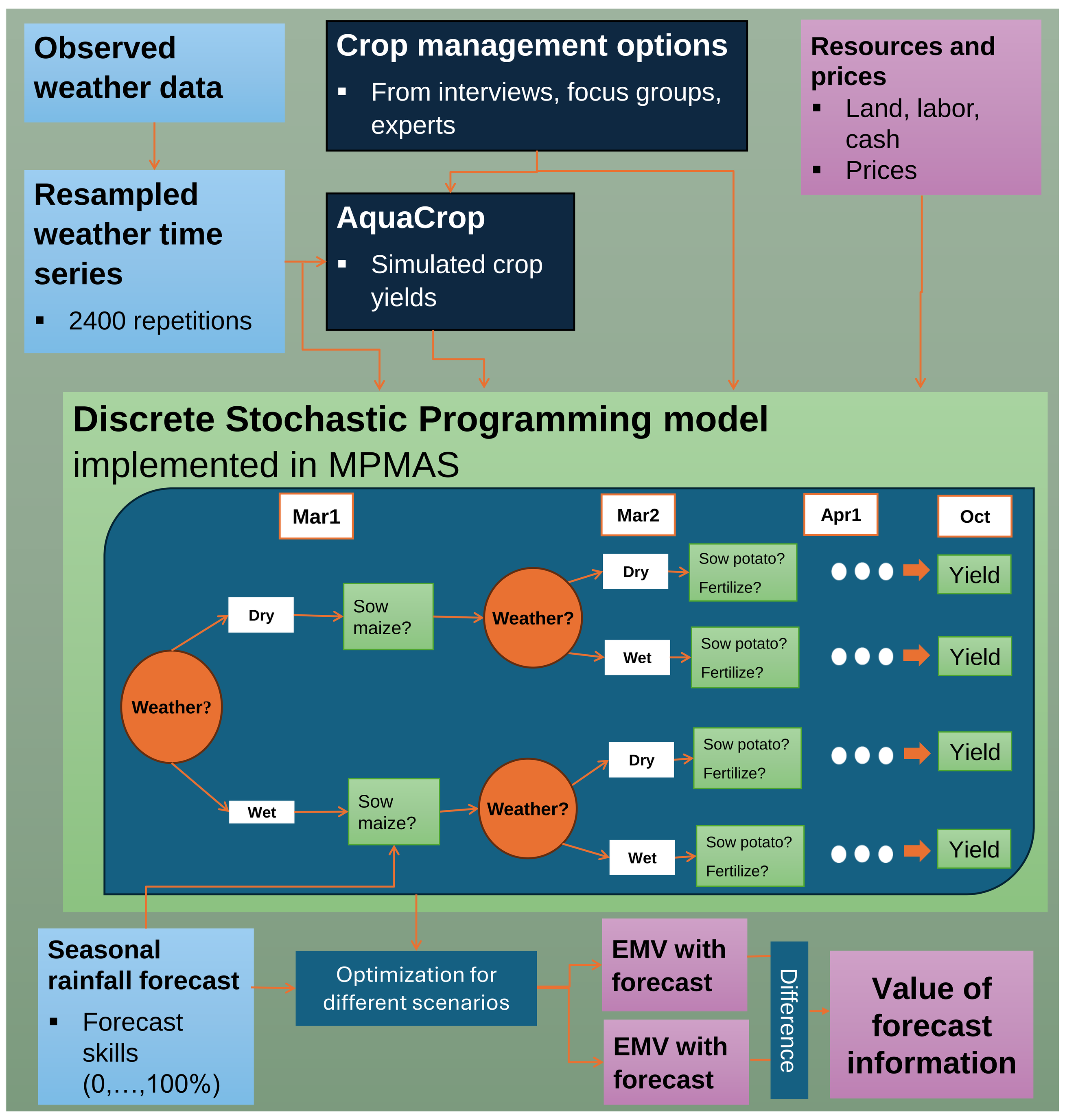

Figure 3. Description of DSP model.

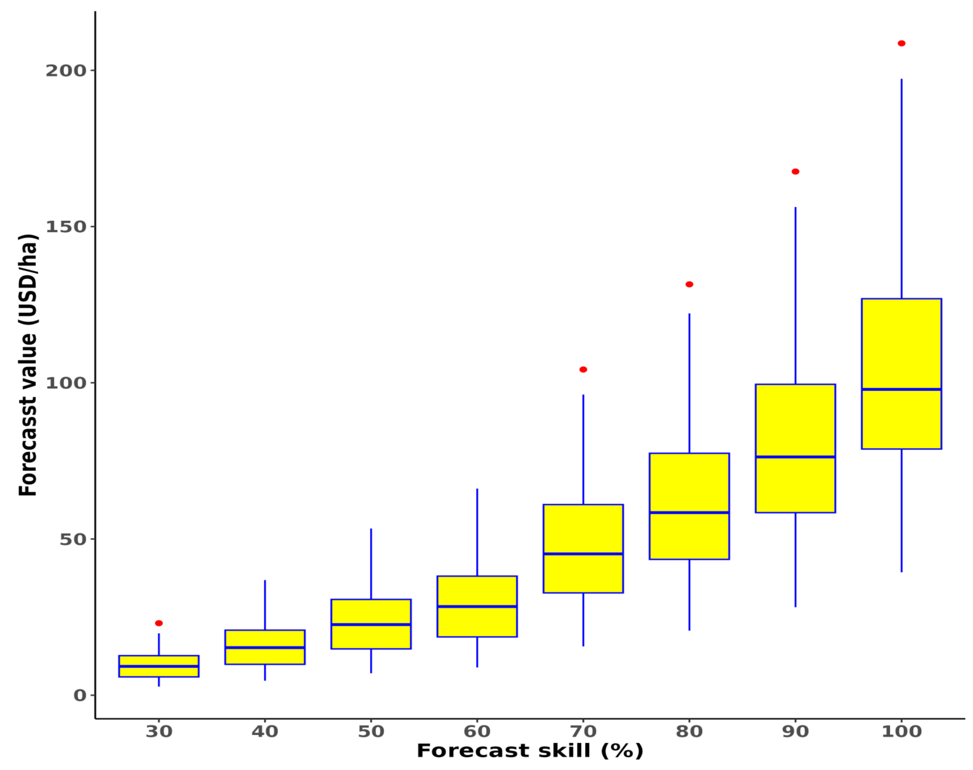

Fig.5. Economic values of the seasonal rainfall forecast over different level of seasonal forecast skills

The value of an imperfect forecast

- The average gross margin without using forecasts is $2,555.88 USD ha-1, and our simulation suggests that integrating seasonal rainfall forecasts into farm-level decision-making for rainfed agriculture can lead to slight improvements in gross margins, depending on the forecast accuracy (see Fig. 5).
- At the current SRF skill level of 70% (based on forecast quality of EMI[8]), a forecast value of 48 USD ha^{-1} might be realized.
- An improvement of 10% in forecast skill (to 80% accuracy) could potentially result in an additional benefit of USD 12 USD ha^{-1}.
- A perfect rainfall forecast could lead to a value up to 100 USD ha^{-1}.

Discussion & Conclusion

- Preliminary results indicate that sufficiently accurate forecasts can modestly increase average expected income.
- However, it is important to note that our valuation is based on four crops at one location.
- Results might differ in other locations, soil types, and pricing structures.
- Additional research is needed to evaluate the value of seasonal forecasts in various regions and cropping systems for broader applicability.

Acknowledgement

The authors recognize funding by the German Academic Exchange Service (DAAD) through the German-Ethiopian SDG Graduate School: Climate Change Effects on Food Security (CLIFOOD).

References:

1. Meza et al., (2008). https://doi.org/10.1175/2007JAMC1540.1
2. Kayamo et al., (2023). https://doi.org/10.1016/j.crm.2023.100541
3. Alexander & Block (2022). https://doi.org/10.1016/j.crm.2022.100417
4. Kassie et al.,(2014) https://doi.org/10.1016/j.fcr.2014.02.010
5. Mössinger et al. (2022): https://doi.org/10.1016/j.agsy.2021.103315
6. Berger et al. (2024): https://mp-mas.uni-hohenheim.de
7. https://www.fao.org/aquacrop/en/
8. Korecha and Sorteberg, (2013), https://doi.org/10.1002/2013WR013760
9. OCHA Ethiopia (2024), https://data.humdata.org/organization/ocha-ethiopia.

CLIFOOD SDG Graduate School
SDG Graduate Schools Alliance
Federal Ministry for Economic Cooperation and Development
DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service